BTO RESEARCH REPORT 740

Sensitivity mapping for breeding waders in Britain: towards producing zonal maps to guide wader conservation, forest expansion and other land-use changes.

Report with specific data for Northumberland and north-east Cumbria.

Peadar O'Connell, Mark Wilson, Anthony Wetherhill & John Calladine

BTO
Looking out for birds

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Sensitivity mapping for breeding waders in Britain: towards producing zonal maps to guide wader conservation, forest expansion and other land-use changes. Report with specific data for Northumberland and north-east Cumbria.

A report to the Forestry Commission, England

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EXECUTIVE SUMMARY

1. Breeding waders in Britain are high profile species of conservation concern because of their declining populations and the international significance of some of their populations. Forest expansion is one of the most important, ongoing and large-scale changes in land use that can provide conservation and wider environmental benefits, but also adversely affect populations of breeding waders. We describe models to be used towards the development of tools to guide, inform and minimise conflict between wader conservation and forest expansion.

2. Extensive data on breeding wader occurrence is typically available at spatial scales that are too coarse to best inform wader conservation and forestry stakeholders. Using statistical models (random forest regression trees) we model the predicted relative abundances of 10 species of breeding wader across Britain at 1-km square resolution. Bird data are taken from *Bird Atlas 2007–11*, which was a joint project between BTO, BirdWatch Ireland and the Scottish Ornithologists' Club, and modelled with a range of environmental data sets.

3. Overall, the predictive models performed well, as assessed by correlation with empirical data within the Bird Atlas data set and other independent data sets at both national (Britain) and regional (Northumberland and NE Cumbria) levels. Principal amongst which were the BTO/JNCC/RSPB Breeding Bird Survey (BBS) and bespoke surveys undertaken in 2021. The BBS involved using data collected for a wider annual monitoring programme (not just breeding waders) across the whole of Britain, while the bespoke surveys were undertaken within two areas of specific interest a) Northumberland and the NE Cumbria Forest Investment Zone FIZ (reported here) and b) the Cairngorms National Park (reported elsewhere).

4. The predictive models were most successful for Curlew and Oystercatcher and least successful for Ringed Plover and Greenshank. Limitations to modelling were associated with species that have a restricted distribution and/or occupy restricted habitats. In considering lowland or enclosed farmland, the model predictions for Curlew and Oystercatcher, potentially supplemented with those for Lapwing and Redshank, are likely to best represent the relative importance of areas for breeding waders. For more upland and unenclosed areas the predictions for Curlew and Golden Plover potentially provide the most reliable information.

5. The most practical interpretation of the model outputs will be to categorise the predicted relative abundances for each species in each 1-km square into discrete strata, producing a 'heat map' of relative importance for each species at 1-km resolution. Five strata are presented with the aim of informing decisions on thresholds, to identify a final three strata that will guide actions for wader conservation and inform the levels of scrutiny required for new forest planting or other developments.

6. In addition to guiding wader conservation, forest planning and other proposals, the model outputs can be used to assess the relative importance of particular landscapes, land uses and areas with statutory designations for breeding waders. These can be used to inform high-level policy decisions affecting breeding waders.

7. The outputs presented here are model outputs for the whole of Britain with bespoke ground- truthing specific to Northumberland and north-east Cumbria (that for the Cairngorms NP is reported separately). These are presented and discussed to facilitate discussions on how the outputs should be best made available in the public domain to facilitate the objectives of guiding, informing and minimising conflict between wader conservation and forest expansion.

1. INTRODUCTION

Most breeding waders in Britain are now on either UK Red (Lapwing *Vanellus vanellus*, Curlew *Numenius arquata*, Ringed Plover *Charadrius hiaticula*) or Amber (Oystercatcher *Haematopus ostralegus*, Common Sandpiper *Actitis hypoleucos*, Redshank *Tringa totanus*, Snipe *Gallinago gallinago*, Dunlin *Calidris alpina*, Greenshank *Tringa nebularia* lists of Birds of Conservation Concern on account of their rates of decline in breeding populations (Eaton *et al.* 2015). Golden Plover *Pluvialis apricaria* remains the only relatively widespread breeding wader that is not so listed.

Although important, and in some cases sizeable, breeding populations of all of these species remain in parts of Britain, their numbers have declined over the past 25 years. For example, populations of Curlew (now a priority species for conservation action) have declined by 48% (95% confidence interval: -55% to -41%) since 1995 across the UK (Harris *et al.* 2020). In the same period, Lapwing populations have declined by 43% (-51 to -36%), Redshank by 42% (-61 to -7%) and Oystercatcher by 24% (-34 to 14%) (Harris *et al.* 2020). These declines have been attributed to changes in land use, including agricultural intensification, drainage and forest expansion, and to increased influences of predation which have in turn been influenced by changes of land use. Improved knowledge on the distributions of breeding waders will facilitate effective targeting of conservation management for them and guide operations that could add further constraints for them away from important areas.

Forest expansion is taking place at a large scale, and arguably has a greater potential for adverse impacts on breeding wader populations than many other land-use changes likely to happen in Britain in the foreseeable future (Burton *et al.* 2018, Thomas *et al.* 2019). For example, the Scottish Forestry Strategy sets out ambitious goals for woodland expansion and aims to achieve 21% land cover by 2032 through increasing annual afforestation targets to 150 km^2 by 2025 (Scottish Government 2019).

New woodland creation and regeneration provide opportunities for biodiversity (including birds) but also involve risks to some bird species and assemblages. Waders have a high profile among the species of conservation concern that can be negatively affected by forest expansion through replacement and fragmentation of their required open habitats and associated changes in predation risk (Calladine *et al.* 2018). While forest expansion is likely to adversely affect breeding wader populations it should also be recognised that forest expansion in Scotland is providing opportunities for other birds which are also conservation priorities, notably some migrant passerines that rely on woodlands and shrublands (Gillings *et al.* 2000, Calladine *et al.* 2019).

Changing land uses can provide both constraints and opportunities to species of conservation concern. There is therefore a need to provide tools for use by those who are responsible for deciding whether, where and in what manner land changes take place, and by those who want to target management for specific groups of birds, for example breeding waders. Such tools would indicate areas where:

- Risks to birds of open habitats and landscapes are greatest;
- Risks to birds of open habitats and landscapes are low;
- Opportunities to enhance conservation of forest and woodland birds are greatest.

This report describes work towards the development of tools to identify important areas specifically for breeding waders, but equivalent tools to indicate where opportunities for woodland species of conservation concern are greatest could also help decision-makers to effectively prioritise between overall costs and benefits for conservation, as well as other kinds of societal benefit. Such tools should enable proposals, such as for new forests, to more effectively target areas where conservation conflicts would be minimised and net benefit could be maximised.

A tool to model species-specific risks and opportunities requires detailed spatial knowledge of species distributions. This can be achieved through modelling the relationship between a species' abundance (from appropriate sample-based surveying) and various environmental variables that determine their distribution (e.g. Brambilla *et al.* 2009, Maleki *et al.* 2016). As well as generating information on previous or existing spatial patterns of distribution and abundance, this approach can allow us to understand how a species is likely to respond to changes in its environment. This understanding can be useful to decision-makers aiming to conserve the species, as well as those wishing to make changes to existing landscapes for any purposes that have the potential to compete with conservation management.

This report builds on and combines the outputs from closely-related but regionally-restricted projects (in Northumberland and north-east Cumbria, the Cairngorms National Park, the Northern Upland Chain partnership area in the Northern Pennines and in the Scottish Borders). We present results based on models for all of Britain as well as one regional example (Northumberland and the north-east Cumbria Forestry Investment Zone (NE Cumbria FIZ)) as an area for which this work has been specifically commissioned. A separate report has been written for the Cairngorms National Park.

As well as reprocessing the mapped information to improve the resolution (from 2-km to 1-km), the outputs are tested with independent data and bespoke fieldwork in 2021 to assess their predictive capabilities at both national and regional levels. There remains a need for the draft maps presented here to be critically assessed by stakeholders, to determine what further refinements are necessary and how they are best presented and made available to ensure their suitability for distinguishing areas of relative importance for breeding waders. Such maps could be used to inform and mitigate potential risks associated with land-use change (such as new forest creation), to target conservation action for waders, or to plan research aimed at improving our understanding of breeding wader declines. In addition, we also explore the relationship between certain land area categories (i.e. geographic and political boundaries, landscapes, designations and particular land management systems) and their importance for breeding waders.

2. METHODS

For each of 10 species of breeding wader (Lapwing, Oystercatcher, Curlew, Snipe, Golden Plover, Ringed Plover, Redshank, Greenshank, Dunlin and Common Sandpiper) the relative importance of areas across Britain was predicted using random forest regression tree modelling. Bird data to inform these predictions were sourced from extensive national atlases of breeding bird distribution (Section 2.1) and modelled with a range of environmental variables (Section 2.2) to produce indices of expected abundance at 1-km square resolution (Section 2.3). The resulting indices were then used to identify strata of predicted relative importance for breeding waders (Section 2.3).

The predictive capabilities of the models are assessed by comparing their outputs with independent data and professional fieldwork carried out in Northumberland and the NE Cumbria FIZ designed specifically to ground truth the models predicted strata and help derive a density estimate for each of these strata (Section 2.4).

2.1 Bird data for predictive modelling

Data on breeding distribution and abundance were derived from the bird atlas fieldwork conducted in 2008-11 (Balmer *et al.* 2013, hereafter BA2010). Excluded were data from the Channel Islands, Isle of Man or from the island of Ireland, due to some of the environmental data sets used in the models being unavailable for these areas. Bird recorders surveyed a sample of tetrads (2 km by 2 km), making two one-hour visits to each tetrad (a timed-tetrad-visit or TTV); one in the early part of the breeding season (April–May) and one in the late part (June–July). Within each hectad (10 km by 10 km square), at least eight tetrads were sampled. In some cases, two-hour visits were made to each tetrad but counts were recorded for each hour separately. To assess and map breeding wader abundance, we used the BA2010 atlas data and extracted the maximum count of the early and late season visits per tetrad. Where a two-hour visit was made, the mean of the two hour-long counts was used as the count contributing to the maximum between the two seasonally separated visits.

It should be noted that bird recorders for BA2010 were volunteers and recorded all species or individuals seen regardless of whether they were actively breeding. This means that observers sometimes encountered non-breeding flocks of waders. To limit the influence of these records on modelled outputs, any counts or presence information outside the known range (judged from recorded breeding evidence as less than 'probable' within the hectad including the tetrad count) were turned to zeroes/absences. Despite this, a small proportion of wader counts within the national data set was very large (for example, up to 400 Curlew per tetrad) indicating that some non-breeding flocks had been included within the breeding range. Prior to modelling, counts greater than 18 were capped by changing them to the median count, in order to minimise the influence of large, non-breeding flocks on models aimed at estimating breeding abundance. Examination of the distribution of data suggested that 18 was an appropriate cut-off (Table 1).

2.2 Environmental variables for predictive modelling

A number of environmental data sets were used to represent the available variables that were deemed most likely to affect breeding waders and woodland birds. Wherever possible, data were selected that were well matched, temporally and spatially, to the Bird Atlas data.

2.2.1 Climate (temperature and precipitation)

Climate data was available at the 5-km resolution from the Met Office's UK climate projections for 2009 (available at: www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/download/index.html). The data are generated for a regular 5-km grid via regression and interpolation of raw data derived from the irregular weather station network, taking into account longitude, latitude, elevation, terrain shape, coastal influence, and urban land use (Perry & Hollis 2005). To encompass conditions when the birds were breeding we used the mean of mean monthly temperatures and the mean of total monthly rainfall from the months April, May, June and July. For winter conditions, the mean of mean winter temperatures and the mean of total rainfall from the months of December, January and February before the breeding season of interest (i.e. December 2007 for 2008 survey) were calculated. The mean of these variables for each 5-km square was then calculated for each 5-km square for the years 2008 to 2011.

2.2.2 Topography (elevation and slope)

Elevation (in meters above sea level) was extracted from the GGIAR-SRTM 90m raster (Jarvis *et al.* 2008, available at http://srtm.csi.cgiar.org) taking the mean elevation over each tetrad or hectad (depending on the scale of the analysis). Slope was calculated from elevation in ARCGIS (ESRI 2017). The slope of each elevation raster cell is the maximum rate of change in elevation in one raster cell compared to its eight neighbours. The lower slope values indicate flatter areas, higher values indicate steeper areas. The median slope was taken for each 1-km square or tetrad, as this represents mostly flat areas more effectively than mean slope.

2.2.3 Habitat

Land cover data came from the 1-km square percentage cover summary of the 2015 Land Cover Map (LCM) from the Centre for Ecology and Hydrology (Rowland *et al.* 2017). Seven land cover categories were derived from the LCM dataset: (i) semi-natural unimproved grassland (including rough grassland, neutral grassland, calcareous grassland, acid grassland and fen, marsh and swamp); (ii) mountain, heath and bog (including heather, heather grassland, montane habitats and inland rock); (iii) intensively managed arable land; (iv) intensively managed improved grassland; (v) urban and suburban habitats (including built land, and suburban land); and (vi) broadleaved woodland and (vii) coniferous woodland. The mean percentage of organic carbon in topsoil from the European soil data centre (Jones *et al.* 2003) was used as an indication of the peat content of soils.

For more in-depth data on the availability and configuration of woodland we used the Forestry Commission's National Forest Inventory for 2011 (www.forestresearch.gov.uk/tools-and-resources/national-forest-inventory). The relevant variables were extracted at 1-km square level by intersection of the relevant forestry shape files and a polygon layer of 1-km squares in ARCGIS. Percentage cover was calculated by summing over each 1-km square. As a measure of patchiness, the perimeter length of mature woodland was calculated for each 1-km square and a measure of heterogeneity (to represent both structural diversity and patchiness) was also calculated by summing the number of separate woodland habitat parcels in each 1-km square. Here, we combined regenerating shrubby under-storey, young growth stage plantations and shrub woodland into 'young growth stage trees' and bare ground, rock, forest tracks and grass into 'clearings'.

The data available on forestry structure for the whole of Britain does not extend to types of trees beyond conifer or deciduous. Data on tree age and density of woodland is also limited to broad categories such as low density, scrub, clearings and young trees.

2.2.4 Wind farms and roads

Data on wind farm developments came from the Renewable Energy Planning Database (REPD) (Available from: www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract). The dataset gave the energy output expected for the wind farm (MW) and a central coordinate for the location of the wind farm but not an area. Therefore we estimated the area from a formula derived by Bright *et al.* (2008):

footprint (km^2) = (7E-5 × Output2) + (0.0505 × Output) + 0.0295.

Then, because a recent paper found breeding bird densities may be reduced within a 500-m radius of wind turbines, we added 1-km square to the total footprint area (Pearce-Higgins *et al.* 2009). Then we converted this area into a circular buffer centred on the coordinates given for the wind farm to use as an approximation of the footprint of impact of a wind farm. Lastly we intersected these buffers and a shapefile of

1-km grid squares to determine the percentage of each tetrad/1-km square was likely to be effected by wind developments.

We used the Annual Average Daily Flows (AADF) data from the department of transport for major roads (A roads and motorways) as an indication of heavy road traffic. The AADFs are calculated from around 10,000 manual point counts and automatic traffic counters, the observed data was roads adjusted to compensate for road length (Available at: www.dft.gov.uk/traffic-counts).

2.2.5 Predation risk

There is not currently robust tetrad/hectad level data on mammal abundance for the whole of Britain and even presence-absence data are in short supply. Due to the lack of detailed distribution data, mammalian predators were assumed present throughout mainland Britain, which meant the resulting variable was highly skewed, predominantly consisting of presences. Fox *Vulpes vulpes* trends generated from the Breeding Birds Survey (Massimino *et al.* 2018) were also used to calculate an index of Fox abundance in 2007.

Better data are available for avian predators, from the Atlas. In order to generate tetrad-level estimates of abundance for individual avian predator species, we carried out random forest regression tree modelling, following the methods outlined below. All of the above environmental variables, including those pertaining to mammalian predators, were included in these models. We used these models to predict relative abundance (average TTV count) of Buzzard *Buteo buteo*, Raven *Corvus corax* and Carrion/Hooded Crows *Corvus corone* (combined) in every tetrad. The abundances of these predatory species were included in our models of wader abundance as surrogates for the risk of avian predation on the eggs and chicks of breeding waders.

An important factor influencing the variation in predation risk across mainland Britain is predator control, which is particularly associated with management for Red Grouse *Lagopus lagopus scotica*. The control of predators (typically corvids, Fox, Stoat *Mustela erminea* and Weasel *Mustela nivalis*) is a key management practice for grouse moors aiming to enhance survival and breeding success of ground-nesting gamebirds (Tharme *et al.* 2001, Fletcher *et al.* 2010). Such areas arguably represent the only areas in Britain where predator control is effective at a landscape scale. Other studies (e.g. Franks *et al.* 2017, Douglas *et al.* 2013) have inferred variation in intensity of predator control from spatial patterns in muirburn (a practice closely associated with grouse management whose effects on vegetation can easily be detected in aerial photos). However, not all areas subject to predator control aimed at enhancing Red Grouse populations are intensively burned. We therefore used estimated Red Grouse densities as a more direct index of the intensity of management for that species which would be inclusive of predator control. We modelled the relative abundance of Red Grouse using Bird Atlas data, as described above for avian predators (and in more detail below for waders). However, we included avian predators as explanatory variables in the models of Red Grouse abundance.

2.3 Predictive modelling

All data analysis and manipulations were carried out in R 3.6.1. The following packages were used: randomForest, rgdal, sf, birdatlas and stringr. The explanatory variables, most of which were at a resolution of 1-km, were rescaled to tetrad level in order to make them correspond with Bird Atlas data. All variables were retained in every model, as one of the advantages of random forest models is that collinearity among explanatory variables (that is, explanatory variables that are closely correlated with one another and so are likely to bear similar relationships to the response variable) is much less problematic than it is in traditional linear modelling approaches.

2.3.1 Modelling wader abundance and occurrence

Random Forest modelling was used to generate models of abundance and occurrence for the 10 wader species (Common Sandpiper, Curlew, Dunlin, Golden Plover, Lapwing, Oystercatcher, Redshank, Greenshank Ringed Plover and Snipe). These species were selected as the most widespread and therefore potentially best suited breeding waders for extensive modelling, but also including some species with more restricted breeding ranges (e.g. Greenshank) and preferences for more fragmented habitats (e.g. Common Sandpiper) to be able assess the modelling limitations. Random Forest Regression Trees (RFRTs) were used to model relative abundance (with hourly TTV counts as the response variable) to derive maps of relative importance for breeding waders during the time of BA2010.

The models were built using the R package randomForest (Liaw & Weiner 2002), which is based on the random forest classifier described by Breiman (2001). A random forest is a classifier consisting of a larger number of regression or classification trees. Each tree recursively partitions a dataset; repeatedly subdividing based on thresholds values of explanatory variables that best explain variation in the dependent variable (for regression) or predict discrete outcomes (for classification). The predicted value for each terminal node (or 'leaf') of the tree is simply the sample mean of the dependent value for all data points in that subdivision. In a random forest, each tree is based on a bootstrapped data set, generated by sampling the original data set with replacement. For any given data point, the predicted values for each tree are averaged to yield a prediction from the whole random forest.

For the RFRTs, the number of 'trees' in each 'random forest' was set at 500, and the number of variables sampled as candidates for each tree set at 5 (derived as p/3, where p is the number explanatory variables included in the full model). These models were used to predict relative abundance (from BA2010 data) for all tetrads in Britain. We used iterative Chi-squared tests to determine which threshold (from 0.01 to 1) most effectively discriminated between modelled count values for tetrads in 10km squares with and without probable (or better) evidence of breeding. Values of modelled abundance or probability of occurrence that were lower than this threshold were set to zero.

The 'fit' of random forest models (i.e. how well they performed in predicting wader abundance occurrence values) was assessed as R-squared for RFRTs. In both cases, the performance of the forest was made using out-of-the-bag (OOB) predictions. This means that our estimates of predictive power for these models are effectively based on independent data, and so should provide a good indication of their ability to model abundance and occurrence in areas where no Atlas data were collected. The importance of each variable in determining random forest model predictions was assessed according to increase in node purity (Breiman 2001). Node purity was measured as the mean decrease in sum of squares subsequent to splits based on the variable for RFRTs.

2.3.2 Rescaling to derive model outputs at 1-km square resolution

In order to refine the scale at which we could predict and present information about abundance and distribution of birds, we took 1-km resolution data for each of our explanatory variables and summarised them to tetrad level for each of four shifted tetrad grids (Figure 1). We applied the abundance and distribution models described above to all four grids to generate predicted values for each tetrad in the grid. For every 1-km square in the areas of interest we extracted the predicted value from each of the four tetrads that contained the centroid of that 1-km square. We used the averages of these tetrad-level estimates as measures of relative abundance and occurrence at the 1-km level. It should be noted that these values, although applied to 1-km squares, are at the same scales of abundance and occurrence probability as the original (tetrad-level) Atlas values. This means that values of relative abundance and probability of occurrence at the 1-km scale can be directly compared with those at the tetrad scale. However, if interpreting these literally as probabilities of occurrence or number of birds likely to be counted during TTVs, or if summarising these 1-km values across larger areas, it should be borne in mind that the values are tetrad means.

2.3.3 Stratification of importance for breeding waders

Five provisional and somewhat arbitrary abundance strata were developed from the model predictions of relative abundance to illustrate the potential uses of this approach. The 99.5th percentile of the index of relative abundance was taken as a maximum marker value in order to exclude a very small number of high outlying predictions for some species. The 'hot' stratum included all squares where the predicted index of abundance was greater than 40% of the 99.5th percentile value. Three intermediate 'warm' strata included all squares where the predicted index of abundance lay between 10–40% of the 99.5th percentile value (these strata comprising predicted abundances of 10–20%, 20–30% and 30–40%). The 'cool' stratum comprised all remaining squares (i.e. with predicted abundances in the bottom 10% of values).

Once assessed and, if necessary, adjusted according to stakeholder needs, these strata could be used to gauge national importance based on the variation in predicted abundance indices across Britain. In this report, we present provisional maps of zonal abundance for all Britain and for Northumberland and the NE Cumbria FIZ.

