Landscape -scale habitat associations in an urban Stock Dove *Columba oenas* population

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Abstract

While some species are known to thrive in urban areas, urban expansion is a major driver of biodiversity loss. Columbids such as feral Rock Doves *Columba livia domestica* and Common Woodpigeon *Columba palumbus* have adapted extremely well to the urban environment in Europe and beyond, but the Stock Dove *Columba oenas*, a bird of farmland and woodland edge in the UK and of national conservation concern, is encountered far more rarely in urban areas. Here we explore the multi-scale landscape associations of the little-studied Stock Dove within the urban matrix of Greater Manchester, UK, as a step towards identifying its long-term conservation needs. We built a pilot model from historical citizen science records to identify potentially occupied patches within the city, and then surveyed these patches for Stock Dove during Spring 2019. We combined the survey results with citizen science records from the same period. We described the habitat and landscape characteristics of these patches using four variables at different scales and twelve unscaled variables. We used a three-stage random forest approach to identify a subset of these variables for interpretation and a subset for prediction for the presence of Stock Dove within these patches. Key variables for predicting Stock Dove presence were their relative abundance in the region immediately beyond the core urban area, the greenness (NDVI) of the environment around patches, and the canopy cover of individual trees over 20m high within patches. Stock Doves tended to be associated with habitats with more surface water during the non-breeding season than the breeding season. Our results highlight the importance of large trees within urban greenspace and the importance of softer boundaries around urban patches for Stock Doves. While Stock Dove share many traits with species that are successful in the urban environment, they remain relatively poor urban adapters.

Introduction

Urbanisation drives the loss, degradation and fragmentation of natural habitats (Bar-Massada et al. 2014; McKinney 2006). Urban matrices typically consist of a patchwork of different habitats, of varying size and quality (Crooks et al. 2004; Davis et al. 2014) in addition to offering entirely novel habitats with no historical analogues (Werner, 2011). Urbanisation consequently results in biodiversity loss and turnover, favouring generalist species that adapt better to novel environments over specialist species (Werner 2011) which can drive the homogenisation of urban wildlife assemblages (Chace and Walsh 2006). Increasing urbanisation may lead to an increase in animal biomass but a decrease in species richness (Chace and Walsh 2006) and an increase in non-native species (McKinney 2006). However, cities that retain more remnant habitat are more likely to retain native species (Chace and Walsh 2006).

Analysis of urban biodiversity levels has often focused on the rural-urban gradient (Nielsen et al. 2014; Beninde et al. 2015), a focus which may miss variation in the underlying structure of the urban matrix of different cities (Werner 2011; Beninde et al. 2015). Instead, an approach that identifies individual habitats as urban patches (sometimes referred to as urban greenspaces) within an interconnected urban matrix allows a more finely grained understanding of species response to urbanisation to be gained (Aronson et al. 2017). Patches are connected by their proximity to others or by functional habitat corridors (Lepczyk et al. 2017) such as river valleys, off-road cycle routes, canals, or wooded streets. Species response to urbanisation can then be understood by local habitat features determining habitat suitability and landscape features defining the permeability of the landscape for species dispersal (Beninde et al. 2015). The response of an individual species to these habitat and landscape features will vary due to species-specific niche requirements (Jokimäki et al. 2016) and dispersal ability (Martin et al. 2017). Thus, while a patch might provide the required habitat and the landscape the required corridors for dispersal, a species' life history may still prevent settling in a patch. This could be due to either failure to adapt to novel resources available in the urban environment (Spotswood et al. 2021; Shochat et al. 2006), or due to intraspecific competition (Lees 2018).

The pigeons and doves *Columbidae* are a speciose avian family including some consistent urban adaptors across most of the world (Sol et al. 2014). In the UK, for example, there are large urban populations of commensal feral Rock Doves *Columba livia domestica* (McKinney 2006; Isaksson 2018) as well as Common Woodpigeons *Columba palumbus* (hereafter Woodpigeons) and Collared Doves *Streptopelia decaocto*. In rural and agricultural habitats Woodpigeons occur in sympatry with Stock Doves *Columba oenas* (Snow et al. 1998; Murton et al. 1964). Although widespread, there are estimated to be just 320,000 Stock Dove territories in the UK compared with an estimated 5,400,000 Woodpigeon territories (Woodward et al. 2020). While Woodpigeons have adapted to the urban environment (Fey et al. 2015; Ó hUallacháin 2014; Bea et al. 2011), Stock Doves remain uncommon in urban areas (Robinson 2005). A major life history difference between the two species is their choice of nest sites; Stock Dove are cavity nesters whereas Woodpigeon nest on open branches. Stock Doves prefer ecotonal areas between woodland and open country where mature trees have cavities and hollows for nesting but are within easy access of fields for foraging as well as close to a source of convenient drinking water (Snow et al. 1998). Nest site requirements may well affect Stock Dove's urban abundance as tree cavities are sparser in urban areas when compared to continuous woodland (Davis et al. 2014). Stock Doves have suffered recent declines in the UK, which holds an important European breeding population, (Robinson 2005) and are classified as Amber under the Birds of Conservation Concern 4: The Red List for Birds (2015). Understanding their habitat requirements is a necessary step towards improving their conservation status.

