BTO Research Report No. 317

Evaluation of species coverage and precision using the BBS indexing method

Authors

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A report by the British Trust for Ornithology

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EXECUTIVE SUMMARY

1. The Breeding Bird Survey (BBS) is a volunteer based survey, funded by the British Trust for Ornithology (BTO), Joint Nature Conservation Committee (JNCC) and the Royal Society for the Protection of Birds (RSPB) and has been running since 1994. It was primarily set up to increase both the geographical coverage and the range of habitats and species covered compared to the earlier CBC. Annual bird population trends for a range of common and widespread birds are provided for the United Kingdom, the four countries (England, Wales, Scotland and Northern Ireland) and the nine Government Office Regions/Regional Development Agency (RDA). Volunteers are required to survey a 1 x 1 km square using two 1 km parallel routes, with each transect split into five 200 m sections. Habitat information is recorded in April with two later visits; one in April/early May and the latter in late May/June to record the birds. All bird registrations (both sight and sound) are recorded into either one of three distance categories along the transect (<25m, 25-100 m and beyond 100 m) or noted as in flight for each of the 200 m sections.

2. BBS population indices are estimated using a log-linear model with Poisson error terms, with the sum of the counts across the four distance categories for the 1 km square being modelled as a function of year and site effects. Counts are corrected for over-dispersion and weighted to account for differences in sampling effort amongst regions. Only squares that have been surveyed in two or more years in the period of interest can be included in the analysis. With current methodology, national population trends are reported for all species which occur in greater than 50 squares on a yearly basis with this being decreased to a sample size of 30 for country level and 20 for the RDAs. It is important to ensure these indices are reliable and reflect the true population. This report aims to develop a protocol that can be used to determine whether datasets for particular species and geographical areas should be used to calculate population indices. The protocol takes account of both the relationship between sample size and precision and aspects of species biology that determine whether BBS methods are likely to produce reliable indices.

3. This report aims to assess the precision of the indices and formulate objective criteria for the reporting of population trends based on sample size (yearly average of squares in which the species is seen), below which it is inappropriate to report population change due to low precision. This will focus on exploration of the existing data and the statistical models used to produce the trends and secondly simulation-based power analysis to assess effects of sample size and variability of counts on the power of the statistical model. This report uses data collected between 1994-2000.

4. For most species, count data is over-dispersed in relation to the Poisson distribution. This is especially the case for several geese, gulls and waders. Missing site by year combinations in the index model account for less then half of the whole site by year data matrix for species for which the BBS model is currently run. Species with a low mean count tend to have low variance and dispersion. Most species which show a tendency to flock (waders, gulls, terns, geese, wild fowl and colonial seabirds) have high mean counts, maximum counts, dispersion and spatial variability. This suggests that it is appropriate to exclude large counts for these species, as routinely done for current BBS indices. There is little difference in the shape of the distribution when birds in flight are included or excluded, although maximum counts are likely to be different.

5. The precision of the population change index between 1994 to 2000 was assessed using the minimum detectable effect size (‘effect size’), this is the minimum change which could be detected as significant. Greatest variation in effects size with sample size occurs below 200; decreasing sample size increases minimum detectable effect size, i.e. it is harder to detect small significant changes in the population. As percent of zero’s and degree of missing values in the model increases, the ability to detect a small significant change decreases. Mean count and over-dispersion have less influence on effect size. For the period covered, only population changes

greater than 50% are likely to be detected for species with a sample size less than 40. Population changes in the range 20-50% can potentially be detected with sample sizes between 40 and 100.

6. With the simulation-based approach, the majority of species with a sample size >20 and <100 have a power less than 70% to detect a 25% population decline over a period of 25 years. This is likely to be an overestimate due to the simple approach used in simulation. Power increased with sample size and decreasing percent of zero's. Little association existed between the power from the simulation-based approach and the minimum detectable effect size. Due to the simplistic nature of the simulation approach, the results from the effect size analysis are more likely to reflect the true characteristics of the data in terms of over-dispersion, spatial and temporal variability.

7. The precision of the reported population trends at the country and regional level are likely to be poor using the current criteria of sample size above 30 and 20 respectively. Using a sample size above 40 is more appropriate and is in line with the national criteria for reporting. Precision is clearly still relatively low for species with a sample size below 100 at the national level. Restricting the reporting of trends to those species above 100 at the national level, as opposed to 50, would result in 14 more species being excluded.

8. A protocol is suggested for the reporting of BBS trends based on both numerical sample size and biological criteria. Sample size (yearly mean number of squares in which the species is seen) has the most influence. Three levels are proposed. The first includes species seen in greater than 40 squares on an annual basis (sample size) and where the BBS sampling design is appropriate. For these species there should be a high probability that we can detect a 50% decline and for which it is appropriate to report BBS indices/trends. A sample size of greater than 40 is required to be able to detect a 50% or less population change. For species seen in less than 40 squares, one is only likely to be able to detect a change of greater than 50%. However, there are a number of 'difficult' species where their mean sample is at least 40 squares, for which the BBS trends should be treated with caution (category two). For these species (see Table 1), population trends should be reported with a caveat signifying that the reported trend may not reflect the status of the breeding population in the UK, as their counts are likely to be strongly influenced by non-breeders, migrants, or because the BBS methodology may not reliably sample the population (e.g. nocturnal or colonial species). The third category includes species for which indices should not be produced as sample sizes are less than 40 or for species whose counts include a high proportion of non-breeding birds, wintering birds or those seen during migration (Table 1 lists the latter species for category 3).

Table 1 Species classed as category 2 and 3 under the protocol for reporting BBS indices

Category 2: Species with a sample size of at least 40 and for which BBS trends should be reported with a caveat.

Species name	Category ; colonial/flocking (C) and nocturnal (N) species
Cormorant	C
Grey heron	C
Greylag goose	C
Canada goose	C
Oystercatcher	C
Golden plover	C
Lapwing	C
Curlew	C
Common tern	C
Feral pigeon	C
Wood pigeon	C
Swift	C
Sand martin	C
House martin	C
Rook	C
Crow	C
Jackdaw	C
Tawny owl	N

Category 3: Indices should not be produced for species with sample sizes less than 40 or for species whose counts are mainly non-breeding birds, wintering birds or those seen during migration.

Species name	Category ; colonial/flocking (C) and nocturnal (N) species
Black-headed gull	C
Common gull	C
Lesser black-backed gull	C
Herring gull	C
Great black-backed gull	C
Fieldfare	C

1. INTRODUCTION

The BBS is organised by the British Trust for Ornithology (BTO) and is funded jointly by the BTO, Joint Nature Conservation Committee (JNCC) and the Royal Society for the Protection of Birds (RSPB). It has been running since 1994 and is designed to provide a national index of annual bird population trends for the United Kingdom for a range of common and widespread birds in the UK. It has taken over from the long established and recognised Common Birds Census (CBC) as the main census tool for monitoring populations of common British birds. Summaries of population trends are provided for all constituent parts of the UK (England, Wales, Scotland and Northern Ireland), in addition to the Government Office Regions/Regional Development Agency (RDA).

The BBS was set up after an initial desk based study and a two-year pilot census designed to assess the suitability and efficiency of different survey methods and sampling strategies. It was developed with the aim of increasing the geographical coverage and the range of habitats and species included compared to the earlier CBC. The CBC is extremely valuable, but is strongly biased to the south and east of the UK and is largely restricted to farmland and woodland habitats.

The population and status of wild birds are an important indicator of the health of the countryside and their importance is evident from the inclusion of the national wild bird indicator on the governments ‘quality of life’ statistic. The precision and the representativeness of the population index should be known to ensure only reliable estimates of population size are given at a range of varying levels from national, country and regional level. It is vital that these indices reflect the situation in the ‘real’ bird populations. The precision of the BBS is to some extent ensured by the survey design (Field & Gregory, 1999). The aim of this report is to more fully assess the precision of the indices and formulise objective criteria for the reporting of trends (population change) for species at different spatial and landscape scales. This will largely be based on determining the threshold of sample size (yearly average of squares in which the species is seen in), below which it is inappropriate to report population change due to low precision. The report will focus on two approaches; the first involves the exploration of the existing data and the statistical models used to produce the trends and secondly, a form of power analysis to assess effects such as sample size on the power of the statistical model. This will involve running simulations of data with realistic parameters of distribution derived from exploratory work for species of particular concern. As the data collected for 2001 was not representative due to foot and mouth problems (Raven *et al.*, 2002), the period covered in this report concerns 1994 to 2000. The number of squares covered in 2000 was 2,248, considerably more than the 1,569 in the first year of the survey in 1994 (Noble *et al.*, 2001). Details of the summary results and coverage for 2000 at the national, country and regional level can also be found in the report (Noble *et al.*, 2001).

1.1 Aims

- Assess the impact of spatial and temporal variation in counts on the precision of the annual estimates.
- Assess the influence of including birds in flight on the distribution of the counts.
- Use simulations of data to assess the effects of various factors on the precision of the BBS trends for those species reported on >20 and <100 sites nationally, with particular regard to the assessment of the likelihood of detecting a significant decline of 25% over 25 years. Conclusions from this analysis can be extrapolated to the four countries and regional level.
- Discussion of the merits and drawbacks of the current statistical model used to produce the annual estimates.

1.2 Background to the BBS methodology

1.2.1 Data collection

The BBS is a volunteer based survey and involves surveying a 1 x 1 km square using a transect method. Each of the squares is randomly selected from 83 sampling regions. The methodology requires each surveyor to walk a pair of 1 km parallel routes, orientated either north-south or east-west during the breeding season. Ideally the transects should be 500 m apart and 250 m from the edge of the square. Each one of the transect lines is split into five 200 m sections, giving a total of ten 200 m sections in which separate bird and habitat information is recorded. All bird registrations (both sight and sound) are recorded into either one of three distance categories along the transect (<25 m, 25-100 m and beyond 100 m) or noted as in flight for each of the 200 m sections. Two morning visits to the square are required to record the birds; one in April/early May and the latter in late May/June. In addition an earlier visit, normally made in April is made to record habitat information at four hierarchical levels using an established BTO coding scheme. Observers are requested to only conduct surveying in relatively fair weather conditions, and in this respect reduce the risk of adverse weather influencing detectability of the birds and biasing BBS indices. Recording of the ambient weather by the observers allows an assessment of the potential effects of weather conditions on the BBS indices. The influence of the weather conditions in different years on BBS indices was assessed by Field & Gregory, (1999). The influence of year to year variation and species count variation in terms of the timing of the two visits and their effects on the BBS indices was also explored in this earlier report (Field & Gregory, 1999). Observers are required to revisit the same square year after year and thus BBS squares are fairly constant across time. However, even if an observer is unable to resurvey their square, a replacement observer is normally found, maintaining the constancy of squares surveyed from year to year.

