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Review of data and monitoring options for assessing the status of breeding wader populations in the Yorkshire Dales National Park

Mark Wilson, David Jarrett & John Calladine

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A report to the Yorkshire Dales National Park Authority

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BTO Research Report 713

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YORKSHIRE DALES
National Park Authority

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EXECUTIVE SUMMARY

1. Breeding waders are among the birds of highest conservation concern in the UK. The findings of recent national scale surveys suggest that the Yorkshire Dales National Park (YDNP) supports important breeding concentrations of several wader species.

2. This report assesses the availability and quality of information relating to breeding populations of six of the most numerous wader species (Oystercatcher, Golden Plover, Lapwing, Snipe, Curlew, Redshank) in the YDNP. We make recommendations about how the ability of these datasets to inform the Park Authority (YDNPA) about wader population trends and distributions can be maintained or enhanced, and how this information can be deployed to inform planning for and management of waders in the YDNP.

3. We considered nine potential sources of information on breeding waders in the YDNP: The BTO/JNCC/RSPB Breeding Bird Survey (BBS); BTO/SOC/BWI Bird Atlases; the BTO/Natural England Breeding Waders of English Upland Farmland survey (BWEUF); the YDNPA/RSPB Enclosed Grassland Survey (EGS); the NCC Moorland Bird Survey; the results of distribution modelling carried out by Leeds University; Gamekeeper surveys of breeding waders; BTO/RSPB/BWI/SOC/WOS BirdTrack and surveys carried out for agri-environment schemes (AESs).

4. BBS data for the YDNP show significant changes, over a 24 year period, in the breeding populations of all six species of waders. However, the size of population change that could be reliably detected in the YDNP at current levels of BBS coverage varies markedly between species. Modelling indicates that detection could be reliable for relatively small changes (e.g. 20–30%) in populations of Lapwing and Curlew, but only for larger changes (e.g. 50–70%) in populations of Golden Plover and Redshank.

5. 1-km squares surveyed for BBS in the YDNP cover a broadly representative range of habitats, but are skewed slightly towards areas with high levels of cover of non-acid semi-natural grassland, and away from areas with high levels of woodland and urban cover. The distribution of survey activity is consistent with a preference among BBS surveyors for landscapes at the moorland fringe.

6. Coverage from wader-targeted surveys such as BWEUF, the EGS and the Moorland Bird Survey was greater in eastern areas of the YDNP than in the west. However, information from Bird Atlas and BirdTrack (for which coverage is more evenly distributed), as well as from the modelling work carried out at Leeds University, suggest that western areas of the Park, where survey coverage was low, most likely support low abundances of breeding waders.

7. Maps distinguishing areas of high and low value to waders within the YDNP could help to improve regulation and planning for wader populations. Data from the Bird Atlases and from BWEUF could be used to define and refine the zones in these maps.

8. Current levels of BBS coverage in the YDNP are suitable to monitor population changes in breeding waders. However, for relatively scarce species such as Redshank, only large changes will be reliably detected. To inform population trend assessment in such species, larger samples would be needed. Possibilities that could enable this include extending the area under consideration beyond the YDNP (e.g. including other areas within the 'Northern Uplands Chain' or NUC), augmenting BBS information with data from other sources, such as gamekeeper surveys, or carrying out more intensive, targeted surveys (such as BWEUF) on a periodic basis.

9. Gamekeeper surveys following a method developed in collaboration between BTO and Wensleydale in 2017 have been carried out on several estates in the YDNP, as well as in Nidderdale AONB. These surveys have the potential to generate valuable information on wader populations in the YDNP and other upland areas. In the short term, local survey participants and organisers should be provided with support and guidance, to ensure that survey protocols are robust and consistent, and that data collation makes them straightforward to analyse. In the longer term, work will be needed to determine how best to use information from gamekeeper surveys, particularly to augment information from the BBS to increase our ability to detect changes in wader populations. Opportunities to validate the findings of gamekeeper surveys, through comparisons with data from other established survey methods, should be taken where possible.

10. The ongoing development of a Results Based Agricultural Payment Scheme (RBAPS), which has been trialled in the YDNP, may provide opportunities for improving the information collected on breeding waders. Ensuring that appropriate monitoring of waders is effectively embedded within this scheme could improve our ability to assess the impact of AES measures on breeding wader populations.

11. There is an urgent need for the development of methods to enable the collection of robust and reliable information on breeding productivity of waders. Opportunities for participants in wader surveys in the YDNP to trial methods of measuring productivity should be encouraged.

12. Improved information on predator numbers and activity, predator management, and the effects of these on waders, would be useful. Distribution of muirburn, or spatial variation in corvid abundance, could be used as proxies for variation in predator control activities and its consequences, but the scale of such effects should be considered carefully before interpreting relationships between proxies and wader populations. Information on predator control could also be sought directly from game managers. In the longer term, gathering better information on (especially mammalian) predators will be a worthwhile aim.

13. Horizon scanning should be carried out to identify and engage with initiatives outside of the Park to increase information on waders within the YDNP. Work undertaken through or with the support of the Northern Upland Chain (NUC) partnership could be especially relevant.

1. INTRODUCTION

The Yorkshire Dales National Park (YDNP) was established in 1952. It is the second largest National Park in England and, as other National Parks, has a two-fold, statutory function:

1. To maintain and enhance wildlife, scenic landscape and cultural heritage (conservation);

2. To promote enjoyment of the park, and of the outdoors in general, by the public (recreation).

The main habitats within the YDNP include enclosed farmland, most of which is managed as pasture or for grass crops, at a range of altitudes and intensities; and unenclosed upland areas used for extensive grazing, including moorland managed for recreational shooting of Red Grouse (*Lagopus lagopus*). Conditions at the interface between unenclosed and enclosed land can be particularly well suited to breeding waders, especially where there is a well-developed gradation between the agriculturally more improved 'in-bye', through more extensively managed 'intake' or 'allotment' ground, to adjoining moorland and mires. The benefit that breeding waders derive from these habitat mosaics can be further enhanced by the effects of predator control associated with management for Red Grouse.

To ensure that the YDNP maintains its high value for breeding waders, areas of little potential value to waders should be distinguished from areas that could benefit from improved management (for example through agri-environment schemes) and existing high-value areas where it might be most important to avoid negative local impacts on waders through inappropriate developments (e.g. poorly sited forest plantations) or changes in land management. Also, it is important to be able to assess whether overall management within the Park, as well as well individual elements of this management, are working to maintain and enhance wader populations.

To these ends, this report assesses the availability and quality of information relating to breeding wader populations in the YDNP. Breeding waders have been included in, or else been the principal subject of a number of surveys and monitoring programmes within the YDNP area. This report focuses on the six most abundant breeding waders species in the YDNP: Curlew (*Numenius arquata*), Lapwing (*Vanellus vanellus*), Redshank (*Tringa totanus*), Oystercatcher (*Haematopus ostralegus*), Golden Plover (*Pluvialis apricaria*) and Snipe (*Gallinago gallinago*). The YDNP also supports populations of other wader species, but as well as being relatively small (and so yielding fewer data that could be used to inform decisions relating to regulations, management and development within the Park), most of these are less closely associated with managed farmland and moorland habitats. Modest but locally important numbers of Dunlin (*Calidris alpina*: probably less than 100 breeding pairs) are found mostly in areas of blanket bog habitats on the higher hills in the YDNP. Ringed Plover (*Charadrius hiaticula*) and Little Ringed Plover (*Charadrius dunius*) are present in smaller numbers, with breeding very localised (e.g. disused quarries). Common Sandpiper (*Actitis hypoleucos*) is present at low densities throughout the Park in riparian habitats. Woodcock (*Scolopax rusticola*) are very infrequently detected by normal wader survey methods, and are positively associated with woodland.

This report summarises the information that these surveys have produced for the six most abundant breeding wader species in the Park, and examines what it could be used for and how it might best be supplemented or improved. Specifically, we assess the likely suitability of this information for evaluating historical and future population changes, as well as for providing a basis for policy and decision making relating to zoning, management and development within the Park. These assessments are used to highlight the need for further targeted management and development of other conservation and research projects. The report also considers options for enhanced future monitoring including opportunities for people, especially from local communities, including a range of land managers. These monitoring opportunities are considered not only in the context of achieving a more comprehensive and integrated approach to wader monitoring, but also in the potential they hold for advancing ecological skills and understanding among a wide range of stakeholders.

1.1 AIMS

Specific aims of this scoping review are:

- to review the available data on past and current populations and distributions of breeding waders within the YDNP;

- to evaluate how reliable detection of wader population changes in the YDNP is likely to be affected by availability of data, wader species, and magnitude of population change;

- to assess the suitability of existing information for identifying areas of importance for breeding waders;
- to outline potential modules for the integration of existing data, monitoring programmes and new data collection to establish a robust monitoring programme for breeding waders that informs conservation action by the YDNP Authority and others.

2. METHODS

2.1 EXISTING DATA SOURCES

Most of the datasets considered by this report are currently held in electronic format by either BTO or the YDNPA. This allowed the suitability of these datasets for contributing relevant information on wader populations within the YDNP to be assessed and analysed by the authors. The potential value of some other sources was also considered, even though information from these sources could not be compared directly with the other datasets. Each source of information considered in this review is described briefly below, along with the way in which this information was used.

2.1.1 THE BTO/JNCC/RSPB BREEDING BIRD SURVEY

This is a national, annual survey aimed at generating information on terrestrial breeding populations of birds in the UK (Field & Gregory 1999). The birds in randomly selected one kilometre squares are sampled along two, broadly parallel 1-km transects. In each Breeding Bird Survey (BBS) square, the maximum count of each species over two survey visits (carried out mostly in April, May and June) is taken as a measure of abundance for that year. This information is mainly used to assess national trends of relatively common and widespread species, including breeding waders (e.g. Harris *et al.* 2018). An informal partnership between BTO and the YDNPA has specifically aimed to encourage participation in the BBS by volunteers within the YDNP. Bespoke periodic reporting, as part of this partnership, has provided some information on trends since 1994 within the YDNP (e.g. de Palacio *et al.* 2018) but despite good coverage (Figure 1a), indices for breeding waders can have relatively large confidence intervals and therefore low power to detect change. BBS surveys currently provide the main source of data to inform population trends of waders in the YDNP. The power of BBS data to detect different levels of change was formally assessed using power analysis. All data pertaining to the BBS are held by BTO, but locations of BBS squares in the YDNP are given in Supplementary material.