We aim to understand the spatial distribution of Stock Dove in Manchester, a major UK city, and to identify the landscape-scale predictors that best explain this distribution. We undertook a field survey across Greater Manchester to identify patches occupied by Stock Dove and combined the results with citizen science data. We then identify the predictors for the landscape and habitat associations of Stock Dove based on the field survey results. Finally, we explore differences in habitat and landscape associations between the breeding and non-breeding season.

Methods

Study Area

Greater Manchester (53°29'N 2°14'W) is a metropolitan county in the North West of England with a population of 2.8 million. The metropolitan county is close to sea level with a mean elevation of 38 m and a temperate oceanic climate. The M60 ring-road forms an obvious physical border around the city and contains parts of the metropolitan boroughs (local administrative districts) of Manchester, Salford, Trafford, Stockport, Tameside, Rochdale and Bury. Manchester (metropolitan borough), which is mostly retained within the M60 ring-road, is 20.4% greenspace and therefore the 8th greenest city in the UK (The Guardian, 2017). That greenspace consists of patches of remnant woodland, brownfield regrowth, local nature reserves (LNR), managed parkland, cemeteries, and sports fields. The greenspaces are connected via canals, rivers, green cycleways, and treelined streets.

Citizen Science Records

We used citizen science data from eBird (eBird 2019), The Manchester Birding website (Manchester Birding 2019) and Bird Track (BTO 2019) to provide a list of previous Stock Dove records from inside the Manchester M60 ring-road. These were combined to produce a list of every patch within the M60 ring-road that had a previous sighting recorded (Figure 1). These records included the patch name, the record source, and the date and time of the observation.

Survey

A field survey was undertaken between 1 March-31 May 2019 to identify greenspaces within the M60 ring-road occupied by Stock Doves. Potential patches occupied by Stock Dove were identified using a ‘pilot’ maxent model built using the citizen science records along with environmental data from the Ordnance Survey and Forestry Commission (Appendix I). JR visited each of the potential patches twice during the survey period, during which every hectare was visited, and each survey took at least 2.5 minutes per hectare for open habitat and up to 5 minutes per hectare for patches with more closed habitat. Additionally, in May 2019 JR visited patches that had previous Stock Dove sightings recorded but had not yet had a recording made during the survey period. In these patches, where possible, JR used knowledge from the person who had made the previous record to target his visits to the most probable areas of those patches.

For the survey results, presence records were created for each patch where either Stock Dove were found during a survey; an eBird checklist was submitted containing a Stock Dove; a sighting was recorded on Manchester Birding; or a sighting was sent to us from the South Manchester Raptor Group. Absence records were created for each patch that was identified to be surveyed and JR failed to find Stock Dove during the survey period; or had an area of at least 0.25 km^2 and had at least one visit recorded on either eBird or Manchester Birding during the survey period which did not list Stock Dove.

Predictor Variables

Stock Dove require habitat with large trees for cavity nesting, ideally close to both water and to grassland for foraging (Snow 1998). Additionally, as we want to test the position of that habitat within the wider landscape, landscape variables for distance from city centre, surrounding greenness (NDVI), and surrounding levels of Stock Dove relative abundance were included from the British Trust for Ornithology (BTO) (2019b). Spatial variables were measured using a shape file containing vectors for each surveyed patch which came from the Ordnance Survey Greenspace dataset (Ordnance Survey 2018a), the LNR dataset (Natural England 2020), or were created using QGIS (QGIS Development Team 2019) based on the Open Street Map (OpenStreetMap contributors 2015).

Modelling Approach

We used the random forest approach of Genuer et al. (2010) designed for high dimensional problems where the number of predictors (p) is high compared to the number of samples (n). This approach has been shown to work well in the field of ecology (Fox et al. 2017) and has been previously adapted for selecting the appropriate scale of landscape variables (Bradter et al. 2013). The approach has three stages, a ranking stage, a removal stage, and then a selection stage. We then alter the selection stage depending on whether the aim is to find predictor variables highly related to the response variable for interpretation purposes, or to find predictor variables for building a prediction model (Figure 2). The first stage ranks the variables based on their average importance from 50 runs with 2000 trees in each forest. The second stage drops variables when the standard deviation of their importance is below the minimum prediction value of the CART model fitted to the curve of all predictor variables' standard deviations (Genuer et al. 2010).

The final stage for selecting variables for interpretation computes the error rate of random forests from 50 runs of nested models starting with the model with the single most important predictor variable and then adding each remaining predictor variable in turn. A minimal model is selected with an error rate below the lowest error rate augmented by standard deviation. In contrast, the final stage for selecting variables for prediction again starts with the most important predictor variable and then adds in each remaining variable in turn, however, a variable is only added when the error rate exceeds a threshold. The threshold is set to the mean of the absolute values of the first order differentiated out of the bag (OOB) errors between the model selected for interpretation and the one with all predictors, this ensures the error decrease from adding additional predictors is greater than variation added by noisy predictors (Genuer et al. 2010). The prediction model is likely to contain more variables than the interpretation model.