For the purposes of the BBS, the number of birds of each species recorded in the square includes birds in all the distance categories (summed) and is taken as the maximum of the counts from the two visits. Where needed, density calculations and estimates of the detectability of different species can be obtained from applying distance sampling methods. These methods are however not needed for the BBS indexing model.

1.2.2 Calculation of the BBS indices using statistical models

Population changes and standard indices for the BBS are estimated using a log-linear model with Poisson error terms. Counts are modelled as a function of year and site effects (categorical variables) and only those squares that have been observed in two or more years between 1994 and 2000 are included in the analysis. In addition to restricting entry of 1 km squares to those that have been surveyed more than once, only squares where the species is seen for at least one year (i.e. non-zero value) are entered into the model. Thus, squares where the species was not seen in any year, but still surveyed more than once are excluded from the model (i.e. zero count for all years surveyed). Counts are corrected for over-dispersion (using the 'pscale' option in SAS proc genmod) and weighted to account for differences in sampling effort amongst regions of the UK (weights for each region are calculated based on the proportion of the total number of squares in that region actually sampled i.e. a region which receives little coverage obtains a higher weighting in the analysis).

Under the current model framework the sum of the counts across the four distance categories for each transect section within the 1 km square is used in the model. Examination of the frequency counts of the species is based on 1 km square level as this represents the data used by the model to estimate the BBS index. This differs to the earlier report on the BBS by Field and Gregory (1999), in which histograms were based on the sum across the four distance categories for each transect section. For the influence of large flocks and large counts on the frequency distribution of 200 m transect section counts, readers are referred to the Field and Gregory (1999) report. Taking each transect section as the sampling unit, as opposed to the whole 1 km square will potentially generate different count frequencies, especially with regard to the number of zero counts. For instance, at the level of the whole square, a non-zero count is obtained even if a species occurs in only one of the transect sections. In comparison, a large number of zero counts would exist at the level of individual transect sections.

1.2.3 Reporting of the BBS indices

At present, with a few exceptions, population trends are only reported for species which are seen in greater than 50 1 km UK squares nationally on an annual basis (yearly mean). Reporting of country and regional population trends is relaxed to include all species recorded annually in 30 and 20 squares respectively. Assessment of the reliability and precision of these trends or indices is necessary, especially for species on the boundary of these chosen sample sizes.

1.3 Power analysis

Power analysis is often considered to be analogous with the number of samples needed to obtain particular statistical results or to reject the null hypothesis. Collectively, power analysis is about estimating the sampling effort necessary for the study to be powerful enough to detect the trends of interest. In statistical terms it is the probability of correctly rejecting the null hypothesis when the null hypothesis is false. The probability (between 0 and 1) is often expressed as the percentage chance that a particular design (study) will detect a trend of the specified magnitude (Walsh *et al*., 2001). There are two main outcomes from a statistical analysis of population trends; the first is that a significant trend may be detected when in reality none occurs and the second is that a real trend may occur in the population but none is detected with the statistical model. In the context of population declines, the worst scenario is that a population could undergo a decline without the model detecting a significant decline. This could prevent conservation action necessary to halt this decline being implemented and in the worst case scenario lead to species extinction.

Power in a monitoring program is affected by a number of factors; count variability over space and time, the magnitude of the change or trend in population over time (effect size), survey length, number of survey plots, sampling error associated with the survey and the statistical level of significance or alpha (the probability of wrongly rejecting the null hypothesis or Type I error).

Within any population there will be stochastic year to year fluctuations in the population and this 'noise' will hinder the detection of any real trends in the population ('signal'). Such count variance may represent true changes in the population, resulting from changes in birth, death, immigration and emigration rates, as well as artificial variance reflecting sampling bias and measurement error. The larger the year to year variance, the higher the magnitude of a particular change is required for it to be detected with any statistical significance. The power of any monitoring programme will increase with time (number of years), sample size per year, effect size and Type I error level (α), whereas power will decrease with increasing count variance over space and time and Type II error level (β).

A viable approach to assess sample size requirements and power is to use simulations (Castelloe, 2001). It is necessary to realistically simulate the data, compute a test statistic and determine if the null hypothesis can be rejected. This process is repeated a number of times and power is expressed as the percentage of rejections of the null hypothesis (Castelloe, 2001). This is the approach used in this report. As this approach is computationally intensive, simulations are restricted to 100 runs for each species considered.

2. METHODS

2.1 Exploration of the data

2.1.1 Rationale for selection of species

The first step was to exclude very rare species and identify a suite of species for which indices can 'potentially' be calculated. Firstly, basic statistics related to the counts and statistics relating to the BBS index model are given for those species which had a yearly average greater than 10 squares in which they were seen (for sample sizes below this the index model often fails to converge and may yield wildly inaccurate results). In this report, any reference to yearly mean/average refers to the mean number of squares in which the species is seen on an annual basis between 1994 to 2000. To assess the precision and power to detect population changes for species which have small sample sizes, a subset of 35 species were selected, which had a yearly mean of >20 and <100 squares nationally (hereafter called 'target species').

2.1.2 Comparison of the frequency distribution of counts between inclusion and exclusion of birds in flight

Frequency distributions were examined for those species routinely reported by the BBS (yearly mean >50 1 km squares across the period of 1994-2000). The count of birds seen in the three distance categories and also in flight (standard BBS method) are compared with the sum seen in the three distance categories only (excluding birds in flight). Comparison is based on the proportion of counts, rather than actual number of counts.

2.1.3 Defining characteristics of the count data for the 35 target species

A number of measures were devised to more fully assess the variability of the counts and the degree of missing values in the site by year data matrix; all of which are likely to affect the confidence and precision of the population index. Counts of the species can vary in terms of spatial and temporal variance, for example species which have the same mean count may differ in terms of spatial and temporal variance. Conceptually, one can distinguish between (1) spatial variance; a species is recorded in a similar number of squares on an annual basis, but where it is recorded differs among years from (2) temporal variance; a species is consistent with respect to 1 km squares, but on an intermittent basis.

The percent of zero counts for each species was used to assess this combined spatial/temporal variance; those species with a large percent of zeros have high spatial/temporal variance (equation 1).

Equation 1

$$\%\ \text{zero's} = \left(\frac{Z}{NZ}\right)100$$

Where;
Z = number of zero counts between 1994-2000
NZ = number of all counts between 1994-2000 (including zero's)

In addition a ratio was calculated based on the yearly average number of squares in which the species was seen and the total number of different 1 km squares (equation 2). This primarily represents spatial variance. A large total number of different 1 km squares relative to the average yearly number indicates the species has high spatial variance. This is referred to as 'ratio of total to mean squares'.

Equation 2

Ratio of total to mean squares = $\dfrac{T}{A}$

Where;
T = total number of 1 km squares between 1994-2000
A = yearly mean number of 1 km squares between 1994-2000

Squares which are entered into the model, but not surveyed in all the years receive a 'missing count' and represent a missing site by year combination. This is a common feature of monitoring programmes. In terms of the model fitting process, the greater the proportion of the missing counts the poorer the overall model fit will be and the greater the reliance on the statistical model to estimate missing counts (Pannekoek & Strien, 2001). To get a measure of this, the proportion of the number of missing counts (years in which sites not surveyed) in the model compared to the number of observations used by the model (years where sites surveyed) was calculated (equation 3). This was referred to as 'proportion missing' and gives some estimate of the degree of square turnover; squares will still enter the model as long as they were surveyed for more than two years. Turnover in terms of squares covered is likely to be greatest in upland areas where access is difficult or the effort and contribution required by the observer is expected to be high.

Equation 3

Proportion missing = $\dfrac{M}{NM}$

Where;
M = number of missing site by year combinations (not surveyed)
NM = number of site by year combinations surveyed

2.1.4 Minimum detectable effect size

The SE of the index for the change from 1994 to 2000 was used to assess the precision of the indices. The minimum detectable effect size is the minimum change which could be detected as significant considering the current data and model and is twice (1.96) the SE, expressed as a percent. Spearman Rank correlations were used to assess the relationship of effect size with: (1) proportion missing; (2) over-dispersion; (3) percent zero; (4) number of different 1 km squares and (5) yearly average of number of squares. This was done in a series of steps with continual selection of a subset of the original species (yearly mean greater than 10) to reduce the influence of outliers.

2.2 Simulation of the data and power analysis

Simulation was used to assess the power of the monitoring programme in detecting a significant population decline; power measured in terms of the percentage of runs in which a statistically significant decline was detected at an alpha of 0.05. This was based on simulating a 25% decline over 25 years. This magnitude of change was considered relevant as it is the minimum decline needed for inclusion on the amber list or a medium BTO alert. Due to the time constraints of running several simulations, this was restricted to particular species selected from those which are seen on >20 and <100 squares on a yearly average between 1994 and 2000 ('target species'). Simulation was based on randomly generating counts of species based on the Poisson distribution. The parameter for the Poisson distribution (mean) was based on the mean of the actual count data used in the standard BBS model for each species. To more closely simulate the true characteristics of the count data, an over-dispersed Poisson distribution was used to simulate the counts. This was achieved by first simulating the data with a mean half of that required and then multiplying each value by 2 to get the required mean and a greater variance than expected under the normal Poisson distribution (over-dispersion approximately 2). A 25% decline over the 25 years was simulated. The steps used for the simulation are outlined in more detail below. The simulation process simulates the counts for the sites on a year by year basis, from start to end year. So for the first year (year 1) the counts are simulated using the mean from the actual data, this is done for all the sites for year 1. For year 2 this is repeated, except that the mean is reduced by a constant determined to simulate a 25 % decline within 25 years (this is achieved by using a constant to the power of that year for the simulation run year). This is repeated for subsequent years, with each time the mean reduced by a set amount. The standard BBS site by year effect model is run on this dataset to assess the significance of the population change from start to end year (no weightings used in the simulation). To generate power, expressed as a percentage of times in which a significant decline was detected, simulation and running the BBS model on the simulated data was repeated a further 99 times to give a total of 100 runs.