2.4 Assessing the predictive capabilities of models

A combination of existing independent survey data, bespoke breeding wader surveys and additional relevant fieldwork was used to assess the predictive capabilities of the RFRT models and also potential changes since the source bird data for the models were collected (2008–11). Assessments were made at the both national (all of Britain) and regional (Northumberland and NE Cumbria).

2.4.1 The BTO/JNCC/RSPB Breeding Bird Survey 2008–2019

A principal source of independent contemporary data used to assess the predictive capabilities of the RFRT models and also subsequent change was the BTO/JNCC/RSPB Breeding Bird Survey (BBS; e.g. Harris *et al.* 2020). The BBS sampled between 3,247 and 3,341 randomly selected 1-km squares across the UK per year during the same period as covered by BA2010 permitting both extensive and representative assessments of the predictive models across Britain. In addition a further 61 1-km 'BBS augmentation squares' in south-west Scotland (Calladine *et al.* 2014) were also included within the assessment.

Although the BBS is not targeted specifically towards surveying breeding waders, it samples all birds (including waders) during the time of year when waders are breeding in Britain. Birds are recorded from two 1-km long survey transects within a 1-km square, noting the 200 m transect section (there are 10 such sections per survey square) and distance bands (0–25 m; 25–100 m and 100 m+ from the transect line) they occur in. The distance information allows density estimates to be calculated for each survey square (see below) which we have used as empirical data against which we could test the RFRT predictions for the same squares.

Uncapped distance bands (as in the third >100 m BBS band) cannot be used in distance analyses; however, many waders will typically be recorded in the >100 m band during BBS surveys (for example 42% of Curlew between 2008–11) and restricting further analyses to registrations within 100 m (as per Newson *et al.* 2008 for passerines) would likely compromise the calculation of density estimates for waders. To be able to include all data, and based on our experience in the field, we assumed that the third distance band was truncated at 250 m.

BBS surveys involve two visits per year, one early (early April–mid May) and one late (mid May–late June). For the purposes of this study only the visit with the highest number of individuals counted for each species (discarding flocks) per 1-km square each year was used to estimate densities for each species using distance sampling methods.

The densities of breeding waders within each square surveyed using BBS methodology were calculated using distance sampling (Bibby *et al.* 2000, Thomas et al. 2010) and the Distance package (ver. 1.0.1) for R (R Development Core Team 2019). Distance sampling works on the principle that objects tend to become more difficult to detect as their distance from an observer increases. As a result, the proportion of the objects that are present, but that go undetected during a survey, will tend to be negatively related to their distance from the surveyor. A half normal model with null adjustments (best fitting models judged by lowest AIC scores) was run for each species to calculate mean densities for every survey square in each of the two survey periods (BA2010 and 'Recent'). The 5th, 25th, 50th (the median), 75th and 95th percentiles of the ordered Distance derived density estimates for each species were calculated for each of the BA2010-RFRT modelled strata (Section 2.3.3) to directly compare the modelled predictions with the BBS-derived empirical data.

BBS-derived empirical abundance strata were allocated to each survey square using the mid-points between the median abundances for all squares within each RFRT-derived stratum. For example, for Curlew, the mid-point between the median abundances for squares lying in the 2008–11 period RFRT-predicted strata 2 and 3 is 1.2 birds per km^2 (after Table 12). Similarly the mid-point between strata 3 and 4 is 2.0 birds per km^2. Therefore, all survey squares with a mean abundance between 1.5 and 2.0 birds per km^2 were allocated to the BBS-derived empirical abundance stratum 3. Contingency tables were produced to compare the numbers of squares in each combination of BBS-derived and RFRT-predicted abundance strata.

Acknowledging that the RFRT model predictions are based on data that are now 10 years old, similar comparisons to those made with concurrent data were made with a more recent run of BBS data (2016–19) as one approach to assess any changes and the continued representativeness of modelled outputs. A further approach to assess change included comparisons with bespoke fieldwork and BBS data from 2021 (see Section 2.4.3).

2.4.2 Other datasets contemporary with BA2010

A number of other data sets were also investigated so that comparisons could be made with the BA2010-RFRT predictions. These were: (i) Shetland Biodiversity Records Centre's Breeding Bird Survey (2004–19); (ii) Natural England's moorland bird surveys of the North Pennines (2006–07); (iii) the BTO/RSPB/SNH Uist wader surveys (2007–2010 and 2014); (iv) RSPB combined data sets from Scotland (2004–2019); (iv) RSPB Hiraethog data for Curlew (2010); (v) Redshank surveys around Britain (2011); (vi) BTO/Natural England/RSPB Breeding Waders of English Upland Farms surveys (2016)

These data sets were not interrogated to the same extent as the BBS data, often because there were insufficient data. Most of these were dedicated wader surveys and covered discreet areas which could, in many cases, be considered to be hotspots for breeding waders, as these areas are more likely to be surveyed as part of a targeted wader survey. The one exception to this is the Shetland Biodiversity Records Centre Breeding Bird Survey (SBRCBBS; Hughes *et al.* 2021) which follows similar, but not identical, methodology to the standard BBS survey rather than specifically targeted at waders.

In order to permit direct comparisons with the RFRT modelled predictions, count data from these surveys were converted to densities per 1-km square or where shapefiles were provided to density within the survey area, noting that many 1-km squares were not surveyed in their entirety. The median, 25th and 75th percentiles were then calculated for 1-km squares lying within each of the RFRT predicted abundance strata (Section 2.3.3). Where data derived from surveys where multiple visits of each surveyed area were undertaken, maximum counts were used. Data that comprised 'pair summaries' were used as provided, accepting any assumptions made by the providers of these data. Data from the Breeding Waders of English Upland Farms surveys were provided at tetrad resolution and so, to permit comparison, the relevant RFRT predictions were converted from 1-km square to tetrad resolution.

2.4.3 Ground-truthing the model with fieldwork in 2021

To ground truth the model predictions, data from two different field based projects in 2021 were used: (a) bespoke fieldwork undertaken by professional surveyors; and (b) data extracted from the annual national monitoring programme, the BBS undertaken by volunteer surveyors.

Bespoke wader surveys were undertaken in the spring and summer of 2021 in the Northumberland and the NE Cumbria FIZ. Priority species surveyed were Curlew, Lapwing, Oystercatcher and Redshank; however, all waders encountered were recorded. With a given priority for new surveys to sample marginal hill ground, a constant-effort-search approach was chosen as the most appropriate survey methodology. This ensures compatibility with approaches widely used to survey inbye farmland (the O'Brien & Smith (1992) method) and open moorland (the Brown & Shepherd (1993) method). In total 78 1-km squares were surveyed within the study area by professional BTO staff in 2021 as part of this project. Survey squares (Figure 2, Table 2) were selected at random within the study area after being stratified to sample the provisional strata of relative abundance for Curlew (Figure 3). Nine squares from the modelled 'cool' stratum (stratum 1), 53 squares from the 'warm' stratum (strata 2-4) and 16 squares from the 'hot' stratum (stratum 5) were selected.

Each square was surveyed twice, an early visit between early April to mid-May and a late visit between mid-May to late June. Surveys were conducted between the hours of dawn and noon; exceptionally surveys were conducted after 12:00 when this could not be avoided. All parts of the survey square were walked to within 100 m where possible, or adjacent fields were scanned from a good vantage point where there were unobstructed views. All waders encountered were recorded and plotted along with their relevant behaviour. This permitted calculation of density estimates (apparent territories) for the sampled areas.

When possible, simultaneous registrations of birds were used to identify different territories. Where this was not possible, the arbitrary but accepted recommendations for defining separation distances within mostly open landscapes for apparent territories of different species was used (Brown & Shepard, 1993). This states that distinct territories are recorded when separated by 500 m or more (200 m for Dunlin, Ringed Plover and Snipe) on the same survey visit and 1000 m or more (500 m for Dunlin, Ringed Plover and Snipe) if combining data from more than one survey visit. The survey areas were relatively small when compared to these apparent territory separation distances. To account for this we looked at the sensitivity of interpretation by reducing that distance by half (500 m (100 m for Dunlin, Ringed Plover and Snipe)) between visits; however, this made negligible difference and so we opted to use the original criteria as it had precedent. Although some survey squares consisted of predominantly enclosed fields rather than open ground, it was important to have a standard method to estimate apparent territories.

An additional 77 1-km squares within Northumberland and NE Cumbria in 2021 were surveyed by volunteers as part of the national monitoring programme the BBS. Survey methods and interpretation were identical to that described for earlier years in Section 2.2.1.

The number of apparent territories calculated for each species within each 1-km square following two bespoke breeding wader visits by professional surveyors was used to provide a density estimate for each square surveyed. To make comparable with the BBS data, the numbers of apparent territories calculated for each square for each species were multiplied by two to obtain an estimate of individuals for each square. These values were appended to the analysed BBS data from Northumberland and the NE Cumbria FIZ. Percentiles representative of both sets of data were then produced (Table 6) for the species encountered in sufficient numbers (Curlew, Lapwing, Oystercatcher, Snipe and Golden Plover).

2.5 Relative importance of landscapes, land uses and designated areas

To illustrate other potential uses of the predictive models, we explored the relationship between certain land area categories (i.e. geographic and political boundaries, landscapes, designations and particular land management systems; Table 16, Figure 18) and their importance to breeding waders. The land area categories used to demonstrate this were:

Countries (England, Scotland, Wales);

Landscapes (Upland, Lowland, Mixed);

Statutory designation (SPAs, SACs, National Parks);

Restricted suites of and/or abundances of potential nest predators (Islands, managed grouse moors);

Nature reserves (RSPB).

Shape files for boundaries of the above categories were sourced from:
Country boundaries (NUTS Level 1 Full Clipped Boundaries in the United Kingdom) – https://data.gov.uk/dataset/26053db7-6caf-446f-8f7e-9775a19970e0/countries-december-2017-full-extent-boundaries-in-great-britain;
SACs for Scotland – https://www.nature.scot/professional-advice/protected-areas-and-species/protected-areas/international-designations/european-sites/special-areas-conservation-sacs;
SACs for England – https://sac.jncc.gov.uk/site/england;
SACs for Wales – https://sac.jncc.gov.uk/site/wales;
SPAs for Scotland – https://www.nature.scot/professional-advice/protected-areas-and-species/protected-areas/international-designations/european-sites/special-protection-areas-spas;
SPAs for England – https://naturalengland-defra.opendata.arcgis.com/datasets/special-protection-areas-england/explore?location=52.803785%2C-2.229306%2C6.78;
SPAs for Wales – https://lle.gov.wales/catalogue/item/ProtectedSitesSpecialProtectionAreas/?lang=en;
RSPB Reserves – https://opendata-rspb.opendata.arcgis.com/;
Scotland National Parks – https://www.spatialdata.gov.scot/;
England National Parks – https://environment.data.gov.uk/DefraDataDownload/;
Wales National Parks – http://lle.gov.wales/catalogue/ .

The derivation of shape files for landscapes and managed grouse moors is described below. The proportion of each species' population supported by each land area category was estimated in R, using the packages rgdal and sf. Subsets of wader data (RFRT predicted abundances) were extracted according to their overlap with the shape files for each category (as listed above). All grid squares completely or partially overlapping the polygons in each shapefile were included in the calculation.

Special Area of Conservation (SAC) and Special Protection Areas (SPA) area figures were acquired from the JNCC website (https://sac.jncc.gov.uk/site & https://jncc.gov.uk/our-work/list-of-spas). Sites classed as "offshore" were excluded from the final area figure, although inshore sites with marine components are still included.

We have assumed that areas with relatively high densities of Red Grouse recorded during BA2010 broadly coincide with areas managed for grouse shooting. The relative abundance of Red Grouse was modelled using RFRT, following the same approach as previously described for breeding waders (Section 2.3.1) but excluding Red Grouse as an indicator of predation risk. Clusters of two or more adjacent 1-km squares where the predicted densities were equivalent to one or more red grouse encountered per hour per 1-km square were assumed to represent high densities of red grouse likely to be associated with managed grouse moors. Additionally, a 500 m buffer was included around these areas to be inclusive of all areas where active control of potential predators might influence breeding wader abundance.

There is no universally accepted definition that consistently defines upland from lowland areas. Although altitude clearly has an influence, a single altitudinal threshold cannot be used to separate these strata across the whole of Britain. For example, extensive blanket mires are widely accepted as a typical upland habitat but occur close to sea level in exposed northern and western areas. For the purposes of this analysis, each 10-km square (hectad) of the Ordnance Survey's national grid was classed into one of three categories ('Upland', 'Mixed' and 'Lowland') by using habitat data from the Land Cover Map 2015 (LCM2015; Rowland *et al.* 2017). Firstly, an 'upland habitat' category was created by combining the categories for heath, mire and acid grassland. Each 1-km square was then defined as of 'upland character' if 30% or more of that square was classed among the 'upland habitat' categories by the LCM2015. Each hectad was then classed as: 'Upland' if 76% or more of the 1-km squares were of upland character; 'Mixed' if between 26% and 75% (inclusive) of the 1-km squares were of upland character; and 'Lowland' if 25% or less of the 1-km squares were of upland character.

3. RESULTS

3.1 Predictive capabilities of breeding wader abundance models

The predictive capabilities of the models across Britain performed best for Curlew, then Oystercatcher, Redshank, Snipe, Golden Plover, Lapwing, Dunlin, Common Sandpiper, Greenshank with those for Ringed Plover being the least satisfactory. Predictive performance was assessed by the proportion of variation explained by the factors included in the models (Table 3).

The relative importance of variables included in the models, as indicated by their inclusive node purity, varied between species (Table 4). Factors important for at least some breeding waders included habitat type (e.g. improved grassland or mountain, heath and bog habitats), soil chemistry (soil carbon), predation risk (Red Grouse, Raven, Buzzard and crows), weather (rainfall and temperature) and geographic location (latitude and longitude). The relative predictive importance of these variables models does not necessarily reflect the relative strengths of any causal effects. Each variable is inter-correlated with many others, including other model variables, as well as variation not explicitly accounted for in the models.

Maps depicting strata defining areas according to their predicted importance for breeding waders were produced for all 10 species for all of Britain and Northumberland and the north-east Cumbria FIZ (Figures 3–12). The thresholds defining the zones for each species are set according to the spread of abundance values across the whole of Britain. This should be borne in mind when comparing maps of different species. By and large, these thresholds define reasonably coherent zones for most species, drawing attention to relatively large areas (rather than simply a scatter of 1 km squares) that are likely to be of high value to breeding waders.

3.2 Comparisons of predicted outputs with empirical data

Spatial variation in empirical densities of breeding waders determined from BBS were broadly comparable with those predicted from the RFRT modelling of BA2010 with environmental data sets, both at the regional (Northumberland and NE Cumbria) scale (Table 6) and across Britain (Table 7). For example, the median number of Curlews found nationally within the highest predicted stratum was 6.4 (25th–75th percentile range, 3.6–11.47) during the BA2010 period, with 1.2 (0.4–2.4) within the middle three strata and 0 (0–1.2) in the lowest predicted stratum (Table 7). Comparisons between BBS-derived population densities between the BA2010 (2008–11) and recent (2015–18) periods illustrate the continued decline by many breeding waders and across all strata of relative abundance at the national scale (Table 7). For example, Curlew numbers in 2015–18 in the three categories were 5.1 (0.6–8.3), 1.2 (0–2.4) and 0 (0–0) (Table 7).

Regional data suggest that declines have not been as marked within Northumberland and NE Cumbria as they have been across Britain as a whole, and some may even have increased (Table 6). For example, the median number of Curlew found in the stratum with highest predicted abundance within Northumberland and NE Cumbria had increased from 5.3 (25th to 75th percentiles, 3.2–13.7) in 2008–11 to 7.1 (3.9–12.1) in 2008–11 (Table 6), though the difference was unlikely to have been statistically significant (considerable overlap between the 25th–75th percentile ranges). Surveys from 2021 however, recorded generally reduced densities (e.g. for Curlew, 2.8 (2.0–6.0) birds per km^2 within the highest predicted stratum; Table 6). Note that too few Greenshank records were included in the BBS data, as survey coverage within the breeding range of this species is generally poor.

Contingency tables showing where empirical densities (derived from BBS) fall within the RFRT predicted abundance strata further support that the effectiveness of the predicted models but importantly also show where the mismatches between predicted and empirical data lie, with square importance more often overestimated than underestimated by RFRT modelling

(Table 8). Visual, qualitative assessments suggest that most overestimates are in areas where many squares have high predicted abundance (Figures 13–17). Overestimates often relate to squares dominated by unsuitable habitats (e.g. wooded or steep slopes) that are close to squares with suitable habitats that would be likely to support high densities of waders. This is to be expected of 1-km resolution estimates based on tetrad-level counts. In terms of consequences for end users, these are likely to be small, as overestimates tend to be close to areas where wader densities are likely to be genuinely high and the level of scrutiny required for pre-development assessment or (other decisions relating to management and land use) would already be high.

Similarly, underestimates by the wader sensitivity modelled predictions were mostly in areas where density predictions are generally low. At a national scale, these included some coastal and known local hotspots (e.g. nature reserves) but for some, there appears to be no obvious reasons for the underestimates. However, there were very few 'seriously mismatched' squares (i.e. their BBS densities suggested 'Hot' and the Atlas prediction suggested 'Cool') at least for species where the statistics indicate good model performance.

The additional independent data sets examined were highly skewed towards areas with higher predicted wader densities as can be seen in the proportion of records in the "hottest" predicted areas (stratum 5; Tables 9–15). This is arguably to be expected as many wader surveys would have targeted areas that were known to be important for breeding waders or, in the case of the Shetland BBS, be part of a wider monitoring programme for an area that happens to be important for breeding waders. However, for some of the larger data sets, covering larger areas, such as RSPB Scotland's amalgamated breeding wader data (Table 11) and the Breeding Waders on English Upland Farms surveys (Table 12), the distribution for most of the wader species within the strata follows the same trend (higher to lower) as the predicted data..

3.3 Relative importance of landscapes, land uses and designated areas across Britain

Comparing the proportions of the British breeding waders within the landscape and other categories with their proportionate cover of Britain's land area provides some insight into the relative importance of certain landscapes, land uses and designations (Table 16). Upland landscapes supported disproportionately high densities of Golden Plover, Dunlin, Curlew and Common Sandpiper. Mixed landscapes appeared important for Curlew, Snipe and Oystercatcher. While lowland landscapes appeared most important for Lapwing, Redshank and Ringed Plover, none exceeded the proportionate land cover categorised as predominantly lowland. The role of predation as a constraint on breeding waders is implied by the relative importance of both islands, with naturally restricted suites of predators, and grouse moors where the abundances of predators are actively controlled.

Scotland supported a relatively high proportion of all 10 species likely reflecting the proportion of that country classed as uplands, islands and managed as grouse moors. Designated areas (SPAs and SACs) generally support favourable densities of breeding waders but there is considerable spatial overlap with managed grouse moors (Figure 18 g). Similarly, national parks support broadly favourable densities of breeding waders but these areas too include significant areas of uplands managed as grouse moors. Nature reserves, at least those managed by RSPB, constitute a relative small area of the land mass of Britain but supported relatively high densities of breeding waders.

4. DISCUSSION

4.1 Predictive capabilities of wader models

The predictive models were most successful for Curlew and Oystercatcher and least successful for Ringed Plover and Greenshank, with broad consensus in model success derived from independent data at both extensive national and more intensive regional levels. The performance of the models depends, in part, on the reliability with which observers detected the species in question during one-hour survey visits to a tetrad.

Curlew and Oystercatcher are likely to have been among the species most readily detected where present because they are relatively conspicuous, both visually and aurally (Grant *et al.* 2000, Wilson & Browne 1999). Species for which the models performed least well included species that are known to be challenging to survey and/or are associated with restricted habitats (e.g. Common Sandpiper, Dunlin and Ringed Plover; Dougall *et al.* 2010, Grant & Pearce-Higgins 2012, Conway *et al.* 2019). Therefore, when using the outputs of the models, greater emphasis should be given to those deriving from better performing models. In considering lowland or enclosed farmland, the heat maps for Curlew and Oystercatcher, potentially supplemented with those for Lapwing and Redshank, are likely to best represent the relative importance of areas for breeding waders. For more upland and unenclosed areas the heat maps for Curlew and Golden Plover potentially provide the most reliable information.

Although populations of breeding waders in Britain have continued to decline extensively (but not uniformly) since collection of data used in the models (2008–11), the predictions of density estimates still performed well against BBS data from the more recent period (2015–18) we looked at and also against bespoke data collected in 2021. For some species, the declines appeared to be less marked in Northumberland and the north-east Cumbria than for across the whole of Britain. Low numbers recorded in 2021 could be indicative of subsequent declines but there is some anecdotal evidence that breeding waders were affected by the particularly cold spring in 2021, with birds either failing early in their breeding attempts or potentially not breeding and, therefore, simply not being present or detected on breeding areas during the surveys. This highlights the importance of stochastic influences on wader surveys from single years.

4.2 Use of wader model outputs

The model outputs for waders are presented here at 1-km square resolution with five strata representing different relative abundances for each species. The resolution of outputs at 1-km is a workable compromise between the 'ideal' but impractical delivery of field-by-field information and the resolution of the extensive bird data available (a sample of tetrads).

Based on comparison with independent data, the three middle-ranking strata are the least well-defined from each other. Original discussions with stakeholders indicated that three strata of relative abundance/importance for breeding waders was considered by many to be the desired outcome. The main reason for presenting five strata in this report is to facilitate consideration of where the thresholds between three final strata might best be drawn. Ultimately, it is anticipated that the strata will be used to indicate areas where positive management for breeding waders may be most beneficial, and to inform the planning and assessment procedures for land-use change and developments that could be detrimental to breeding waders, such as the creation of new forests or the expansion of existing forested areas. Potential interpretations of the relative abundance zones could include:

Most important or 'Hot' areas – Priority areas, suitable for targeting measures aimed at maintaining their value for waders, or else areas within which prospective changes in management or land use (such as afforestation) should require detailed surveys of breeding waders to be carried out before these changes are consented;

Mid-range important or 'Warm' areas – Areas where appropriate measures might result in increased wader populations, or else areas within which plans for other management changes, such as afforestation, should be accompanied by some surveys of breeding waders to confirm, or otherwise, their importance;

Least important or 'Cool' areas – Areas likely to be of low priority for breeding wader conservation, or else areas within which plans for management changes such as afforestation may require minimal collection of additional supporting information on breeding waders.