To select the most appropriate spatial scale for the scaled variables, the first stage of this approach was initially run with every predictor variable at every scale. The highest ranked scale for each variable was then selected and all other scales were discarded. The first stage was then repeated with just the 'best' scale for each scaled variable, the rest of the approach was then followed in full, and two models were selected: one for interpretation and one for prediction (Figure 2). Finally, a random forest model was generated from the survey data using the variables selected for prediction, probabilities were generated for each patch from the OS Greenspace data set (Ordnance Survey 2018a) using the R random forest package (Liew and Wiener 2002).

To understand if there is a season variation in Stock Dove distribution the historical sightings, from eBird (2019), Bird Track (BTO 2019) and Manchester Birding (2019), were examined to see if the landscape and habitat predictor variables identified from the survey data varied between breeding and non-breeding seasons. The historical citizen science records (before 2019) were split into breeding (March – August inclusive) and non-breeding season (September – February inclusive) and then reduced to ensure there was at most one presence record per patch per annual season. Wilcoxon signed-ranked tests were then completed for each predictor variable to compare the means between the breeding and non-breeding season patches.

Results

Field Survey Results

In total, 65 patches were included in the analysis. Stock Doves were found at 28 of these patches during the survey period (Figure 3). Stock Doves were found on patches that included nine LNRs, eight parks, four playing fields, four golf courses, and a water treatment works, a cemetery and cycling infrastructure (the full list of 65 patches included 20 LNR, 20 parks, eight playing fields, seven golf courses, four cemeteries, and then cycling infrastructure and a water treatment works). The 65 patches included 28 patches visited during the survey, 23 patches where Stock Dove were recorded in citizen science or by the South Manchester Raptor Group, and 14 patches which were added as absences using the absence criteria. The area of the 65 patches averaged 0.4 ± 0.49 km^2 (0.04 - 2.9 km^2) compared to the area of the 28 presence patches which averaged 0.51 ± 0.69 km^2 (0.04 - 2.9 km^2). Eight of the 28 presence patches were patches identified from the pilot maxent model where Stock Dove had not previously been recorded. Many presence sites lay along rivers, either the Mersey in the South, or the Irwell in the North.

Landscape and Habitat Associations

The spatial scales selected were a 13 km buffer around patches for average BTO relative abundance; a 500 m buffer around patches for average NDVI; 20 m for the density of individual trees above a certain height; and 20 m for the density of individual trees above a certain height. This left 16 variables which were entered for variable selection. The first two stages of Geneur's method reduced these 16 variables to six (Table 2), of these the top three were selected for interpretation and the top five were selected for a prediction model.

The prediction model shows a clustering of potentially suitable patches in the northwest and south of Manchester (Figure 4). This distribution mirrors the average BTO relative abundance around Manchester. The average BTO relative abundance of Stock Dove within the M60 ring-road is lower (2.2) than the more rural areas in the 13 km buffer outside the ring-road (4.2). Moreover, the average relative abundance within the 13km buffer is higher in the West than in the East, which mirrors Stock Dove being found in the West of the urban area (average relative abundance within each quarter of the 13 km buffer: northwest 4.2, southwest 6.2, northeast 3.0, southeast, 3.7).

The citizen science data contained records from 38 patches, with 36 patches in the breeding season and 25 patches in the non-breeding season. The non-breeding season added just two additional patches which had no records during the breeding season. The only predictor variable to have a significant difference between the breeding and non-breeding season was the total area covered by water. Patches with Stock Dove in the non-breeding season had a larger area of water cover than those in the non-breeding season (Table 3). There was also a near-significant difference in the total area covered by grassland, suggesting that Stock Dove may choose more open habitats in the non-breeding season. There was no significant difference between the function of the patches used between breeding and non-breeding seasons (χ^2 = 5.65 df = 8, p = 0. 69), however, there are four samples in the breeding season for golf courses but none in the non-breeding season.

Discussion

Ours is the first detailed study of the spatial distribution and habitat choice of Stock Doves within an urban environment and provides insight into the impacts of urbanisation on the species. We found Stock Doves to be largely restricted to 'greener' habitat patches with large trees geographically proximate to rural source populations. Stock Doves are more abundant in the lowland arable and 'mossland' landscapes west of the city than in the upland moorland fringe to the east (BTO 2019b; Figure 1). These broader scale differences in abundance likely lined to topoedaphic differences which define habitat quality for Stock Doves may explain the relative rarity of the species in the eastern half of the city in comparison to the west – if areas outside of the city are important as source populations for colonists of the urban area. The higher levels of NDVI around occupied patches indicate a preference for greener areas of the city (Purevdorj et al. 1998), indicating that the amount of landscape-level greenspace is also important and not just patch-level characteristics.

Species responses to urbanisation depends on their niche requirements (Jokimäki et al. 2016); we have shown that large trees are important in explaining Stock Dove's distribution, as the species is a secondary cavity nester (Kosiński et al. 2011). These larger trees are more likely to offer suitable nest holes, with trees over 20m high selected in two different predictor variables at different spatial scales. Previous studies have shown that Stock Dove prefer nest sites in large Scots Pine *Pinus sylvestris* or Beech *Fagus spp.* with two or more cavities (Kosiński et al. 2011) and taller trees are more likely to have more cavities (Struebig et al. 2013). Urbanisation benefits cavity nesters over ground nesters, as cavity nesters may more readily adapt to manmade cavities (Jokimäki et al. 2016) which may a necessity if the number of natural cavities in urban environments is lower (Davis et al. 2014; Newson et al. 2011).