Simulation of the data was therefore primarily designed to see the effect of varying sample size on the power of the monitoring program. For each of the target species, the 100 runs were done with a different number of sites included in the simulation: the first set of 100 runs was based on the lower number of yearly average of squares seen in over the period 1994-2000; the second was based on the larger total number of 1 km squares seen in over the period 1994-2000. The second run was believed to be more representative of the actual number of sites entered into the BBS model. To allow comparison with the true data in terms of the percent of zeros, this was calculated for each run and the mean of the 100 runs was taken. In addition, for ten of these species, the simulation was repeated using twice the total number of 1 km squares seen in. This allowed the assessment of the increase in power associated with a doubling of the survey effort in terms of the number of squares covered by the BBS. To reiterate, the species differ only in respect to the sample sizes used in the simulation and the mean of the counts used for the Poisson distribution. Both the sample size and mean for each species is reported in Table 3.2.1a & b.

3. RESULTS AND DISCUSSION

3.1 Exploration of the data

3.1.1 Descriptive statistics

Basic statistics for species which had a yearly mean number of 1 km squares greater than 10 (for sample sizes below this the index model often failed to converge) are detailed in Table 3.1.1. These include; mean, maximum, inter-quartile range, variance and coefficient of variance of the counts, percent of zero's, ratio of total to mean squares, yearly average of squares species seen in and total number of different 1 km squares. In addition, value of over-dispersion, number of observations used and number of missing, proportion missing, SE and the minimum detectable effect size are also given.

The yearly mean between 1994 to 2000 varies from less than 1 to 1,812. The following 22 species have a yearly mean number of squares greater than 1000 (in decreasing order of number of squares); Woodpigeon, Chaffinch, Blackbird, Wren, Robin, Blue Tit, Great Tit, Dunnock, Starling, Swallow, Magpie, Skylark, Song Thrush, Greenfinch, Willow Warbler, Pheasant, House Sparrow, Jackdaw, Blackcap, Goldfinch, Linnet, Yellowhammer. Species counts clearly differ in their degree of variability as expressed using the percent of zeros (number of site by year combinations with zero counts expressed as a percent of the total number of site by year combinations) and ratio of total to mean squares (total number of different 1 km UK squares relative to the yearly average for number of 1 km squares in which the species is seen).

As expected, those species with a high yearly average for the number of 1 km squares, also tend to have the smallest ratio of total to mean squares and percent of zeros. There is in fact a significant strong negative correlation between yearly average of squares and percent of zeros (r_s = -0.82, n = 137, P <0.0001). This means that widespread species also tend to be abundant or at least very frequently detected. There is also a significant strong negative correlation between percent of zeros and maximum count over all the years (r_s = -0.60, n = 137, P <0.0001). This is perhaps surprising as bird species with large maximum counts are more likely to be flocks, which by their nature are more variable in location from year to year. However, inspection of the scatter plot suggests the correlation coefficient is a poor indicator of the association between the two variables, being largely influenced by a few species with a large maximum count.

Species with a mean count per square >10 include Starling, Woodpigeon, Rook, House Sparrow, Blackbird and Chaffinch. A number of gulls, Herring and Common Gull have a mean between 5 and 10, along with Shag, and some commoner passerines; Meadow Pipit, Blue Tit, Wren, Robin and Skylark and two aerial feeders; Swift and Swallow. Those at the lower end of the range for mean count include a number of the raptors and some woodland species, such as; Lesser Spotted Woodpecker, Spotted Flycatcher and Willow Tit. Birds of rivers and freshwater include Kingfisher, Grey Wagtail and Dipper.

Species which have a coefficient of variance greater than 1 do not have a Poisson distribution and a number of species have a coefficient of variance greater than 50, including; Common Gull, Mute Swan, Shag, Fieldfare, Swift, Rook, Golden Plover, Herring Gull, Lesser Black-backed Gull, Feral Pigeon, Starling, Sand Martin and Greylag Goose. Species with low coefficient of variance are generally those species with a small mean as mentioned above (several raptors for instance). Species with a large maximum count (>500) include the following; Swift, Common Gull, Woodpigeon, Pheasant, Rook, Mute Swan, Starling, Swallow, Feral Pigeon, Carrion Crow and Lesser Black-backed Gull. Not surprisingly, species with a low maximum count include those mentioned above with a low mean count and coefficient of variance. In the case of percent of zeros, species with a percent higher than 75 include the following species; Hobby, Quail, Fieldfare, Barn Owl, Merlin, Lesser Spotted Woodpecker and Tawny Owl. Species with a percent of zeros less than 25 include; Woodpigeon, Blackbird, Chaffinch, Carrion Crow, Wren, Blue Tit, Robin, Great Tit, Starling, Magpie, Skylark, House Sparrow, Dunnock, Yellowhammer, Pheasant, Swallow, Greenfinch and Song Thrush.

A number of species have high values of over-dispersion, ranging from 66 to 2,170. Species with over-dispersion greater than 1,000 are Rook, Fieldfare, Starling, Golden Plover, Dunlin and Common Gull. The inclusion of flocking species violates the assumption of the Poisson distribution. The large counts of some of these species with large over-dispersion clearly represent non-breeding groups as many are rare breeders in the UK and also tend to occur in large numbers in winter. Species with over-dispersion value less than 100 include the following species; Lesser Spotted Woodpecker, Little Owl, Nightingale, Green Woodpecker, Hobby, Mandarin, Kingfisher, Tawny Owl, Marsh Harrier, Sparrowhawk, Great Spotted Woodpecker, Lesser Whitethroat, Woodlark, Barn Owl, Kestrel, Nuthatch and Moorhen.

All species with a yearly mean of squares greater than 10 have a ratio of missing less than 0.5 (range of 0.18 to 0.45). In other words, non-zero counts account for more than half of the whole site by year data matrix. It is possible that a number of species which are likely to have high values of missing site by year combinations are already excluded due to limited sample size. The bottom species all have small yearly averages.

3.1.2 Descriptive statistics from the BBS index model for waders, gulls, terns, geese, water birds and colonial seabirds

Table 3.1.2 allows easier comparison of the statistics for waders, gulls, terns, geese, water birds and colonial seabirds; those considered to have high maximum counts and high spatial variability. These are restricted to species with a yearly mean number of squares >10. A number of gull and wader species have a minimum effect size above 100 % and these have a high % of zeros and tend to have a yearly mean below 50 squares, with the majority below 20 squares. Gulls generally have large maximum counts, with Common Gull having an extremely high count (1,173). Mute Swan, Golden Plover and Oystercatcher have high counts. As mentioned above these are likely to represent counts of non-breeding birds.

3.1.3 Descriptive statistics from the BBS index model for the 35 target species

Table 3.1.3 reports statistics for the 35 target species which are seen on >20 and <100 squares nationally, thereby allowing easier comparison (the range of each statistic is given at the base of the table). Species include colonial and coastal species (Fulmar, Common Tern, Great Black-backed Gull), waders (Whimbrel, Ringed Plover, Common Sandpiper, Dunlin, Redshank, Golden Plover), species found on/near freshwater (Teal, Kingfisher, Dipper, Little Grebe, Gadwall, Common Tern, Common Sandpiper, Reed Warbler, Great Crested Grebe), species found in upland areas (Ring Ouzel, Whinchat, Golden Plover, Pied Flycatcher, Wood Warbler) and species with distributional limits (Nightingale, Pied Flycatcher).

Reference to 'high' and 'low' for values of these statistics are only relative to these target species, i.e. a 'high' value of over-dispersion may in fact be an average level of over-dispersion when compared to the full list of species. Common Crossbill, Dunlin, Fulmar, Fieldfare, Greylag Goose, Golden Plover, Redshank and Sand Martin all have values of their mean, maximum count and coefficient of variation in the top 10. In contrast, Dipper, Grasshopper Warbler, Little Owl, Lesser Spotted Woodpecker, Nightingale, Peregrine and Tawny Owl have their values for mean, maximum count and coefficient of variation in the lowest 10. Species with a high % of zeros include Hobby, Little Owl, Peregrine, Tawny Owl, Willow Tit, Lesser Spotted Woodpecker, Kingfisher and Goosander. Whereas Dipper, Common Sandpiper, Dunlin, Redshank and Golden Plover have low % of zeros. Species with a high value for 'proportion missing' (a missing count represents a year in which that site was not surveyed) include amongst others; two species of woodland (Pied Flycatcher, Wood Warbler), two waders (Dunlin, Golden Plover), Dipper and with the highest 'proportion missing', Stonechat.

3.1.4 Comparison of the frequency distribution of counts between inclusion and exclusion of birds in flight

Figure 3.1.4 compares the frequency of counts (proportion) between the sum of the three distance categories and birds seen in flight (standard BBS method) with the sum of the three distance categories, excluding the birds in flight. These are restricted to selected species from those seen in greater than 50 different 1 km squares across the period of 1994-2000. Species with a large outlying maximum count are not illustrated. The species frequency distributions can be characterised by several features, the proportion of zero counts, the range of the counts (skew) and influence of large outlier counts, which ultimately effects the shape of the distribution. Robin, Wren, Chaffinch, Dunnock, Blue Tit, Great Tit and Song Thrush are the few species to have a distribution similar to the Poisson distribution and have zeros in the proportion of 10 to 20 % of the total number of squares. The remainder of the species tend to be positively skewed with a modal class of zero. Species with a small range in counts (maximum count of approximately 20) include, not surprisingly the raptors, Dipper, Common Sandpiper, Greenshank, Grey Wagtail, Little Grebe, Kingfisher, Great Spotted Woodpecker, Lesser Spotted Woodpecker, Nuthatch, Treecreeper, Marsh Tit, Willow Tit, Pied Flycatcher, Spotted Flycatcher, Redstart, Nightingale, Wood Warbler, Garden Warbler, Grasshopper Warbler, Lesser Whitethroat.