It is important to note that the above categories and possible implications associated with them are offered here as examples only. It is also important to consider the possible consequences of actions based on these categories in situations where the relative abundance of breeding waders in a 1-km square is very different from the predicted value. Compared with strata based on independent surveys, abundance strata based on RFRT predictions were more often overestimated than underestimated. Over-predicting abundance was mostly within areas of actual high abundance, for example squares which were often wooded that were close to squares that are of suitable habitat and are likely to support high densities. This is to be expected given that the bird data originate from tetrad counts. In terms of consequences for end users looking to develop areas, for example by tree planting, these are likely to be small, in that they are close to high density areas and, therefore, any developments would deserve higher levels of scrutiny.

Furthermore, when considering plans for forest establishment or expansion, the area of influence, or 'buffer effects', will likely exceed that of the actual footprint of the affected area (Wilson *et al.* 2013) and there may also be a risk of cumulative negative effects (due to processes such as habitat fragmentation) arising from multiple new forests, even where the effects of any one of these might have been small (Douglas *et al.* 2013). The scale of buffer effects are poorly understood and are likely to vary between areas and landscapes and be, in part, determined by land use. For example, whether a wood impacts on the hydrology of neighbouring land or on risks of nest or chick predation will likely be determined by local soil types, climate and topography for hydrological impacts or on local levels of predator control for predation risk.

The scale at which cumulative effects operate in the landscape is also poorly understood, making it likely that a somewhat precautionary approach will be necessary in order to avoid a high risk of negative impacts. Such an approach might involve taking the importance of the surrounding area into consideration, in addition to that of the area accounted for by the direct footprint of a development. Occasional over-estimates of importance for waders in squares that are mostly situated in wider areas with relatively high wader densities could contribute to such a precautionary approach.

Underestimates by the wader sensitivity modelled predictions are mostly in areas of predicted low density. These arguably present a greater risk to stakeholders, as they could result in some sites with high wader densities being overlooked. Where this happens, the sites in question are likely to be relatively small, but they may still be of local or regional importance. In such situations, it is always likely that a combination of existing local knowledge and further pre-development assessment will be needed to minimise the risk of such small but significant sites being lost.

If using predicted abundance strata to direct conservation efforts or inform land management, it is important to bear in mind that they do not include any specific information on productivity. At a large scale, it is probably reasonable to conclude that regions and habitats with lots of waders have high levels of productivity too. However at 1-km scale, it is entirely possible that small patches of apparently high wader density could be acting as population sinks, maintained by immigration from more productive areas, and producing few if any fledged young each year. A better understanding of where productivity is higher and lower would greatly improve our understanding of where key areas for waders are at different spatial scales.

4.3 Evaluation, revision and finalisation of mapping zones

The zoned mapping outputs presented and discussed in this report require agreement from stakeholders and, potentially, revision in the light of any final comments. Before these maps are used to guide decision-making relevant to wader conservation, they should be critically evaluated by the stakeholder community in order to:

a) Assess whether the categories are defined at an appropriate resolution and agree the criteria for thresholds between a final three strata of relative importance, to allow stakeholders to make the best decisions based on the value of different areas for breeding waders;

b) Decide on the levels of scrutiny that should be associated with each category for any proposed developments;

c) Consider how to address cumulative impacts and the resolution at which to interrogate the mapping tool. For example, if a proposed development was within a square identified as low importance for breeding waders but nearby squares were of importance, then at what distance should this inform any decision process?;

d) Are the risks associated with inaccurate model predictions acceptable?;

e) How to accommodate differences in regional importance while maintaining a consistent approach across Britain?;

f) Is there value in knowing the relative importance (in terms of the proportion of wader populations supported) of different landscapes, designations and land uses and, if so, are other strata and areas that would be useful to assess in this way?

As well as constraints for biodiversity reliant on open habitats, forest expansion offers opportunities for species and assemblages reliant on woodlands. Considering the outcomes of forest expansion as a constraint on breeding waders through the replacement of habitats with others that are broadly unsuitable is relatively straightforward, though could benefit from a better understanding of how some constraints operate. However, understanding the opportunities for birds presented by forest expansion requires a much better understanding of the influences of factors such as tree (including crop) species composition, silvicultural treatments and landscape context (Calladine *et al.* 2018, Fuller & Robles 2018). In addition to mapping constraints of forest expansion for ground nesting birds (like the waders considered in this report) it will be important to also consider the opportunities presented for other species. Further work is needed to develop these models into tools that inform both the constraints and opportunities associated with forest planting and ongoing management plans.

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6. TABLES

Table 1. The proportion of timed-tetrad counts across Britain that were greater than 18 (and therefore capped to reduce the influence of non-breeding flocks on modelled outputs) and the median counts with which those higher counts were replaced.

Common name	Scientific name	Proportion of TTV counts < 18	Median count
Curlew	*Numenius arquata*	97%	2
Lapwing	*Vanellus vanellus*	94%	2
Oystercatcher	*Haemotopus ostralegus*	93%	2
Golden Plover	*Pluvialis apricaria*	93%	2
Redshank	*Tringa totanus*	95%	2
Dunlin	*Calidris alpina*	88%	2
Ringed Plover	*Charadrius hiaticula*	95%	2

Table 2. One-kilometre squares surveyed for breeding waders in Northumberland and NE Cumbria in 2021 by: (a) bespoke surveys undertaken by BTO staff; and (b) the BTO/JNCC/RSPB Breeding Bird Survey by volunteer surveyors.

(a) bespoke surveys undertaken by BTO staff

NT9024	NT9119	NT9120	NT9206	NT9217	NT9228	NT9306	NT9326
NT9414	NT9426	NT9507	NT9722	NU0000	NU0022	NU0514	NU0530
NU0824	NU1016	NU1022	NU1304	NU1427	NY3767	NY3964	NY4066
NY4074	NY4367	NY4678	NY4758	NY4771	NY4967	NY4974	NY4975
NY5071	NY5072	NY5368	NY5378	NY5476	NY5669	NY6063	NY6457
NY6563	NY6658	NY6860	NY6963	NY7495	NY8195	NY8292	NY8387
NY8394	NY8487	NY8492	NY8593	NY8689	NY8877	NY8893	NY8977
NY9178	NY9179	NY9187	NY9379	NY9395	NY9477	NY9499	NY9696
NY9782	NY9886	NZ0188	NZ0189	NZ0292	NZ0390	NZ0491	NZ0792
NZ1186	NZ1377	NZ1381	NZ1581	NZ1690	NZ1694		

(b) the BTO/JNCC/RSPB Breeding Bird Survey by volunteer surveyors.

NT7400	NT7503	NT7707	NT7911	NT7912	NT9040	NT9134	NT9136
NT9139	NT9910	NT9913	NT9914	NU0020	NU0134	NU0310	NU0416
NU0426	NU0804	NU0840	NU1019	NU1024	NU1100	NU1402	NU1800
NU1812	NU2110	NU2127	NY3673	NY5882	NY6080	NY6081	NY6558
NY6659	NY6758	NY7385	NY7762	NY7885	NY8065	NY8087	NY8274
NY8353	NY8360	NY8479	NY8692	NY8859	NY8870	NY8890	NY9059
NY9294	NY9567	NY9980	NZ0063	NZ0081	NZ0096	NZ0184	NZ0260
NZ0262	NZ0383	NZ0460	NZ0473	NZ0499	NZ0554	NZ0561	NZ0651
NZ0684	NZ0693	NZ0790	NZ1064	NZ1083	NZ1989	NZ2091	NZ2582
NZ2598	NZ3091	NZ3174	NZ3276	NZ3476			

Table 3. Measures of the predicative capabilities of models trained on BA2010 data for Scotland, England and Wales. R^2 indicates the proportion of variation in indices of abundance explained by the models variables. Correlation shows:

Species	R^2
Curlew	0.44
Lapwing	0.24
Oystercatcher	0.35
Snipe	0.29
Golden Plover	0.25
Redshank	0.30
Dunlin	0.17
Common Sandpiper	0.17
Ringed Plover	0.12
Greenshank	0.15

Table 4. The inclusive node purity for variables included within models to predict breeding wader abundance. The greater the value of node purity is an indicator for greater importance in the model. Node purity is scaled so that, for each species, the score for the highest variable is 100.

Curlew		Lapwing		Oystercatcher		Redshank		Greenshank	
Northing	100	Northing	100	Northing	100	Easting	100	Northing	100
Grouse	82	Easting	68	S Temp	93	Elevation	75	Buzzard	82
Easting	51	Grouse	68	S Rain	64	Northing	66	Raven	66
Imp Grass	33	Imp Grass	64	Fox	54	Imp Grass	65	Slope	62
S Temp	31	Crow	64	Crow	48	Crow	60	MHB	61
Crow	31	Buzzard	61	Elevation	48	Grouse	55	Peat	61
W Temp	29	Elevation	59	Buzzard	45	Buzzard	52	Easting	61
Buzzard	27	Raven	57	Imp Grass	45	Fox	46	S Rain	59
Raven	27	Fox	57	Easting	45	Raven	45	Crow	59
Fox	26	Slope	52	W Temp	45	S Rain	42	W Rain	57
Peat	25	Peat	52	W Rain	41	Slope	42	Grouse	55
Elevation	25	S Rain	50	Grouse	39	W Rain	39	Elevation	49
MHB	25	W Rain	48	Raven	38	Peat	35	S Temp	48
Slope	23	W Temp	42	Peat	37	S Temp	30	W Temp	44
S Rain	23	S Temp	41	Slope	33	W Temp	29	Fox	38
W Rain	20	SN Grass	40	Built	21	Built	27	Forest Edge	22
SN Grass	17	Broadleaf	37	MHB	20	Broadleaf	25	Imp Grass	21
Arable	11	Arable	34	Broadleaf	20	MHB	24	SN Grass	20
Broadleaf	11	Built	33	SN Grass	19	Arable	24	Built	20
Built	11	MHB	30	Arable	18	SN Grass	22	Mixed	15
Hetero	10	Hetero	26	Hetero	15	Hetero	15	Hetero	15
Conifer	7	Conifer	19	Forest Edge	13	Mixed	10	Broadleaf	13
Mixed	5	Understorey	16	Conifer	12	Understorey	7	Conifer	7
Understorey	5	Mixed	14	Mixed	9	Conifer	7	Understorey	6
Forest Edge	3	Roads	13	Understorey	8	Roads	5	Arable	4
Roads	3	Forest Edge	7	Roads	8	Forest Edge	5	Clearings	2
Clearings	2	Clearings	6	Clearings	5	Clearings	3	Roads	2
Windfarms	1	Windfarms	2	Windfarms	1	Windfarms	0	Windfarms	0

Snipe		Golden Plover		Dunlin		Common Sandpiper		Ringed Pliover	
Imp Grass	100	Grouse	100	Northing	100	Northing	100	Northing	100
Northing	80	Northing	56	Easting	86	Easting	68	Raven	92
Grouse	63	MHB	53	Raven	69	Grouse	67	Grouse	91
Easting	56	Peat	46	Crow	68	Crow	67	Peat	90
Peat	50	Easting	42	Imp Grass	58	Peat	65	Easting	90
Raven	50	Elevation	42	Grouse	58	MHB	64	S Temp	85
Fox	46	Slope	37	Buzzard	55	Buzzard	63	Crow	83
MHB	38	Buzzard	37	Peat	52	Raven	58	Imp Grass	82
W Temp	37	Fox	34	Slope	50	Elevation	56	Buzzard	81
Buzzard	37	Crow	33	Fox	45	Slope	55	S Rain	74
Elevation	37	Raven	33	W Temp	44	Fox	52	Elevation	72
W Rain	34	W Temp	26	MHB	43	W Temp	51	Slope	57
SN Grass	34	W Rain	26	Elevation	42	S Temp	50	W Temp	55
S Rain	33	S Rain	24	W Rain	33	W Rain	45	W Rain	53
Slope	32	S Temp	23	S Temp	33	S Rain	44	Fox	47
Crow	28	SN Grass	20	S Rain	30	SN Grass	32	MHB	43
S Temp	27	Imp Grass	20	SN Grass	13	Broadleaf	29	SN Grass	43
Broadleaf	15	Broadleaf	12	Built	12	Imp Grass	27	Arable	36
Forest Edge	14	Hetero	8	Arable	11	Arable	23	Built	35
Arable	11	Arable	6	Broadleaf	10	Forest Edge	23	Broadleaf	34
Hetero	11	Built	5	Hetero	8	Hetero	20	Hetero	24
Built	10	Mixed	4	Roads	2	Conifer	17	Understorey	10
Conifer	7	Understorey	4	Windfarms	1	Understorey	17	Conifer	8
Mixed	6	Conifer	3	Forest Edge	1	Mixed	16	Roads	6
Windfarms	5	Windfarms	3	Conifer	1	Built	12	Mixed	4
Understorey	5	Roads	3	Clearings	0	Clearings	9	Forest Edge	3
Clearings	3	Forest Edge	2	Understorey	0	Roads	8	Windfarms	2
Roads	3	Clearings	1	Mixed	0	Windfarms	2	Clearings	2

Table 5. The numbers of occupied 1-km squares and individual birds recorded, using the visit with the highest number of each wader species recorded, for Northumberland and NE Cumbria in 2021.

	Curlew	Lapwing	Oystercatcher	Snipe	Golden Plover	Redshank	Dunlin	Common Sandpiper	Ringed Plover
No. occupied 1-km squares (Bespoke survey; out of 78 squares surveyed)	45	20	14	27	8	1	1	1	1
No. occupied squares (BBS; out of 77 squares surveyed)	38	35	28	14	3	4	0	13	0
Total no. of apparent territories (Bespoke survey)	70	57	21	39	10	1	1	1	1
Total no. of individuals (BBS)	134	125	76	33	6	8	0	36	0

Table 6. Regional densities of breeding waders. Densities (individuals per km2) of breeding waders derived from BBS surveys for the periods 2008-11 and 2015-18 and a combination of BBS and bespoke surveys in 2021 in Northumberland and NE Cumbria. Median and other percentile values (25th and 75th) are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

CURLEW

(a)

Period	Stratum	Percentile		
		Median (50th)	25th	75th
2008–11	5	5.3	3.2	13.7
	4	1.6	0.8	2.7
	3	1.3	0.4	2.2
	2	0.7	0.1	1.2
	1	0	0	0.4
2015–18	5	7.1	3.9	12.1
	4	4.0	2.6	6.0
	3	2.0	1.7	3.0
	2	0.5	0	1.3
	1	0	0	0.7
2021	5	2.8	2.0	6.0
	4	2.0	0.9	2.0
	3	0.7	0	2.0
	2	0	0	2.0
	1	0	0	0

(b)

Period	Stratum	Percentile		
		Median (50th)	25th	75th
2008–11	5	5.3	3.2	13.7
	2–4	0.8	0.4	2.1
	1	0	0	0.4
2015–18	5	7.1	3.9	12.1
	2–4	1.3	0.2	2.5
	1	0	0	0.7
2021	5	2.8	2.0	6.0
	2–4	0.7	0	2.0
	1	0	0	0

LAPWING

(a)

Period	Stratum	Percentile		
		Median (50th)	25th	75th
2008–11	5	4.5	1.7	10.2
	4	1.7	0.3	6.8
	3	0.6	0	2.4
	2	0	0	1.1
	1	0	0	0
2015–18	5	7.1	4.0	11.9
	4	2.0	0.3	4.7
	3	0.7	0	2.7
	2	0	0	0.9
	1	0	0	0
2021	5	1.5	0	3.7
	4	0	0	2.0
	3	0	0	1.3
	2	0	0	0
	1	0	0	0

(b)

Period	Stratum	Percentile		
		Median (50th)	25th	75th
2008–11	5	4.5	4.0	10.2
	2–4	0.6	0	1.7
	1	0	0	0
2015–18	5	7.1	1.7	11.9
	2–4	0.4	0	2.3
	1	0	0	0
2021	5	1.5	0	3.7
	2–4	0	0	1.3
	1	0	0	0

Table 6. (cont) Regional densities of breeding waders. Densities (individuals per km2) of breeding waders derived from BBS surveys for the periods 2008-11 and 2015-18 and a combination of BBS and bespoke surveys in 2021 in Northumberland and NE Cumbria. Median and other percentile values (25th and 75th) are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

OYSTERCATCHER

(a)

		Percentile		
Period	**Stratum**	**Median (50th)**	**25th**	**75th**
2008–11	5	4.4	2.2	7.4
	4	0.6	0.6	0.6
	3	1.4	0.3	3.3
	2	0	0	1.2
	1	0	0	0
2015–18	5	6.1	4.3	8.0
	4	4.5	4.5	4.5
	3	3.6	0.9	5.4
	2	0	0	1.8
	1	0	0	0
2021	5	2.2	1.4	2.5
	4	3.2	2.1	7.0
	3	2.0	0.6	2.2
	2	0	0	0
	1	0	0	0

(b)

		Percentile		
Period	**Stratum**	**Median (50th)**	**25th**	**75th**
2008–11	5	4.4	2.2	7.4
	2–4	0.4	0	1.2
	1	0	0	0
2015–18	5	6.1	4.3	8.0
	2–4	0.9	0	2.5
	1	0	0	0
2021	5	2.2	1.4	2.5
	2–4	0	0	2.0
	1	0	0	0

SNIPE

(a)

		Percentile		
Period	**Stratum**	**Median (50th)**	**25th**	**75th**
2008–11	5	NA	NA	NA
	4	2.2	1.4	4.3
	3	1.4	0	2.7
	2	0.7	0	2.2
	1	0	0	0
2015–18	5	1.0	0.5	1.5
	4	NA	NA	NA
	3	1.0	1.0	2.0
	2	0.7	0	3.3
	1	0	0	0
2021	5	1.7	1.1	4.1
	4	4.0	3.0	4.0
	3	2.0	0	2.0
	2	0	0	2.0
	1	0	0	0

(b)

		Percentile		
Period	**Stratum**	**Median (50th)**	**25th**	**75th**
2008–11	5	NA	NA	NA
	2–4	0.9	0	2.2
	1	0	0	0
2015–18	5	1.0	0.5	1.5
	2–4	1.0	0	3.1
	1	0	0	0
2021	5	1.7	1.1	4.1
	2–4	0	0	2.0
	1	0	0	0

Table 6. (cont) Regional densities of breeding waders. Densities (individuals per km2) of breeding waders derived from BBS surveys for the periods 2008-11 and 2015-18 and a combination of BBS and bespoke surveys in 2021 in Northumberland and NE Cumbria. Median and other percentile values (25th and 75th) are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

GOLDEN PLOVER

(a)

		Percentile		
Period	**Stratum**	**Median (50th)**	**25th**	**75th**
2008–11	5	4.1	2.0	11.5
	4	6.6	6.6	6.6
	3	2.2	1.1	2.7
	2	0.3	0	1.0
	1	0	0	0
2015–18	5	1.5	1.3	1.8
	4	NA	NA	NA
	3	0	0	0
	2	0	0	0.5
	1	0	0	0
2021	5	1.2	0.6	2.6
	4	0	0	1.0
	3	0	0	1.2
	2	0	0	0
	1	0	0	0

(b)

		Percentile		
Period	**Stratum**	**Median (50th)**	**25th**	**75th**
2008–11	5	4.1	2.0	11.5
	2–4	0.8	0	1.9
	1	0	0	0
2015–18	5	1.5	1.3	1.8
	2–4	0	0	0.4
	1	0	0	0
2021	5	1.2	0.6	2.6
	2–4	0	0	0.3
	1	0	0	0

Table 7. National densities of breeding waders. Densities (individuals per km^2) of breeding waders derived from BBS surveys for the periods 2008–11 and 2015–18 for the whole of Britain. Median and other percentile values (25th and 75th) are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

CURLEW

(a)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**6.4**	0.8	3.6	11.4	21.3
	4	**2.4**	0	1.2	4.1	6.8
	3	**1.6**	0	0.6	2.9	5.4
	2	**0.7**	0	0	1.8	3.9
	1	**0**	0	0	0.2	1.2
2015–18	5	**5.1**	0.6	2.6	8.3	19.8
	4	**2.1**	0	1.22	4.3	7.0
	3	**1.4**	0	0.6	2.8	5.4
	2	**0.6**	0	0	1.7	3.7
	1	**0**	0	0	0	1.2

(b)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**6.4**	0.8	3.6	11.4	21.3
	2–4	**1.2**	0	0.4	2.4	5.3
	1	**0**	0	0	0.2	1.2
2015–18	5	**5.1**	0.6	2.6	8.3	19.8
	2–4	**1.2**	0	0.2	2.4	5.5
	1	**0**	0	0	0	1.2

LAPWING

(a)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**5.1**	0	1.6	11.6	36.4
	4	**1.6**	0	0.2	4.9	13.4
	3	**0.4**	0	0	2.4	8.0
	2	**0**	0	0	1.0	4.6
	1	**0**	0	0	0	1.4
2015–18	5	**4.6**	0	1.2	10.1	30.1
	4	**1.4**	0	0	4.0	11.5
	3	**0.4**	0	0	2.1	7.2
	2	**0**	0	0	0.9	4.3
	1	**0**	0	0	0	1.5

(b)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**5.1**	0	1.6	11.6	36.4
	2–4	**0.3**	0	0	1.8	7.4
	1	**0**	0	0	0	1.4
2015–18	5	**4.6**	0	1.2	10.1	30.1
	2–4	**0.2**	0	0	1.6	6.4
	1	**0**	0	0	0	1.5

Table 7. (cont) National densities of breeding waders. Densities (individuals per km^2) of breeding waders derived from BBS surveys for the periods 2008–11 and 2015–18 for the whole of Britain. Median and other percentile values (25th and 75th) are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

