# Modelling use of forest recreation routes; an application for woodlark (Lullulaarborea) conservation

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## Introduction

Forests are popular recreation destinations(Marzano & Dandy 2012) often enhanced through provision of extensive footpath or trackwaynetworks, picnic sites and car parks. However, it may benecessary to manage recreational use of a forest if species sensitive to disturbance are present (Marzano & Dandy 2012). Spatially explicit models of recreational use provide a tool for recreation management. Here we model recreational use of a forest trackway network to estimate disturbance rates on habitats managed for woodlark (*Lullulaarborea*), a disturbance-sensitive speciesof European concern.

During the 20$^{th}$ century large parts of the UK were afforested to provide a strategictimber reserve (Peterken, 1993, pg. 85). Afforestation of open habitatsreduced the extent of unimproved grasslands, heathlands and wetlands, with consequent declines in associated species. To mitigate these impacts the UK Forestry Standard (Forestry Commission 2011) recommends a minimum 10% open space. In Thetford Forest (18,730 ha)the Forestry Commission is wideningverges along 278 km oftrackway to increaseopen habitat(current extent 7.1%) and createan 'Open Habitat Network' (OHN)to enhance habitat and population connectivity for rare and protected species(Armour-Chelu et al. 2014).

The OHN has the potential to offsetwoodlark population declines within the managed plantationsby providing additional breeding habitat. However, providing this as strips alongsidetrackwaysused for recreation may mean fewer woodlark settle. Breeding woodlarks are sensitive to disturbance; the probability of colonisation of suitable habitat in Dorset (n = 16) was less than 50% at 8.3 (5.8-10.9 95% CI) disturbance events hour-1(DEs h-1; Mallord, Dolman, Brown, & Sutherland, 2006). For linear habitat bounding or spanning a trackway, lack of a 'refuge' may increase avoidance costs (requiring escape flight across the adjacent trees), so disturbance thresholds may be lower.

In the present study we model recreational flow throughout theThetford Forest trackway networkto estimate DEs h-1on all elements of the proposed OHN. From estimatedthresholdsfor woodlark we quantify the number of trackway elements in the OHN unlikely to be colonised and therefore the potential loss of conservation benefit due to recreation. This tool is then used to assess mitigation through access point closure.

## Methodological Approach

One of the challenges of landscape-scale recreational modelling is that number and type of visits depend uponmany factors including proximity to an access point, type of entry point, car park capacity, trackwaytype, time of day,day of week, and size of local source population. To capture this variability and calibrate our model,recreational visit datawas collected over 5 non-consecutive years (2007-2014). Surveyors spent 1 hour periods recording recreationists (dog walkers and walkers) encountered at trackwayelements adjoining intersections (sampling points) randomly located throughout forest (n = 338; Fig. 1a). Annually, each point was surveyed approximately 3 times during April-September with time of day ('time') and day of week ('day') varied and included as predictors in separate models of dog walker and walker recreational behaviour.

To generate potential explanatory variables for these recreational visits, several spatial layers were imported into ArcGIS 10.3 (Copyright © ESRI, USA). These included a line feature class delineating the trackway network with attributes for trackwayelement length and class ('forest road': a well-maintained hard surface road; fire route: all-weather hard surfacemaintained for fire truck access;trackway: less well maintained, usually grass or mudsurface), a point feature class of car park access points with car capacity as an attribute (indexed by visual assessment on Google Earth), and a point featureclass delineatingsampling points (Fig. 1a). Car park capacity is important due to the size of the forest, distance from urban areas and barriers to pedestrian access created by major roads, meaning that most users arrive at Thetford Forest by car. We included trackway class as we hypothesised that wide, well maintained forest roads and fire routes would be preferred to narrower, potentially overgrown or muddy trackways. From these layers we calculated a weighted network distance ('net. dist.') from access to sampling points. The 'New Closest Facility' tool in ArcGIS Network Analyst was used to find the closest access pointfor each sampling point based on weightings for 1) car park capacity, 2) road crossings and 3) trackway class. This generated a line feature class of lowest cost routes connecting each sampling point with an access point, accounting for car park capacity, road crossings and trackway classes along the whole route. Routes were generated a number of times, varying the weightings for these three components. The observed number of recreationists (separately for dog walkers and walkers) was then modelled in relation to the accumulated weight attribute from the routes feature classes (net. dist.), time, day, and the number of households in 3 distance bands around access points. The weighting combination in net. dist. that resulted in the lowest AIC (best model fit) was retained for subsequent modelling.

## Application

Resulting predictive models were used to estimate the mean (± 95% CI) DEs $h^{-1}$ ofdog walkers and walkers for every trackway elementin the network. The combined 95$^{th}$ percentile predictions for dog walkers and walkers were mapped (Fig. 1b) and overlaid with the OHN. The number and location of OHN trackwaysunlikely to be colonised due to recreational disturbance was estimated, through sensitivity analysis of potential woodlark disturbance thresholds. We illustrate the utility of our model for mitigation through testing closure of access points under current and future housing scenarios and re-estimating amount of OHN unsuitable for woodlark.

## Challenges

Modelling recreational use of routes presents many challenges, including the time and effort required to sample a large forest network (1,694 person-hours in this study) and to generate a classified trackway for use in the network analysis. Assessment of appropriate weightings for components of the network analysis is also time consuming. However, once the model is calibrated, predictions are simple and quick for extrapolations to larger areas and repeat runs for scenario testing.

## Acknowledgments

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

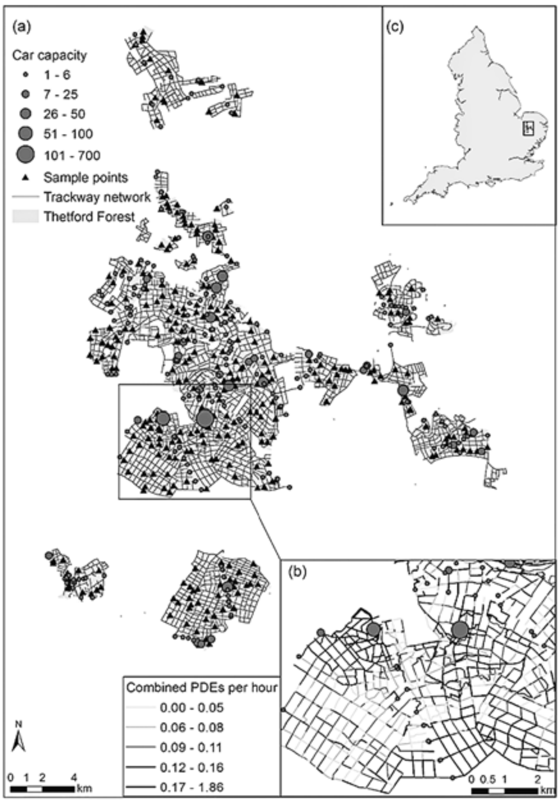


Figure 1. *(a) Thetford Forest boundary,trackway network, access points with parking (circles) proportionate to car capacity and sampling points used in model calibration (triangles); (b) Predicted disturbance events h-1 (95th percentile) from dog walkers and walkers combined (shown for part of the forest trackway network); (c) Location of Thetford Forest within England.*

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