Modelling current and future recreational demand in rural England; the development of tools to mitigate against potential conflicts with biodiversity

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Outdoor recreation is popular worldwide and demand is on the increase (Patthey *et al.* 2008). The situation in the UK is no exception (Sen *et al.* 2014). Although outdoor recreation improves mental and physical wellbeing (Pretty *et al.* 2007), there is an abundance of evidence of its adverse effects on biodiversity, whether direct (e.g. trampling (Liddle 1991)) or indirect (e.g. reducing breeding bird success (Liley & Sutherland 2007; Mallord *et al.* 2007)). Globally increasing human populations and urban spread are contributing to greater recreational pressure on natural habitats (Sharp et al. 2008; Clarke et al. 2013). Therefore, the need to mitigate such adverse effects on biodiversity is becoming even more urgent.

The aim of this current research is to investigate the spatial distribution of recreational pressure across England using a national level recreation model. This model is then used to predict the outcome of future projected increases in population and house building upon recreational visits to rural areas. Using this model we then test a range of mitigation strategies to reduce pressures on highly visited sites. These include the provision of alternative green space to relieve pressure on important conservation areas and altering footpath density at highly visited locations. Various scenarios at national, regional and local scales are explored.

The recreation model was developed through comparison of 31,550 geo-referenced recreational visits against 63,100 randomly selected countryside locations (controls) representing potentially available sites (Manly *et al.* 2002). Observed visit sites were taken from the Monitor of Engagement with the Natural Environment (MENE) survey (2009-2012) (Natural England 2012), an extensive, year-round, England-wide 3 year data set from in-house interviews of visits to the natural environment. The likelihood of a site being visited was modelled using information on land cover (Morton *et al.* 2011), path network density (OpenStreetMap 2013) and mean elevation (OST50 2013), controlling for size of surrounding visitor source populations (ONS 2011) and potential regional differences in behaviour. Predictor variables were generated in ArcGIS 10.1 (Copyright © ESRI, USA) and analysis by a generalised linear mixed model with binomial error was performed in R (version 3.0.2).

The best-fit recreation model indicates a preference for high path density and low elevation (Table 1), as expected due to accessibility and preference for flat, lowland areas respectively. Coastal and freshwater sites exerted the greatest attraction on recreationists followed by broadleaved woodlands (Table 1). All other land cover types, including semi-natural grassland, heathland and arable land reduced the probability of a site being visited by recreationists.

Table 1. Best-fit model predicting recreational demand in the English countryside, controlling for region. Dependent variable: the likelihood of visitation

	Standardised Coefficient	Std. Error	T	p
Non-land cover variables				
Path length	0.8231	0.0143	57.5772	<0.001
Built up	0.7088	0.0247	28.7093	<0.001
Population	0.4445	0.0221	20.1201	
Elevation	-0.3307	0.0157	-21.1087	<0.001
Land cover types with positive effect				
Beaches	0.2834	0.0164	17.2289	<0.001
Freshwater	0.1713	0.0110	15.5400	<0.001
Cliffs	0.1583	0.0144	11.0049	<0.001
Broadleaved	0.1549	0.0175	8.8439	<0.001
Land cover types with negative effect				
Arable	-0.5585	0.0364	-15.3577	<0.001
Upland	-0.1128	0.0204	-5.5299	<0.001
Improved	-0.0898	0.0264	-3.3957	<0.001
Lowland	-0.0893	0.0127	-7.0143	<0.001
Coniferous	-0.0790	0.0139	-5.6749	<0.001
Semi-natural	-0.0557	0.0171	-3.2579	<0.01
Constant	-0.9514	0.1476	-6.4478	<0.001
Observations	94,650			

To extrapolate from our survey sample to produce an England wide map of recreational demand, England was divided into a grid of 800 m cells (approximately 207,000 cells), predictor variables used to fit the recreation model were extracted for each cell and the probability of visitation predicted from the estimated coefficients from the recreation model. The annual number of visits to each cell was predicted by rescaling the predictions of visitation probability, using an estimate of the total annual number of recreational visits across England (provided by Natural England 2012). This provides the first mapped distribution of recreational pressure across England.

This model was then used as a planning tool to assess the consequences of urbanisation and demographic change on a national and regional scale. National and regional population projections were examined and used to produce new population distribution maps for two future time periods 2030 and 2050. These future populations were then used to create new maps showing the spatial distribution of recreational pressure under future scenarios of population growth and urbanisation for 2030 and 2050. The final stage in the analysis examined potential strategies to mitigate against the projected increases in recreation pressures. We used the predictive model, which incorporates land use effects, to show how recreational pressure can be redistributed to relieve pressure on important conservation areas by provision of alternate recreational habitat as mitigation. We experimented with different configurations of alternative sites (e.g. one large site versus a larger number of smaller and more spatially disaggregated sites). The findings will be discussed with reference to strategic planning and policy.

Acknowledgments

This research was funded by a Natural Environment Research Council Ph.D. Studentship.

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