OYSTERCATCHER

(a)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**3.9**	0	1.5	8.7	25.4
	4	**2.1**	0	0.5	4.1	9.6
	3	**0.9**	0	0	2.1	6.7
	2	**0.2**	0	0	1.2	4.0
	1	**0**	0	0	0	1.0
2015–18	5	**3.7**	0	0.9	8.7	23.2
	4	**2.2**	0	0.6	4.6	9.7
	3	**0.5**	0	0	1.9	5.4
	2	**0**	0	0	1.2	3.7
	1	**0**	0	0	0	1.0

(b)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**3.9**	0	1.5	8.7	25.4
	2–4	**0.5**	0	0	1.9	6.2
	1	**0**	0	0	0	1.0
2015–18	5	**3.7**	0	0.9	8.7	23.2
	2–4	**0.4**	0	0	1.9	6.2
	1	**0**	0	0	0	1.0

SNIPE

(a)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**3.5**	0	1.2	8.6	11.7
	4	**2.6**	0	1.2	4.9	8.7
	3	**1.2**	0	0.4	3.5	7.2
	2	**0.6**	0	0	1.8	5.5
	1	**0**	0	0	0	1.8
2015–18	5	**1.8**	0	0	5.4	11.1
	4	**1.8**	0	0.9	3.7	9.6
	3	**1.2**	0	0	3.7	7.4
	2	**0.5**	0	0	2.0	6.1
	1	**0**	0	0	0	1.8

(b)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**3.5**	0	1.2	8.6	11.7
	2–4	**0.9**	0	0	2.5	6.5
	1	**0**	0	0	0	1.8
2015–18	5	**1.8**	0	0	5.4	11.1
	2–4	**0.9**	0	0	2.6	6.6
	1	**0**	0	0	0	1.8

Table 7. (cont) National densities of breeding waders. Densities (individuals per km^2) of breeding waders derived from BBS surveys for the periods 2008–11 and 2015–18 for the whole of Britain. Median and other percentile values (25th and 75th) are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

GOLDEN PLOVER

(a)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**7.4**	0.2	3.4	15.2	26.3
	4	**3.2**	0	1.0	5.3	9.2
	3	**1.1**	0	0	3.4	7.8
	2	**0.4**	0	0	1.1	3.6
	1	**0**	0	0	0	1.7
2015–18	5	**6.5**	0	1.4	13.9	22.3
	4	**2.1**	0	0.7	5.1	9.3
	3	**1.7**	0	0.2	4.3	7.7
	2	**0.4**	0	0	1.5	5.1
	1	**0**	0	0	0	1.8

(b)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**7.4**	0.2	3.4	15.2	26.3
	2–4	**1.0**	0	0	3.4	8.2
	1	**0**	0	0	0	1.7
2015–18	5	**6.5**	0	1.4	13.9	22.3
	2–4	**1.1**	0	0	3.4	8.3
	1	**0**	0	0	0	1.8

REDSHANK

(a)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**2.1**	0	0	4.8	11.6
	4	**0**	0	0	2.6	6.1
	3	**0.2**	0	0	1.2	5.7
	2	**0**	0	0	1.1	3.7
	1	**0**	0	0	0	0.3
2015–18	5	**1.6**	0	0	4.4	11.8
	4	**0**	0	0	2.9	6.7
	3	**0**	0	0	0.8	5.5
	2	**0**	0	0	0.5	3.6
	1	**0**	0	0	0	0.2

(b)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**2.1**	0	0	4.8	11.6
	2–4	**0**	0	0	1.1	4.6
	1	**0**	0	0	0	0.3
2015–18	5	**1.6**	0	0	4.4	11.8
	2–4	**0**	0	0	0.8	5.7
	1	**0**	0	0	0	0.2

Table 7. (Cont) National densities of breeding waders. Densities (individuals per km²) of breeding waders derived from BBS surveys for the periods 2008–11 and 2015–18 for the whole of Britain. Median and other percentile values (25th and 75th) are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

DUNLIN

(a)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**2.4**	0	0.5	4.3	10.4
	4	**1.7**	0.2	1.0	3.1	5.6
	3	**0**	0	0	0	1.7
	2	**0**	0	0	0.3	1.7
	1	**0**	0	0	0	0.5
2015–18	5	**1.0**	0	0	3.7	13.3
	4	**3.1**	0.3	1.6	4.7	5.9
	3	**0**	0	0	2.1	2.7
	2	**0**	0	0	0	1.4
	1	**0**	0	0	0	0.6

(b)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**2.4**	0	0.5	4.3	10.4
	2–4	**0**	0	0	1.6	3.1
	1	**0**	0	0	0	0.5
2015–18	5	**1.0**	0	0	3.7	13.3
	2–4	**0**	0	0	0.7	2.9
	1	**0**	0	0	0	0.6

COMMON SANDPIPER

(a)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**0**	0	0	2.0	7.3
	4	**0**	0	0	0.4	6.8
	3	**0**	0	0	0	3.3
	2	**0**	0	0	0	1.9
	1	**0**	0	0	0	0
2015–18	5	**0**	0	0	1.2	6.7
	4	**0**	0	0	0.6	6.2
	3	**0**	0	0	0	2.7
	2	**0**	0	0	0	2.1
	1	**0**	0	0	0	0.3

(b)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**0**	0	0	2.0	7.3
	2–4	**0**	0	0	0	2.8
	1	**0**	0	0	0	0
2015–18	5	**0**	0	0	1.2	6.7
	2–4	**0**	0	0	0	2.8
	1	**0**	0	0	0	0.3

Table 7. (Cont) National densities of breeding waders. Densities (individuals per km^2) of breeding waders derived from BBS surveys for the periods 2008–11 and 2015–18 for the whole of Britain. Median and other percentile values (25th and 75th) are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

RINGED PLOVER

(a)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**0**	0	0	0.7	8.2
	4	**0**	0	0	0	3.5
	3	**0**	0	0	0	0.2
	2	**0**	0	0	0	0.5
	1	**0**	0	0	0	0
2015–18	5	**0**	0	0	1.3	7.3
	4	**0**	0	0	0	3.5
	3	**0**	0	0	0	0.2
	2	**0**	0	0	0	0.5
	1	**0**	0	0	0	0

(b)

		Percentile				
Period	**Stratum**	**Median (50th)**	**5th**	**25th**	**75th**	**95th**
2008–11	5	**0**	0	0	0.7	8.2
	2–4	**0**	0	0	0	1.1
	1	**0**	0	0	0	0
2015–18	5	**0**	0	0	1.3	7.3
	2–4	**0**	0	0	0	0.5
	1	**0**	0	0	0	0

Table 8. Contingency tables comparing the numerical distribution of wader abundance in BBS survey squares and their abundance predicted by RFRT modelling of Bird Atlas data with environmental datasets. Empirical data are derived from the BBS and the numbers of survey squares are those which had wader abundances within ranges based on typical ranges found with within directly comparable abundance strata based on RFRT modelling. For example, BBS_1 is the number of BBS survey squares with an empirically derived abundance equivalent to the predicted value, RFRT_1. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

CURLEW

(a) Five separate abundance strata within the BA2010 period (2008–11)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	203	80	20	36	13
RFRT_4	11	36	19	20	19
RFRT_3	8	37	26	39	49
RFRT_2	4	32	33	62	137
RFRT_1	3	13	15	71	958

(b) three abundance strata where the intermediate three are combined within the BA2010 period, 2008–11

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	216	112	24
RFRT_2-4	33	262	237
RFRT_1	3	67	990

(c) five separate abundance strata within the more recent period (2015–18)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	123	74	15	19	14
RFRT_4	16	35	16	14	22
RFRT_3	12	37	29	32	48
RFRT_2	8	39	31	45	145
RFRT_1	4	22	22	75	1132

(d) three abundance strata where the intermediate three are combined within the more recent period (2015–18)

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	138	89	18
RFRT_2-4	49	242	238
RFRT_1	4	91	1160

Table 8. (Cont) Contingency tables comparing the numerical distribution of wader abundance in BBS survey squares and their abundance predicted by RFRT modelling of Bird Atlas data with environmental datasets. Empirical data are derived from the BBS and the numbers of survey squares are those which had wader abundances within ranges based on typical ranges found with within directly comparable abundance strata based on RFRT modelling. For example, BBS_1 is the number of BBS survey squares with an empirically derived abundance equivalent to the predicted value, RFRT_1. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

LAPWING

(a) Five separate abundance strata within the BA2010 period (2008–11)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	169	89	49	27	69
RFRT_4	40	44	35	30	87
RFRT_3	35	70	64	48	273
RFRT_2	16	69	84	100	584
RFRT_1	4	26	53	72	1511

(b) three abundance strata where the intermediate three are combined within the BA2010 period, 2008–11

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	185	140	78
RFRT_2-4	114	421	1044
RFRT_1	7	114	1545

(c) five separate abundance strata within the more recent period (2015–18)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	151	93	33	24	57
RFRT_4	40	54	38	35	82
RFRT_3	37	87	54	53	270
RFRT_2	24	89	91	107	614
RFRT_1	11	56	57	85	1725

(d) three abundance strata where the intermediate three are combined within the more recent period (2015–18)

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	170	120	68
RFRT_2-4	126	507	1042
RFRT_1	13	151	1770

Table 8. (Cont) Contingency tables comparing the numerical distribution of wader abundance in BBS survey squares and their abundance predicted by RFRT modelling of Bird Atlas data with environmental datasets. Empirical data are derived from the BBS and the numbers of survey squares are those which had wader abundances within ranges based on typical ranges found with within directly comparable abundance strata based on RFRT modelling. For example, BBS_1 is the number of BBS survey squares with an empirically derived abundance equivalent to the predicted value, RFRT_1. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

OYSTERCATCHER

(a) Five separate abundance strata within the BA2010 period (2008–11)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	49	21	13	10	16
RFRT_4	20	25	17	13	26
RFRT_3	17	28	33	33	89
RFRT_2	12	31	40	65	226
RFRT_1	3	16	32	86	1429

(b) three abundance strata where the intermediate three are combined within the BA2010 period, 2008–11

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	52	37	20
RFRT_2-4	63	227	385
RFRT_1	8	87	1471

(c) five separate abundance strata within the more recent period (2015–18)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	58	18	10	12	26
RFRT_4	25	27	19	12	27
RFRT_3	15	24	35	27	106
RFRT_2	8	27	52	54	232
RFRT_1	4	17	44	85	1496

(d) three abundance strata where the intermediate three are combined within the more recent period (2015–18)

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	61	33	30
RFRT_2-4	72	206	412
RFRT_1	8	93	1545

Table 8. (Cont) Contingency tables comparing the numerical distribution of wader abundance in BBS survey squares and their abundance predicted by RFRT modelling of Bird Atlas data with environmental datasets. Empirical data are derived from the BBS and the numbers of survey squares are those which had wader abundances within ranges based on typical ranges found with within directly comparable abundance strata based on RFRT modelling. For example, BBS_1 is the number of BBS survey squares with an empirically derived abundance equivalent to the predicted value, RFRT_1. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

SNIPE

(a) Five separate abundance strata within the BA2010 period (2008–11)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	11	4	3	4	6
RFRT_4	14	6	7	5	8
RFRT_3	19	9	10	15	26
RFRT_2	24	28	34	34	151
RFRT_1	10	22	33	52	930

(b) three abundance strata where the intermediate three are combined within the BA2010 period, 2008–11

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	15	7	6
RFRT_2-4	75	128	187
RFRT_1	21	96	930

(c) five separate abundance strata within the more recent period (2015–18)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	9	2	1	5	10
RFRT_4	9	1	4	9	9
RFRT_3	18	1	5	14	31
RFRT_2	29	3	18	33	128
RFRT_1	23	6	18	52	1025

(d) three abundance strata where the intermediate three are combined within the more recent period (2015–18)

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	11	4	12
RFRT_2-4	70	56	186
RFRT_1	32	51	1041

Table 8. (Cont) Contingency tables comparing the numerical distribution of wader abundance in BBS survey squares and their abundance predicted by RFRT modelling of Bird Atlas data with environmental datasets. Empirical data are derived from the BBS and the numbers of survey squares are those which had wader abundances within ranges based on typical ranges found with within directly comparable abundance strata based on RFRT modelling. For example, BBS_1 is the number of BBS survey squares with an empirically derived abundance equivalent to the predicted value, RFRT_1. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

GOLDEN PLOVER

(a) Five separate abundance strata within the BA2010 period (2008–11)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	75	34	10	11	9
RFRT_4	9	12	5	6	7
RFRT_3	6	16	10	11	26
RFRT_2	1	3	6	17	31
RFRT_1	4	7	11	20	320

(b) three abundance strata where the intermediate three are combined within the BA2010 period, 2008–11

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	86	34	19
RFRT_2-4	18	56	92
RFRT_1	4	20	338

(c) five separate abundance strata within the more recent period (2015–18)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	38	7	9	9	15
RFRT_4	6	6	5	11	11
RFRT_3	8	12	8	12	20
RFRT_2	3	4	2	26	47
RFRT_1	5	5	5	15	322

(d) three abundance strata where the intermediate three are combined within the more recent period (2015–18)

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	42	16	20
RFRT_2-4	18	62	101
RFRT_1	5	18	329

Table 8. (Cont) Contingency tables comparing the numerical distribution of wader abundance in BBS survey squares and their abundance predicted by RFRT modelling of Bird Atlas data with environmental datasets. Empirical data are derived from the BBS and the numbers of survey squares are those which had wader abundances within ranges based on typical ranges found with within directly comparable abundance strata based on RFRT modelling. For example, BBS_1 is the number of BBS survey squares with an empirically derived abundance equivalent to the predicted value, RFRT_1. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

REDSHANK

(a) Five separate abundance strata within the BA2010 period (2008–11)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	17	6	1	2	14
RFRT_4	7	0	0	1	12
RFRT_3	5	4	1	4	24
RFRT_2	16	9	3	7	82
RFRT_1	7	11	1	16	1060

(b) three abundance strata where the intermediate three are combined within the BA2010 period, 2008–11

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	17	9	14
RFRT_2-4	31	26	118
RFRT_1	8	27	1060

(c) five separate abundance strata within the more recent period (2015–18)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	16	5	2	3	15
RFRT_4	8	0	0	0	12
RFRT_3	4	4	2	6	26
RFRT_2	11	5	5	12	81
RFRT_1	8	7	8	27	1043

(d) three abundance strata where the intermediate three are combined within the more recent period (2015–18)

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	20	6	15
RFRT_2-4	29	22	125
RFRT_1	11	29	1053

Table 8. (Cont) Contingency tables comparing the numerical distribution of wader abundance in BBS survey squares and their abundance predicted by RFRT modelling of Bird Atlas data with environmental datasets. Empirical data are derived from the BBS and the numbers of survey squares are those which had wader abundances within ranges based on typical ranges found with within directly comparable abundance strata based on RFRT modelling. For example, BBS_1 is the number of BBS survey squares with an empirically derived abundance equivalent to the predicted value, RFRT_1. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

DUNLIN

(a) Five separate abundance strata within the BA2010 period (2008–11)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	6	2	0	0	3
RFRT_4	1	2	0	0	1
RFRT_3	0	1	0	0	4
RFRT_2	0	1	1	0	5
RFRT_1	4	4	9	2	259

(b) three abundance strata where the intermediate three are combined within the BA2010 period, 2008–11

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	7	1	3
RFRT_2-4	4	2	10
RFRT_1	6	11	261

(c) five separate abundance strata within the more recent period (2015–18)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	2	3	2	0	6
RFRT_4	1	0	0	0	1
RFRT_3	0	0	4	0	5
RFRT_2	0	0	3	0	12
RFRT_1	2	1	14	2	199

(d) three abundance strata where the intermediate three are combined within the more recent period (2015–18)

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	6	1	6
RFRT_2-4	2	6	18
RFRT_1	4	13	201

Table 8. (Cont) Contingency tables comparing the numerical distribution of wader abundance in BBS survey squares and their abundance predicted by RFRT modelling of Bird Atlas data with environmental datasets. Empirical data are derived from the BBS and the numbers of survey squares are those which had wader abundances within ranges based on typical ranges found with within directly comparable abundance strata based on RFRT modelling. For example, BBS_1 is the number of BBS survey squares with an empirically derived abundance equivalent to the predicted value, RFRT_1. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

COMMON SANDPIPER

(a) Five separate abundance strata within the BA2010 period (2008–11)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	32	8	3	2	57
RFRT_4	14	3	2	1	54
RFRT_3	16	2	1	1	79
RFRT_2	17	13	3	5	215
RFRT_1	10	7	6	5	646

(b) three abundance strata where the intermediate three are combined within the BA2010 period, 2008–11

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	36	9	57
RFRT_2-4	57	21	348
RFRT_1	13	15	646

(c) five separate abundance strata within the more recent period (2015–18)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	34	12	3	2	95
RFRT_4	14	4	3	1	54
RFRT_3	11	2	1	1	92
RFRT_2	16	12	3	5	210
RFRT_1	14	5	8	5	579

(d) three abundance strata where the intermediate three are combined within the more recent period (2015–18)

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	42	9	95
RFRT_2-4	53	20	356
RFRT_1	18	14	579

Table 8. (Cont) Contingency tables comparing the numerical distribution of wader abundance in BBS survey squares and their abundance predicted by RFRT modelling of Bird Atlas data with environmental datasets. Empirical data are derived from the BBS and the numbers of survey squares are those which had wader abundances within ranges based on typical ranges found with within directly comparable abundance strata based on RFRT modelling. For example, BBS_1 is the number of BBS survey squares with an empirically derived abundance equivalent to the predicted value, RFRT_1. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

RINGED PLOVER

(a) Five separate abundance strata within the BA2010 period (2008–11)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	5	3	1	0	13
RFRT_4	3	0	0	0	10
RFRT_3	0	1	1	0	23
RFRT_2	1	2	2	0	30
RFRT_1	9	1	4	0	781

(b) three abundance strata where the intermediate three are combined within the BA2010 period, 2008–11

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	7	2	13
RFRT_2-4	4	6	63
RFRT_1	10	4	781

(c) five separate abundance strata within the more recent period (2015–18)

STRATUM	BBS_5	BBS_4	BBS_3	BBS_2	BBS_1
RFRT_5	7	2	0	0	17
RFRT_4	2	0	0	0	15
RFRT_3	0	1	0	0	27
RFRT_2	2	1	0	0	39
RFRT_1	5	5	0	0	865

(d) three abundance strata where the intermediate three are combined within the more recent period (2015–18)

STRATUM	BBS_5	BBS_2-4	BBS_1
RFRT_5	7	3	16
RFRT_2-4	4	5	78
RFRT_1	5	7	861

Table 9. Comparisons with North Pennine Moors SPA breeding wader surveys 2005–2007 Empirical densities (birds per km²) of breeding waders derived from the North Pennine Moors SPA breeding wader surveys (2005–2007). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

CURLEW

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	1485	3	2	5
4	37	2	1	3
3	2	1	1	1
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	1485	3	2	5
2–4	39	2	1	2.5
1	0	NA	NA	NA

LAPWING

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	672	2	1	4.25
4	40	2	1	3
3	31	1	1	2
2	18	1	1	2
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	672	2	1	4.25
2–4	89	2	1	3
1	0	NA	NA	NA

OYSTERCATCHER

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	29	2	1	3
4	48	1	1	2
3	86	1	1	2
2	75	1	1	2
1	23	1	1	1

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	29	2	1	3
2–4	209	1	1	2
1	23	1	1	1

GOLDEN PLOVER

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	991	3	2	5
4	95	2	1	3
3	60	2	1	3
2	31	2	1	3
1	13	1	1	2

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	991	3	2	5
2–4	186	2	1	3
1	13	1	1	2

Table 9. (Cont) Comparisons with North Pennine Moors SPA breeding wader surveys 2005–2007 Empirical densities (birds per km²) of breeding waders derived from the North Pennine Moors SPA breeding wader surveys (2005–2007). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

SNIPE

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	141	2	1	3
4	117	1	1	2
3	142	1	1	2
2	204	1	1	2
1	66	1	1	1

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	141	2	1	3
2–4	463	1	1	2
1	66	1	1	1

REDSHANK

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	36	2	1	3
4	24	1	1	2.3
3	40	1	1	3
2	51	1	1	2
1	58	1	1	1

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	36	2	1	3
2–4	115	1	1	2
1	58	1	1	1

DUNLIN

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	5	3	2	4
4	0	NA	NA	NA
3	3	3	2	3
2	21	1	1	3
1	82	1	1	1.8

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	5	3	2	4
2–4	24	2	1	3
1	82	1	1	1.8

COMMON SANDPIPER

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	22	1	1	2
4	9	1	1	2
3	13	1	1	1
2	22	1	1	1
1	21	1	1	2

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	22	1	1	2
2–4	44	1	1	1
1	21	1	1	2

Table 9. (Cont) Comparisons with North Pennine Moors SPA breeding wader surveys 2005–2007 Empirical densities (birds per km²) of breeding waders derived from the North Pennine Moors SPA breeding wader surveys (2005–2007). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

RINGED PLOVER

(a)

		Percentile		
Stratum	**Records**	**Median (50th)**	**25th**	**75th**
5	0	NA	NA	NA
4	0	NA	NA	NA
3	0	NA	NA	NA
2	2	1	1	1
1	1	1	1	1

(b)

		Percentile		
Stratum	**Records**	**Median (50th)**	**25th**	**75th**
5	0	NA	NA	NA
2–4	2	1	1	1
1	1	1	1	1

Table 10. Comparisons with the Shetland Breeding Bird Survey 2008–2011. Empirical densities (pairs per km²) of breeding waders derived from the Shetland BBS concurrent with BA2010 (2008–11) and the more recent periods (2015–18). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

CURLEW: 2008–11

(a)

Stratum	Records	Percentile: Median (50th)	25th	75th
5	175	1	0	2
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

Stratum	Records	Percentile: Median (50th)	25th	75th
5	175	1	0	2
2–4	0	NA	NA	NA
1	0	NA	NA	NA

CURLEW: 2015–18

(a)

Stratum	Records	Percentile: Median (50th)	25th	75th
5	192	1	0	3
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

Stratum	Records	Percentile: Median (50th)	25th	75th
5	192	1	0	3
2–4	0	NA	NA	NA
1	0	NA	NA	NA

LAPWING: 2008–11

(a)