2.1.2 BTO/SOC/BWI BIRD ATLASES

These atlases map the national distribution and relative abundance of all birds at 20 year intervals, the most recent covering breeding seasons 2008–11 (Balmer *et al.* 2013). Timed counts of all birds encountered during one or two hour long survey visits are carried out in a minimum of 8 tetrads per 10-km square. Results from these surveys are used, along with those of less systematic surveys, to provide information on presence, breeding status and abundance, which are typically presented at 10-km or coarser resolution. Coverage in the YDNP during surveys for the most recent Bird Atlas was very high (Figure 1b; Supplementary material). Of the 637 tetrads overlapping the YDNP, timed tetrad visits (TTVs) for the most recent Bird Atlas were carried out during the breeding season in 569 (89%). Waders were recorded on one or more of these visits in 509 (89%) of these tetrads. Bird Atlas data were used to assess the quality and coverage of information on wader populations within the YDNP. The Atlas was one of three data sources used to assess the likelihood that important concentrations of waders might occur outside areas where detailed surveys (such as BWEUF and the Moorland Bird Surveys; see Sections 2.1.3 and 2.1.5) had taken place. All Bird Atlas data are held by BTO, but grid references of tetrads where TTVs were carried out are given in Supplementary material.

2.1.3 BTO/NATURAL ENGLAND BREEDING WADERS OF ENGLISH UPLAND FARMLAND (BWEUF)

This was a one-off survey of the waders breeding in areas corresponding to 'in-bye' agricultural land, and is one of three comprehensive (i.e. aiming to record all breeding waders occurring within the surveyed areas) surveys reviewed in this report. This is relatively unimproved enclosed upland farmland (excluding unenclosed moorland and more improved, often lowland, fields). The survey was carried out in 2016 (Siriwardena *et al.* 2017) and focused on upland farmland within 1 km of the moorland boundary. The survey aimed to deliver population sizes and habitat associations for waders within the sampled habitats across England and includes sampled tetrads (2 km by 2 km squares) within the YDNP. Pre-survey stratification for BWEUF estimated that the total area of in-bye in the YDNP, according to this definition, was 504 km^2. Of this total, 24% (120 km^2) was surveyed for waders using a two-visit methodology similar to that described by O'Brien & Smith (1992). Surveys were carried out in 61 tetrads (Figure 1c), out of a total of 269 tetrads with a minimum of 80 hectares of target farmland. The average cover of in-bye land within these tetrads (46.1%) being very similar to average cover of in-bye in the remaining 208 non-survey tetrads (47.1%). BWEUF data were used to assess the quality and coverage of information on wader populations within the YDNP, with comparisons between BWEUF data and other datasets (such as the Bird Atlas) informing consideration of whether existing coverage could be relied on to identify important concentrations of waders in the Park. BWEUF data are held by BTO, and are owned jointly by BTO, RSPB and Natural England. The locations of tetrads and size of areas included in this survey within the YDNP are given in Supplementary material.

2.1.4 YDNPA/RSPB ENCLOSED GRASSLAND BIRD SURVEY

This survey was carried out in 2000, and was similar to BWEUF in that it targeted areas of enclosed upland grassland, and was similarly comprehensive in its intent, using field-based recording as described by O'Brien & Smith (1992). The survey targeted breeding waders covering 88 1-km squares within the YDNP (Figure 1d). Data from this survey were mapped at the level of individual fields within sampled squares. However, although these data are held in paper form by the YDNPA, they have not been digitised at this resolution. We digitised data from this survey at the level of the 1-km square (Supplementary material). These data contribute to detailed understanding of abundance and distribution of breeding waders within the YDNP.

2.1.5 NATURE CONSERVANCY COUNCIL MOORLAND BIRD SURVEYS

Breeding bird surveys of selected areas of unenclosed moorland (Figure 1e) were carried out during the 1990s (following on from territory mapping in the 1980s based on multi-visit (up to four per year) transect surveys, as set out in Reed et al. 1985). These involved an area-based search methodology similar to that described by Brown & Shepherd (1993), and so aimed to record all pairs of breeding waders present within the areas surveyed. Data are held in digital format, with individual bird records from the survey having been captured as points in a GIS shapefile (Supplementary material). Five of the six species considered in this report were encountered during the Moorland Bird Surveys (MBS); Oystercatcher were not recorded presumably because of their closer association with enclosed farmland however the MBS includes records of breeding Dunlin. MBS data were used to assess the quality and coverage of information on wader populations within the YDNP, with comparisons between these data and other datasets (such as the Bird Atlas) informing consideration of whether existing coverage could be relied on to identify important concentrations of waders in the Park.

2.1.6 UNIVERSITY OF LEEDS SPECIES DISTRIBUTION MODELLING

A map of potentially suitable breeding wader habitats was derived from model habitat data and sample surveys of breeding waders carried out in the late 2000s. Sixty-one survey transects, each 2 km long, were centred on randomly selected grid intersections, and subsequently moved and oriented to coincide with public rights of way, bridleways and minor roads (Figure 1f). Presence and absence data of Curlews and Lapwings along 200 m sections of these transects, collected during three survey visits between April and July in 2008, were modelled using environmental variables (including habitat, topography, field size, and rainfall data) to generate maps of occurrence probability for these two species (Bradter *et al.* 2013). We used these maps to evaluate whether areas of high Curlew or Lapwing probability indicated by these models could be missed by assessments based directly on survey data. The locations of sampling transects are given in Supplementary material.

2.1.7 GAMEKEEPER SURVEYS OF BREEDING WADERS IN THE YDNP

A study undertaken in Wensleydale in 2017 tested the efficacy of engaging gamekeepers and farmers in monitoring breeding waders and their nests as an approach to achieve wider engagement and increase survey coverage (Jarrett *et al.* 2017). One of the methods considered by the study was designed to fit easily into the daily working routines of gamekeepers by following 'traplines', routes along which traps set for small mustelids were regularly checked by keepers. The study found that this method had the capacity to generate survey results comparable to those of standard wader survey methods typically employed in ecological surveys of similar moorland and upland farmland habitats (e.g. O'Brien & Smith 1992, Brown & Shepherd 1993). Since this study was completed, the Yorkshire Dales Moorland Group has promoted this survey method among its constituent shooting estates. Between 12 and 15 of the 23 moorland estates managed for grouse shooting in the Yorkshire Dales are active members of this group. Of these, members of staff on at least nine estates have carried out surveys in 2018 (Sonya Wiggins pers. comm.). One survey was carried out at each estate, except at Bolton Castle (which hosted the pilot study in 2017) where two routes were surveyed (one by the head keeper, one by the under-keeper). The data collected by these surveys have yet to be collated or analysed, but this report considers the potential for this survey method to contribute to annual monitoring in the YDNP.

2.1.8 BTO/RSPB/BWI/SOC/WOS BIRDTRACK

BirdTrack (https://www.bto.org/volunteer-surveys/birdtrack/about) is an international initiative that collects data on sightings of birds made by members of the public. These data are more difficult to interpret than those generated by systematic and structured surveys, because they are accompanied by little or no information relating to surveyor effort. Variation in BirdTrack data may relate as much to the distribution and behaviour of survey participants as it does to underlying patterns in abundance of birds. However, BirdTrack records can nevertheless be useful, particularly when those submitted to BirdTrack as 'complete lists', which include all species encountered by the observer at a particular time and place. We used BirdTrack wader records drawn from complete lists to check for evidence that the more systematic surveys may have missed or failed to detect areas with relatively high densities of waders.

2.1.9 AGRI-ENVIRONMENT SCHEMES

Farm Environmental Partnerships (FEPs) were drawn up for individual farms during the course of their applying for and participating in the Environment Stewardship Scheme. These plans were based on surveys of the habitats, wildlife and other notable features of environmental, historical or cultural value. The results of these surveys determined whether and in what form a farm was eligible for funding, as well as the kind of management that should be carried out under the scheme. Sites found to be holding habitats or species of high conservation value were eligible for maintenance grants, with an aim of maintaining or enhancing these features. Funding received by farms where habitats and species were deemed to be in poor condition or absent could be aimed at improving or restoring them. FEP surveys are no longer carried out, since the inception of the new Countryside Stewardship Scheme. However, similar surveys (covering number and behaviour of waders, as well as information about habitat, on a field basis) are carried out for this new scheme. Data from FEPs, as well as from the surveys that replaced these, are held by the YDNPA, but are not digitised in any form suitable for assessment of wader populations at a scale larger than that of the farm. We discuss the contribution that data from such surveys could make to monitoring, as well as to assessment of management carried out for waders, within the YDNP.

2.1.10 LAND COVER AND ELEVATION DATA

We used the LCM2000 land cover dataset (Figure 2; Fuller *et al.* 2002) to distinguish cover of broad land cover types at the 1-km square level. The categories of land cover drawn from this dataset were Heath & Mire, Acid Grassland, Non-acid Semi-natural Grassland, Improved Grassland, Arable, Woodland, and Urban. Elevation data were drawn from the Ordnance Survey Landform Panorama dataset, which provides mean elevation at 100 m resolution (https://www.ordnancesurvey.co.uk/opendatadownload/products.html). We summarised these values to derive mean elevation for every 1-km square within the YDNP. We used land cover and elevation data to test whether BBS coverage has been representative of the landscapes within the Park.

Figure 1. Maps illustrating coverage within Yorkshire Dales National Park for the following six surveys: a) Breeding Bird Survey (all 1km squares monitored in any year since 1994 are shaded red); b) Bird Atlas 2007–11 (all tetrads where timed breeding season visits were carried out between 2008 and 2011 are shaded red); c) Breeding Waders of Enclosed Upland Farmland (all tetrads included in this 2016 survey are shaded in red); d) Enclosed Upland Grassland survey (all 1 km squares surveyed in 2000 are shaded red); e) NCC Moorland Wader Survey (all areas surveyed for waders are shaded in red); and f) 61 wader transects surveyed in 2008 to inform habitat suitability modelling carried out at Leeds University. In these maps, as in other maps presented in this report, the YDNP boundary (along with the boundary between the original Park area and the 417 km² extension made in August 2016) and all 10-km grid squares overlapping the Park are shown.