Cavity availability may be further reduced by interspecific competition with other cavity nesters (Strubbe and Matthysen 2007), in the context of our study and elsewhere in the UK, this may include native Tawny Owls *Strix aluco* and introduced Grey Squirrel *Sciurus carolinensis* and, in some cities, including Manchester Ring-necked Parakeets *Psittacula krameria*. Neither of these latter two species have been found to have a demonstrable impact on the abundance of native cavity nesters (Craig et al. 2016; Hewson and Fuller 2003; Newson et al. 2009; Newson et al. 2011; Strubbe and Matthysen 2007), they could still have a significant impact on cavity availability and suppress the abundance of other species without being the primary driver of community change (Didham et al. 2005). With insufficient large cavities, nesting sites could be a limiting factor for Stock Doves' success in the urban environment. Given that we found Stock Doves using raptor nest boxes during our field survey, a behaviour which is well known (Møller et al. 2016) then provisioning of nest boxes may be one way of boosting Stock Dove reproductive success in cities.

Stock Dove are primarily granivorous (Snow et al 1998) and urbanisation often favours granivores in Europe (Jokimäki et al. 2016). Stock Dove have been found to respond positively to grassland improvement (when inorganic fertilizer has been added) than in unimproved grassland due to an increase in grass seed available (Barnett et al. 2004) but in this study we did not differentiate between types of grassland (such that monocultural playing fields were lumped with pasture and grassland managed for wildlife). Therefore, the effect of grassland type may have been masked in our study. Stock Doves are reported to feed on seeds on the ground (Snow et al, 1998) and in a study of the species in inner London Goodwin (1960) records that he only saw Stock Dove feeding on the ground twice – we only recorded the species feeding on the ground on four occasions during our survey (in Broadoak Park, Platt Fields Park, and Reddish Vale LNR). Thus, food availability could also be a limiting factor for Stock Dove within the urban environment.

While there is potentially suitable habitat available in urban areas, Stock Dove may need to cross substantial areas of unsuitable habitat to find suitable patches. Habitat loss and land use intensification increases the costs of dispersal for dispersive species more so than for sedentary species like Stock Doves (Martin et al. 2017). During our field survey we observed Stock Doves using habitat corridors such as cycle paths, canals and rivers, - dispersing birds following these linear features into the city may be more likely to find suitable breeding habitat. However, in Madrid there was no evidence of Stock Doves using treelined streets despite other ground-feeding (Woodpigeon, Blackbird *Turdus merula*, Common Starling *Sturnus vulgaris* and European Serin *Serinus serinus*) and cavity-nesting (Coal Tit *Periparus ater* and Great Tit *Parus major*) species using them (Fernández-Juricic 2000). The significance of high NDVI around patches with Stock Dove also indicates that they prefer patches without hard edges; this sensitivity to edge effects may limit their ability to occupy many urban areas (With and King 2001). This edge sensitivity is reinforced by the finding that the species has a clear preference for habitat away from roads in farmland in England (Fuller et al. 2001) a preference for the interior of parks in Spain where Woodpigeon were found largely at the park edges (Fernández-Juricic 2001). The edge effect from roads may not only relate to habitat fragmentation but also noise pollution (Šálek et al. 2010) and it may be that Stock Dove are sensitive to other *anthropogenic sound sources*.

While Stock Dove exhibit some traits associated with urban adapters such as granivory and cavity-nesting, they do not appear to be flourishing in urban Manchester. However, in London, Stock Dove appear to be maintaining healthy population in some parks (e.g. Regents Park, eBird 2019). London is a greener city than Manchester (23% covered by greenspace compared to 20.4%, The Guardian, 2017) and its parks are larger and older. These more mature parks could provide more suitable habitat for Stock Dove with more natural cavities in older trees, or better connectivity of greenspace for their dispersal needs and potential sensitivity to edges. Further studies are required to compare Stock Dove distribution and abundance across multiple cities to more fully understand the balance between resource availability and Stock Dove habitat requirements in the urban environment.

Declarations

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Conflicts of interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Availability of data and material

Presence records available via eBird (https://ebird.org/). Habitat variables provided as supplementary material

Code availability

Available via request to authors

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Tables

Table 1

Variable	Unit	Scales
Density of individual trees over X metres *	trees km^{-2}	12, 14, 16, 18, 20, 22 and 24 m
Total area covered by canopy of individual trees over X metres *	km^2	12, 14, 16, 18, 20, 22 and 24 m
BTO Relative Abundance within X km around patch †	0 - 9	0.5 km, 1 km, and then every km to 13 km
Average NDVI within X metres around patch ‡	NDVI	Every 50 m, from 50 m to 1000 m.
Woodland cover *	km^2	-
Percentage of total area covered by woodland *	%	-
Maximum individual tree height *	m	-
Average individual tree height *	m	-
Water cover §	km^2	-
Distance to water §	m	-
Grassland cover ‖	km^2	-
Percentage of total area covered by grassland ‖	%	-
Total area ¶	km^2	-
Distance from centre of Manchester #	km	-
Function of the greenspace **	-	-
Land cover smoothness ††	-	-

Table 1: Predictor variables explored; scales given when multiple scales were investigated.