Stratum	Records	Percentile: Median (50th)	25th	75th
5	164	1	0	2
4	4	NA	NA	NA
3	7	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

Stratum	Records	Percentile: Median (50th)	25th	75th
5	164	1	0	2
2–4	11	NA	NA	NA
1	0	NA	NA	NA

LAPWING: 2015–18

(a)

Stratum	Records	Percentile: Median (50th)	25th	75th
5	192	1	0	3
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

Stratum	Records	Percentile: Median (50th)	25th	75th
5	192	0	0	3
2–4	0	NA	NA	NA
1	0	NA	NA	NA

Table 10. (Cont) Comparisons with the Shetland Breeding Bird Survey 2008–2011. Empirical densities (pairs per km²) of breeding waders derived from the Shetland BBS concurrent with BA2010 (2008–11) and the more recent periods (2015–18). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

OYSTERCATCHER: 2008–11

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	168	1	0	2
4	0	NA	NA	NA
3	7	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	168	1	0	2
2–4	7	NA	NA	NA
1	0	NA	NA	NA

OYSTERCATCHER: 2015–18

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	1	0	3
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	1	0	3
2–4	0	NA	NA	NA
1	0	NA	NA	NA

SNIPE: 2008–11

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	175	1	0	2
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	175	1	0	2
2–4	0	NA	NA	NA
1	0	NA	NA	NA

SNIPE: 2015–18

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	1	0	3
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	0	0	3
2–4	0	NA	NA	NA
1	0	NA	NA	NA

Table 10. (Cont) Comparisons with the Shetland Breeding Bird Survey 2008–2011. Empirical densities (pairs per km²) of breeding waders derived from the Shetland BBS concurrent with BA2010 (2008–11) and the more recent periods (2015–18). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

GOLDEN PLOVER: 2008–11

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	35	1	0	2
4	0	NA	NA	NA
3	11	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	129	1	0	2
2–4	46	NA	NA	NA
1	0	NA	NA	NA

GOLDEN PLOVER: 2015–18

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	1	0	3
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	1	0	3
2–4	0	NA	NA	NA
1	0	NA	NA	NA

REDSHANK: 2008–11

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	168	1	0	2
4	7	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	168	1	0	2
2–4	7	NA	NA	NA
1	0	NA	NA	NA

REDSHANK: 2015–18

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	1	0	3
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	0	0	3
2–4	0	NA	NA	NA
1	0	NA	NA	NA

Table 10. (Cont) Comparisons with the Shetland Breeding Bird Survey 2008–2011. Empirical densities (pairs per km²) of breeding waders derived from the Shetland BBS concurrent with BA2010 (2008–11) and the more recent periods (2015–18). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

DUNLIN: 2008–11

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	145	1	0	2
4	27	NA	NA	NA
3	3	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	145	1	0	2
2–4	30	NA	NA	NA
1	0	NA	NA	NA

DUNLIN: 2015–18

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	1	0	3
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	1	0	3
2–4	0	NA	NA	NA
1	0	NA	NA	NA

RINGED PLOVER: 2008–11

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	175	1	0	2
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	175	1	0	2
2–4	0	NA	NA	NA
1	0	NA	NA	NA

RINGED PLOVER: 2015–18

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	1	0	3
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	192	0	3	1
2–4	0	NA	NA	NA
1	0	NA	NA	NA

Table 11. Comparisons with RSPB Scotland amalgamated breeding wader data 2004–2011. Empirical densities (pairs per km^2) of breeding waders derived from RSPB Scotland amalgamated breeding wader data (2004–2019). The data was provided as polygons and a grid reference was assigned to each polygon by selecting the mid-point of the polygon. The area of the polygon was divided by the count to get a density per square. This was very high in some instances. Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

CURLEW

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	8.2	2.9	20
4	61	4.4	1.7	7.1
3	52	2.5	1.3	5.5
2	58	1.1	0	2.4
1	52	0	0	0.2

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	8.2	2.9	20
2–4	171	2.2	1.0	5.3
1	52	0	0	0.2

LAPWING

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	8.5	3.7	20.4
4	61	7.9	2.7	17.7
3	52	6.4	2.9	12.1
2	58	3.9	1.0	7.1
1	52	0	0	2.3

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	8.5	3.7	20.4
2–4	171	5.9	1.9	12.6
1	52	0	0	2.3

OYSTERCATCHER

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	14.3	4.37	29.3
4	61	9.5	3.87	20
3	52	8.2	3.97	12.7
2	58	2.6	1.2	8.0
1	52	1.7	0	3.1

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	14.3	4.1	29.3
2–4	171	6.4	1.9	13.7
1	52	1.7	0	3.1

SNIPE

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	5. 6	2.5	17.4
4	61	2.1	0	5.3
3	52	1.8	0	4.3
2	58	0	0	2.1
1	52	0	0	0

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	5. 6	2.5	17.4
2–4	171	1.0	0	4.8
1	52	0	0	0

Table 11. (Cont) Comparisons with RSPB Scotland amalgamated breeding wader data 2004–2011. Empirical densities (pairs per km²) of breeding waders derived from RSPB Scotland amalgamated breeding wader data (2004–2019). The data was provided as polygons and a grid reference was assigned to each polygon by selecting the mid-point of the polygon. The area of the polygon was divided by the count to get a density per square. This was very high in some instances. Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

REDSHANK

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	3.3	0.8	14.7
4	61	0.4	0	2.0
3	52	0	0	2.3
2	58	0	0	0.4
1	52	0	0	0

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	3.3	0.8	14.7
2–4	171	0	0	1.9
1	52	0	0	0

DUNLIN

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	0	0	0.6
4	61	0.3	0	0.4
3	52	0	0	0
2	58	0	0	0
1	52	0	0	0

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	0	0	0.6
2–4	171	0	0	0.1
1	52	0	0	0

RINGED PLOVER

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	0	0	0
4	61	0	0	0
3	52	0	0	0
2	58	0	0	0
1	52	0	0	0

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	176	0	0	0
2–4	171	0	0	0
1	52	0	0	0

Table 12. Comparisons with Breeding Waders on English Upland Farmland (BWEUF) data 2016. Empirical densities (birds per tetrad) of breeding waders derived from Breeding Waders on English Upland Farmland (BWEUF) data (2016). Median and other percentile values are given for tetrads falling within each predicted abundance stratum (stratum values for tetrads correspond to the highest individual 1 km stratum value within each tetrad) for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

CURLEW

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	340	7	3	12.3
4	30	2	1	3
3	41	1	0	3
2	49	0	0	1
1	62	0	0	0

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	340	7	3	12.3
2–4	120	1	0	2
1	62	0	0	0

LAPWING

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	322	12	4	29
4	58	1	0	5
3	42	0.5	0	2.8
2	30	0	0	1
1	70	0	0	0

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	322	12	4	29
2–4	130	1	0	3
1	70	0	0	0

OYSTERCATCHER

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	52	9	4.8	12
4	71	4	2	9.5
3	90	3	1	5.8
2	98	1	0	3
1	211	0	0	0

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	52	9	4.8	12
2–4	259	3	0.5	5.5
1	211	0	0	0

SNIPE

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	59	5	2	10
4	39	3	1	7
3	69	2	0	5
2	134	0	0	2
1	221	0	0	0

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	59	5	2	10
2–4	242	1	0	3
1	221	0	0	0

Table 12. (Cont) Comparisons with Breeding Waders on English Upland Farmland (BWEUF) data 2016. Empirical densities (birds per tetrad) of breeding waders derived from Breeding Waders on English Upland Farmland (BWEUF) data (2016). Median and other percentile values are given for tetrads falling within each predicted abundance stratum (stratum values for tetrads correspond to the highest individual 1 km stratum value within each tetrad) for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

GOLDEN PLOVER

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	85	0	0	0
4	23	0	0	0
3	43	0	0	0
2	74	0	0	0
1	297	0	0	0

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	85	0	0	0
2–4	140	0	0	0
1	297	0	0	0

REDSHANK

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	22	8	2.3	11
4	18	5.5	0	7
3	28	1.5	0	6.5
2	74	0	0	2
1	380	0	0	0

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	22	8	2.25	11
2–4	120	1	0	4
1	380	0	0	0

Table 13. Comparisons with data from Hiraethog in 2010. Empirical densities (birds per km²) of breeding Curlew derived from survey data from Hiraethog in Wales (2010). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

CURLEW

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	0	NA	NA	NA
4	2	2.5	1.8	3.3
3	4	1	0.8	1.5
2	12	1.5	0.8	3
1	12	1	0.8	2

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	0	NA	NA	NA
2–4	18	1	1	3
1	12	1	0.8	2

Table 14. Comparisons with Uists breeding wader surveys 2007–10 and 2014. Empirical densities (birds per km²) of breeding waders derived from survey data from Uists breeding wader surveys (2007–10 and 2014). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

CURLEW: 2007–10

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	0	NA	NA	NA
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	0	NA	NA	NA
2–4	0	NA	NA	NA
1	0	NA	NA	NA

CURLEW: 2014

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	0	NA	NA	NA
4	0	NA	NA	NA
3	1	1	1	1
2	1	1	1	1
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	0	NA	NA	NA
2–4	2	1	1	1
1	0	NA	NA	NA

LAPWING: 2007–10

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	141	12	5	26
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	141	12	5	26
2–4	0	NA	NA	NA
1	0	NA	NA	NA

LAPWING: 2014

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	155	7	3	17
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	155	7	3	17
2–4	0	NA	NA	NA
1	0	NA	NA	NA

Table 14. (Cont) Comparisons with Uists breeding wader surveys 2007–10 and 2014. Empirical densities (birds per km²) of breeding waders derived from survey data from Uists breeding wader surveys (2007–10 and 2014). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

OYSTERCATCHER: 2007–10

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	159	10	3.5	21
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	159	10	3.5	21
2–4	0	NA	NA	NA
1	0	NA	NA	NA

OYSTERCATCHER: 2014

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	161	13	5	21
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	161	13	5	21
2–4	0	NA	NA	NA
1	0	NA	NA	NA

SNIPE: 2007–10

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	53	2	1	4
4	3	2	2	2
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	53	2	1	4
2–4	3	2	2	2
1	0	NA	NA	NA

SNIPE: 2014

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	85	2	1	3
4	3	1	1	1.5
3	1	1	1	1
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	85	2	1	3
2–4	4	1	1	1.25
1	0	NA	NA	NA

Table 14. (Cont) Comparisons with Uists breeding wader surveys 2007–10 and 2014. Empirical densities (birds per km²) of breeding waders derived from survey data from Uists breeding wader surveys (2007–10 and 2014). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

REDSHANK: 2007–10

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	117	14	6	23
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	117	14	6	24
2–4	0	NA	NA	NA
1	0	NA	NA	NA

REDSHANK: 2014

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	141	8	3	16
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	141	8	3	16
2–4	0	NA	NA	NA
1	0	NA	NA	NA

DUNLIN: 2007–10

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	98	4.5	3	11.75
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	98	4.5	3	11.75
2–4	0	NA	NA	NA
1	0	NA	NA	NA

DUNLIN: 2014

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	79	3	2	6
4	1	1	1	1
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	79	3	2	6
2–4	1	1	1	1
1	0	NA	NA	NA

Table 14. (Cont) Comparisons with Uists breeding wader surveys 2007–10 and 2014. Empirical densities (birds per km²) of breeding waders derived from survey data from Uists breeding wader surveys (2007–10 and 2014). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

RINGED PLOVER: 2007–10

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	93	4	2	9
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	93	4	2	9
2–4	0	NA	NA	NA
1	0	NA	NA	NA

RINGED PLOVER: 2014

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	71	3	1.5	5.5
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	71	3	1.5	5.5
2–4	0	NA	NA	NA
1	0	NA	NA	NA

COMMON SNADPIPER: 2007–10

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	7	1	1	1
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	7	1	1	1
2–4	0	NA	NA	NA
1	0	NA	NA	NA

COMMON SANDPIPER: 2014

(a)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	0	NA	NA	NA
4	0	NA	NA	NA
3	0	NA	NA	NA
2	0	NA	NA	NA
1	0	NA	NA	NA

(b)

		Percentile		
Stratum	Records	Median (50th)	25th	75th
5	0	NA	NA	NA
2–4	0	NA	NA	NA
1	0	NA	NA	NA

Table 15. Comparison with Breeding Redshank on Saltmarshes Survey of Great Britain 2011 Empirical densities (birds per km²) of breeding Redshank derived from survey data from the Redshank Breeding on Saltmarshes Survey of Great Britain 2011 (Malpas *et al.* 2013). Median and other percentile values are given for survey squares falling within each predicted abundance stratum for: (a) five separate abundance strata and (b) three abundance strata where the intermediate three are combined. Predicted abundances are lowest in stratum 1 and highest in stratum 5.

REDSHANK

(a)

		Percentile		
Stratum	**Records**	**Median (50th)**	**25th**	**75th**
5	73	15.5	9.0	45.2
4	29	9.7	3.3	22.2
3	25	7.5	3.0	19.7
2	32	0	0	7.4
1	37	0	0	0

(b)

		Percentile		
Stratum	**Records**	**Median (50th)**	**25th**	**75th**
5	73	15.5	9.0	45.2
2–4	86	6.5	0	15.6
1	37	0	0	0

Table 16. The proportions of breeding waders predicted to be found within political, landscape, land use and designation categories in Britain. The '% of land area' is the proportion of Britain covered by each category. Species are: CU – Curlew; L – Lapwing; RK – Redshank; OC – Oystercatcher; GP – Golden Plover; SN – Snipe; DN – Dunlin; GK – Greenshank; CS – Common Sandpiper; RP – Ringed Plover.

	% of land area	CU	L	RK	OC	GP	SN	DN	GK	CS	RP
Country											
Scotland	34	50	32	49	69	74	76	96	100	86	63
England	56	47	66	48	28	25	22	3	0	10	21
Wales	10	3	2	3	3	1	2	1	0	4	6
Landscape											
Uplands	17	29	13	17	19	68	39	57	75	52	18
Mixed	24	37	21	24	30	28	40	32	22	35	29
Lowlands	74	33	66	59	52	4	21	11	3	12	53
Islands											
All	5	11	8	34	17	25	35	64	36	16	45
Northern Isles	1	9	4	14	7	9	18	23	8	2	20
Western Isles	1	1	2	13	4	13	10	35	22	8	12
Inner Hebrides	1	1	1	3	3	2	5	4	1	3	5
Grouse moors											
All	7	36	17	9	14	47	23	13	8	19	3
Scotland	4	12	6	3	9	23	12	11	8	15	2
England	3	24	11	6	5	23	11	2	0	4	1
Wales	0	0	0	0	0	0	0	0	0	0	0
SACs											
Britain	18	27	17	30	24	38	26	40	35	27	35
Scotland	10	9	6	11	14	21	16	37	35	22	18
England	5	17	11	17	8	17	9	2	0	4	12
Wales	3	1	1	2	2	0	1	0	0	1	5
SPAs											
Britain	10	24	15	37	19	42	27	50	38	23	37
Scotland	5	8	4	13	10	25	19	47	37	20	18
England	4	16	11	22	8	17	8	2	0	3	15
Wales	1	0	0	2	1	0	0	0	0	0	4
National Parks											
Britain	10	22	11	9	11	21	15	5	1	15	6
Scotland	3	5	3	2	5	10	6	4	1	10	2
England	5	16	9	6	5	11	8	1	0	4	2
Wales	2	1	0	1	1	0	1	0	0	1	2
RSPB Nature reserves											
Britain	1	2	2	8	3	3	5	7	4	2	6

7. FIGURES

Figure 1. In order to generate 1-km resolution estimates from tetrad level models, a) model-based predictions were generated using not only the original tetrad-based prediction data, but also using explanatory datasets summarised on shifted tetrad grids. The predicted abundance in each 1-km square was then calculated as b) the mean abundance of the four tetrads overlapping the square.

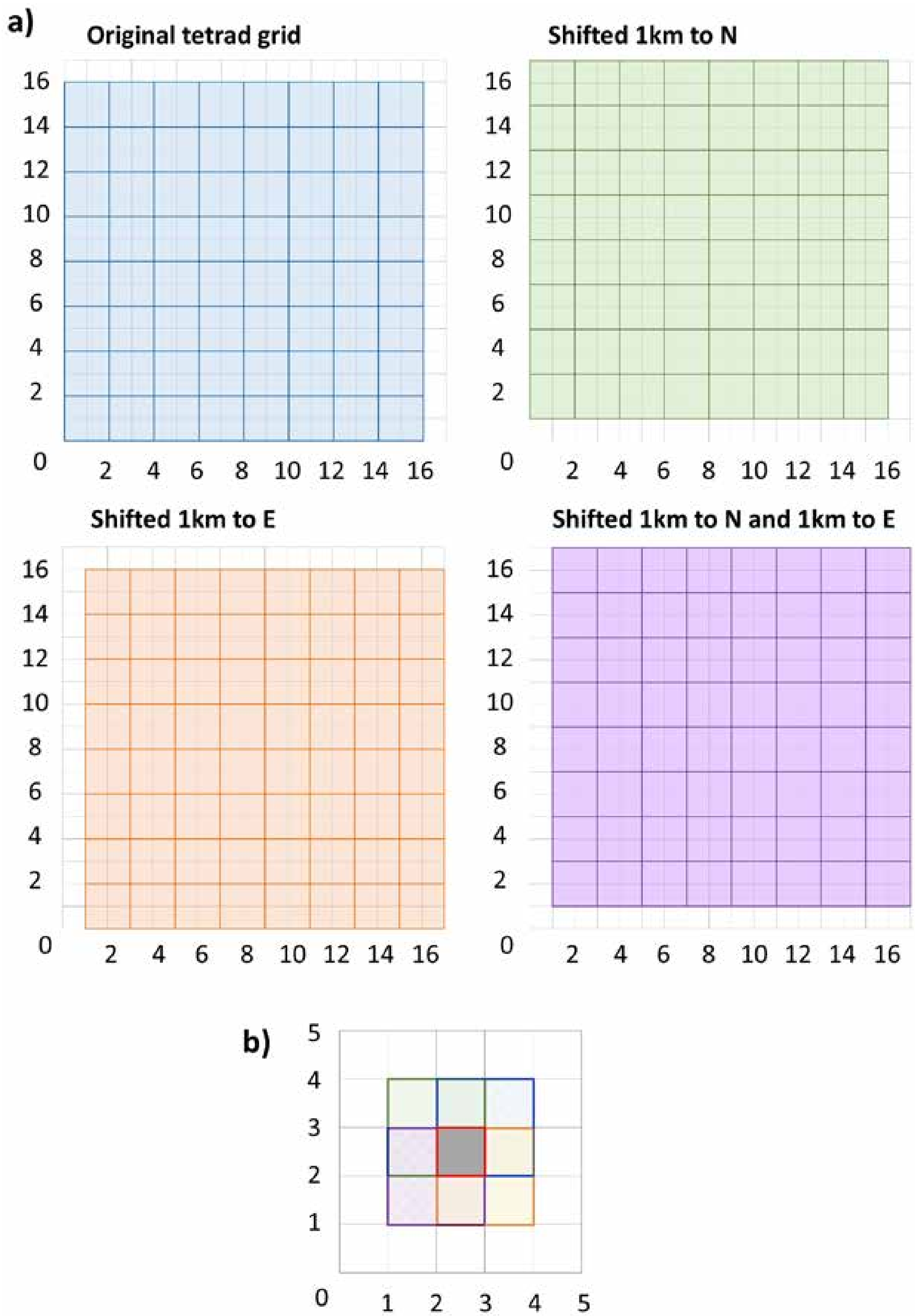


Figure 2. Locations of randomly selected 1-km squares surveyed for bespoke surveys of breeding waders in Northumberland and NE Cumbria in 2021.

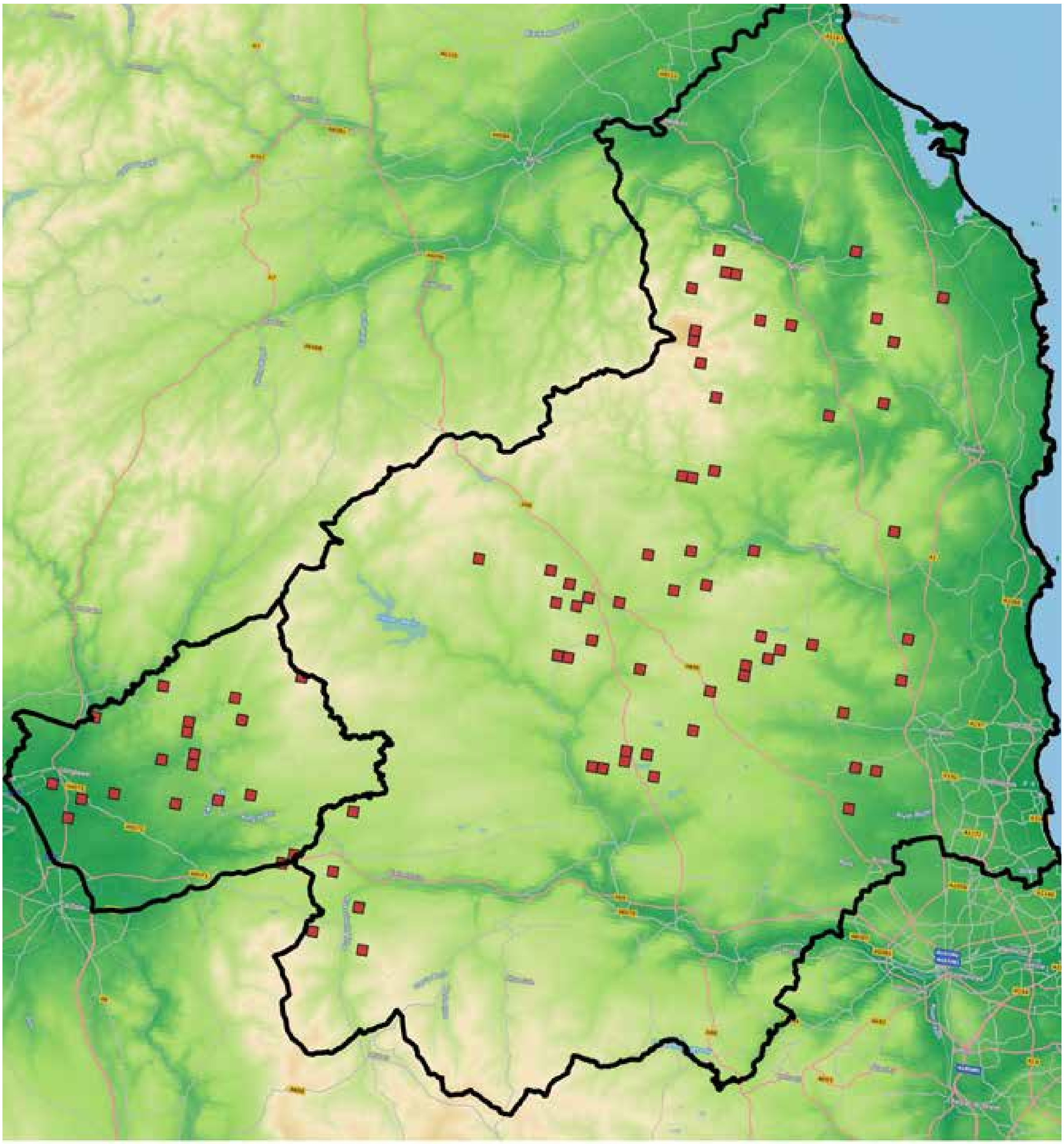


Figure 3. The predicted relative abundance of Curlew in Britain, (insert) Northumberland and the NE Cumbria FIZ. The highest relative abundances are represented by red, then in declining abundances by dark green, light green, yellow and blue.