Exclusion of birds in flight may decrease the number of squares in which each species was seen in if a bird was only seen in flight in any one square. Additionally, if this results in a square having zero counts for all the years it was surveyed, the square will be dropped from the model. In terms of the frequency distribution, exclusion of birds in flight can have two main effects; firstly the number of squares with zero counts may increase and secondly the magnitude of non-zero counts may actually decrease. For the majority of the species the difference between the two methods is only a few percent and there is little difference in the shape of the distribution when birds in flight are included or excluded. However, there is likely to be a difference in terms of the maximum count. Large maximum counts may well appear as outliers to the model and may adversely affect the fit of the BBS indexing model. The effect of excluding large counts on the BBS index was not explored in this report as it was covered by Field & Gregory (1999).

3.1.5 Relationships of minimum detectable effect size at the UK level with descriptive statistics of the counts and BBS index statistics

The SE of the index for the change from 1994 to 2000 was used to assess the precision of the indices. The minimum detectable effect size (referred to as 'effect size' hereafter) is the minimum change which could be detected as significant considering the current data and model and is twice the SE (1.96), expressed as a percentage. Spearman Rank correlations were used to assess the relationship of effect size with: (1) proportion missing; (2) over-dispersion; (3) percent zero; (4) ratio of total to mean squares; (5) number of different 1 km squares and (6) yearly average of number of squares. This was done for an increasingly smaller subset of species to remove the influence of outliers.

With species with yearly mean greater than 10, there was a significant strong correlation (r_s =0.99 n = 137, P < 0.0001) between yearly average number of squares and total number of different squares between 1994-2000. As there was a strong significant positive correlation between percent of zeros and ratio of total to mean squares (r_s = 0.98, P <0.0001, n = 137) (also for the 35 target species, r_s = 0.97, P <0.0001, n = 35); reference will only be made to percent zeros for the rest of this report. To exclude the bias from outliers, Figure 3.1.5a compares the association of minimum detectable effect size with the yearly average number of squares (seen in) and the total number of different squares in the dataset; restricted to those species seen in less than 100 squares (yearly average). There is a stronger relationship (negative correlation) between effect size and yearly average, compared to the poor association and large variation with total number of squares. Variation seems greatest for species with small minimum detectable effect size.

Table 3.1.5 reports Spearman Rank correlation matrix between effect size and yearly average and total number of different squares, proportion missing, over dispersion (deviance/degrees of freedom) and percent of zero‘s for species with an effect size less than 100 %. In addition, Figure 3.1.5b allows comparison of species positions within bivariate scatter plots. There is considerable variation in effect size and sample size for those species with sample size below 200 (Figure 3.1.5b (i)). Increases in sample size above 200 seem to have little influence on reducing the minimum detectable effect size.

As percent of zeros increases and proportion missing decreases, the effect size increases. Thus a small significant change is unlikely to be detected. However, the relationship of proportion missing with effect size is weak and indeed there appears no relationship when the analysis is restricted to the target species (see below). Variation in effect size increases with percent of zeros above 40 %. A low proportion missing means that for species in which the squares entered into the BBS model have been surveyed more or less every year, then effect size is small and thus a small significant change can be detected. Moreover, as squares are only entered into the BBS index model if they are surveyed at least twice, for some species found in upland areas it is conceivable that the majority of squares in which the species is recorded are dropped from the analysis and so the proportion missing underestimates the true degree of square turnover for that species. In contrast, mean count and value of over-dispersion from the BBS index model have less association with lower effect size, although species with a mean count below five have greater variation in effects size (Figure 3.1.5b (iv)). It would have been interesting to assess if the effect size was also related to the magnitude of the change or parameter estimate of the trend from the model. It is conceivable that an increasing magnitude of change results in a smaller effect size being detected.

For the target species alone (yearly average of number of squares seen in of ≥20 and ≤100), yearly mean number of squares is the most important variable in determining the effect size, compared to proportion missing and percent zeros (relationships are however in the same direction as reported above, but of lower magnitude) (Figure 3.1.5c). Fieldfare was an outlier in the plots with a high effect size and percent of zeros and proportion missing and hence it was removed from the plots. It is also likely that many of the counts for Fieldfare represent winter visitors from the early visit to the BBS square and are thus not part of the breeding population. With Fieldfare excluded, symbols were used to represent high and low values for proportion missing and percent of zeros on a plot of effects size against yearly mean number of squares (Figure 3.1.5d). There appears little clear separation of high and low values for proportion missing and percent of zeros in the bivariate space of yearly mean number and effect size. However, this may partly reflect the criteria used for the selection of the target species i.e. the yearly mean number of squares seen in. The target species are clearly diverse with respect to the other variables, which may obscure their relationships with them.

It is clear that a sample size below 100 generally is insufficient to detect a significant change in population less than 20%. For species with a sample size less than 50, only population changes greater than 40% are likely to be detected. For those species with a sample size above 50, population changes in the range 20-40 % can potentially be detected. This negative relationship between yearly mean average and effect size applies equally well to the four countries; England, Scotland, Wales and Northern Ireland (Figure 3.1.5e). Although linear regression lines have similar degree of fit for the four countries, the relationship for Northern Ireland has a steeper slope than the remaining three countries. Figure 3.1.5f clarifies this with an overlay of the UK and the four countries and regression lines. Indeed the relationship is remarkable similar for the UK, England, Wales and Scotland, despite there being differences in the species represented in the target group (target species within each country and UK are different as they are the species that are seen on >20 and <100 squares within the UK or country, i.e. yearly mean number of squares between 1994-2000). The agreement between UK, England, Wales and Scotland seems robust as it holds when both curvilinear relationships and a linear relationship imposed after first taking the logarithm of the yearly mean number of squares. The steeper decline of effect size with yearly mean number of squares observed for Northern Ireland effectively means that for sample sizes above 40, effect size is less and hence smaller population changes can be detected compared with the other three countries. Preliminary exploration of this steeper decline for the Northern Ireland target species suggests that it may be due to the relatively smaller number of total squares covered by the BBS scheme and hence the truncation or lack of species with sample size above 60 squares. For example the number of squares covered in 2000 for England, Scotland, Wales and Northern Ireland are: 2,567; 631; 355 and 82 respectively (Noble *et al.*, 2001). Species which fall in the sample size range of 40 to 60 squares for Northern Ireland are in fact species which are widespread and abundant and so one would expect them to have a higher precision for population changes (i.e. Blackbird, Robin, Wren, Chaffinch, Magpie and Woodpigeon). In contrast, for the other three countries, the total number of squares covered by the BBS is higher and so species which fall into this range for the other countries tend to be those species which are less widespread and are likely to have a greater variance associated with their population trends due to year to year variation in their counts.

In relation to the reporting of the trends from BBS and the agreement between the UK as a whole and the four countries; using a >50% decline as the threshold to detect a population decline (potential inclusion on the red list or as a high BTO alert under the Wider Countryside Report if based on smoothed trend), a sample size of 40 or more would be needed to report trends with any confidence (Figure 3.1.5f). Time constraints excluded exploration of this relationship for the nine RDAs, but it is expected that the negative relationship of effect size and sample size would be apparent, although perhaps to different degrees. Within this overall negative relationship of effect size with sample size, it is conceivable that species with the same sample size between regions may have different degrees of variance between regions and hence different effect sizes. Thus a method of selecting species for reporting BBS trends not solely on sample size may offer advantages in ensuring precision of those reported.

3.2 Simulation of the data and power analysis for the 35 target species at the UK level

Power is expressed as a percent and is the proportion of the 100 runs to which a significant change was detected at an alpha of 0.05 (2-tailed test), using the standard BBS indexing model with no weighting applied. For each species, results are presented for two types of runs; one using the yearly average of squares with the species present and the other the total number of 1 km squares in which the species was recorded in (Table 3.2.1a). For the majority of the species the total number of squares is three to four times the yearly mean number of squares seen in. There is a low, but significant correlation between the power results for both sample sizes (yearly mean and total number), $r_s = 0.54$, $P = 0.001$, n = 35). Figure 3.2.1 illustrates this association and highlights several species as outliers in the scatter plot, removal of these species would clearly improve the association. Not surprisingly, there was a small positive correlation between the power to detect a 25 % population decline over a period of 25 years with sample size; yearly mean number of squares ($r_s = 0.34$, P=0.05, n = 35) and number of 1 km squares ($r_s = 0.35$, P=0.04, n = 35).

Four of the 35 target species have a power above 80 % (Sand Martin, Greylag Goose, Golden Plover and Fieldfare) using sample sizes similar to those of the true data (number of 1 km squares).
The majority however, have a power less than 70 %. In addition to sample size, there is clearly a negative relationship between power and the mean % of zeros in the simulated data (Figure 3.2.2). This relationship being stronger for the number of different squares (Figure 3.2.2 (ii)). Although the % of zeros in the simulated data is artificially related to the mean count due to sampling from a Poisson distribution; the closer to zero the mean is, the greater the number of zero counts are expected ($r_s = -0.98$, P=<0.0001, n = 35), species with a higher % zeros, regardless of their mean will have reduced power. The association between the actual and simulated percent of zeros indicates the degree to which the simulated data match that of the actual data; $r_s = 0.54$, $P = 0.0008$ indicates a reasonable matching in terms of percent of zeros. Generally the species occupy similar positions relative to one another in Figure 3.2.2 (i) and (ii), although rankings for Fieldfare, Hobby, Lesser Spotted Woodpecker and Peregrine are different between actual and simulated data.

For ten selected species the simulation was run using twice the total number of 1 km squares in which the species was seen to assess the role of doubling the effective sample size of the species. The ten species varied in both their mean count and sample size. Table 3.2.1b reports the sample sizes, mean count, mean percent of zeros in the simulated data, actual percent of zeros and the power. Four species have a power above 70 % (Great Black-backed gull, Golden Plover, Great Crested Grebe and

Common Tern), but for the other species the samples sizes are still insufficient to ensure high power to detect a 25 % change. These four species do not necessarily have the largest sample sizes, but rather higher mean counts and correspondingly lower % of zeros in the simulated data.