* Measured from Manchester City of Trees Team and the GM Combined Authority (2019). This contains two datasets for trees across Greater Manchester. The first is a Lidar dataset for individual trees and includes the height and canopy cover of each tree. The second is for denser areas of woodland where individual trees could not be measured by Lidar and only includes the area covered by that woodland. This allows large individual trees to be identified but adds complexity by spreading tree data across two datasets.

† Measured from relative abundance maps published by the BTO (British Trust for Ornithology) (BTO, 2019b). These maps contain 10 levels from 0 to 9 with 9 being the highest relative abundance.

‡ Measured from imagery published by European Space Agency (2020). The image from the 29 June 2018 was used as being the day closest to the survey period with 0% clouds and including all of

Manchester. The 20x20m pixel image was used as a compromise between accuracy and computation speed.

§ Measured from OS Open MasterMap (Ordnance Survey, 2018b). Includes all topography with a theme of water.

|| Measured from vectors using QGIS (QGIS Development Team, 2019). Includes all topography with a theme of land, a primary description of general surface, an empty secondary description, and a make of natural.

¶ Measured from vectors using QGIS (QGIS Development Team, 2019).

Measured from vectors using QGIS (QGIS Development Team, 2019). Centre of Manchester defined as Albert Square at (383797, 398105; EPSG:27700)

** Function from Ordnance Survey Greenspace dataset (Ordnance Survey, 2018a), LNR, or Brownfield

†† The standard deviation of the percentage grassland and woodland cover.

Table 2

Variable	I	P	Mean ± SD for Presence patches	Mean ± SD for Absence patches	Wilcox Test (p-value)
Average BTO Relative Abundance within 13 km	Y	Y	3.6 ± 0.4	3.2 ± 0.6	< 0.0001
NDVI within 0.5 km	Y	Y	0.53 ± 0.11	0.46 ± 0.10	0.001
Canopy Cover of individual trees over 20 m (km^2)	Y	Y	0.008 ± 0.010	0.005 ± 0.012	0.03
Tree density of individual trees over 20 m (trees km^{-2})		Y	99.1 ± 125.9	113.6 ± 190.2	0.3
Maximum individual tree height (m)		Y	26.7 ± 4.5	23.2 ± 5.1	0.02
Total area (km^2)			0.51 ± 0.69	0.24 ± 0.19	0.6

Table 2: Variables selected for Interpretation (I) and Prediction (P) from the variables remaining after stage 2 of variable selection. Wilcox tests used to compare the means of patches with and without Stock Dove.

Table 3

Variable	Mean ± SD for Breeding Season	Mean ± SD for Non-Breeding Season	Wilcox Test p-value
Average BTO Relative Abundance within 13 km	3.70 ± 0.46	3.62 ± 0.48	0.37
Average NDVI within 0.5 km	0.54 ± 0.13	0.55 ± 0.13	0.41
Canopy Cover of individual trees over 20 m (km^2)	0.007 ± 0.011	0.010 ± 0.014	0.21
Tree density of individual trees over 20 m (trees km^2)	57.5 ± 99.4	42.1 ± 81.7	0.70
Max tree height (m)	23.5 ± 7.06	24.9 ± 6.51	0.29
Total area (km^2)	0.62 ± 0.79	0.89 ± 1.01	0.22
Total area covered by grassland (km^2)	0.19 ± 0.30	0.30 ± 0.38	0.06
Total area covered by water (km^2)	0.09 ± 0.13	0.14 ± 0.15	0.007
Distance to city centre (km)	5.59 ± 1.69	5.90 ± 1.60	0.17

Table 3: Differences between predictor variables for patches with citizen science Stock Dove records in the breeding season (March - August) and the non-breeding season (September - February).