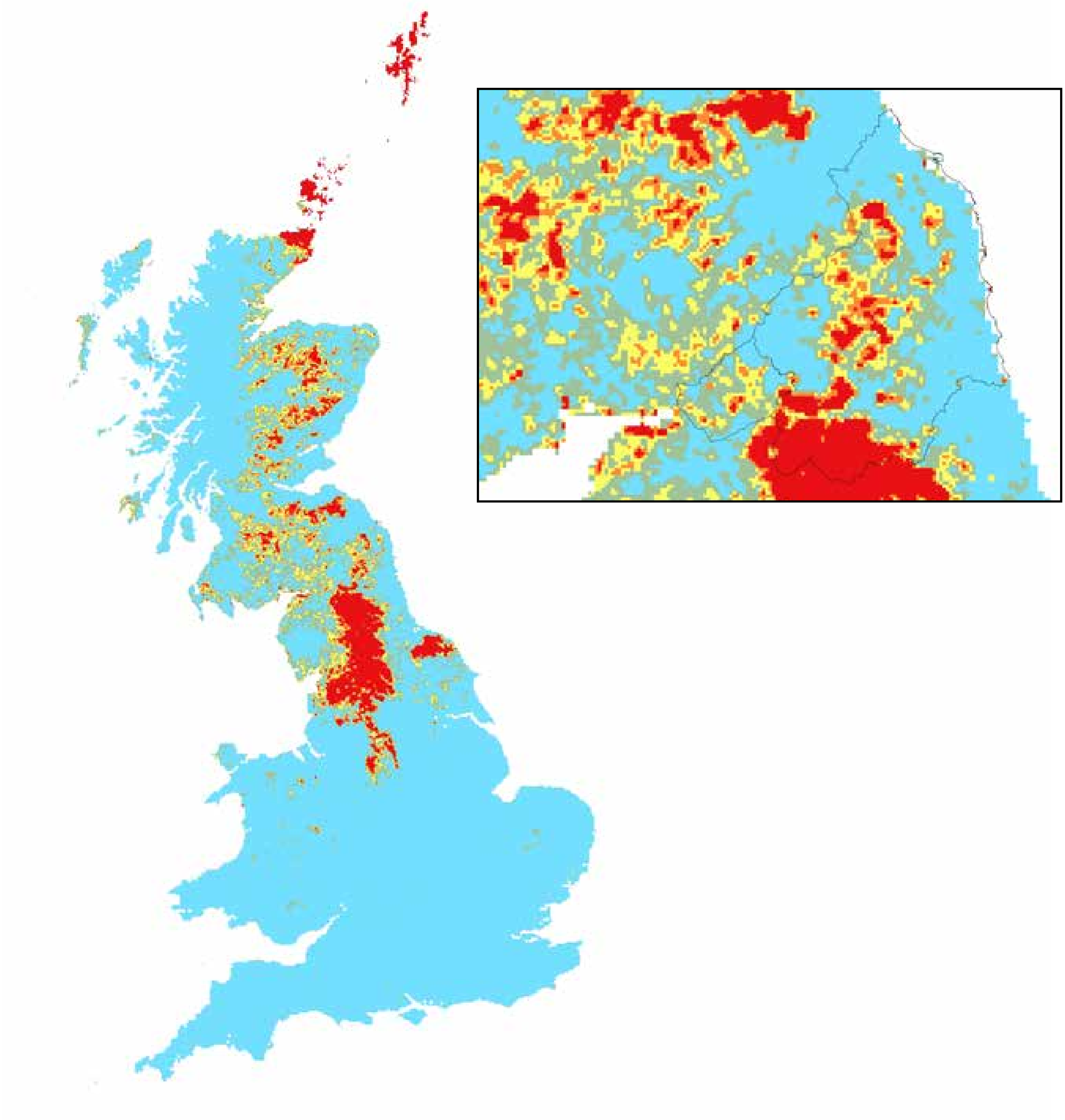


Figure 4. The predicted relative abundance of Lapwing in Britain, and (insert) Northumberland and the NE Cumbria FIZ. The highest relative abundances are represented by red, then in declining abundances by dark green, light green, yellow and blue.

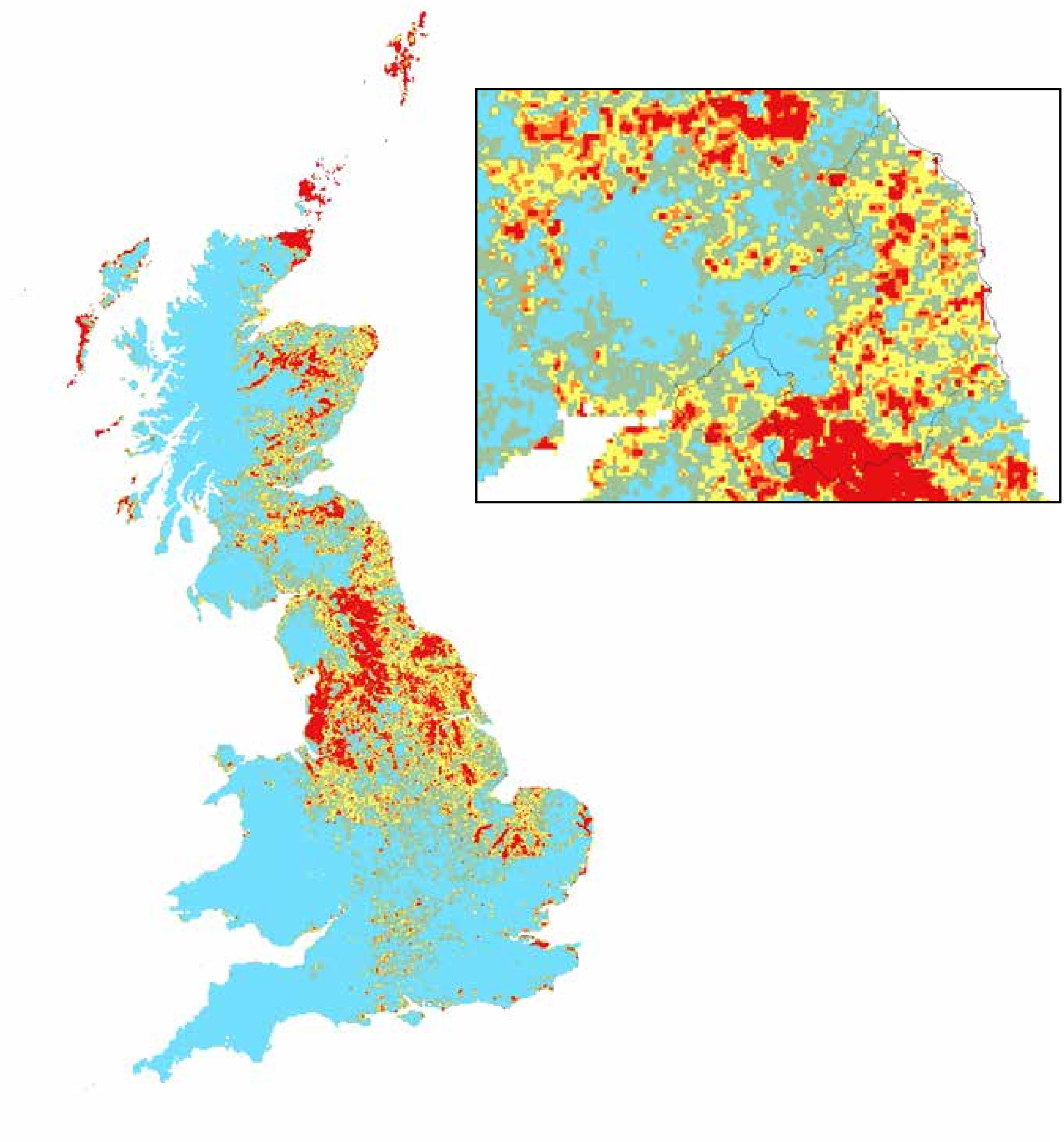


Figure 5. The predicted relative abundance of Oystercatcher in Britain, and (insert) Northumberland and the NE Cumbria FIZ. The highest relative abundances are represented by red, then in declining abundances by dark green, light green, yellow and blue.

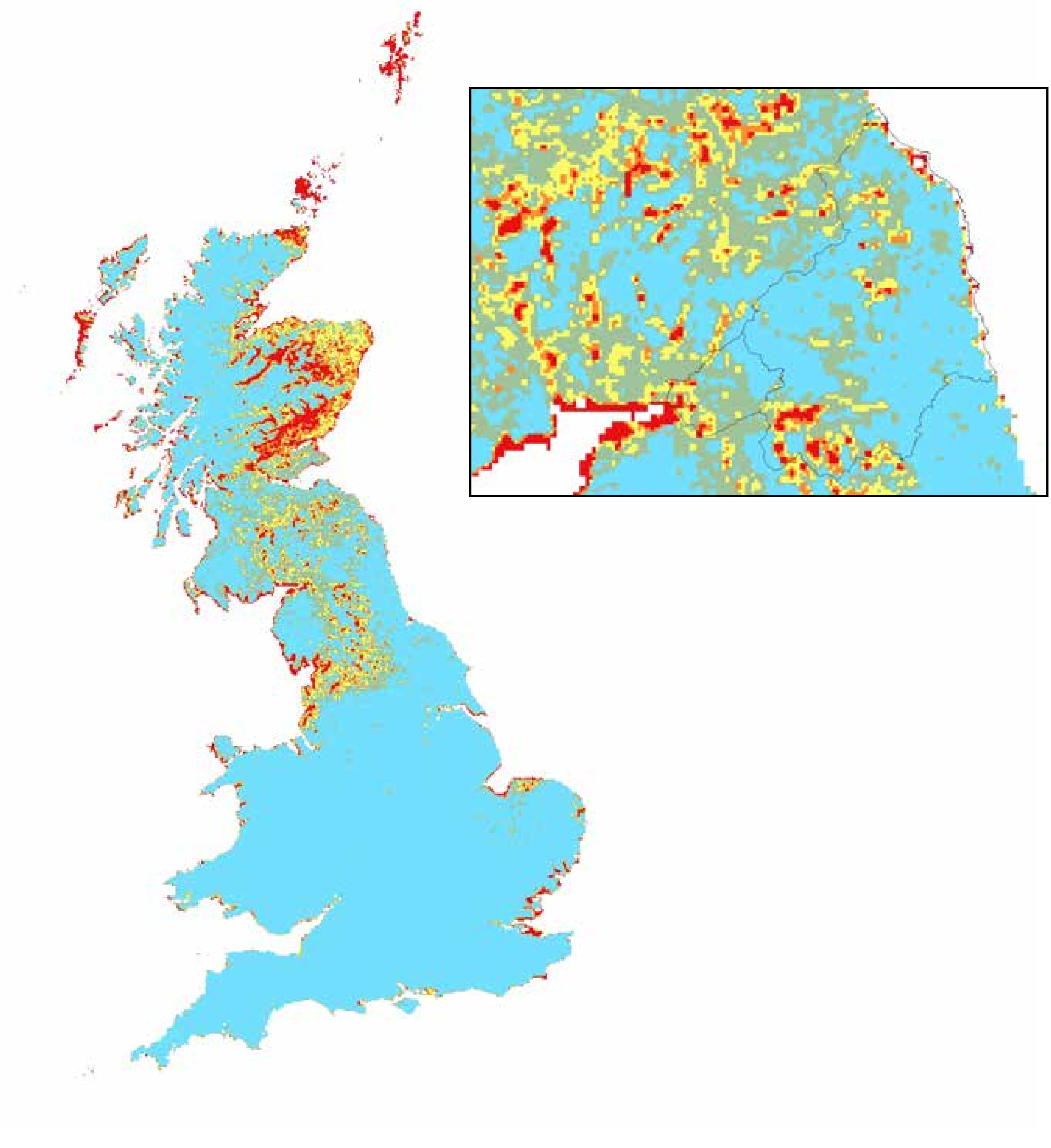


Figure 6. The predicted relative abundance of Redshank in Britain, and (insert) Northumberland and the NE Cumbria FIZ. The highest relative abundances are represented by red, then in declining abundances by dark green, light green, yellow and blue.

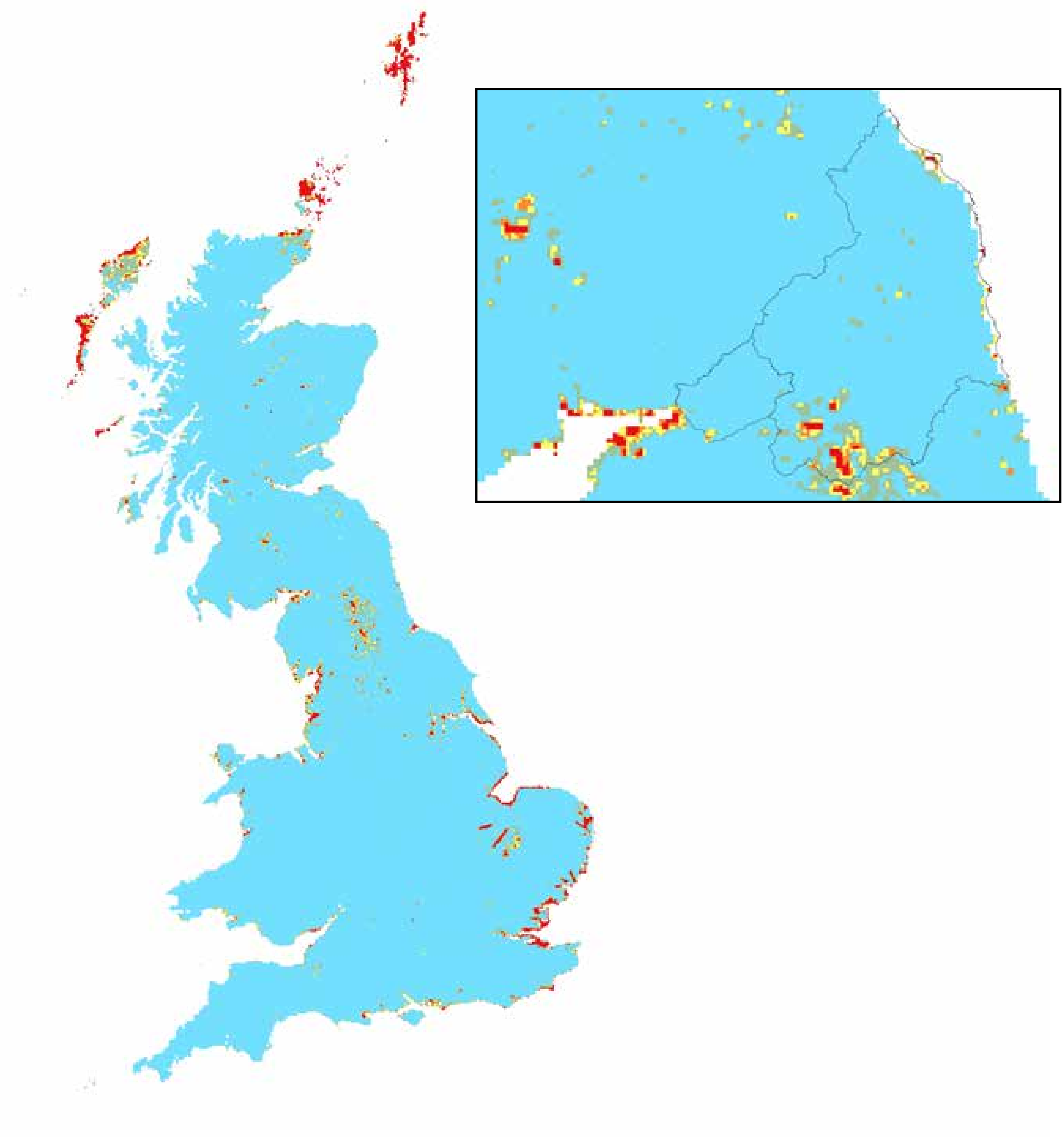


Figure 7. The predicted relative abundance of Greenshank in Britain, and (insert) Northumberland and the NE Cumbria FIZ. The highest relative abundances are represented by red, then in declining abundances by dark green, light green, yellow and blue.

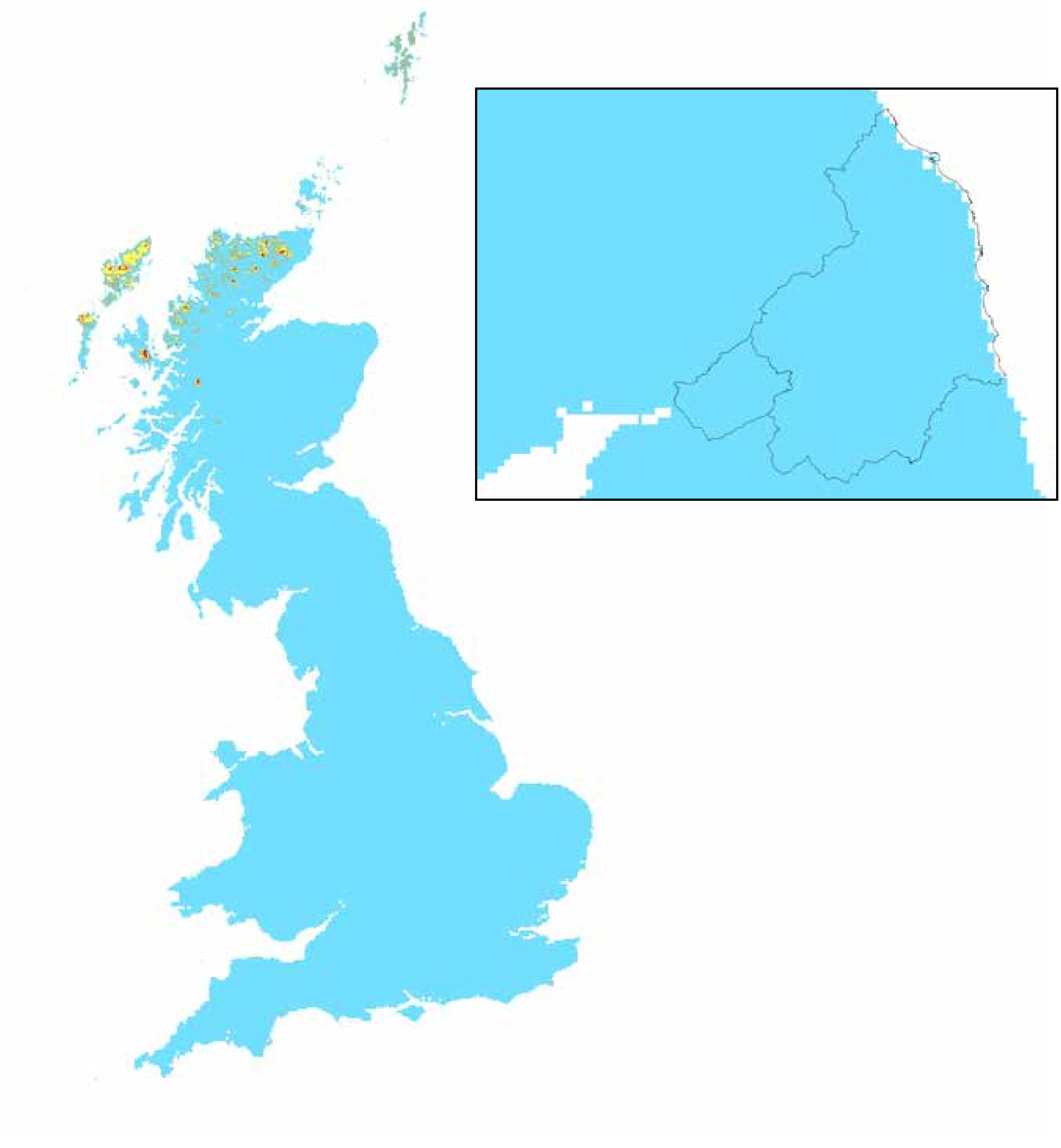


Figure 8. The predicted relative abundance of Snipe in Britain, and (insert) Northumberland and the NE Cumbria FIZ. The highest relative abundances are represented by red, then in declining abundances by dark green, light green, yellow and blue.

