Depending of Editor feedback, this paper will be submitted as a companion paper to the fox movement paper being submitted to *Movement Ecology*. The content of this draft may change considerably prior to submission and then following peer review.

Habitat use of Red Foxes in wet meadow habitats used by breeding waders

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Running title: Fox habitat use in wet grasslands

Abstract

350 words. Separate into sections:

- Background
- Methods
- Results
- Conclusions

Keywords

3-10 keywords.

Background

Similar general introduction to fox movement paper, but more focus on lack of understanding of fox habitat use in wet grasslands, and how this knowledge could guide location of wader nesting habitat.

In this paper, we use estimates of home ranges obtained from GPS tagging of foxes during the wader nesting season to understand differences in habitat composition between fox territories, and use of different habitats within territories. We use the GPS data to characterise fox movements in relation to linear habitat features. We also examine the location of cubbing earths in an environment with a high-water table, given the expectation that slightly higher terrace areas will be important for earth location and the availability of drier areas may influence territory size.

Methods

Study areas

Our fox study was part of an EU-LIFE funded GWCT project called Waders for Real (hereafter W4R) which took place between 2015-2019 in the Avon Valley in central Southern England. The River Avon is a Special Area of Conservation (SAC) designated under the EU Habitats Directive (Council Directive 92/43/EEC) and its lower reaches also lie within the Avon Valley Special Protection Area (SPA) which is classified as a separate site under the EU Birds Directive (Directive 2009/147/EC). The W4R project (LIFE13 BIO/UK/000315) aimed to expand the existing local breeding range of Lapwing and Redshank, by instigating enhanced habitat and predation management measures in the lower valley, where these birds still breed. The intention was to improve their breeding success to bolster local numbers and to encourage subsequent recolonization of the upper valley, where numbers of breeding pairs of both species had contracted to almost zero.

We anticipated that environmental differences in the upper and lower valley, such as the availability of food resources and local fox culling pressure, might influence fox population density and dynamics, so we tagged foxes caught on wet grassland areas at two representative sites at Britford and Somerley (Figure 1). Understanding any local differences in predator pressure between valley locations is important if W4R is to fulfil its ambition of recovering breeding waders throughout the Avon Valley.

Britford (upper valley)

Include more detail than in fox movement paper?

Somerley (lower valley)

Include more detail than in fox movement paper?

Fox capture and tagging

Only include brief description here and refer to fox movement paper for full details.

Data preparation and home range estimation

Only include brief description here and refer to fox movement paper for full details. Provide the selected home range estimates in an Appendix?

All relocations (latitude-longitude) were converted to British National Grid for analysis in metres.

We analysed data for the period 15 March to 15 June. Although some foxes were tagged for a few days outside of this period, the aim was to understand the habitat use by foxes during the wader nesting season.

Habitat use

To examine the home range composition and habitat use of each fox, we constructed a habitat map layer at the field scale. We obtained OS MasterMap [1] Topography polygon layer which detailed features including agricultural land, woodland, garden, watercourses, static water, fence lines, roads, paths, bridges, natural surface, manmade surface or structure, and buildings. As we expected different types of agricultural land to be used differently by foxes, we updated 'agricultural land' field descriptions using the Priority Habitat Indicator (PHI) map data [2] where there was overlap, or contemporary satellite imagery otherwise. This reclassified agricultural land into arable (all crop types), pasture (combining rough, semi-improved, improved pastures and wood pasture and parkland, and includes fields cut for hay), field margin, floodplain grazing marsh (PHI), lowland meadow (PHI), lowland calcareous grassland (PHI), lowland heathland (PHI). Habitat layers were constructed to cover the areas used by foxes at Britford (Figure S1) and Somerley (Figure S2).

Calculate the proportion of different habitat types within each home range (expect floodplain grazing marsh to be main habitat).
Examine how home range size varies with proportion of floodplain grazing marsh (or other important habitat type).

Movement along linear features

Convert the habitat polygon layer to polylines.
Calculate the distance of each relocation to its nearest edge.
Classify those relocations within 5m, 10m, 20m buffers as being associated with the edge.
Summarise the proportion of total relocations within each buffer.
Expect these proportions to be high if movement is predominantly along the linear features.