Figures

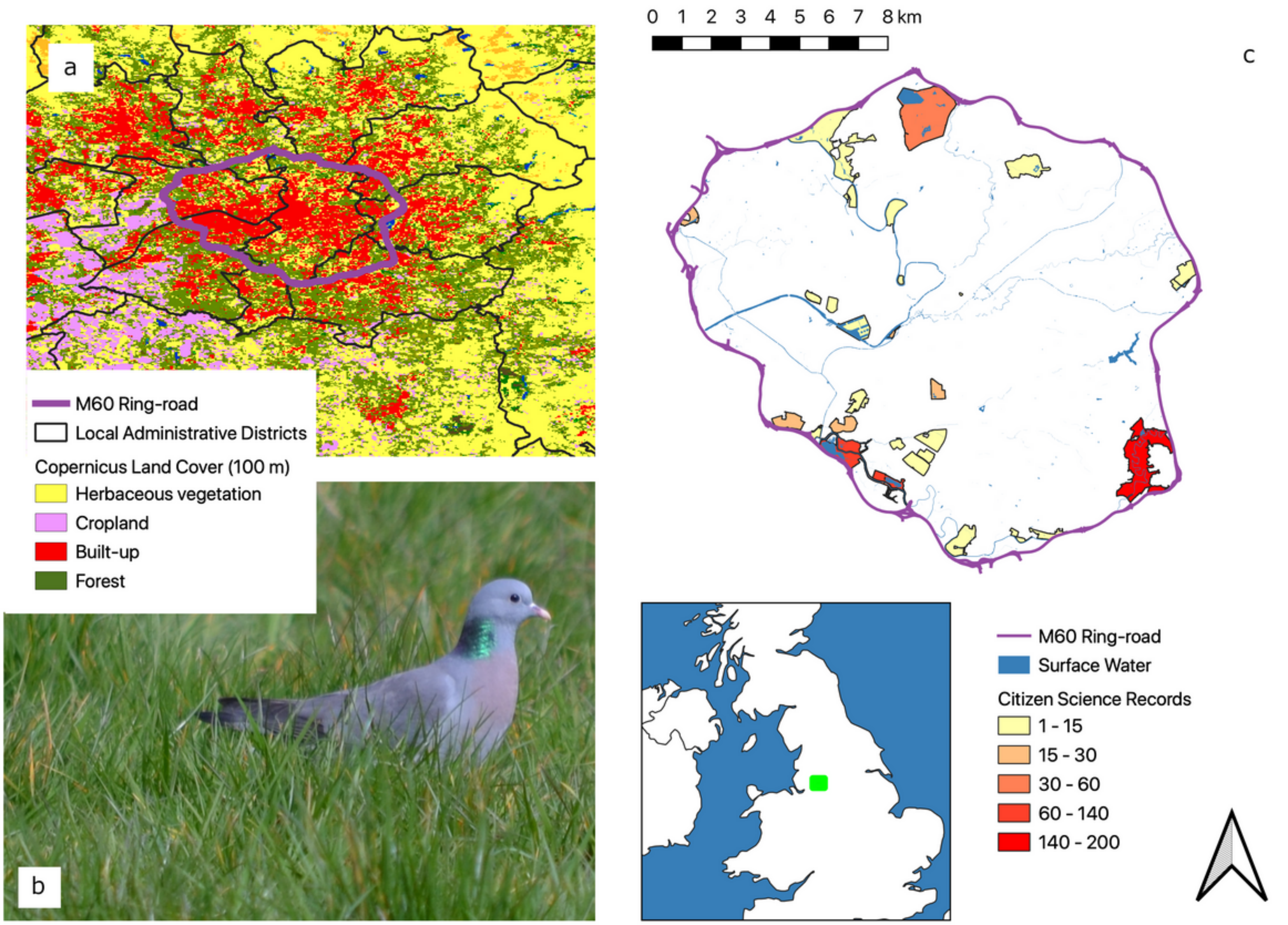

Figure 1

(a) Land cover in the region surrounding Manchester (Buchhorn et al 2020). (b) Urban Stock Dove in Alexandra Park (April 2020). (c) Patches with previous Stock Dove Sightings inside the Manchester M60 Ring-Road from Citizen Science sources.