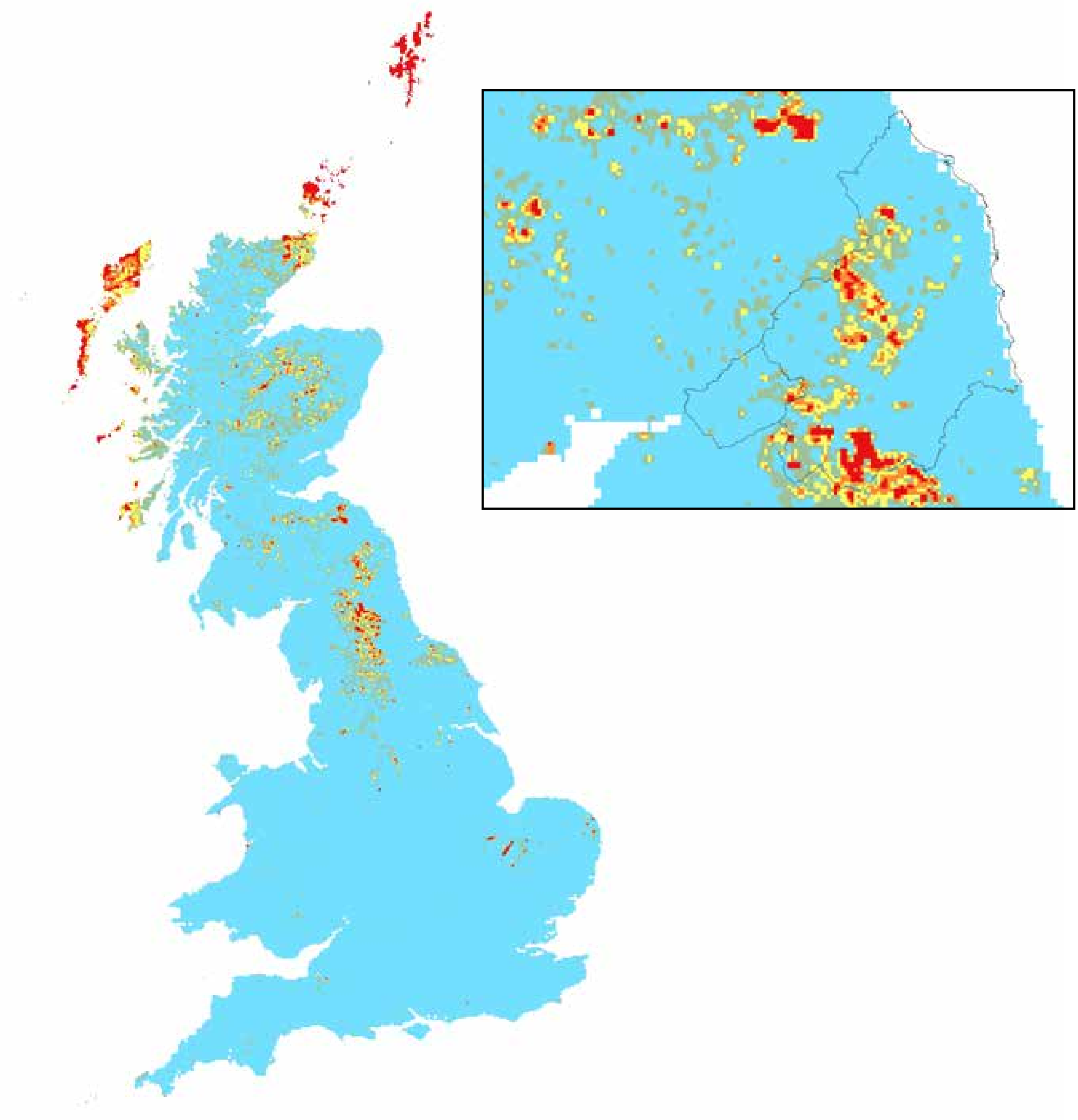


Figure 9. The predicted relative abundance of Golden Plover in Britain, and (insert) Northumberland and the NE Cumbria FIZ. The highest relative abundances are represented by red, then in declining abundances by dark green, light green, yellow and blue.

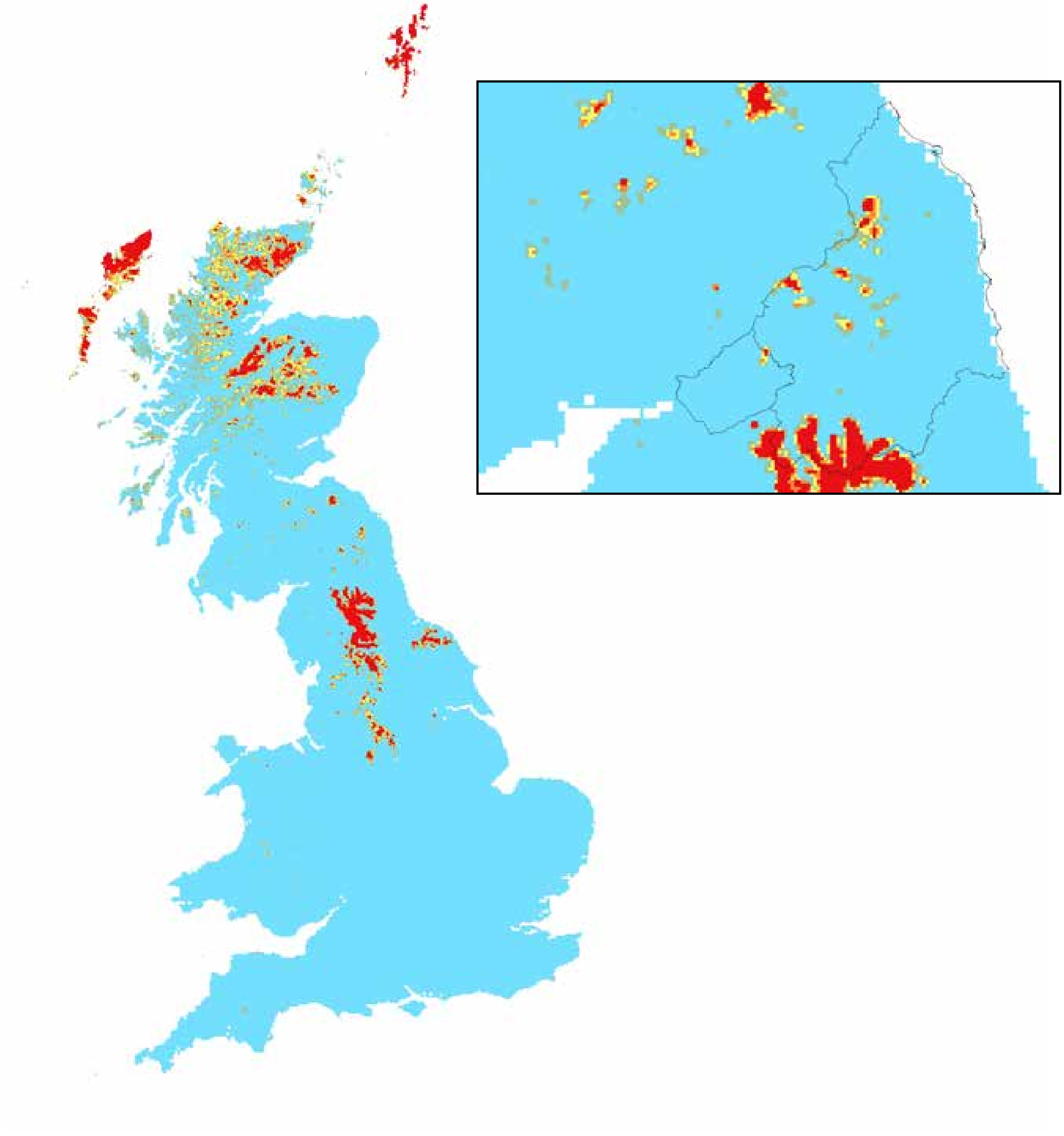


Figure 10. The predicted relative abundance of Dunlin in Britain, and (insert) Northumberland and the NE Cumbria FIZ. The highest relative abundances are represented by red, then in declining abundances by dark green, light green, yellow and blue.

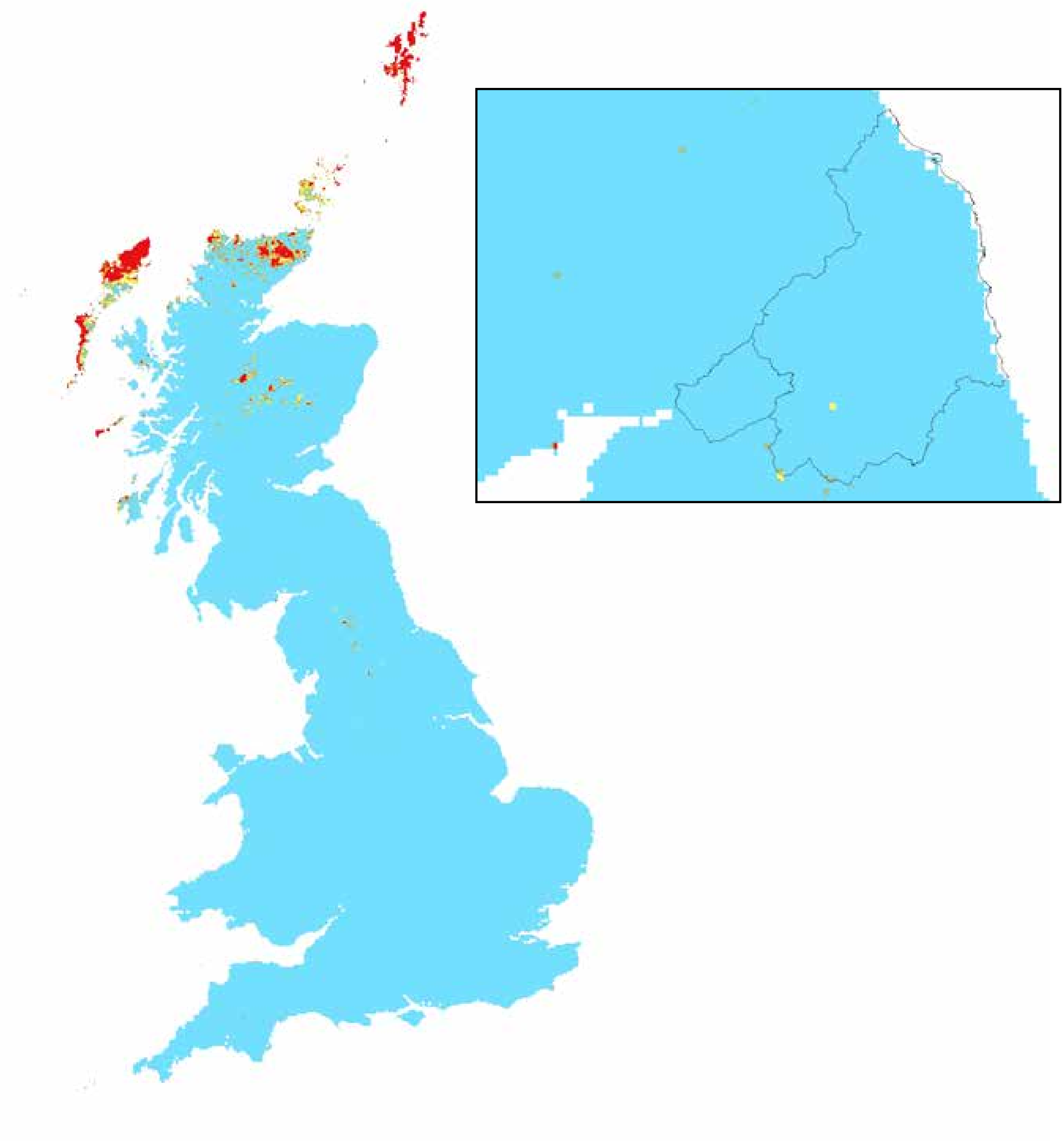


Figure 11. The predicted relative abundance of Common Sandpiper in Britain, and (insert) Northumberland and the NE Cumbria FIZ. The highest relative abundances are represented by red, then in declining abundances by dark green, light green, yellow and blue.

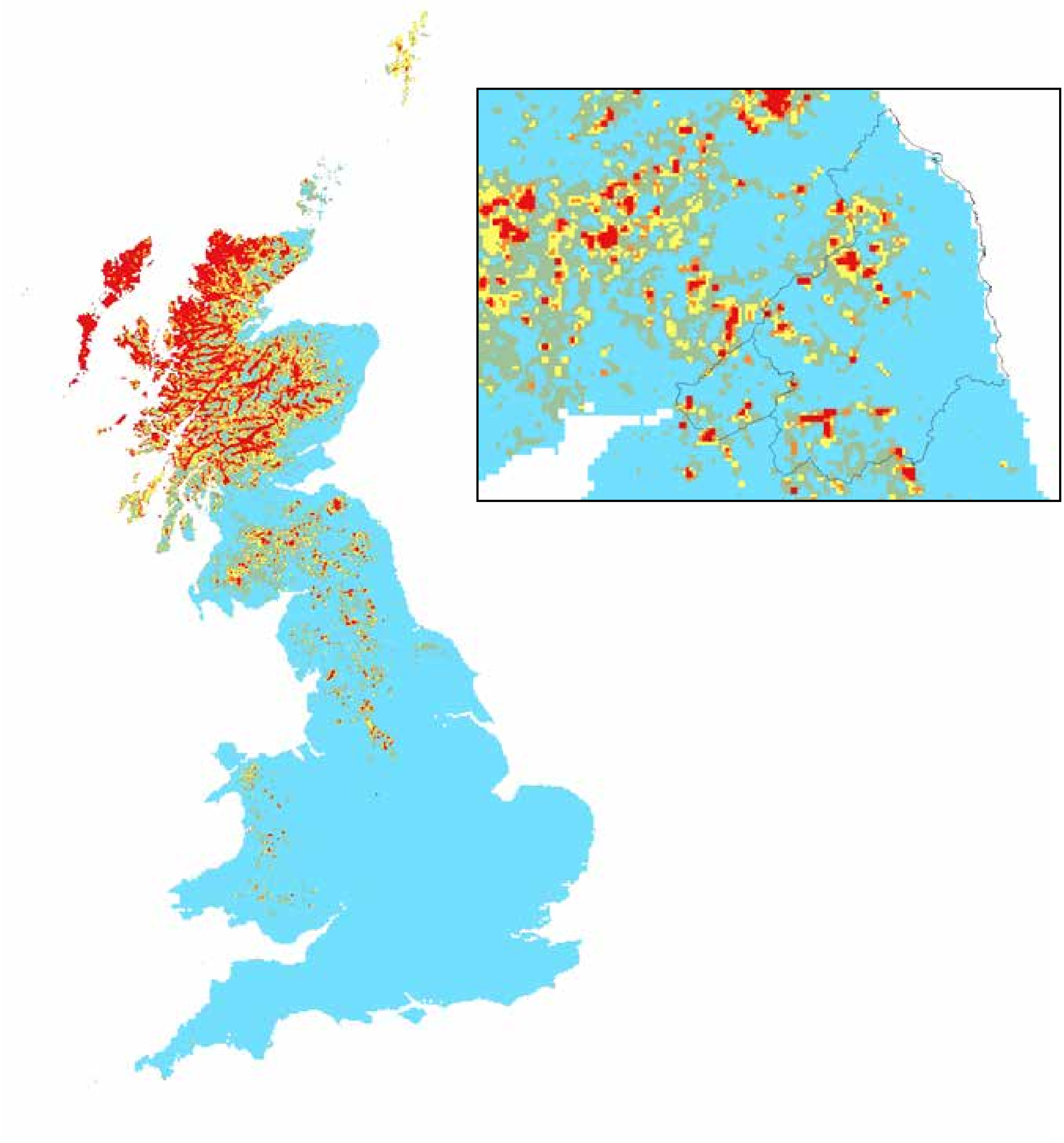


Figure 12. The predicted relative abundance of Ringed Plover in Britain, and (insert) Northumberland and the NE Cumbria FIZ. The highest relative abundances are represented by red, then in declining abundances by dark green, light green, yellow and blue.

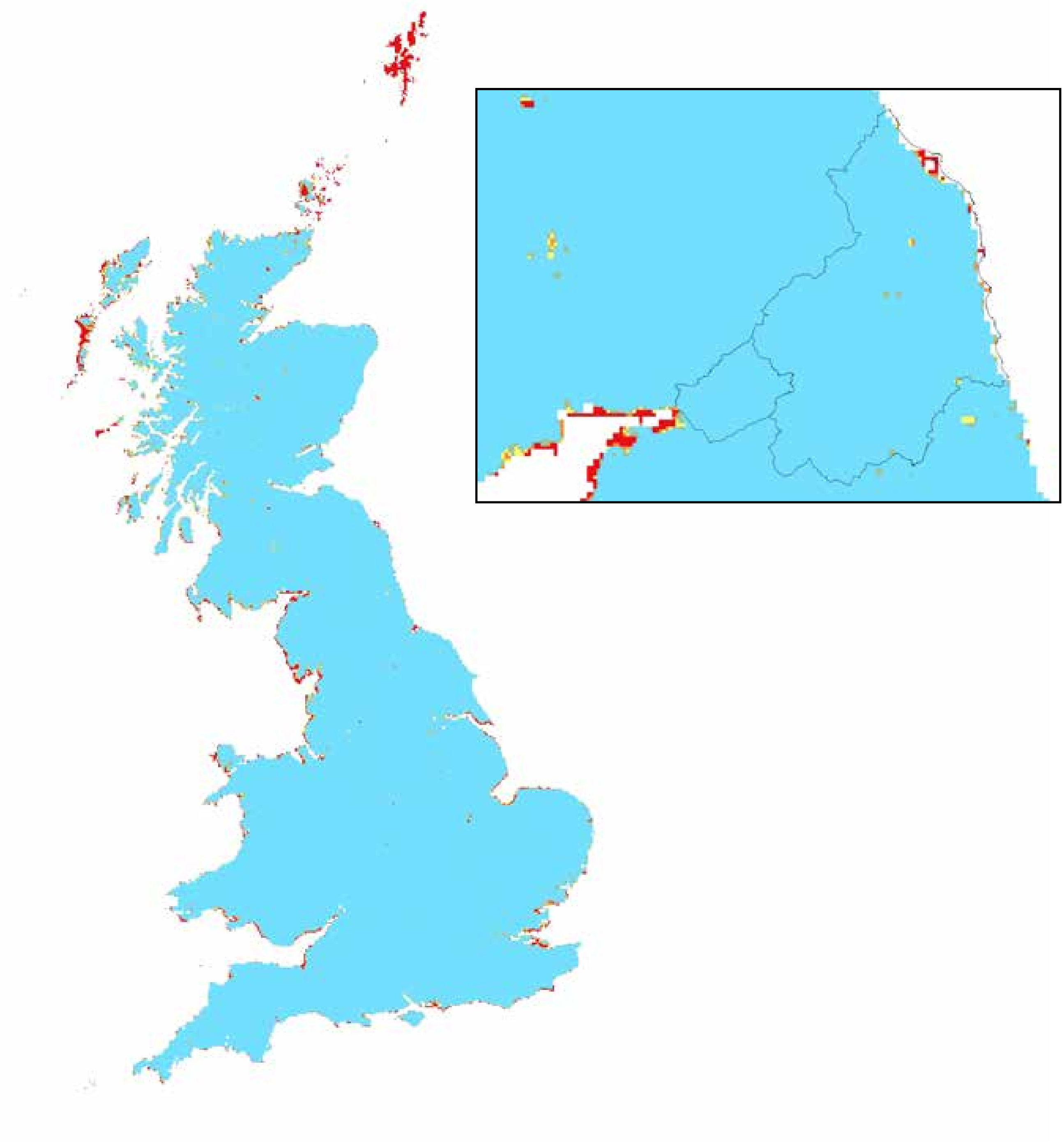


Figure 13. Plotted distribution of abundances of breeding Curlew in 2021 based on field surveys (Density estimates) with the predictions of the RFRT model based Bird Atlas fieldwork in 2007–11.

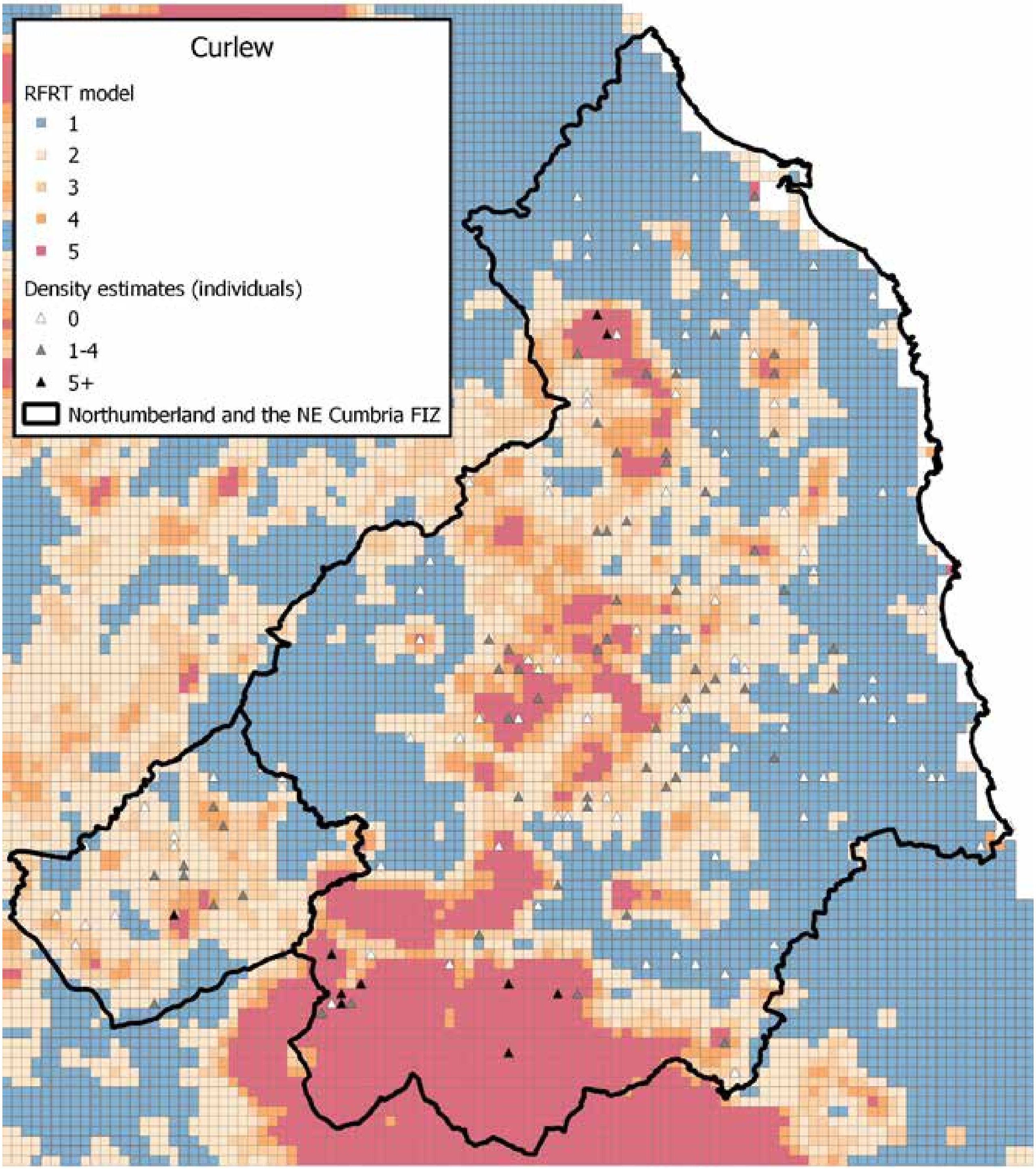


Figure 14. Plotted distribution of abundances of breeding Lapwing in 2021 based on field surveys (Density estimates) with the predictions of the RFRT model based Bird Atlas fieldwork in 2007–11.