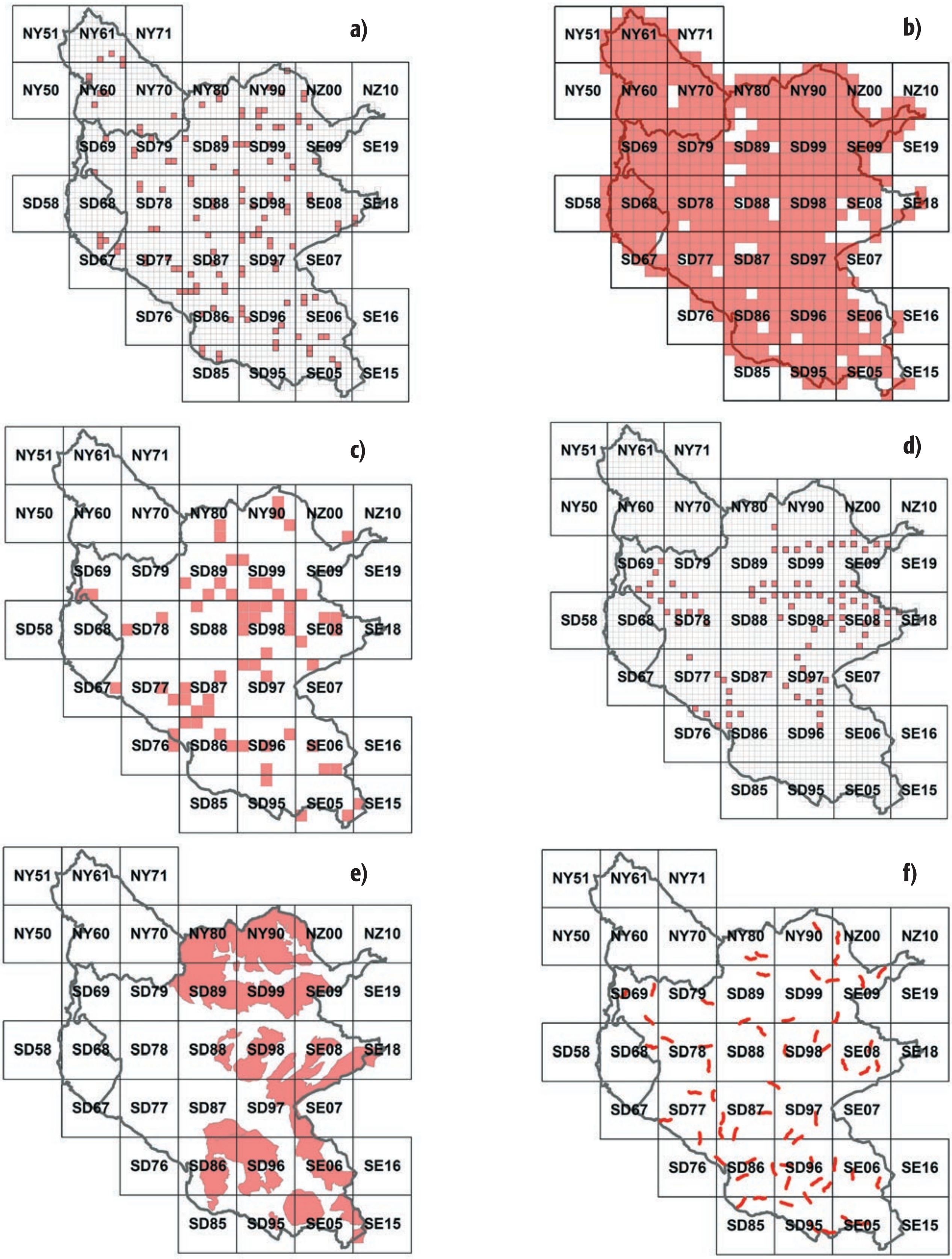
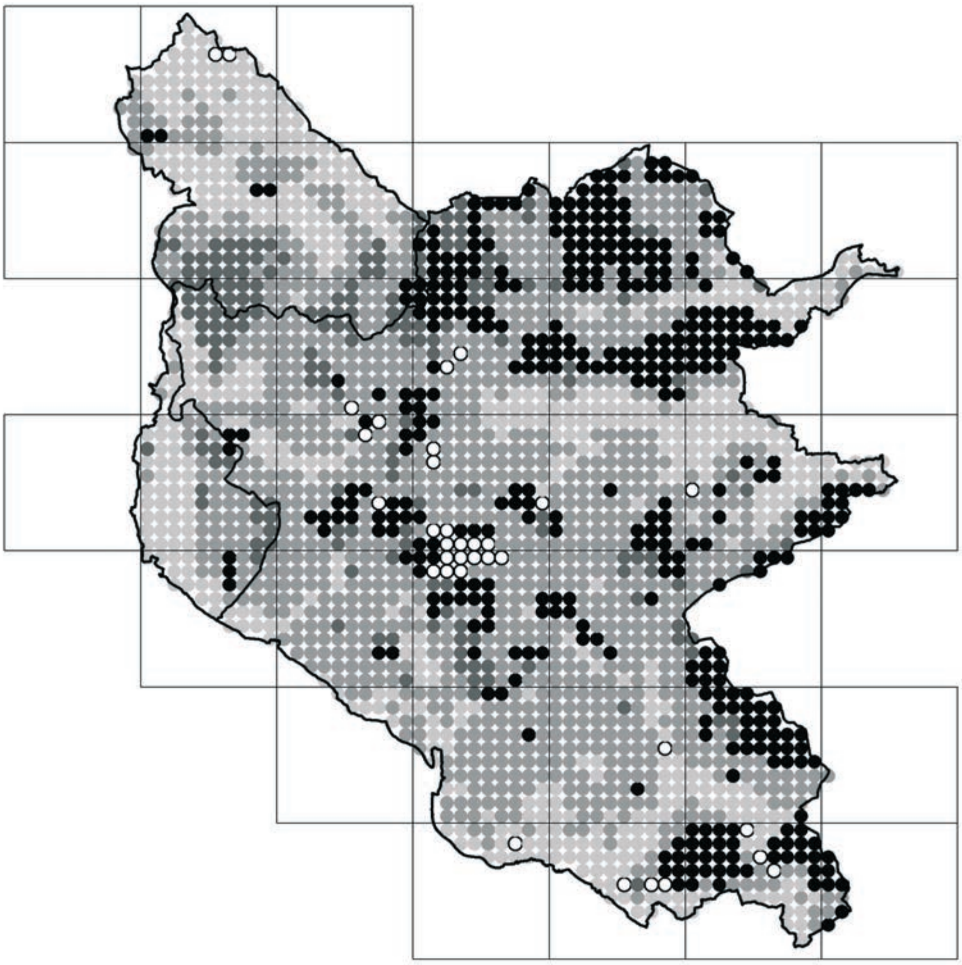


Figure 2. Dominant land cover within 1-km squares in the YDNP, according to LCM2000 land cover dataset. Black = Heath & Mire, dark grey = Acid Grassland, medium grey = Non-acid Semi-natural Grassland, light grey = Improved Grassland and Arable, and white with a black outline = Woodland.



2.2 PREPARATION OF DATA FOR ANALYSES

BBS and Bird Atlas data were filtered in order to minimise the influence of non-breeding flocks of waders on the analyses they were used in. BBS data comprised total counts of each wader species over all (typically 10) 200 m transect sections in each 1-km square. Bird Atlas data were counts of each wader species during the first hour of TTVs. For both surveys, maximum counts over early and late breeding season visits were used. For BBS data, we followed established practice for BBS trend analysis (Field & Gregory 1999) of applying a cut-off of 10 individuals per transect section for each wader species (larger counts were removed from analysis). For Bird Atlas data, a similar approach was followed to cap counts for the whole tetrad. Recent work on breeding season Curlew data from the Bird Atlas indicated that 99% of tetrads counts were 15 or less. Wader data from the Bird Atlas were therefore capped at 15, with any higher counts being set to 15.

Datasets for BWEUF and the Enclosed Grassland Survey both comprised counts of waders in individual fields, as well as estimates of the number of pairs in survey squares (tetrads for BWEUF and 1-km squares for the Enclosed Grassland Survey). The latter metric was used for both of these surveys. Individual bird records from the Moorland Bird Survey had been digitised as points in a GIS shapefile. These points were imported into ArcGIS Desktop 10.5.1, and overlayed against an OS 1:25,000 map. From this information, and the knowledge that the Moorland Bird Survey was carried out on unenclosed land, the area covered by this survey was estimated and mapped. Both the extent of survey coverage and the number of records of each species of wader encountered could then be summarised at a tetrad level. This allowed direct comparisons to be made at resolutions of 2-km and (higher) between data from BWEUF and the Moorland Bird Survey, and TTV counts from the Bird Atlas. When combining data BWEUF and the Moorland Bird Survey, the latter were divided by two in order to (conservatively) convert numbers of individual birds to numbers of breeding pairs.

The number of records for each focal wader species taken from BirdTrack complete lists within the YDNP, at a resolution of 1-km, and recorded with breeding status of either confirmed or probable, was taken as a basic measure of abundance for each 10-km square. This measure was divided by the complete number of 1-km resolution lists submitted for each 10-km square to produce a density of wader records per list, in order to adjust this basic abundance measure according to survey effort. Squares with fewer than 50 lists were excluded from analysis due to their being too data-poor.

2.3 MONITORING TEMPORAL CHANGE IN WADER POPULATIONS

2.3.1 SIGNIFICANCE OF RECENT BBS TRENDS

Temporal trends in abundance for each of the six focal wader species were estimated from BBS data collected in the YDNP. Trends were estimated from Poisson generalised linear models with maximum counts during BBS surveys as the response variable, and year (continuous variable) and 1-km square (factor) as explanatory variables. The contribution of paired upland adjacent squares to the model with an offset of log(2) (other squares had offset of 0). For each species, the annual rate of population change, and overall change over the 24 years spanned by the survey, were calculated from the slope and intercept of the model. The statistical significance of these changes was taken from the z statistic and associated P-value for the model coefficient for year.

2.3.2 POWER ANALYSIS

The effects of sample size and magnitude of population change on power to detect population change from BBS survey data were assessed using simulations. In order to realistically simulate population changes of known size, these simulations were based on data with similar levels of random inter-annual variability (i.e. variation within squares and between years, controlling for overall long-term trends) to those seen in BBS squares in the YDNP. First of all, data in Northern England were sub-setted. For each wader species, a Poisson general linear model was used to model the effect of time and survey square on the maximum count over both survey visits. For each square, the model residuals (the difference between the observed number of waders and the number predicted by the model) were calculated for all years in which there was a survey. The model was also used to predict the maximum number of waders found in 1994 for every square in the sample. This value was used as an abundance index for each square, and rounded up to the nearest 5 birds to produce a category of abundance.

The number of squares in each category was calculated for all 135 BBS squares in the Park. A stratified random subset of 405 squares (three times the number of BBS squares overlapping the YDNP) was then drawn from the larger sample (of BBS squares in Northern England), with a near identical distribution between abundance categories as for the YDNP BBS squares.

This subset of squares, henceforth referred to as the parent set, was used to generate samples for power analysis simulations. For each simulation, a sample of squares was drawn at random from the parent set. The sample was used to generate two sets of abundance values (representing two periods between which change was being assessed). Both of these sets were based on the 1994 predicted values for these squares. Each square in the first set of values was adjusted simply by adding the model residual from a randomly selected survey year. The second set was adjusted by uniformly multiplying all values by the simulated rate of change (e.g. if a 60% decline, all values would be multiplied by 0.4), and then adding the model residual of a different, randomly selected survey year. These two sets of abundance values therefore corresponded to known differences in abundance levels, and displayed realistic levels of variation, both between squares and (within squares) between periods.