3.3 Agreement between simulation based power analysis and effect size

At least for the target species, little association exists between the power from the simulation based approach and the minimum detectable effect size, for sample sizes measured as the yearly mean: r_s = 0.30, P = 0.08 or the total number different squares: r_s = 0.20, P = 0.24, n = 35. This is to be expected as the minimum detectable effect size is based on the true data and will reflect the true characteristics of the data in terms of over-dispersion, spatial and temporal variability. The simulated data for example lacked missing counts, i.e. site by year combinations which were not surveyed and unlike the true data, the dispersion is considerably less, generally less than 2. It is important to remember that the only difference between the species is in terms of the number of sites at which the species is recorded and thus the number of sites (sample size) included in the model and the mean of the counts. A more realistic simulation of the species data would consider the spatial and temporal variance in the counts, unique to each species. Thus power analysis results are likely to be an overestimate of the power of the monitoring programme and the simulated data more closely follows the assumptions of the Poisson distribution and hence the estimation procedures used by the standard BBS indexing model. However, the simulation although simplistic in its representation of the attributes of the count data, represented a viable alternative to some of the well established and standardised power analysis methodology used with classical parametric tests (Castelloe, 2000). It may be feasible to improve the reality of the simulation and consider the actual parameters of the species. Theoretically it is easier to see how one would improve the reality of the simulation, however it is less clear how this could be done in practice. Indeed the simulation approach is a valuable step in itself in helping to assess the properties of the data and the degree to which the model represents the biological reality of the species and count data. Adopting a more sophisticated model to ensure the simulations are realistic may have drawbacks in actually imposing a 'known' prescribed trend for the count data. A more realistic approach could have used a site by site method for imposing a decline, such that each site over the period of interest would still have experienced the set change, but the starting mean count would have differed. This would have accommodated the assumption that counts may differ between sites (perhaps on a habitat basis) but that overall the population change would be consistent from site to site. However, a major problem with any power simulations is that it would be very difficult to validate the model outputs even if you tried to make the simulations more realistic (and undoubtedly more complex).

It is to be expected that the results from the minimum detectable effect size are more likely to be realistic in indicating which sample sizes are sufficient to ensure a high precision of the BBS index. However, a better appreciation of the effect size may be obtained if the confidence intervals are generated using bootstrapping techniques. These are especially valuable as they are based on fewer implicit assumptions compared to SE's, but were not used in this report due to them being computationally intensive. Bootstrapping involves sampling with replacement to form a number of replicate datasets and re-running the analysis on these to generate a frequency distribution and identifying if the actual value is greater than 95% of the values to be thus classed as significant. In this respect the CI's reflect the actual attributes of the data themselves and do not rely on the assumptions of the exponential distribution. The SE's used in this report may be biased in some species due to the failure of the count data to meet the assumptions of the Poisson distribution. This limitation applies to all routinely reported BBS analyses at present.

By default, power analysis tests in this report assume a 2-tailed approach. In statistical terms, 'tailedness' is the number of tails chosen for the hypothesis of interest, in the context of population trends; a 1-tailed test would consider either a population decline or increase (directional trend) as opposed to a 2-tailed test where change could be in any direction. A 1-tailed test is more powerful than a 2-tailed test and could be used to detect population declines of species and so power results are likely to have been higher if 1-tailed tests were adopted. Indeed a 1 tailed approach is used for the BTO alert scheme in the 'Wider Countryside Report' (Baillie *et al.*, 2002). In this case the effect size would need to be re-calculated as 90% confidence limits, as opposed to the current 2-tailed 95% confidence limits. This would reduce the required sample size needed to obtain trends with a set precision or power.

Much of this report has focused on the power to detect a particular level of change, but also of importance is how the sampled population reflects the real population. BBS may not be representative of all habitats and BBS coverage may not be representative of the UK population for all species if the majority of the population occur outside the BBS survey squares. This is particularly true for coastal species, such as gulls and seabirds. In the report by Field & Gregory (1998), habitats surveyed by the observers (actual as opposed to ideal transect route) showed a slight bias towards broadleaved woodland and away from farmland. Their report did, however, conclude that habitat bias was unlikely to have much effect on the BBS results (Field & Gregory, 1998).

3.4 Remarks on the standard BBS indexing model

A question often raised is whether or not to restrict sites entered into the model to those where the species has been seen or to include all the sites that have been surveyed regardless of whether it has been seen or not (Walsh *et al*., 2001). This translates to dealing with zero counts, and in the context of the BBS model relates to the inclusion of all sites which have been surveyed at least twice since 1994. For the BBS, in addition to restricting entry of 1 km squares to those that have been surveyed more than once, only squares where the species is seen for at least one year (i.e. non-zero value) are entered into the model. Thus squares where the species was not seen in any year, but still surveyed more than once are excluded from the model (i.e. zero count for all years surveyed). Thus removal of squares with zero counts in any year surveyed results in the number of actual squares entered into the model differing from species to species. This effects the degree to which the distribution of the counts meets the assumption of the parametric distribution, in this case Poisson. Where a scale parameter is used in the model to adjust for over-dispersion (as is routinely done for the BBS), the difference in degrees of freedom between models based on inclusion of all sites or exclusion of some sites will effect the degree of adjustment for over-dispersion. In the
context of parameter estimates, site and year effects from the model are unaffected, but standard errors (SE's) and confidence intervals (CI's) around these estimates are reduced with inclusion of all sites surveyed (i.e. zero count for all years surveyed), due to model over fitting. Incidentally,

where no scale parameter is estimated and thus no adjustment is made of the dispersion of the model, the results are identical with or without these squares with zero counts for all years surveyed. This is an important point in respect to ensuring simulations are realistic.

The accuracy of the minimum detectable effects size is dependent on the fit of the model and the degree to which the data conforms to the assumptions of the Poisson distribution. Consideration should be given to using the negative binominal distribution as this is more appropriate to deal with zero-inflated count data. It was not possible to assess the fit of the models as the usual deviance statistic or other goodness of fit test is not valid if adjustment for dispersion is used in the model (pscale used in the BBS index model) (Pannekoek & Strien, 2001). The assumptions of the maximum likelihood approach to estimating parameters is also violated if counts exhibit serial correlation i.e. counts from year to year are not independently distributed and are likely to depend on counts in the previous year (Pannekoek & Strien, 2001). One approach which may be used to overcome this problem is generalised estimating equations (GEE'S), first formalised by Liang and Zeger (1986), which can be used to take into account the correlation between related sampling units. This has no influence on the year effect from the model but does adjust the confidence limits and significance of the model parameters accordingly, hence effecting whether any population trend is determined to be significant in the statistical sense. There is the potential to incorporate GEE's as SAS includes an option under the procedure used for the standard BBS index model.

The standard indices of the BBS are based on the yearly change from year to year, with counts modelled as a function of both site and year effects, an alternative model is to consider a linear trend from start to finish using a linear regression framework. This considers the overall change and is less influenced by variations between individual years. A comparison of the two methods was made for 100 of the commonest species by Field and Gregory (1999). Using methods to assess long-term trends reduces the bias of short-term fluctuations and error often associated with using index methods. However, except in rare circumstances such as exponential population growth, a linear trend model is unlikely to provide a realistic description of the population trajectory. In addition to there being linear population trends, there may also be directional or non-linear trends (Urquhart & Kincaid, 1999). Suitable methods to detect non-linear methods may be used and these come under the umbrella of Generalised Additive Models (GAM's), which incorporate smoothing techniques. GAM's can be used either as the main analysis tool or for exploratory purposes before constructing the formal model (Barry & Welsh, 2002). They tend to be regarded as non-parametric data-driven models as opposed to GLM's, which are primarily model-driven (Yee & Mackenzie, 2002). This is because rather than assuming some form of parametric relationship, the data determine the nature of the relationship between the response and the set of the explanatory variables. GAM's can be fitted using a variety of smoothing algorithms, including; smoothing splines, regression splines and lowess (locally weighted regression). Choice of the most appropriate method is important as it has frequently been shown that the direction, magnitude and significance of population trends can vary between analysis methods (Thomas & Martin, 1996). The strength of GAM's lies in their ability to handle highly non-linear and non-monotonic relationships between the response and the explanatory variables through use of a smoothed function (Guisan *et al*., 2002). GAM's have been successfully applied to data for the Common Bird Census (Fewster *et al*., 2000) and are routinely used for reporting trends and alerts based on CBC data (Baillie *et al*., 2002).

Moreover, if appropriate smoothing is used in the BBS, the precision of the trends reported may be improved for comparable sample sizes of the species. This is because smoothing reduces the number of temporal effects, and hence the number of parameters in the model. However, if inter-annual differences are of interest, smoothing would not be an appropriate model.

4 CONCLUSION

Protocol for the reporting of the BBS trends

Two main aspects should be considered when determining which species to include for reporting BBS population trends for the UK or for any particular region. The first is based on numerical or statistical criteria, with sample size (yearly mean number of squares in which the species is seen) having the most influence. The second relates to the sampling design of the BBS. Species for which the BBS may be inappropriate include colonial and flocking species (where a large proportion of these counts are likely to be non-breeders) and species to which squares covered by the BBS are unlikely to be representative of their breeding population (such as coastal and marine species). We propose the following procedure for reporting BBS trends for all species at the national, country or regional level.

1. Report trends for all species where the mean annual sample size is at least 40 sites, and where the BBS sampling design is appropriate. For these species there should be a high probability that we can detect a 50% decline.

2. Report population trends, with a caveat signifying that the reported trend may not reflect the status of the breeding population in the UK for all species where counts are likely to be strongly influenced by non-breeders, migrants, or where the BBS methodology may not reliably sample the population (e.g. nocturnal or colonial species) and where the mean sample is at least 40 squares (Table 4.1a).

3. Indices should not be produced for species with sample sizes less than 40 or for species whose counts include a high proportion of non-breeding birds, wintering birds or those seen during migration (Table 4.1a list the latter type of species).