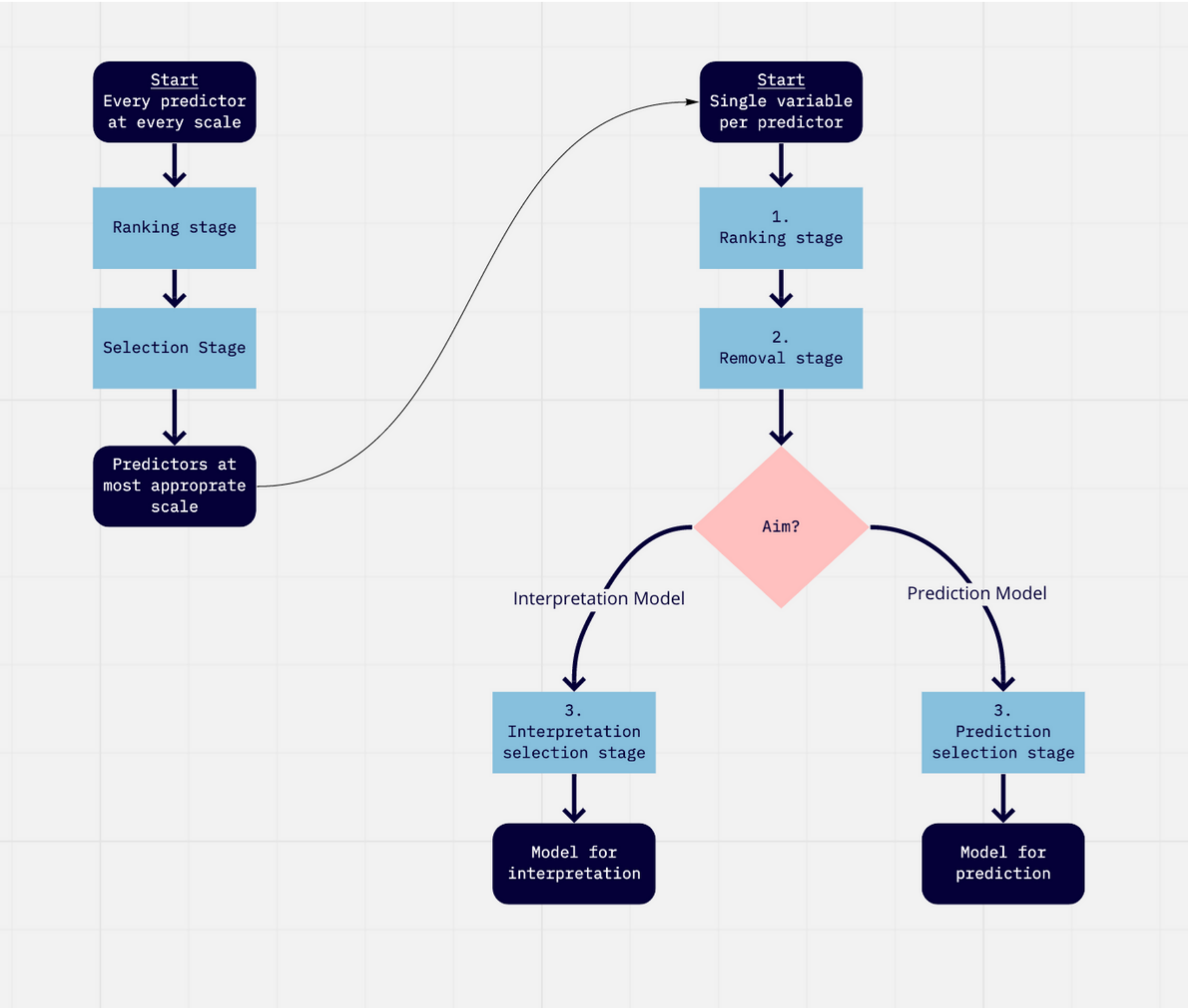

Figure 2

The initial selection of scaled predictors (left), followed by the three stages of model selection based on the method described by Genuer et al. (2010) (right).