2.3.3 REPRESENTATIVENESS OF COVERAGE

In order to assess how well information generated by BBS represents the range of habitats within the wider YDNP, the effect of land cover and elevation on survey coverage was assessed in a binomial general linear model. Explanatory variables were screened to identify co-linear pairs of variables for which Pearson's correlation coefficient was more than 0.7. Out of each such pair of variables, only one was included in the model, on the understanding that any perceived effects of this variable might be surrogate for effects of the other. The proportion of years in which BBS visits were carried out at a square (up to a maximum of 24) was specified as the response variable, with mean elevation and percentage land cover as explanatory variables. Backwards and forwards model selection (according to AIC score) from the full model proceeded until no variables could be added or removed without increasing the AIC value. Generalised linear models were also used to test for differences in the mean value of each variable between BBS survey squares and all squares within the

YDNP. The contribution of each square was weighted according to the years that BBS had been carried out in it.

2.4 IDENTIFICATION OF IMPORTANT AREAS FOR WADERS

The spatial distribution of wader information provided by the surveys described in section 2.1 was mapped, in order to illustrate areas of overlap and gaps in coverage, and also tabulated to show the area covered by each survey within each of the 37 10-km squares within the YDNP. From this information, the proportion of each 10-km square covered by comprehensive surveys (surveys where the aim was to record all waders occurring within the areas covered) and the densities of waders found within the surveyed areas, were calculated.

'Hotspots' (areas holding high densities of waders) identified by these surveys were visually compared with patterns of abundance from three other datasets based on sampling rather than on comprehensive counts; Bird Atlas, BirdTrack and habitat suitability modelling. We also plotted Bird Atlas data against those generated by BWEUF and Moorland Surveys in the same squares, at the level of both the tetrad (for squares with more than 50% coverage by the comprehensive surveys) and the 10-km square (for squares with comprehensive survey coverage of 20% or more). From these comparisons, we assessed whether hotspots identified were consistent across different surveys, and whether there are likely to be significant gaps in wader data (particularly in areas that may hold relatively high numbers of breeding waders) within the YDNP.

3. RESULTS

3.1 MONITORING TEMPORAL CHANGE IN WADER POPULATIONS

3.1.1 SIGNIFICANCE OF RECENT TRENDS

Using all 24 available years of BBS data, populations of five of the six focal wader species changed significantly over time. The populations of four of these species increased (by between 43% and 273%), while population size of Redshank declined by 63%. Restricting the data available for comparison to just two single years at either end of the 24 year period (1994 and 2017) rendered one population change (that of Redshank) non-significant, but rendered another (the increase in Lapwing numbers) significant. An intermediate comparison, between data from three years at the beginning of the period and three years at the end, did not alter the direction of significant population changes from the comparison between single years, but did increase z scores and P-values for all species. Using all available years of BBS data to estimate a linear trend over time yielded broadly similar results to static contrasts of change over two discrete periods. However, the size of population change estimated for some species varied markedly depending on the amount of data used (e.g. for Lapwing from a 10% non-sigificant increase to a 100% significant increase; or for Oystercatcher from a 147% increase to a 520% increase).

Table 1. Estimated population change for six species of wader in the YDNP estimated from BBS data collected between 1994 and 2017 using a) all 24 years of data to estimate a linear trend, b) a comparison between a single year of data drawn from the start and end of the period and c) a comparison between three years of data at either end of the dataset. The size of the estimated change over the 24 years is given as a percentage, and the statistical significance of this change indicated by the z score and associated P-value drawn from the Poisson GLM used to derive these changes.

	a) linear trend			b) 1994 vs. 2017			c) 1994–96 vs. 2015–17		
Species	Change	z score	P-value	Change	z score	P-value	Change	z score	P-value
Curlew	43	6.93	<0.0001	49	3.03	0.002	29	3.55	0.0004
Lapwing	10	1.64	0.11	100	4.04	0.0001	69	6.01	<0.0001
Oystercatcher	279	11.77	<0.0001	520	3.79	0.0002	147	5.41	<0.0001
Redshank	-63	-4.36	<0.0001	12	0.24	0.81	-33	-1.39	0.16
Golden Plover	97	7.57	<0.0001	179	3.29	0.001	149	5.65	<0.0001
Snipe	106	5.33	<0.0001	171	2.26	0.02	230	5.85	<0.0001

3.1.2 POWER ANALYSIS

As shown by Table 2, patterns in the probability of detecting population change associated with sample size and magnitude of change vary markedly between species. For all species, small changes in population size (of 10% or less) are not reliably (i.e. with more than 80% probability) detected, even in comparisons based on information from large numbers (up to 300) BBS squares. Sample sizes of 50–100 squares, similar to those being achieved within the Park, are likely to be sufficient to reliably detect 20–30% changes in population size of relatively abundant and widespread species such as Curlew and Lapwing. However, with similar samples sizes, reliable detection of population changes in less numerous and/or more geographically restricted species, like Redshank and Golden Plover, will require larger changes (e.g. 50–70%).

Table 2. Results of power analysis for BBS coverage in Yorkshire Dales National Park for four species of wader: a) Curlew, b) Lapwing, c) Redshank and d) Golden Plover. The tables show the two-tailed probabilities (expressed as percentages) that population changes of differing size (from 10% to 70%) will be detected in comparisons of data from different sample sizes (from 30 to 300) of BBS squares. Combinations of change and sample size for which the probability of detection is more than 80% are shaded red, while combinations for which detection probability is less than 50% are shaded blue.

a) Curlew

No. squares	Size of population change (%)				
	10	20	30	50	70
30	35	50	69	95	100
40	38	55	78	98	100
50	38	59	84	99	100
60	46	65	89	100	100
80	48	73	94	100	100
100	47	82	96	100	100
120	51	83	98	100	100
150	57	89	99	100	100
200	66	95	100	100	100
300	75	99	100	100	100

b) Lapwing

No. squares	Size of population change (%)				
	10	20	30	50	70
30	37	43	58	84	95
40	36	50	63	90	98
50	40	51	67	94	99
60	41	56	76	96	100
80	46	62	79	99	100
100	45	67	86	100	100
120	48	71	90	100	100
150	54	79	94	100	100
200	57	84	97	100	100
300	64	93	100	100	100

c) Redshank

No. squares	Size of population change (%)				
	10	20	30	50	70
30	14	20	26	37	49
40	17	23	30	43	57
50	18	24	32	48	67
60	18	26	35	53	70
80	20	29	43	64	83
100	20	33	45	69	85
120	20	35	53	77	91
150	22	38	59	81	94
200	25	44	64	90	98
300	27	52	79	97	100

d) Golden Plover.

No. squares	Size of population change (%)				
	10	20	30	50	70
30	31	35	37	52	67
40	31	35	42	58	70
50	33	37	43	60	78
60	35	38	48	66	83
80	34	39	51	71	88
100	34	43	53	76	93
120	35	42	58	83	96
150	37	49	64	87	97
200	38	53	70	93	99
300	41	61	78	98	100

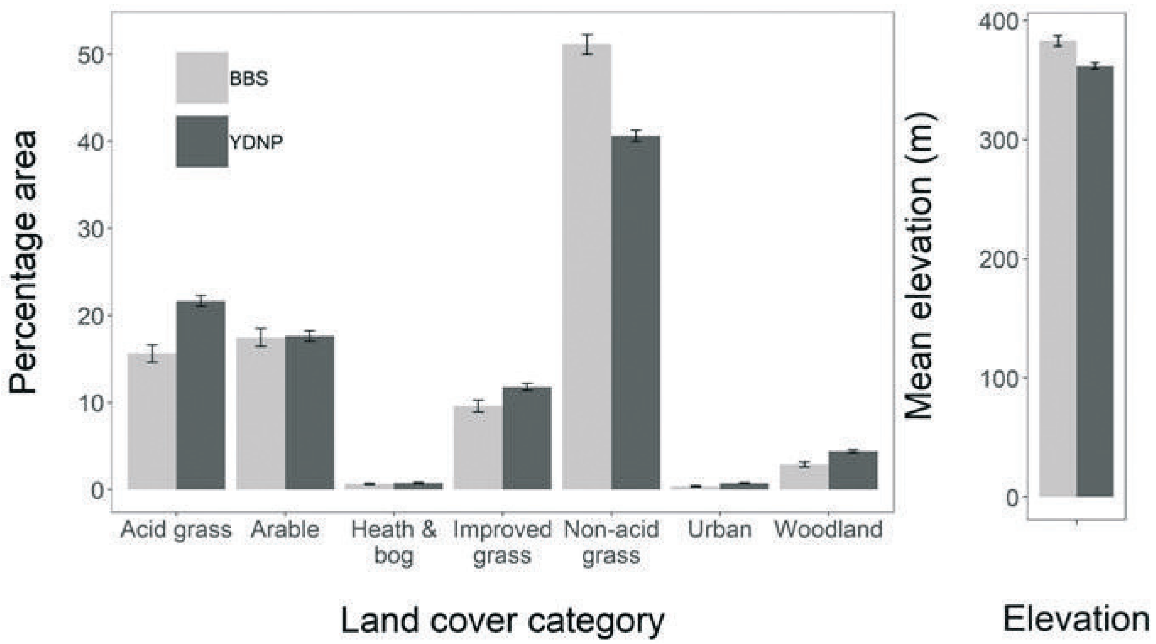
3.1.3 REPRESENTATIVENESS OF COVERAGE

The landscape composition of squares surveyed in BBS was broadly representative of the YDNP, but differed with respect to some land cover types and elevation (Figure 3). Cover of non-acid semi-natural grassland ($t = 7.9$, d.f. = 2317, $P < 0.0001$) and elevation ($t = 4.0$, d.f. = 2317, $P < 0.0001$) were higher in BBS squares, but cover of acid grassland ($t = 2.5$, d.f. = 2317, $P = 0.01$), improved grassland ($t = 5.0$, d.f. = 2317, $P < 0.0001$), urban land ($t = 3.6$, d.f. = 2317, $P = 0.0003$) and woodland ($t = 4.0$, d.f. = 2317, $P < 0.0001$) were all lower (Figure 3). Checks for collinearity before modelling landscape effects on BBS coverage showed that elevation and improved grassland were the only candidate variables for which Pearson's correlation coefficient was more than 0.7 ($r = -0.76$, $n = 2184$, $P < 0.0001$). Elevation was therefore excluded from the starting model. The effect of habitat composition on BBS coverage was significant (Table 3), but the pattern of landscape effects, when different landscape variables were considered all together in the same model, was somewhat different from the pattern illustrated in Figure 3. The number of visits undertaken in squares was positively affected by cover of non-acid semi-natural grassland, heath & mire, and arable land, and negatively affected by cover of woodland and urban land. These effects can only be considered in combination with one another. So, although actual cover of heath and mire habitats in BBS surveyed squares was similar to that in the whole of the YDNP, cover of this habitat still had a positive effect on BBS coverage. Squares with relatively high levels of non-acid semi-natural grassland were more likely to be surveyed than other squares. However, among these, squares with high levels of heath and mire cover saw more BBS surveys than other (presumably more lowland) squares dominated by non-acid semi-natural grassland. This pattern suggests that BBS surveyors may prefer landscapes at the moorland fringe.