Relationships with vegetation height

Preliminary analysis of fox location data obtained between 2016-2018 indicated that foxes spent relatively little time in hay or silage fields after the vegetation grew tall. Over a two-week period at the start of June 2019, we conducted simple snap-shot surveys of sward height and structural density in 47 different fields (including hay meadows, silage grass fields, grazed pasture and marshland) occupied by tagged foxes on Somerley and some adjoining landholdings. Starting at the north-west corner of each field, we measured the vegetation density and maximum height and density (using a dropped circular plate of diameter 22 cm) 10 m in from the field edge, and heading in an easterly direction, we repeated this every 10 m, to generate ten measurements. We repeated this procedure, starting 10 m in from the north-east corner of the field and heading south, to generate a further ten measurements, so that 20 vegetation density and maximum height measurements were taken in each field. For fields that weren't accessible (e.g. horse paddocks) we estimated the approximate vegetation height visually at a single point, or multiple points if the sward height was clearly variable.

We used these data to create a map layer with the mean vegetation height for each field. For each fox tagged during the vegetation survey period, we counted the number of relocations within each field and used linear regression to examine the effect of vegetation height on the number of relocations.

Results

Habitat use

Analyses to be completed once creation of Somerley habitat layer completed.

Discussion

Conclusions

Declarations

Ethics approval

This work falls under The Animals (Scientific Procedures) Act 1986 and was conducted under UK Home Office Licence PPL30/3273.

Consent for publication

Not applicable.

Availability of data and materials

Need to make the data available somewhere

Competing Interests

The authors declare that they have no competing interests.

Funding

This work was undertaken as part of the 'Waders for Real' project funded by the EU LIFE+ scheme (LIFE13 BIO/UK/000315).

Author's contributions

Add this detail.

Acknowledgements

Add this detail.

References

1. Ordnance Survey. OS MasterMap [Internet]. 2019 [cited 2019 Sep 10]. Available from: https://www.emapsite.com/

2. Natural England. Priority Habitats' Inventory for England. Version 2.2. 2019.

3. Reynolds JC, Tapper SC. The ecology of the red fox *Vulpes vulpes* in relation to small game in rural southern England. Wildl Biol. 1995;1:105–19.

4. Meisner K, Sunde P, Clausen KK, Clausen P, Fælled CC, Hoelgaard M. Foraging ecology and spatial behaviour of the red fox (*Vulpes vulpes*) in a wet grassland ecosystem. Acta Theriol (Warsz). 2014;59:377–89.

Tables

Figures

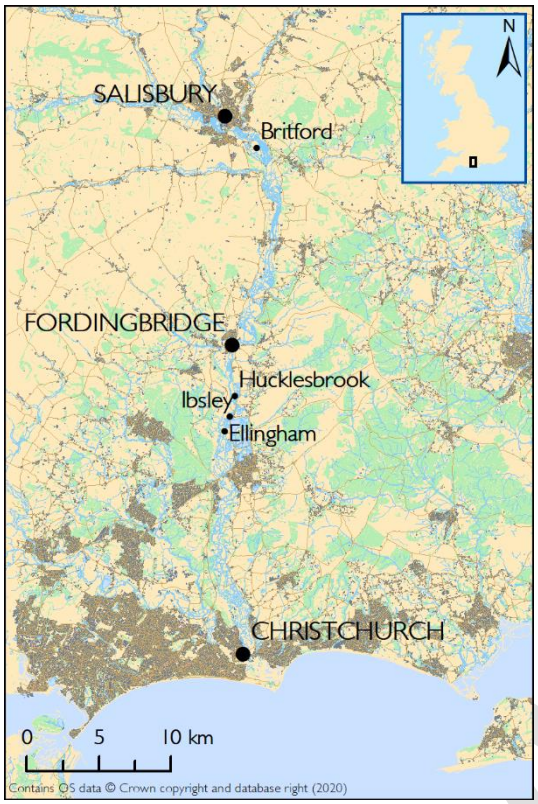

Figure 1. Location of the study sites within the River Avon Valley in central southern England.