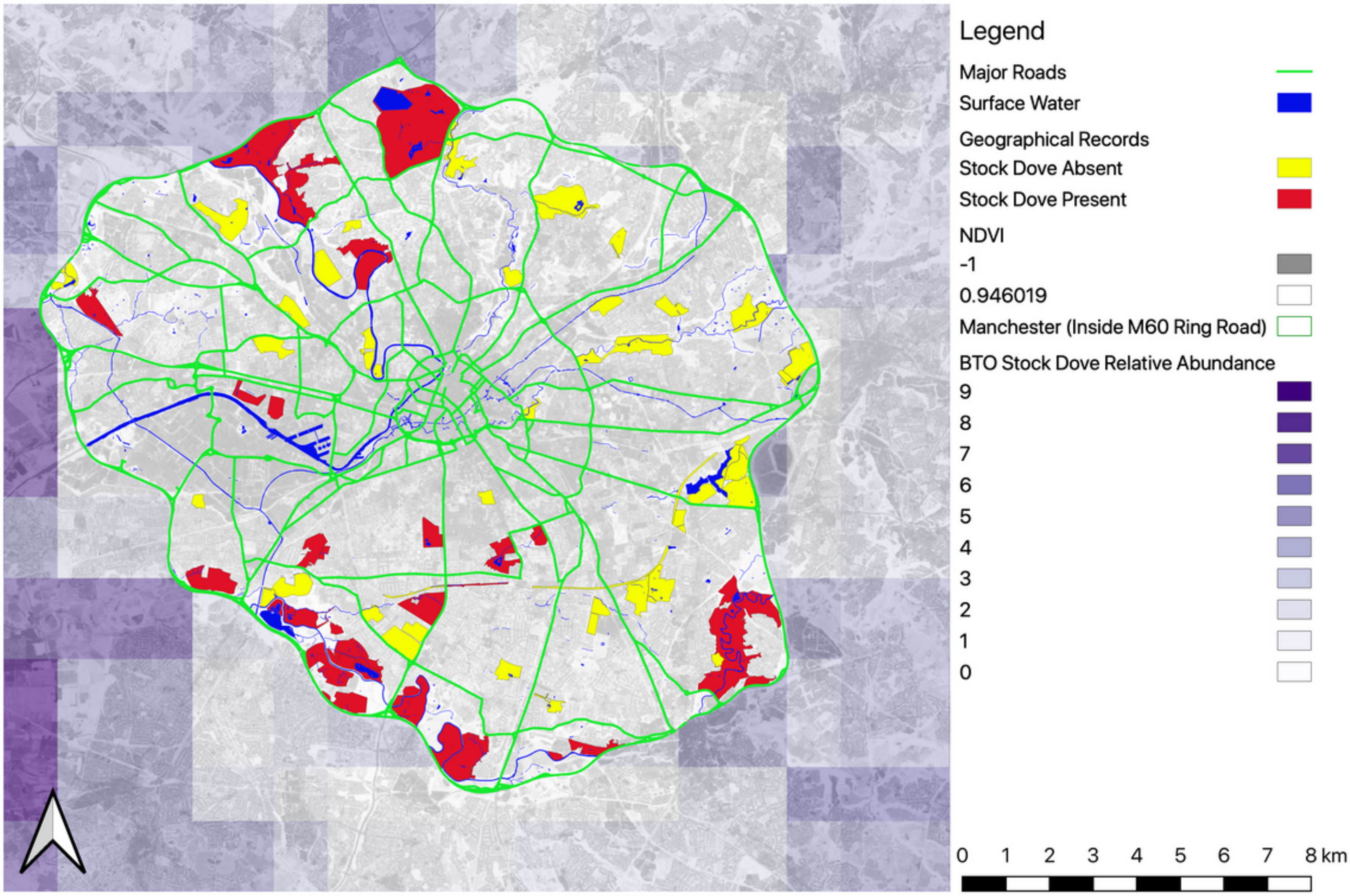

Figure 3

The 65 sample patches across Manchester showing where Stock Dove were present and absent. Base layers for some predictor variables are shown including NDVI, BTO Relative Abundance (outside of the M60 only) and surface water.

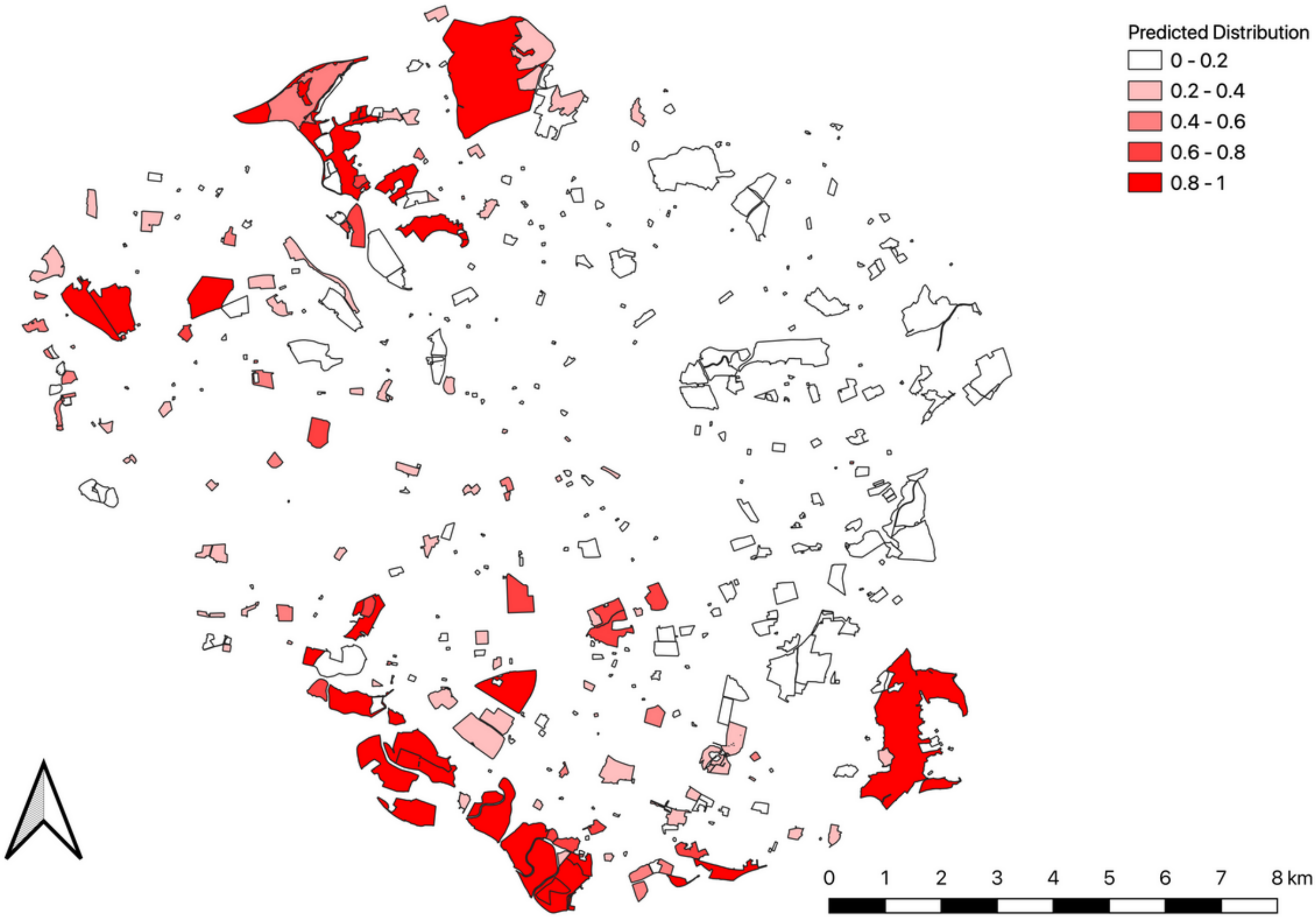

Figure 4

Each patch from the OS Greenspace dataset (Ordnance Survey, 2018a) with the probability of Stock Dove presence calculated using the R random forest package (Liaw and Wiener, 2002) using the model selected for prediction (Table 2).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- fieldsurvey.csv
- historicdata.csv