Table 3. Summary of a binomial generalised linear model describing the effect of land cover on the distribution of BBS surveys between 2184 1-km squares in the YDNP. The overall model fit is statistically significant ($\chi 2 = 188.61$, D.F. = 5, $P < 0.001$) and explains a modest amount of the variation in BBS coverage (Cragg-Uhler pseudo-R2 = 0.09).

	Estimate	S.E.	z score	P-value
(Intercept)	-4.64	0.1	-44.63	<0.0001
Heath/Mire	0.01	0	4.99	<0.0001
Non-acid grassland	0.01	0	10.63	<0.0001
Arable	0.04	0.01	3.61	<0.0001
Woodland	-0.01	0.01	-2.15	0.03
Urban	-0.06	0.02	-2.62	0.01

Figure 3. Differences in percentage area within different classes of land cover, and in elevation, between 135 1-km squares where Breeding Bird Survey has been carried out (light grey bars), and the whole of Yorkshire Dales National Park (dark grey bars). Values for BBS squares were weighted according to number of surveys.



3.2 IDENTIFICATION OF IMPORTANT AREAS FOR WADERS

The area within the YDNP that was covered by one or more of the three comprehensive bird surveys (BWEUF, Enclosed Grassland and Moorland) is illustrated in Figure 4. The area covered by these surveys had a clear eastern bias (even if excluding the areas added to the park in 2016), with 15 of the 24 10-km squares in the east having greater than 50% of their area of overlap with the YDNP covered by these surveys, contrasting with only 1 of the 15 squares in the west.

The coverage of several sampling surveys within the YDNP was less geographically biased than that of the comprehensive surveys. The distribution of TTVs carried out for the Bird Atlas (Figure 5a) and of 1-km resolution complete lists submitted to BirdTrack (Figure 5c) included extensive coverage in the west of the Park. Both of these surveys indicate that wader abundances in areas with poor comprehensive survey coverage are likely to be low (Figure 5b and d).

Although the transect surveys carried out by Bradter *et al.* (2013) for modelling of Curlew and Lapwing distributions were restricted to the area within the old (pre-2016) YDNP boundaries, they were widely distributed within this area (Figure 1f). The models based on these data (Figure 6) suggest that occurrence probabilities for both species are considerably higher in eastern areas (where coverage of comprehensive surveys is relatively good).

Relationships between densities of waders estimated from comprehensive surveys and the relative abundance as estimated from Atlas TTVs are positive, as one would expect. However, both at the tetrad level and at the hectad level, the level of 'noise' in these relationships is high (Figure 7). This noise reflects that fact that Atlas surveys were not designed to accurately map bird distributions (in this case 'hotspots' of waders) at these resolutions.

Figure 4. Coverage of comprehensive area-based and transect-based wader surveys in the YDNP. See Figure 1 for identity and coverage of individual surveys.

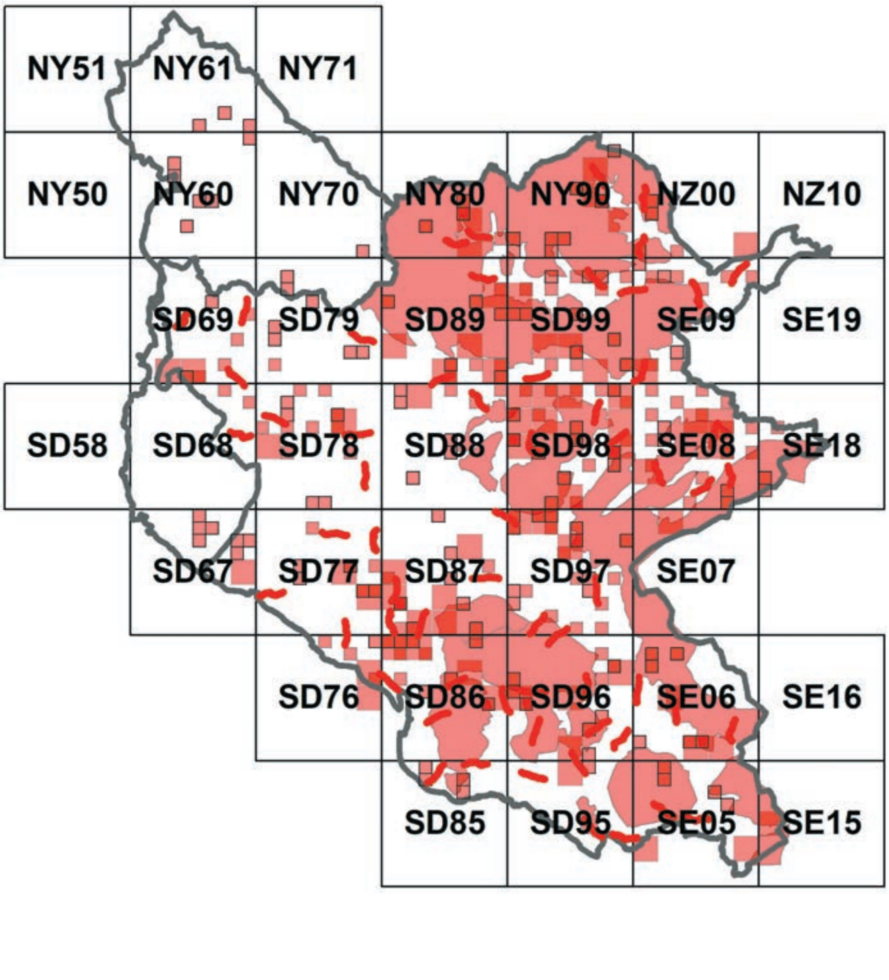


Figure 5. Intensity of survey coverage and densities of wader records in the YDNP for Bird Atlas 2007–11 (a and b) and Bird Track (c and d). Shaded tetrads in a) had TTV surveys during the Bird Atlas, with the intensity of shading in b) indicating the maximum number of waders recorded during the first hour of breeding season TTVs in each of these tetrads. Intensity of shading in c) indicates the number of BirdTrack complete lists submitted for 1-km squares in the YDNP within each 10-km square. The intensity of shading in d) illustrates the average number of breeding waders recorded per complete list in each 10-km square, with the distribution of these records indicated by the red-shading in 1-km squares.

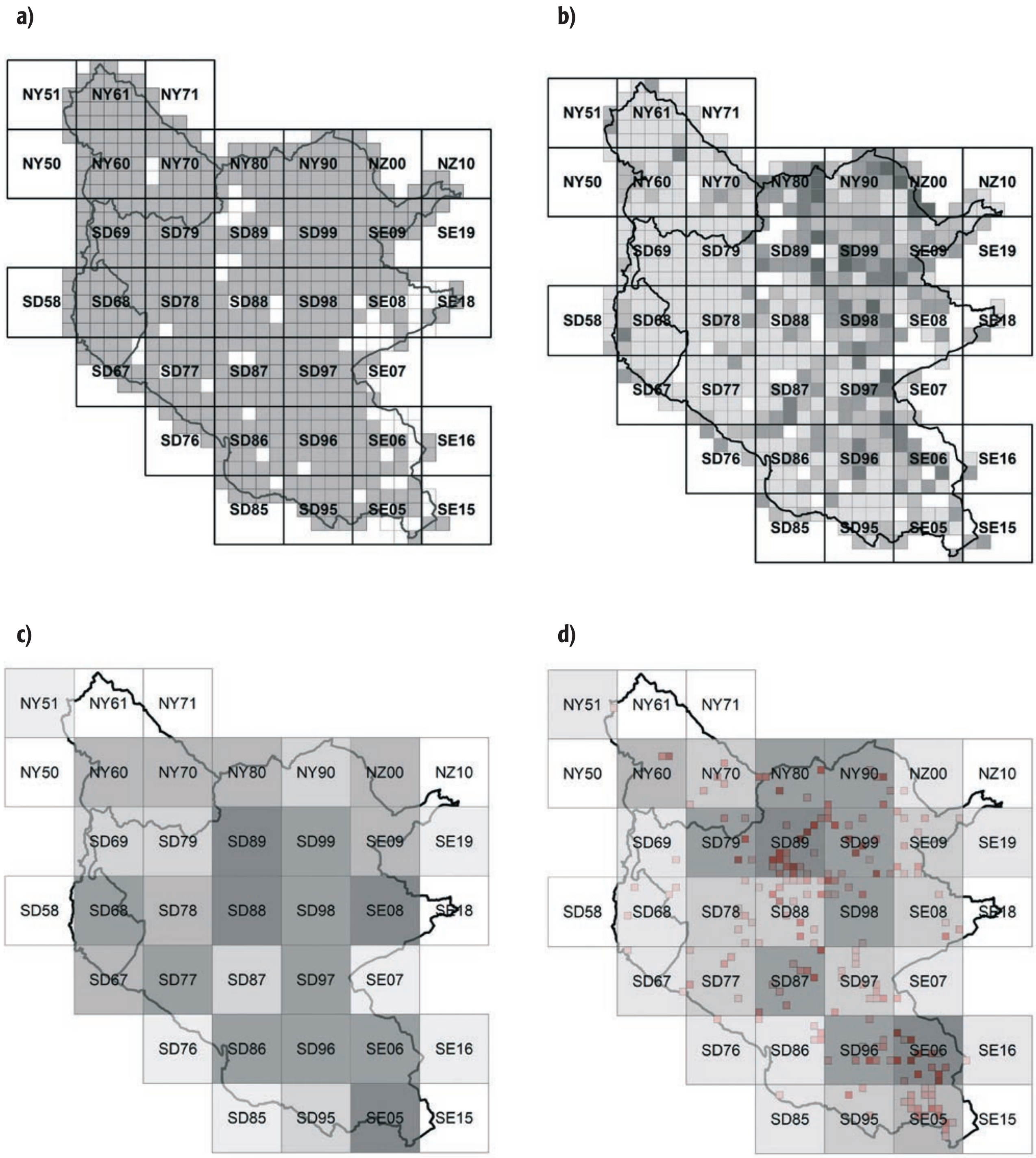


Figure 6. Predicted occurrence probabilities for a) Curlew and b) Lapwing in the YDNP, from models based on presence/absence data along 61 2-km transects, which were modelled against habitat and other environmental data (Bradter *et al.* 2013).