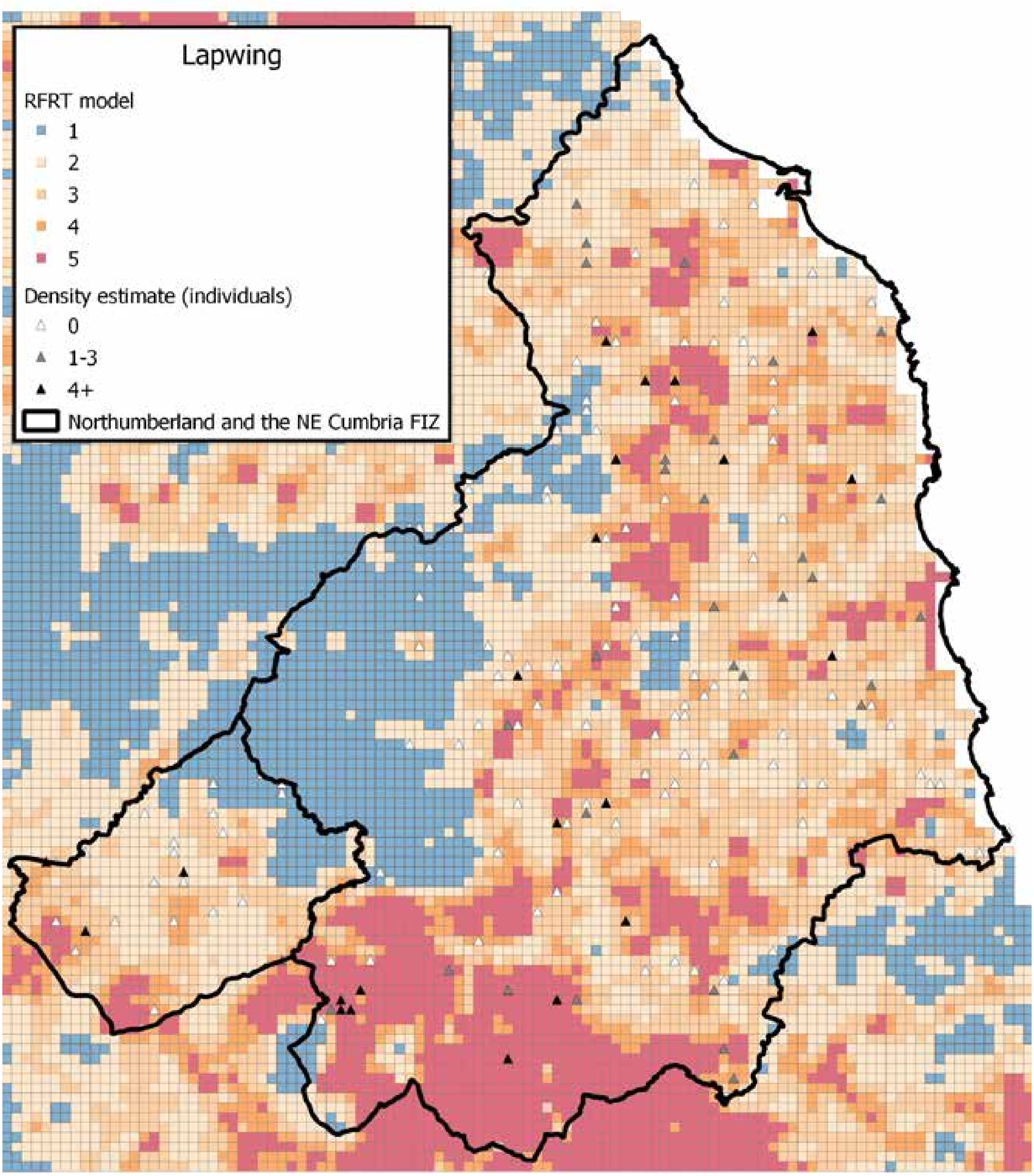


Figure 15. Plotted distribution of abundances of breeding Oystercatcher in 2021 based on field surveys (Density estimates) with the predictions of the RFRT model based Bird Atlas fieldwork in 2007–11.

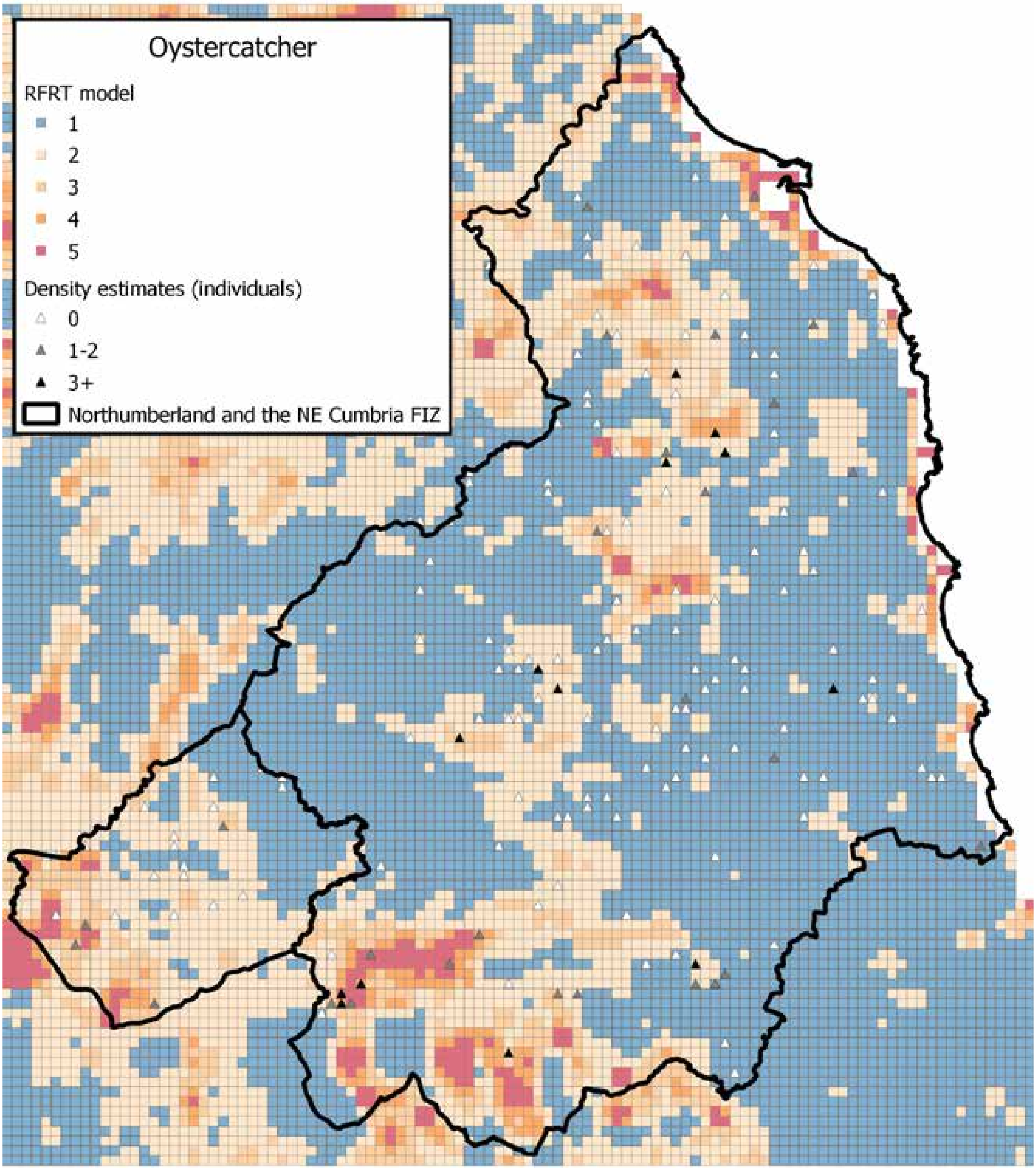


Figure 16. Plotted distribution of abundances of breeding Snipe in 2021 based on field surveys (Density estimates) with the predictions of the RFRT model based Bird Atlas fieldwork in 2007–11.

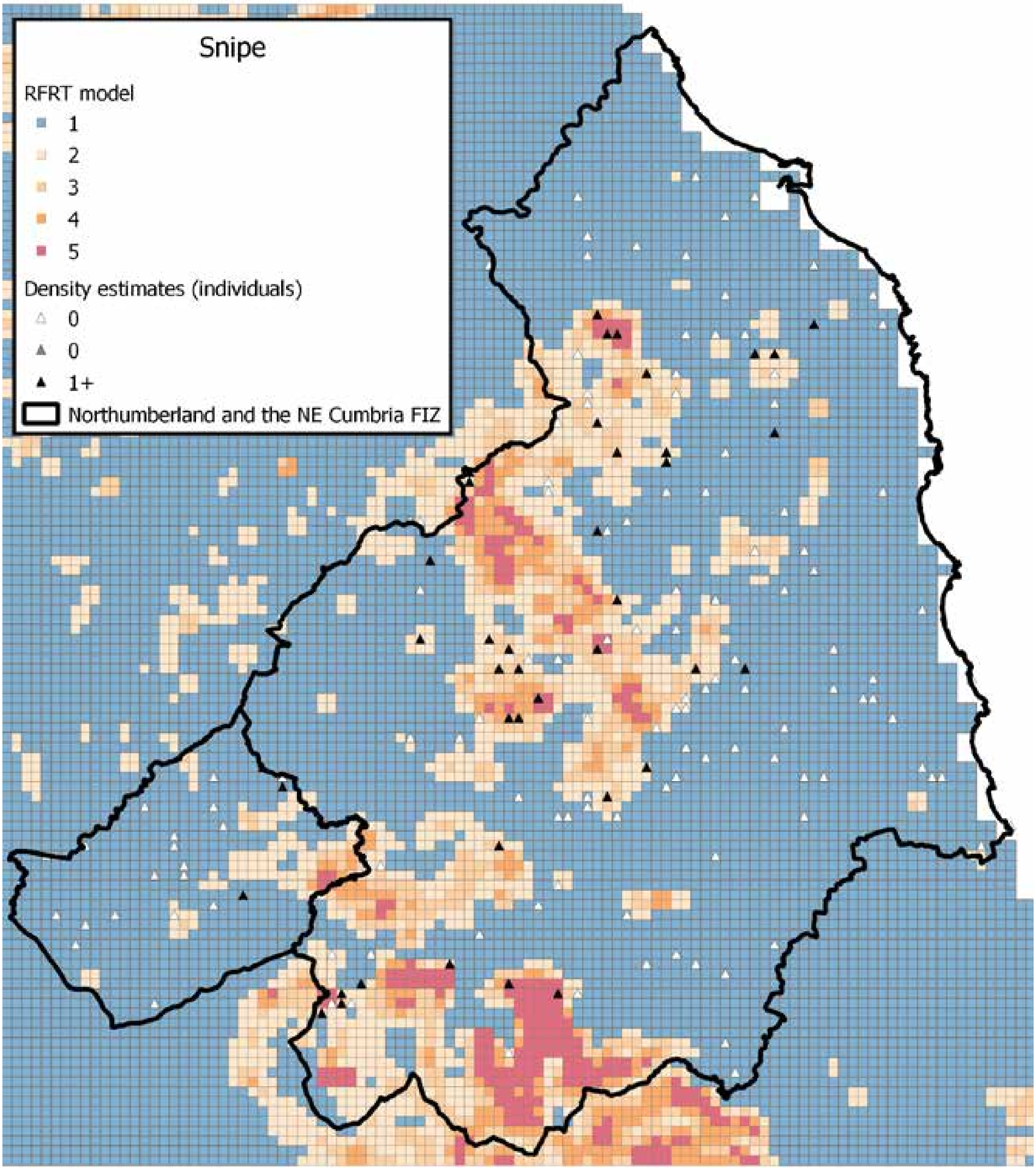


Figure 17. Plotted distribution of abundances of breeding Golden Plover in 2021 based on field surveys (Density estimates) with the predictions of the RFRT model based Bird Atlas fieldwork in 2007–11.

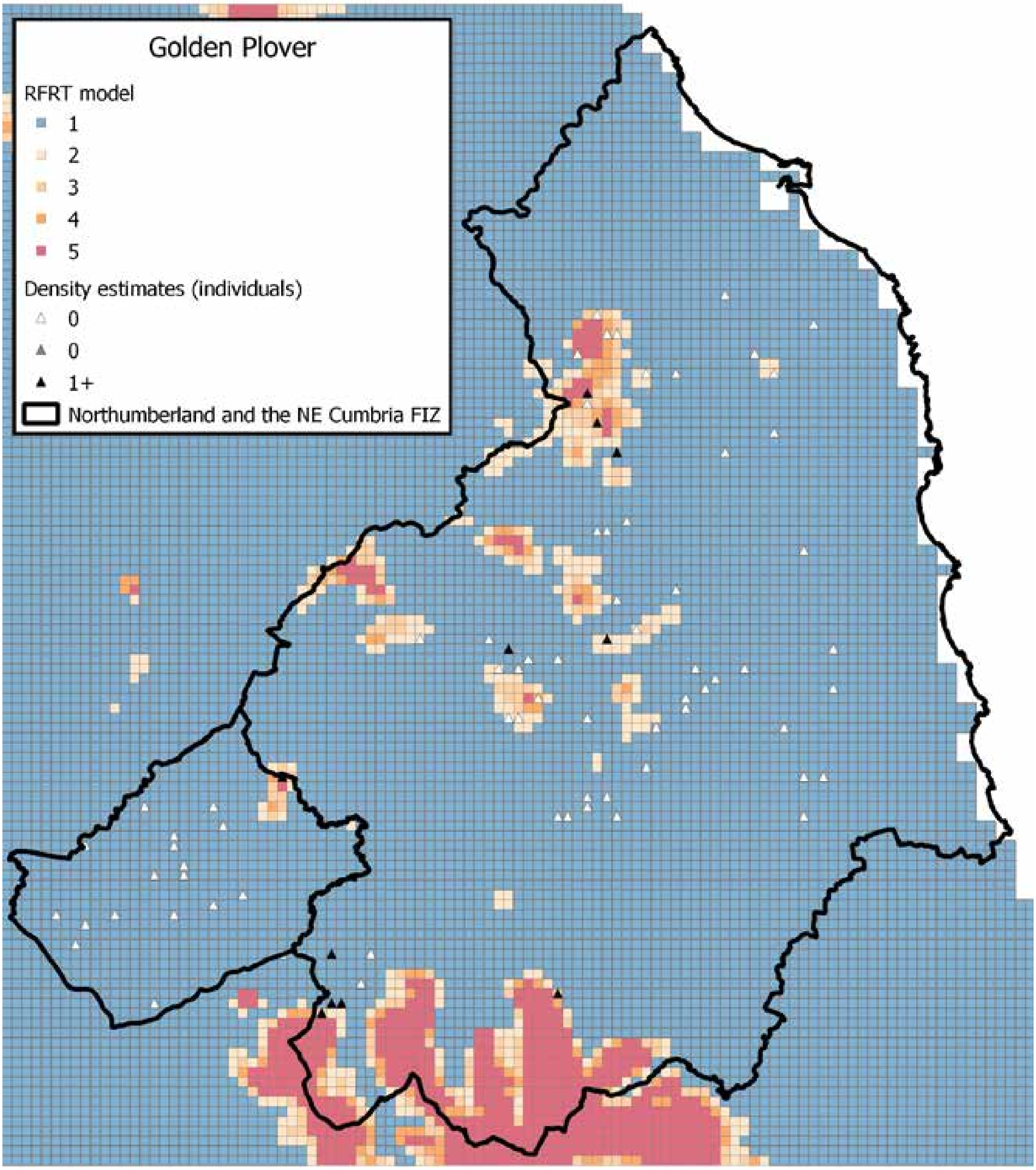
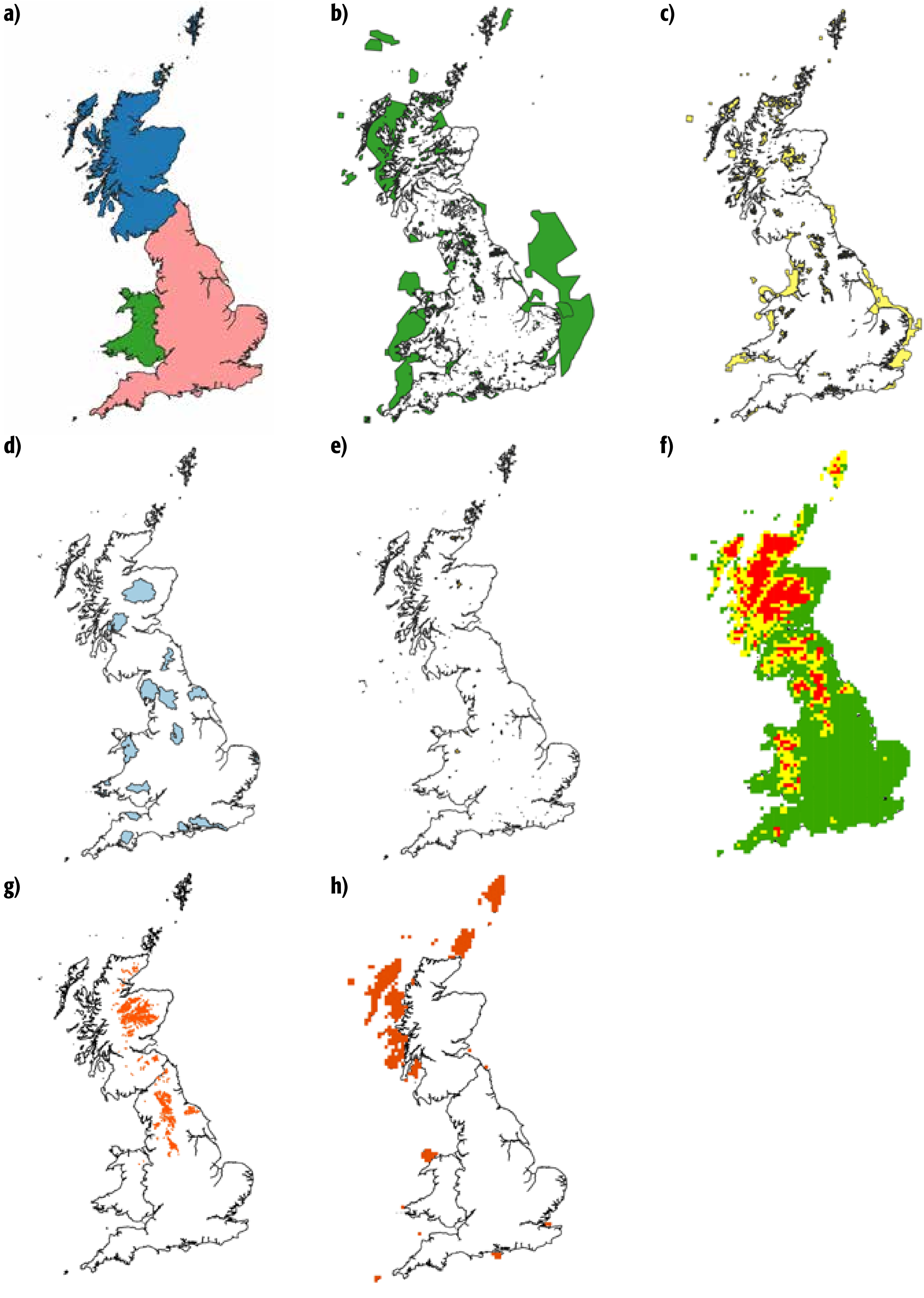


Figure 18 . The landscape, land-use and designation categories which were used to assess the proportions of breeding waders they supported: (a) Countries – England (pink), Scotland (blue), wales (green); (b) Special areas of Conservation (SAC); (c) Special Protection Areas (SPA); (d) National Parks; (e) RSPB nature reserves; (f) Landscape types – Upland- (red), Mixed- (yellow) and Lowland- (green) dominated landscapes; (g) Grouse moors; (h) Islands.



Cover images: Edmund Fellowes

Sensitivity mapping for breeding waders in Britain: towards producing zonal maps to guide wader conservation, forest expansion and other land-use changes. Report with specific data for Northumberland and north-east Cumbria.

Breeding waders in Britain are high profile species of conservation concern because of their declining populations and the international significance of some of their populations. Forest expansion is one of the most important, ongoing and large-scale changes in land use that can provide conservation and wider environmental benefits, but also adversely affect populations of breeding waders. We describe models to be used towards the development of tools to guide, inform and minimise conflict between wader conservation and forest expansion.

Extensive data on breeding wader occurrence is typically available at spatial scales that are too coarse to best inform wader conservation and forestry stakeholders. Using statistical models (random forest regression trees) we model the predicted relative abundances of 10 species of breeding wader across Britain at 1-km square resolution. Bird data are taken from *Bird Atlas 2007–11*, which was a joint project between BTO, BirdWatch Ireland and the Scottish Ornithologists' Club, and modelled with a range of environmental data sets.

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