The guidelines above provide useful rules of thumb for the reporting of BBS trends. It appears that by reporting trends at the country and regional level for many species with mean year sample sizes in the 20 to 40 squares range in the past, we may be including species for which we are unlikely to detect changes less than 50 % over a particular period. Table 4.1b lists the species which would no longer be reported using the BBS for the UK (category 2) and four countries (category 2 & 3) if the new protocol were to be adopted (the total number of species excluded for the nine RDA's is reported only). The BBS has only been running for nine years and relatively few species will have changed in population status so rapidly. Exceptions to this sample size rule of 40 or more may include species whose pattern of occurrence (low variance in counts and consistent presence on squares) mean that a 50 % decline could be detected on a sample of squares less than 40. For research purposes the data should be explored on a case by case basis for these species, but this is not practical for routine reporting at present.

The relationships reported here between statistical features suggest methods for assessing the quality of trend data for each species. Species trends assessed with low % zeros, low proportion of missing squares and lower over-dispersion values for example should be given more credence than those with higher values for the same sample size. This should be further explored at the regional level, because some of the variation may be significantly reduced in a region. However, our power to detect a given level of change (e.g. 50%) is likely to be higher than as presented here for two reasons. Firstly, because we are primarily interested in declines, we should be considering a one-tailed test , with a 90 % instead of a 95 % confidence limit. Secondly, if BBS trends are smoothed, the reduction in the number of parameters increases our power to detect change.

This report has focused largely on issues related to the statistical attributes of the data (sample size, variance etc). In reporting trends, it is also necessary to consider biological aspects in selecting species to be included in the BBS population trends. A number of species recorded by BBS surveyors include many non-breeders, colonial species or those which show a clumped distribution, and care must be exercised in determining criteria for inclusion of counts which represent the breeding population. In contrast there are a number of rare species recorded on BBS squares which are better covered and often counted directly and accurately by a range of specialised surveys. In other cases it is unknown how representative the population recorded on BBS squares is of the whole population. As the focus of this report was primarily on borderline species in terms of sample size for reporting trends at the national, country and regional level, this may merit further exploration at a later date.

It is also important when interpreting population trends to be able to distinguish between statistical and biological significance. Biological significance is a change that is of importance to a species' long-term prospects as opposed to statistical significance, which is the magnitude of a trend relative to the variability of the results and sample size. In the context of expanding the BBS, it is clearly very helpful to assess the statistical power of the data, to determine the appropriate sample sizes for reporting BBS index trends at the national and regional level. This may require a more realistic simulation of the data, rather than assuming Poisson distribution and the use of bootstrapping to generate confidence intervals to estimate the minimum detectable effect size. In addition, analytical power calculations could be explored to supplement simulation based power analyses.

REFERENCES

Baillie, S.R., Crick, H.Q.P., Balmer, D.E., Beaven, L.P., Downie, I.S., Freeman, S.N., Leech, D.I., Marchant, J.H.,Noble, D.G., Raven, M.J., Simpkin, A.P., Thewlis, R.M. and Wernham, C.V. (2002) Breeding Birds in the Wider Countryside: their conservation status 2001. BTO Research Report No. 278. BTO, Thetford. (http://www.bto.org/birdtrends).

Barry, S. C. & Welsh, A. H., (2002) Generalized additive modelling and zero inflated count data. *Ecological Modelling*, 157 pp 179-188.

Castelloe, J. M. (2001) *Power and sample size determination for linear models*. Paper 240-26, SAS Institute Inc., Cary, USA.

Castelloe, J. M. (2001) *Sample size computations and power analysis with the SAS system*. Paper 265-25, SAS Institute Inc., Cary, USA.

Fewster, R.M., Buckland, S.T., Siriwardena, G.M., Baillie, S.R. & Wilson, J.D. (2000) Analysis of population trends for farmland birds using generalized additive models. *Ecology* 81: 1970-1984

Field, R. H. & Gregory, R. D. (1999) Measuring population changes from the Breeding Bird Survey 1994-1997. BTO Research Report No. 217, British Trust for Ornithology, Thetford.

Guisan, A., Edwards, T. C. & Hastie, T. (2002) Generalizied linear and generalizied additive models in the studies of species distributions: setting the scene. *Ecological modelling*, 157, pp 89-100

Liang, K. Y., & Zeger, S. L. (1986) Longitudinal data analysis using generalized linear models. *Biometrika*, pp 13-22.

Noble, D. G., Raven, M. J. & Baillie, S. R. (2001) The Breeding Bird Survey 2000, Report Number 6. British Trust for Ornithology, Thetford.

Pannekoek, J. & Strien, A. V. (2001) *TRIM 3 Manual Trends and Indices for Monitoring data*. Statistics Netherlands, Voorburg.

Raven, M. J., Noble, D. G. & Baillie, S. R. (2002) *The Breeding Bird Survey 2001, Report Number 7*. British Trust for Ornithology, Thetford.

Thomas, L. & Martin, K. (1996) the importance of analysis methods for breeding bird survey population trend estimate. *Conservation Biology*, **10**, p479-490.

Urquhart, N. S. & Kincaid, T. M. (1999) Designs for detecting trend from repeated surveys of ecological resources. *Journal of Agricultural, Biological and Environmental Statistics*, **4**, pp 44-414

Walsh, A. , Catto, C., Hutson, T., Racey, P., Richardson, P. & Langton, S. (2001) *The UK's National Bat Monitoring Programme Final Report*. Bat Conservation Trust, London. http://www.bats.org.uk/nbmp/NBMP01.pdf. pp87-98.

Xiang, D. (2001) *Fitting generalized additive models with the GAM procedure*, (2001) Paper 256-26. SAS Institute Inc., Cary, USA.

Yee, T. W. & Mackenzie, M., (2002) Vector generalized additive models in plant ecology. *Ecological Modelling* **157**, pp141-156.

Table 3.1.1 Basic descriptive statistics of the counts and statistics from the BBS indexing model for count data from 1994-2000

Yearly mean is the mean number of squares a species was seen in between 1994-2000
Ratio total to mean squares is the no. of 1 km squares/yearly mean number of squares
Proportion missing is number of squares missing/number of observations used
Dispersion is deviance/df
Minimum effect size is the minimum detectable effect size (1.96*SE)

Species codes	species name	mean	max	interquartile range	variance	CV	no. 1km squares	yearly mean	% zero's	ratio total to mean squares	observations used	missing	Dispersion (deviance/df)	StdErr	Min. effect size (%)	proportion missing
WP	WOODPIGEON................	19.9	1055	18	622.7	31.3	2618	1812	3.75	1.44	13177	5149	617	0.02	4.0	0.39
CH	CHAFFINCH.................	10.2	236	10	64.6	6.4	2625	1791	5.05	1.47	13200	5175	201	0.01	2.9	0.39
B.	BLACKBIRD.................	10.7	92	11	82.3	7.7	2606	1787	4.78	1.46	13138	5104	151	0.01	2.7	0.39
WR	WREN......................	7.7	104	8	47.5	6.1	2670	1764	8.12	1.51	13440	5250	194	0.02	3.2	0.39
R.	ROBIN.....................	6.1	51	7	27.8	4.6	2578	1703	8.42	1.51	13017	5029	158	0.02	3.5	0.39
C.	CARRION CROW.............	9.4	536	9	179.0	19.1	2550	1698	7.9	1.50	12902	4948	458	0.02	4.9	0.38
BT	BLUE TIT..................	7.8	160	8	53.9	6.9	2509	1666	8.23	1.51	12707	4856	197	0.02	3.9	0.38
GT	GREAT TIT.................	4.0	39	5	15.1	3.7	2454	1520	14.5	1.61	12440	4738	157	0.02	4.8	0.38
D.	DUNNOCK..................	3.1	30	3	9.0	2.9	2445	1467	17.6	1.67	12462	4653	141	0.02	4.9	0.37
SG	STARLING..................	23.0	659	26	1454.4	63.1	2375	1461	15.4	1.63	12094	4531	1454	0.03	6.2	0.37
SL	SWALLOW...................	5.1	600	6	78.0	15.2	2492	1407	22.2	1.77	12666	4778	327	0.03	5.2	0.38
MG	MAGPIE....................	4.3	42	5	21.6	5.0	2291	1388	16.5	1.65	11636	4401	145	0.02	4.7	0.38
S.	SKYLARK...................	6.1	99	8	54.7	9.0	2272	1382	16.6	1.64	11592	4312	201	0.02	3.9	0.37
ST	SONG THRUSH...............	2.6	39	3	8.1	3.2	2433	1371	22.6	1.77	12399	4632	154	0.03	5.3	0.37
GR	GREENFINCH................	4.6	151	5	37.1	8.1	2259	1280	22.5	1.76	11556	4257	230	0.03	5.6	0.37
WW	WILLOW WARBLER............	3.6	66	5	25.6	7.1	2280	1224	26.5	1.86	11659	4301	196	0.02	4.6	0.37
PH	PHEASANT..................	3.6	999	4	116.6	32.2	2129	1223	21.6	1.74	10916	3987	214	0.03	5.7	0.37
HS	HOUSE SPARROW.............	13.7	450	14	480.8	35.2	2020	1221	17	1.65	10293	3847	366	0.02	4.4	0.37
JD	JACKDAW...................	8.4	342	10	198.7	23.7	2144	1166	25.3	1.84	10926	4082	560	0.03	6.2	0.37
BC	BLACKCAP..................	2.1	33	3	5.5	2.7	1957	1026	28.7	1.91	10071	3628	103	0.03	6.2	0.36
GO	GOLDFINCH.................	2.4	52	3	11.8	4.9	2155	1011	36.6	2.13	11167	3918	245	0.04	7.6	0.35
LI	LINNET....................	3.8	106	5	40.7	10.6	2034	1008	33.5	2.02	10612	3626	375	0.04	7.4	0.34
Y.	YELLOWHAMMER..............	3.3	42	4	12.9	3.9	1734	1003	21.6	1.73	8954	3184	131	0.03	5.2	0.36
RO	ROOK......................	16.9	957	19	1387.4	82.0	2034	999	32.6	2.04	10383	3855	2170	0.04	8.5	0.37
CD	COLLARED DOVE.............	3.5	59	5	26.2	7.4	1878	977	29.7	1.92	9726	3420	149	0.03	5.9	0.35
WH	WHITETHROAT...............	2.2	32	3	8.0	3.6	1898	969	31.3	1.96	9872	3414	133	0.03	6.6	0.35
PW	PIED WAGTAIL..............	1.2	26	2	2.8	2.2	2149	951	40	2.26	11085	3958	144	0.04	7.5	0.36
M.	MISTLE THRUSH.............	1.4	56	2	4.3	3.0	2150	939	41.1	2.29	11150	3900	174	0.04	8.4	0.35
CC	CHIFFCHAFF................	2.2	50	3	7.5	3.4	1820	918	31.6	1.98	9389	3351	125	0.03	6.8	0.36
MA	MALLARD...................	3.5	215	4	53.9	15.2	1987	914	38	2.17	10319	3590	267	0.03	7.0	0.35
SI	SWIFT.....................	5.5	1453	5	461.5	84.4	2001	848	43.6	2.36	10515	3492	572	0.04	9.0	0.33
CK	CUCKOO....................	0.9	19	1	1.4	1.6	1825	749	45.6	2.44	9644	3131	118	0.04	8.9	0.32
HM	HOUSE MARTIN..............	4.1	88	5	52.2	12.8	1714	721	43.5	2.38	8937	3061	416	0.04	9.0	0.34
LT	LONG-TAILED TIT...........	1.6	49	2	8.1	5.1	1676	625	50.2	2.68	8782	2950	235	0.06	11.4	0.34
MP	MEADOW PIPIT..............	8.2	148	11	192.5	23.5	1331	620	35.4	2.15	6723	2594	514	0.03	5.4	0.39