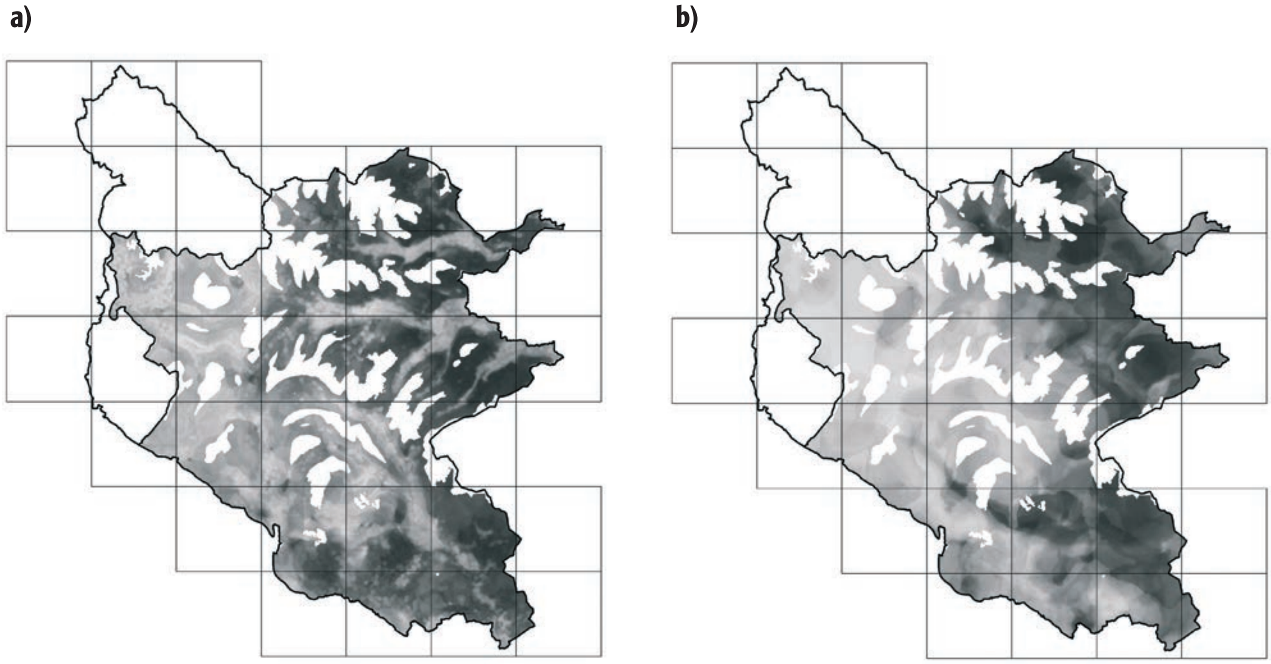
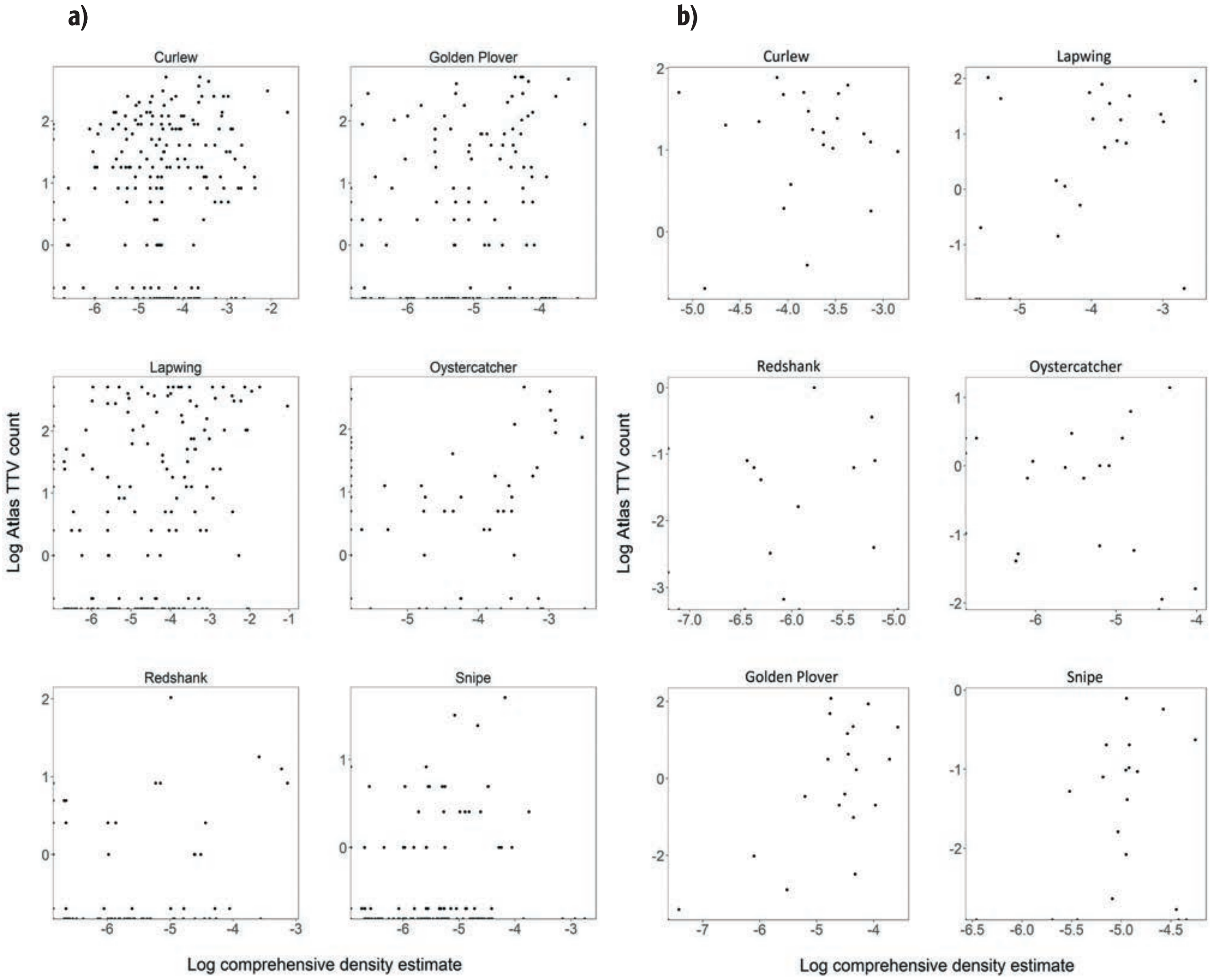


Figure 7. Plots of Bird Atlas 2007–11 TTV counts against combined density estimates from two comprehensive wader surveys: BWEUF (Breeding Waders of English Upland Farmland) and the NCC moorland bird survey in a) tetrads where Atlas surveys were carried out where 2 km² or more of the area was covered by comprehensive surveys and b) in all 10-km squares overlapping the Park where both surveys were carried out.



4. DISCUSSION

Increasing participation by volunteers, including local stakeholders, in bird surveys within the Yorkshire Dales can contribute to both of the national park's main remits, for conservation and for recreation. The societal and health benefits that can accrue from initiatives that increase time spent by the public out of doors, and in contact with and learning about wildlife, are being increasingly recognised by government and statutory agencies.

Moreover, any measures to enhance the conservation status of waders in the park can be viewed as serving not only the remit for nature conservation, but also the aim of enhancing enjoyment of the park by visitors, as well as residents. The recent population declines of wader in general, and of Curlews in particular, have stimulated a high level of public interest and concern, manifesting in successful Curlew-focused fund-raising campaigns by BTO and RSPB, and several cross-sectoral meetings to discuss how these declines can be halted or reversed. Active engagement by and collaboration between local stakeholders (e.g. land managers and conservation volunteers) could benefit wader surveys and monitoring initiatives in several ways. As well as making the most of survey effort, such partnerships could cultivate and enhance a shared understanding of factors affecting the fortunes of breeding waders in the YDNP. Such understanding should encourage and facilitate conservation efforts to secure the long-term future of breeding waders within the national park.

4.1 MONITORING TEMPORAL CHANGE IN WADER POPULATIONS

At current levels of coverage, it would be possible to detect modest population changes in abundant birds such Oystercatcher and Curlew, but more problematic to do this for rarer birds like Redshank, for which even estimates of population change in the YDNP over a period spanning 24 years are not clear-cut. Although Snipe are commoner than Redshank, they are detected at a comparable rate, and could prove similarly challenging to monitor. It is likely that a high proportion of year to year variability in spatial patterns of detection of Snipe will be stochastic, due to low detection probability for this species. Generally low power to detect changes in Golden Plover (Table 2) is partly because these power analyses were carried out on BBS data across a range of upland and lowland habitats. The ability to detect changes in Golden Plover populations will depend primarily on survey effort in moorland habitats. Monitoring of this species would therefore benefit disproportionately from the use of data from gamekeeper surveys. More intensive, area-based survey methods, particularly those employing constant-effort searching, are particularly well-suited to sampling Golden Plover populations, and have been the method of choice for moorland bird surveys since the 1990s. Repeat surveys of moorland areas in the YDNP should adopt similar methodologies in order to ensure comparisons with historic datasets.

The simulations on which our findings are based assume that data from all squares can be treated as independent replicates. This is not, strictly speaking, the case for all squares in the park, as a small number (11 of the 60 squares surveyed in 2017) are 'Upland Adjacent' squares, which were selected on the basis of their proximity to another remote upland square. Also, because all simulated changes were based on decreasing populations, estimates of sample sizes required to detect population change will be a little conservative when applied to situations where populations are increasing. This is because the probability of detecting a change depends on the amount of data available to assess the change. Where populations have increased, more data will be returned from a given number of squares than where numbers have declined.

If data for species such as Redshank are too limited to allow the reliable detection of short-term population changes between individual years, it may be possible to increase the statistical power of comparisons by pooling data from multiple years. This may make sense particularly if the groups of years between which comparisons are made can be related to relevant changes in policy, regulation or landscape-scale land use and management.

Larger sample sizes (enabling more reliable detection of population change), could be achieved through sampling of more BBS squares each year; whether through recruitment of more volunteers or deployment of more staff time. However, there are other options that may be useful to consider. For example, the data from surveys carried out by gamekeepers along traplines (Jarrett *et al.* 2017) could be used to supplement BBS data. This would be relatively straightforward if deriving separate trends for moorland and pasture. However, if using data from gamekeeper surveys to inform a trend for the whole park, care should be taken to weight the contribution from this stratum appropriately in order to avoid skewing the trend towards moorland populations. The same goes for potential contributions from other, non-BBS sources (e.g. information from AES assessments, which could tip the balance of data in favour of reflecting changes in farmland populations). Surveys using different approaches to the BBS could be used to generate indices of abundance which, in turn, could be incorporated into reported trends. However, any changes in survey methods for sites (or types of survey) could introduce biases within those indices that might lead to distorted and unreliable trends. For example, if a survey method designed to generate data on farms, or in areas of moorland, were to be replaced by a transect approach such as that used in the BBS, then a period of calibration during which both approaches were used would be desirable in order to correct for any bias introduced. Such a period of calibration was necessary when converting national monitoring of birds from using territory mapping Common Bird Census methods to transect sampling of the BBS (Freeman *et al.* 2007).

Particularly for relatively abundant species such as Lapwing and Curlew, it might be possible to get enough information to derive trends for different habitats or areas within the Park. This could be useful if the fortunes of waders in these different habitats were strongly divergent, or if it was suspected that particular types of land use or management (e.g. predator control) strongly affected spatial variation in the numbers or productivity of breeding waders in the Park.