Additional files

Appendix A Supporting Figures

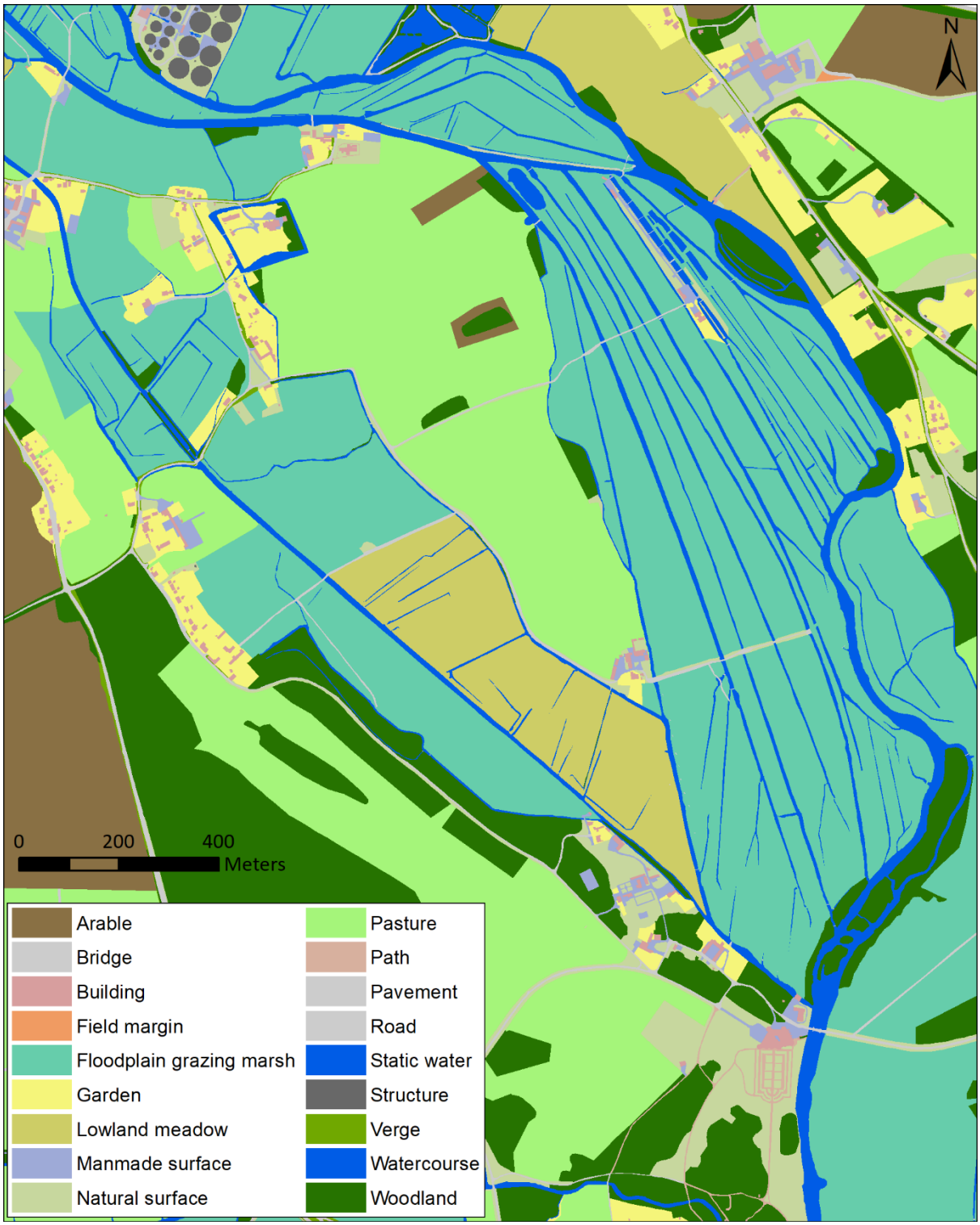

Figure S1. Habitat map layer of the main Britford study site (not including areas to where foxes dispersed). Fence lines within habitat types are not displayed for clarity.

Figure S2. Habitat map layer of the main Somerley study site (not including areas to where foxes dispersed). Fence lines within habitat types are not displayed for clarity.