Species codes	species name	mean	max	interquartile range	variance	CV	no. 1km squares	yearly mean	% zero's	ratio total to mean squares	observations used	missing	Dispersion (deviance/df)	StdErr	Min. effect size (%)	proportion missing
SD	STOCK DOVE................	1.8	184	2	22.1	12.1	1386	582	46	2.38	7544	2158	200	0.05	10.6	0.29
GS	GREAT SPOTTED WOODPECKER..	0.8	11	1	1.3	1.5	1488	576	49	2.58	7908	2508	88	0.05	10.7	0.32
L.	LAPWING...................	3.4	182	4	70.6	20.6	1358	541	47.6	2.51	7225	2281	481	0.05	9.9	0.32
G.	GREEN WOODPECKER..........	1.0	11	1	1.4	1.5	1252	538	43.6	2.33	6683	2081	77	0.05	10.4	0.31
FP	FERAL PIGEON..............	8.4	586	6	550.8	65.3	1329	532	46.7	2.50	6983	2320	681	0.05	10.3	0.33
CT	COAL TIT..................	1.8	45	2	10.1	5.7	1338	528	46.2	2.53	6877	2489	215	0.05	9.2	0.36
GC	GOLDCREST.................	1.8	80	2	11.6	6.5	1272	522	44.9	2.44	6627	2277	188	0.04	9.0	0.34
K.	KESTREL...................	0.5	18	1	0.5	1.1	1684	509	60.4	3.31	8989	2799	97	0.06	12.2	0.31
J.	JAY.......................	0.9	28	1	1.9	2.0	1318	499	50.1	2.64	7004	2222	106	0.05	11.4	0.32
MH	MOORHEN...................	1.2	25	2	2.8	2.3	1127	498	41.4	2.26	5955	1934	100	0.05	10.4	0.32
H.	GREY HERON................	0.7	24	1	1.9	2.7	1460	462	58.3	3.16	7752	2468	114	0.06	11.9	0.32
HG	HERRING GULL..............	5.9	445	3	444.2	75.9	1251	453	51.1	2.76	6488	2269	965	0.06	11.5	0.35
BZ	BUZZARD...................	1.0	13	2	1.9	1.8	1136	448	44.7	2.54	5667	2285	160	0.05	11.3	0.40
BF	BULLFINCH.................	0.8	41	1	1.7	2.1	1357	438	57.4	3.10	7189	2310	149	0.06	13.0	0.32
CU	CURLEW....................	2.8	167	3	33.9	12.1	988	432	40.3	2.29	5070	1846	288	0.04	8.9	0.36
BH	BLACK-HEADED GULL.........	4.6	295	3	228.1	49.6	1175	430	50.9	2.73	6134	2091	751	0.06	11.8	0.34
LB	LESSER BLACK-BACKED GULL..	3.9	500	3	271.8	69.5	1179	414	53.8	2.85	6280	1973	628	0.06	13.5	0.31
GW	GARDEN WARBLER............	0.8	13	1	1.5	1.9	1107	373	55.9	2.97	5913	1836	116	0.06	13.2	0.31
RL	RED-LEGGED PARTRIDGE......	1.8	24	2	6.9	3.8	872	371	44.9	2.35	4709	1395	156	0.06	11.9	0.30
RB	REED BUNTING..............	1.2	25	2	3.8	3.2	877	329	50.3	2.67	4631	1508	151	0.06	12.2	0.33
CG	CANADA GOOSE..............	2.8	140	2	77.7	27.6	886	289	58.1	3.07	4815	1387	314	0.07	15.1	0.29
NH	NUTHATCH..................	1.0	12	2	2.0	2.0	735	282	48.8	2.61	3847	1298	98	0.07	14.9	0.34
TC	TREECREEPER...............	0.6	21	1	1.3	2.1	896	264	61.7	3.39	4831	1441	119	0.08	17.4	0.30
SH	SPARROWHAWK...............	0.3	6	1	0.3	1.0	1180	264	71.3	4.47	6452	1808	87	0.08	17.3	0.28
SW	SEDGE WARBLER.............	1.6	34	2	9.5	5.9	656	241	50.6	2.72	3412	1180	192	0.06	13.3	0.35
W.	WHEATEAR..................	1.2	30	1	6.5	5.3	765	236	58.7	3.24	3995	1360	263	0.07	14.4	0.34
OC	OYSTERCATCHER.............	3.3	251	4	72.3	22.1	514	231	39.3	2.23	2666	932	436	0.05	11.2	0.35
P.	GREY PARTRIDGE............	1.0	31	2	2.8	2.9	724	220	60.9	3.29	3947	1121	175	0.09	18.3	0.28
LW	LESSER WHITETHROAT........	0.5	18	1	0.9	1.6	689	202	63.2	3.41	3836	987	91	0.09	18.3	0.26
SF	SPOTTED FLYCATCHER........	0.5	11	1	0.8	1.7	794	199	67.5	3.99	4298	1260	139	0.09	18.9	0.29
TD	TURTLE DOVE...............	1.0	27	1	3.0	2.9	527	192	53.2	2.74	2875	814	125	0.09	19.2	0.28
CO	COOT......................	2.7	115	3	36.4	13.6	433	188	41.6	2.30	2255	776	170	0.08	16.1	0.34
MS	MUTE SWAN.................	3.3	675	2	812.0	244.5	493	167	56.2	2.95	2670	781	313	0.08	18.1	0.29
RN	RAVEN.....................	1.2	227	2	40.2	34.2	504	160	55.3	3.15	2511	1017	342	0.10	22.6	0.41
YW	YELLOW WAGTAIL............	1.4	55	2	7.3	5.2	436	157	53.8	2.78	2385	667	152	0.09	18.4	0.28
GL	GREY WAGTAIL..............	0.5	11	1	0.8	1.5	571	148	65	3.86	2958	1039	148	0.11	23.0	0.35
CB	CORN BUNTING..............	1.7	41	2	8.1	4.8	365	146	48.3	2.50	1980	575	141	0.09	19.2	0.29
CA	CORMORANT.................	0.9	48	1	5.9	6.3	482	140	63	3.44	2655	719	159	0.09	19.9	0.27
TS	TREE SPARROW..............	1.4	35	2	7.7	5.5	399	134	56.5	2.98	2161	632	270	0.11	23.0	0.29
RT	REDSTART..................	1.4	16	2	4.3	3.0	329	132	46.2	2.49	1713	590	182	0.09	19.7	0.34
CM	COMMON GULL...............	5.7	1173	2	1809.4	319.6	440	124	62.6	3.55	2324	756	1232	0.09	20.1	0.33