4.2 SURVEY COVERAGE

Gaps in surveys within an area the size of the YDNP are probably inevitable, though the park area is relatively well covered by surveys especially when compared to many other comparable upland areas. Temporal coverage of the moorland fringe and 'out-take' areas has also been good, with this area having been sampled by a number surveys over the years, such that assessments of change within this stratum should be possible. Moorland and blanket bog areas have been covered less frequently (at least in recent decades) and more sampling in these habitats would be welcome. Such sampling could take the form of regular sampling in these areas (e.g. trapline surveys by gamekeepers), but it is likely that less frequent, larger scale surveys to provide updated 'snapshots' of wader populations in unenclosed land would also be valuable.

The lack of a tight relationship between BWEUF/Moorland data and Bird Atlas data suggest substantial measurement error in one or both datasets. It is easy to understand the potential for a huge amount of 'noise' in Atlas data to result from variation in where surveyors went during the first hour of tetrad surveys. However, looking at BBS data one can see that even in transect surveys along fixed routes within a 1 km square, inter-annual variation can be substantial. This is presumably due to genuine variation in the number of birds turning up to breed (perhaps depending on conditions in the spring and during the previous winter); as well as to variation in how many of these birds are detected by surveyors (in turn due to temporal variation in bird location and behaviour). The influence of variation (daily and seasonal) in weather on bird densities and detectability is likely to be particularly marked in upland areas.

Predictive models, as illustrated by Bradter *et al.* (2013), can be used to make inferences about presence/absence or abundance of waders in areas where direct survey data are not available, provided those models are supported by adequate, appropriate and robust data (bird and environmental). Such an approach could also be used to update the results of older, more comprehensive surveys using more recent but less complete datasets. By using modelled predictions, conclusions from these datasets could be extended to areas where no recent surveys took place. The predictive maps generated by Bradter *et al.* (2013) seem reasonably successful in identifying those areas where Curlew and Lapwing are, according to several independent datasets, relatively abundant. These models were based on a tiny fraction of the overall dataset available for these species. Moreover, because the models are based on random forest methods, which use iterative machine learning to train, test and refine models, it would be worth exploring whether other datasets could be used to improve and/or update the predictive ability of such models. These data could certainly include some of the wader survey datasets discussed in this report (BBS, gamekeeper surveys and AES data are all promising, having the potential to be updated regularly and to be accompanied by useful habitat and management information), but might also include extensive datasets on landcover, topography or management. In particular, good information on spatial variation in relevant aspects of farmland management (e.g. numbers of livestock, cropping regimes) and game management (particularly predator control) could make these models more useful.

4.3 OTHER SOURCES OF INFORMATION

4.3.1 FARM ENVIRONMENT PLANS (FEPS)

FEPs were based on single walkover surveys carried out on one date, with timing broadly fitting the wader breeding seasons. However, individual surveys might be carried out too early or too late to generate reliable information on breeding waders, or during periods of relatively low activity, and so contain little or no information directly relating to presence or abundance of breeding waders. On such occasions, information on habitat, which was also collected during these surveys, was taken into account when determining the suitability and value of a site for waders. As well as noting presence (and, less reliably, abundance) of breeding waders and habitats on a farm, FEP assessment included simple tests designed to indicate other relevant environmental information (e.g. assessing how difficult it is to push a 6 inch nail into the ground in order to assess soil moisture). Survey data were entered into a spreadsheet where each row matches a field on the farm, and a series of dropdowns was selected to indicate presence of species or habitats, and their condition. Assessments of condition related back to the results of the walkover survey, in order to rate features as A, B or C (from good to bad, with condition A being suited to maintenance grants, and B or C to restoration or improvement). The design of this spreadsheet, and the limitations of the accompanying guidance and instructions, make it likely that data captured by different users will not be entirely standardised or comparable. FEP surveys are no longer carried out, since the inception of the new Countryside Stewardship Scheme. However, similar surveys (covering number and behaviour of waders, as well as information about habitat, on a field basis) are carried out for this new scheme.

Carrying out farm surveys and entering the data from them entails considerable time and effort, and if either the surveys themselves or the recording of information from them could be tweaked to allow comparison with other wader surveys, this could increase their value to the YDNPA. The suitability of these surveys for monitoring may be limited by the fact that most of these are essentially one-off surveys. However, the fact that both pre- and post-survey information may be available from other sources (e.g. BWEUF, Enclosed Grassland Survey, BBS), mean that useful comparisons with the findings of these other surveys might be made on an annual basis. Moreover, the fact that there will often be specific management associated with these areas (presumably carried out and recorded as part of the Countryside Stewardship Scheme) makes them suited to investigating the effectiveness of different types of management for breeding waders.

4.3.2 GAMEKEEPER SURVEYS

At present, the estates participating in wader surveys by gamekeepers in the Yorkshire Dales are being coordinated by the regional Moorland Group Facilitator, who has agreed to collect and collate survey results from them over the winter. It will be useful if BTO/YDNPA could liaise with the MGF in order to provide guidance and support, and to make sure that data are collated in a way that makes them as straightforward as possible to analyse and guide/advise on any future developments or expansion of these surveys. In the MGF's opinion there is the potential to extend participation in this survey to the majority of other estates in the Dales, as well as to increase the number of routes surveyed on most participating estates from one to two. To this end, showing outputs from surveys will be one of the best ways of persuading other estates to take part. Gamekeepers on several estates in Nidderdale (adjacent to but outside the YDNPA area), which are in the same Moorland Group, have also carried out trapline surveys this year.

The MGF has agreed, in principle, that it would be good to identify datasets against which gamekeeper survey data can be verified, in order to demonstrate that findings from these surveys are reliable. In the first instance it may be possible to use some of the datasets considered in this report for this purpose. However, given the inter-annual variability in survey findings that is characteristic of BBS wader data, it may be a good idea to try and engineer one-off or ongoing overlaps between gamekeeper surveys and other, more established formats of wader survey. The ease with which such overlaps can be achieved will likely vary widely according to a range of factors that include accessibility of the areas in question, the attitude of land owners and managers towards other individuals and groups accessing their land to carry out surveys, and the availability of surveyors to take part in overlapping surveys.

4.4 RECOMMENDATIONS

4.4.1 MONITORING FOR TRENDS

The power analyses presented here suggest that BBS data in the YDNP are suitable, on their own, to monitor population changes in some breeding waders. Recent levels of BBS coverage should be sufficient to detect changes of more than 20–30% in Curlew and Lapwing. The probability of detecting declines depends not only on the number of squares covered, but also on the rate at which species of interest are encountered during surveys. Thus, for a relatively scarce species such as Redshank, the current level of coverage would only allow changes of 50–70% or more to be reliably detected.

Opportunities for increasing encounter rates within BBS, and therefore power to detect population changes, include surveying more squares and the inclusion of additional squares as part of the survey. Surveying more squares will require further allocations either as part of the national BBS programme or else as part of a bespoke initiative for the YDNP. Such an approach would likely require more volunteers, the availability of which could prove to be a limitation. Including additional neighbouring squares within the survey has proven an efficient approach to increase the number of registrations within upland areas within the national BBS programme without the need to recruit more volunteers; many surveyors having accessed one square find it straightforward to survey an adjacent square on the same day.

Alternatively, options for combining data from BBS with those from different surveys could be considered as complementary options to increase monitoring power. This latter approach could include incorporation of some of the existing surveys or the development of new bespoke surveys potentially targeted at specific species, groups, habitat or areas. At present, BBS trends are calculated for the whole of the park. There would be a need to consider on what basis data from different surveys could or should be combined. Particularly where these data derive from different methods, habitats, land uses or geographical areas within the Park, there may be a need to ensure that data from different survey types are appropriately stratified or weighted before combining them.

Although not within the scope of this report, the value of BBS monitoring all species and groups of birds (within the limitations associated with encounter rates) makes that approach especially valuable. Although waders are a current conservation priority, changes in the status of other species or groups may become apparent only through a programme of such of objective and extensive monitoring capable of identifying species that are in need of particular attention – as BBS has done for waders.

4.4.2 EXTENSIVE SURVEY COVERAGE

More intermittent surveys (which can also be more extensive, targeted and/or thorough) can identify important areas for breeding waders, which are unlikely to be comprehensively captured by sampling surveys such as BBS or gamekeeper surveys along traplines. They can also be useful for identifying and measuring change in localised or sparse populations that are inadequately captured by sampling surveys (for example, Dunlin). In terms of the timing of these intermittent surveys, horizon-scanning could identify planned large-scale regional or national surveys, in order to make the most of the survey effort they enable. Examples include surveys done for SPA monitoring, and repeats of stratum-specific surveys such as BWEUF or the Moorland Bird Survey. Future Atlas surveys might also afford possibilities for collection of more detailed survey information that would be worth exploring. For example, recording routes taken during standard tetrad surveys could allow Bird Atlas information to be better interpreted with respect to the nature and size of the areas surveyed. It might also be possible to use the momentum of a national project like an atlas to collect data at a finer resolution than that of the tetrad. For an area like the YDNP it might be possible to achieve near-complete coverage at a 1-km level. The number of surveys that would be required to do this (2,178), is only slightly more than the number of tetrads surveyed (1,770) to achieve comprehensive coverage for the South-east Scotland atlas; Murray *et al.* 2018), and could yield much more precise information about patterns of wader abundance.

4.4.3 ZONING AREAS OF IMPORTANCE FOR BREEDING WADERS IN THE YDNP

Using existing data it is feasible to identify categorised zones within the YDNP based on the importance, and potential importance, for breeding waders. Initially, Bird Atlas data could be modelled to formulate zones distinguishing areas of different value to waders. Such zones could include areas of where abundance (or occurrence probability) during the most recent Atlas surveys was high ('hotspots'); areas where waders had declined since the previous Atlas but were still relatively abundant; areas where waders had declined to a level where they were scarce or absent (areas where management could be targeted); and areas where waders had been scarce or absent during all surveys. These zones could be used to improve and streamline decision-making with regard to development and management for wader populations. A separate modelling exercise using BWEUF data could be carried out in areas of in-bye habitat, to ensure that hotspots in these areas identified by this more detailed and more recent dataset were taken into account when classifying zones. In the longer term it may be possible to carry out modelling at higher resolution, using field-based information collected in surveys such as BWEUF. This latter approach would be worthwhile only if appropriately detailed and high-resolution habitat and management datasets were available, to allow predictions from these models to be extended to areas that were not surveyed for waders.

4.4.4 SURVEYS BY THE GAME MANAGEMENT COMMUNITY

Structures and procedures to analyse and coordinate surveys undertaken by the game management community (hereafter 'gamekeeper surveys') should be put in place, and an assessment made of the need and appetite among gamekeepers and others for further training. In the short term, local survey participants and organisers should be provided with support and guidance, to ensure that survey protocols are robust and consistent, and that data collation makes them straightforward to analyse and compatible with their own needs for reporting as well as for wider monitoring purposes. The coverage of these surveys may benefit from support by the Park Authority to encourage and promote gamekeeper surveys. In the longer term, work will be needed to determine how best to combine information from such gamekeeper surveys with BBS and potentially other data, in order to inform assessments of wader population change in the YDNP.

If combining gamekeeper surveys with other sources of annual monitoring data in the YDNP, such as BBS, consideration should be given to the areas represented by these surveys. BBS survey squares are picked at random, and so should (provided survey coverage of these squares remains high) provide a broadly representative sample. However, it is likely that the areas covered by gamekeeper surveys will be drawn from a narrower range of habitats (predominantly moorland and its fringes) and subject to management regimes that, particularly with respect to predator control, are not representative of some other areas in the park. Thus, it is likely that using data from gamekeeper surveys alongside data from other survey datasets (e.g. BBS) to understand population change will require careful stratification or weighting to ensure that trends are representative of the areas they are applied to.

Opportunities to validate the findings of gamekeeper surveys, through comparisons with data from other established survey methods, should be taken where possible. Most gamekeeper surveys will follow protocols that differ slightly from those of other bird survey formats, in order to make them better suited to daily routines of those undertaking them. Those wanting to use the data generated by gamekeeper surveys (including the YDNPA, but also including game estates) should look for and make the most of opportunities to rigorously evaluate these data. These may include comparisons with existing data from other surveys, or the generation of new data by working with bird surveyors who may be willing to carry out surveys in other areas using trapline-like survey methods, or to survey the same areas as gamekeepers using more established methods. There may be some reluctance to encourage or participate in this kind of 'overlap', on all sides, so it may be useful to spend some time explaining to the relevant stakeholders (particularly within the game management community) why these could benefit them.

4.4.5 SURVEYS ASSOCIATED WITH AGRI-ENVIRONMENT SCHEMES

The ongoing development of a Results Based Agricultural Payment Scheme (RBAPS), which has been trialled in the YDNP, may provide opportunities for improving the information collected on breeding waders. During the next phase of RBAPS improvement and expansion, Natural England have called for a demonstration that the effects of the scheme can be monitored. Such monitoring would necessarily involve assessments of waders on entering the scheme, and during the final year of management, and should also include control areas outside of the scheme as well as those in RBAPS. Embedding effective monitoring of waders within the scheme, in a manner that sensibly balances the value of information with the costs and practicalities of collecting it, could revolutionise our ability to assess the impact of AES measures on breeding wader populations. However, the results of this monitoring could in some cases be ill-suited to evaluating the performance of individual farms (i.e. in terms of 'delivery of waders'). Particularly on small farms, areas with few waders and sites supporting relatively isolated populations of waders, factors extrinsic to those on the target farm may play a dominant role in determining variation in wader numbers between farms and between years.

Wader information to inform RBAPS monitoring could potentially be collected by a wide range of stakeholders, including volunteers, YDNPA staff and farmers. It would be worth thinking about the contributions that these different groups could make, and how data collection could best be structured to take advantage of their strengths, and accommodate their limitations. Information collected during AES surveys may also be 'put to work' in other contexts. One possibility is to inform annual population trends. This might be done on the basis of surveys of different farms informing each year's population index (this might only make sense if the numbers of farms surveyed each year were very large). Alternatively, if farms are surveyed multiple times over the course of several years, inter-survey differences might be used (as in BBS), with initial contributions always set to neutral. This type of contribution might be further enhanced if data from another survey (e.g. Enclosed Upland Grassland Survey, or BWEUF) could be used, at least for some farms, to provide a baseline that even the first AES survey on the farm could be compared with. Such comparisons could also be used to calibrate AES surveys with data generated by other types of survey, in order to facilitate use of AES wader surveys in a broader range of contexts.

It is noteworthy that future RBAPS options may include predator control. Ensuring effective monitoring of this aspect of management, as deployed in an AES context, could be particularly valuable in informing the ongoing debate about the potential benefits and limitations of predator control in the wider agricultural landscape (but see also Section 4.4.7).

4.4.6 BREEDING PRODUCTIVITY MONITORING

There is an urgent need for the development of methods to enable the collection of robust , reliable and repeatable information on breeding productivity of waders by a wide survey audience, in a wide variety of situations. Assessments of the value of areas, habitats and management practices that are based solely on variation in the number of breeding waders have serious limitations. These arise, in part, because wader breeding populations may remain stable for years or decades in areas where breeding productivity is unsustainably low, due to long-lived adults returning to breed despite failing to produce young. Also, in some areas, an unknown proportion of young fledging from areas with high productivity may settle in surrounding areas where availability of vacant breeding territories may be higher due to low breeding productivity. This movement of young birds from areas of high to areas of low breeding productivity, often referred to as source-sink dynamics, can make assessments based on numbers of breeding birds unreliable.

Robust methods for measuring clutch survival in waders have been described (Jarrett *et al.* 2017, Calladine *et al.* 2017). However, although many methods to collect information on overall breeding productivity (i.e. success in producing fledged young) have been used by wader surveyors, there is little understanding about how these compare with true levels of wader productivity (or with one another), or which methods are best suited to different species, ecological situations and survey audiences. Research is needed to answer these questions, and though it is likely that the scale of study required will entail work in a larger area than the YDNP, any opportunities to support and collaborate in such work should be taken. In particular, the fieldworkers participating in BBS and gamekeeper surveys in the YDNP may be able to trial some of the methods of measuring productivity being considered by this kind of research. This could have the dual benefit of yielding data collected using these methods, which could potentially be used to evaluate their effectiveness, as well as generating feedback from surveyors about the suitability of the relevant methods to their particular circumstances.

Wherever multiple types of information relating to productivity are being collected (e.g. remote-tracking of chicks, of parent birds, colour-ringing and resighting, assessments of parental behaviour during the course of the breeding season, post-breeding counts of adults and juveniles on breeding grounds), doing this in a way that allows their findings to be compared with one another would be useful. Also, improving our understanding (and use of) source-sink population dynamics, and their effect on trends in wader populations in the YDNP, would benefit our understanding of variation in productivity, and also improve our ability to target conservation measures at high productivity areas.

4.4.7 PREDATORS AND PREDATOR CONTROL

Improved information on predator numbers and activity, predator management, and the effects of these on waders, would be useful in determining, evaluating, and demonstrating the effectiveness of various decisions relating to management and development of the YDNP. Ideally this should include high quality quantitative information on intensities of control (e.g. number of traps set, hours spent lamping) and numbers of animals removed. Much relevant information on spatial patterns of predator control could be provided by game managers if they (as well as their employers and representatives) can be persuaded of the potential for these data to improve societal understanding of some of the effects (e.g. potentially enhanced wader breeding success) of predator control.

Alternative proxies for the effects of predator control could include data on avian predators and of landscapes associated with predator control. Data describing the relative abundance and distribution of controlled avian predators such as Carrion Crow (*Corvus corone*) could act as surrogates for the abundance and impacts of other predators (such as foxes and mustelids) that are subject to legal predator control but for which detailed population information is lacking or of lower quality; assuming that where crows are controlled, then other general licence target species will also be controlled. The Bird Atlases provide a rich source of spatial information for crows and other avian predators. BBS data within the YDNP could also be very useful, due to the fact that both wader and predator species are sampled in the same areas at greater spatial and temporal resolution, and with more precision, than is afforded by Atlas data (due to smaller areas, and more frequent and methodical sampling). A longer-term aim should be to improve the information available on the numbers, distributions and population trends of mammalian predators within the YDNP, as well as the effects of predation on breeding success.

Data describing the location and extent of areas of muirburn may also serve as a useful proxy for predator control activity associated with management for grouse, as it results in a distinctive landscape pattern that can be readily distinguished in aerial photographs. There are already existing datasets (such as the muirburn dataset held by RSPB) that describe spatial variation in muirburn at a 1 km resolution. If access to, or terms of condition for the use of, existing datasets by their owners was problematic, it would be straightforward to digitally map the areas of muirburn in the YDNP. Muirburn data, used alongside other habitat and management variables, could help to explain variation in wader numbers (or, if it becomes available, breeding productivity). However, spatial variation in the intensity of predator control (on and off grouse shooting estates) and its effects on predator numbers and activity, are unlikely to be perfectly described by the distribution of muirburn. Care will therefore be needed in deciding what measures to use in analyses of muirburn, particularly with regard to the scale at which variation in muirburn extent is considered.

4.4.8 INITIATIVES OUTSIDE THE YDNP

National or regional surveys may present opportunities to increase information on waders within the YDNP. Engaging with organisers and participants in such surveys may enable at least some of the survey effort deployed for such surveys to be directed towards areas where information on waders is sparse, lacking, or out of date. Some of the maps in this report could be used to identify and target such areas. Periodic surveys may be particularly valuable for species that are currently sampled at rates that are too low to provide robust information on population change within the YDNP. Work undertaken through or with the support of the Northern Upland Chain (NUC) partnership could be especially relevant in this regard. The NUC not only has the potential to increase information within the YDNP, but may afford opportunities to pool information across multiple upland areas in northern England, in order to better understand trends and processes for which data in the YDNP may be limiting. Several of the actions recommended in this report (including map production, organisation of game keeper surveys, and development of other wader monitoring initiatives) could benefit from economies of scale if inclusive of the NUC area.

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7. SUPPLEMENTARY MATERIAL

Electronic Appendix 1:
Zipped folder containing datasets relevant to this report. These include:

1. A comma-delimited text file with grid references of 1-km squares where BBS surveys have been carried out in the YDNP, and the number of years in which each of these squares has been surveyed.

2. A comma delimited text file with grid references of all tetrads in which TTVs (timed tetrad visits) were carried out for Bird Atlas 2007-11.

3. A comma-delimited text file with grid references of all tetrads surveyed during the Breeding Waders of English Upland Farmland survey in 2016, and the area within each of these squares that was surveyed.

4. A comma delimited text file with 1-km resolution bird and habitat data from the YDNPA/RSPB 2000 survey of birds in enclosed upland grassland.

5. A polygon shapefile representing the areas estimated to have been covered during the 199x NCC Moorland Bird Survey, and a point shapefile with locations and identities of the birds recorded during this survey.

6. A polyline shapefile representing transect routes surveyed for breeding Curlew and Lapwing in order to inform occurrence modelling of these species in the YDNP carried out by Bradter *et al.* (2013).



Images: John Harding / John Proudlock / John Proudlock. Cover image: Paul Hillion

Review of data and monitoring options for assessing the status of breeding wader populations in the Yorkshire Dales National Park

Breeding waders are among the birds of highest conservation concern in the UK. The findings of recent national scale surveys suggest that the Yorkshire Dales National Park (YDNP) supports important breeding concentrations of several wader species.

This report assesses the availability and quality of information relating to breeding populations of six of the most numerous wader species (Oystercatcher, Golden Plover, Lapwing, Snipe, Curlew, Redshank) in the YDNP. We make recommendations about how the ability of these datasets to inform the Park Authority (YDNPA) about wader population trends and distributions can be maintained or enhanced, and how this information can be deployed to inform planning for and management of waders in the YDNP.

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