Species codes	species name	mean	max	interquartile range	variance	CV	no. 1km squares	yearly mean	% zero's	ratio total to mean squares	observations used	missing	Dispersion (deviance/df)	StdErr	Min. effect size (%)	proportion missing
TP	TREE PIPIT................	1.2	33	2	4.8	4.1	365	124	53.7	2.94	1877	678	251	0.10	21.7	0.36
TU	TUFTED DUCK...............	3.1	103	3	55.8	17.8	313	122	49.7	2.57	1702	489	397	0.10	21.8	0.29
MT	MARSH TIT.................	0.6	12	1	1.3	2.2	442	119	66.1	3.71	2461	633	116	0.12	25.5	0.26
LR	LESSER REDPOLL............	1.5	85	2	15.3	10.4	403	118	60.5	3.42	2097	724	454	0.12	25.3	0.35
SN	SNIPE.....................	1.0	23	1	2.8	3.0	347	116	55.8	2.99	1843	586	274	0.10	22.8	0.32
SU	SHELDUCK..................	3.2	203	3	77.7	24.2	304	114	51	2.67	1627	501	366	0.10	21.5	0.31
SK	SISKIN....................	2.0	92	2	28.3	14.2	359	113	58	3.18	1885	628	607	0.11	25.0	0.33
HC	HOODED CROW...............	2.5	311	3	93.6	37.2	240	105	36.5	2.29	1155	525	815	0.14	31.6	0.45
RG	RED GROUSE................	3.0	50	3	27.9	9.2	241	102	39.5	2.36	1186	501	418	0.11	23.2	0.42
SM	SAND MARTIN...............	3.4	300	2	197.0	58.4	360	96	65.9	3.75	1965	555	832	0.12	27.1	0.28
LO	LITTLE OWL................	0.3	4	1	0.3	0.9	389	89	71.1	4.37	2162	561	71	0.14	30.5	0.26
GB	GREAT BLACK-BACKED GULL...	1.3	148	1	27.8	21.8	319	85	64.6	3.75	1688	545	388	0.12	25.4	0.32
RW	REED WARBLER..............	2.3	35	3	16.8	7.3	205	85	46.8	2.41	1122	313	138	0.10	22.8	0.28
GJ	GREYLAG GOOSE.............	2.8	230	2	157.6	55.4	296	82	64.9	3.61	1629	443	851	0.16	35.6	0.27
GP	GOLDEN PLOVER.............	3.3	300	2	255.6	76.4	214	81	49.1	2.64	1107	391	1289	0.13	27.8	0.35
WC	WHINCHAT..................	1.0	32	1	4.3	4.5	279	80	62.6	3.49	1499	454	245	0.13	29.3	0.30
TO	TAWNY OWL.................	0.3	7	0	0.3	1.0	385	77	75.1	5.00	2166	529	85	0.15	33.3	0.24
SC	STONECHAT.................	1.0	26	2	3.2	3.3	249	74	58.3	3.36	1237	506	309	0.16	36.0	0.41
RK	REDSHANK..................	2.0	116	2	32.5	16.0	196	67	56.2	2.93	1073	299	402	0.14	30.4	0.28
CS	COMMON SANDPIPER..........	0.9	9	1	2.0	2.3	199	63	58.6	3.16	1069	324	240	0.13	27.9	0.30
GH	GRASSHOPPER WARBLER.......	0.5	11	1	1.1	2.3	264	59	69.2	4.47	1345	503	171	0.19	45.4	0.37
WT	WILLOW TIT................	0.5	16	1	1.2	2.4	256	59	70.8	4.34	1406	386	135	0.18	41.4	0.27
WO	WOOD WARBLER..............	0.7	17	1	2.4	3.4	219	58	64.1	3.78	1135	398	198	0.15	34.6	0.35
GG	GREAT CRESTED GREBE.......	1.8	24	2	8.9	5.0	126	55	45.8	2.29	706	176	172	0.15	33.6	0.25
LG	LITTLE GREBE..............	0.7	12	1	1.9	2.6	153	46	63.2	3.33	866	205	124	0.19	44.9	0.24
DI	DIPPER....................	0.6	5	1	0.6	1.1	153	45	59	3.40	775	296	199	0.20	47.2	0.38
CN	COMMON TERN...............	1.5	59	2	21.1	13.9	140	44	59.2	3.18	752	228	261	0.17	40.5	0.30
PF	PIED FLYCATCHER...........	1.0	15	1	3.0	3.0	130	43	55.8	3.02	674	236	184	0.16	36.5	0.35
KF	KINGFISHER................	0.3	4	1	0.4	1.0	171	39	70.8	4.38	936	261	84	0.22	54.3	0.28
CR	COMMON CROSSBILL..........	2.1	108	2	43.4	21.2	142	36	66.8	3.94	756	238	787	0.28	73.8	0.31
GD	GOOSANDER.................	0.7	31	1	3.4	5.0	139	32	70.4	4.34	749	224	277	0.24	58.7	0.30
N.	NIGHTINGALE...............	0.6	7	1	1.4	2.3	108	29	65.6	3.72	599	157	72	0.20	48.0	0.26
FF	FIELDFARE.................	5.1	301	0	470.7	92.0	166	28	79.2	5.93	936	226	1803	0.44	135.8	0.24
PE	PEREGRINE.................	0.3	5	1	0.4	1.1	138	27	72.9	5.11	704	262	170	0.24	61.1	0.37
HY	HOBBY.....................	0.2	3	0	0.2	1.0	160	27	79.5	5.93	913	207	78	0.25	61.7	0.23
DN	DUNLIN....................	2.3	130	2	90.6	38.6	82	26	57.2	3.15	430	144	1277	0.27	69.6	0.33
TW	TWITE.....................	1.3	16	2	6.4	4.9	75	23	61.5	3.26	410	115	685	0.32	87.4	0.28
GA	GADWALL...................	1.2	14	2	5.0	4.0	70	23	59.6	3.04	401	89	202	0.28	71.9	0.22
LS	LESSER SPOTTED WOODPECKER.	0.3	5	0	0.4	1.2	123	23	75.8	5.35	669	192	66	0.30	78.7	0.29
WM	WHIMBREL..................	1.6	30	1	18.2	11.1	84	22	68.3	3.82	479	109	402	0.25	63.5	0.23

Species codes	species name	mean	max	interquartile range	variance	CV	no. 1km squares	yearly mean	% zero's	ratio total to mean squares	observations used	missing	Dispersion (deviance/df)	StdErr	Min. effect size (%)	proportion missing
RP	RINGED PLOVER.............	1.5	22	2	9.6	6.3	67	22	60	3.05	382	87	383	0.21	51.8	0.23
F.	FULMAR....................	3.3	40	3	41.4	12.4	47	20	43.9	2.35	246	83	432	0.20	47.1	0.34
T.	TEAL......................	0.8	16	1	3.0	3.9	91	20	71.1	4.55	495	142	336	0.28	74.5	0.29
RZ	RING OUZEL................	0.7	28	1	3.0	4.7	80	20	68	4.00	438	122	240	0.22	53.0	0.28
ML	MERLIN....................	0.3	2	0	0.3	1.0	87	16	76	5.44	455	154	201	0.36	102.1	0.34
Q.	QUAIL.....................	0.3	5	0	0.4	1.6	95	16	79.5	5.94	550	115	101	0.34	94.9	0.21
SE	SHORT-EARED OWL...........	0.4	4	1	0.5	1.3	68	15	71.6	4.53	362	114	225	0.41	123.0	0.31
KT	RED KITE..................	0.5	5	1	0.7	1.4	58	15	63.4	3.87	292	114	154	0.31	82.1	0.39
BO	BARN OWL..................	0.3	2	0	0.2	0.9	82	15	76.8	5.47	443	131	93	0.32	88.2	0.30
RH	RED-THROATED DIVER........	0.9	17	1	4.1	4.4	43	13	60.9	3.31	230	71	545	0.30	80.4	0.31
RC	ROCK PIPIT................	1.3	20	2	6.2	4.9	39	13	57.3	3.00	213	60	325	0.23	58.4	0.28
PO	POCHARD...................	1.2	27	1	9.6	7.8	48	13	67.4	3.69	279	57	309	0.35	99.7	0.20
GK	GREENSHANK................	0.5	9	1	1.1	2.0	58	13	67.6	4.46	290	116	258	0.36	104.2	0.40
WL	WOODLARK..................	0.8	7	1	1.4	1.8	34	12	59.1	2.83	198	40	93	0.31	84.9	0.20
RM	RED-BREASTED MERGANSER....	0.8	13	1	3.0	3.7	39	11	66.5	3.55	230	43	493	0.40	118.1	0.19
HH	HEN HARRIER...............	0.3	3	1	0.3	1.1	60	11	74.5	5.45	310	110	250	0.42	126.3	0.35
SV	SHOVELER..................	0.8	14	1	2.9	3.7	43	11	69.2	3.91	247	54	192	0.37	108.2	0.22
MR	MARSH HARRIER.............	0.4	3	1	0.4	1.0	47	11	70.7	4.27	259	70	86	0.45	139.2	0.27
BK	BLACK GROUSE..............	0.9	7	1	1.8	2.0	30	10	53.8	3.00	145	65	358	0.45	139.5	0.45
RI	RING-NECKED PARAKEET......	2.7	58	2	70.2	26.1	29	10	57.7	2.90	163	40	108	0.35	100.3	0.25
MN	MANDARIN..................	0.7	10	1	2.0	3.0	43	10	71	4.30	231	70	80	0.44	137.9	0.30

Table 3.1.2 Basic descriptive statistics of the counts and statistics related to the BBS indexing model for count data from 1994-2000 for waders, gulls, terns, geese, water birds and colonial seabirds recorded in >10 squares yearly mean

(for notes see table 3.1.1)

	Species code	species	mean	variance	CV	max	Yearly mean	no. 1km squares	% zero's	Dispersion	StdErr	Min. effect size	proportion Missing
Water birds	BH	BLACK-HEADED GULL.........	4.60	228.08	49.6	295	430	1175	50.93	750.7	0.06	11.8	0.34
	CM	COMMON GULL...............	5.66	1809.39	319.6	1173	124	440	62.56	1232.5	0.09	20.1	0.33
	CN	COMMON TERN...............	1.52	21.10	13.9	59	44	140	59.18	260.6	0.17	40.5	0.30
	GB	GREAT BLACK-BACKED GULL...	1.28	27.76	21.8	148	85	319	64.63	388.1	0.12	25.4	0.32
	HG	HERRING GULL..............	5.85	444.21	75.9	445	453	1251	51.11	964.8	0.06	11.5	0.35
	LB	LESSER BLACK-BACKED GULL..	3.91	271.76	69.5	500	414	1179	53.81	627.7	0.06	13.5	0.31
	CG	CANADA GOOSE..............	2.81	77.67	27.6	140	289	886	58.05	313.9	0.07	15.1	0.29
	CO	COOT......................	2.67	36.41	13.6	115	188	433	41.6	170.4	0.08	16.1	0.34
	GA	GADWALL...................	1.25	4.98	4.0	14	23	70	59.6	202.5	0.28	71.9	0.22
	GJ	GREYLAG GOOSE.............	2.84	157.58	55.4	230	82	296	64.89	851.1	0.16	35.6	0.27
	GG	GREAT CRESTED GREBE.......	1.79	8.93	5.0	24	55	126	45.75	171.6	0.15	33.6	0.25
	LG	LITTLE GREBE..............	0.75	1.94	2.6	12	46	153	63.16	124.1	0.19	44.9	0.24
	MA	MALLARD...................	3.54	53.93	15.2	215	914	1987	38.03	266.8	0.03	7.0	0.35
	MH	MOORHEN...................	1.21	2.78	2.3	25	498	1127	41.44	99.8	0.05	10.4	0.32
	MS	MUTE SWAN.................	3.32	812.02	244.5	675	167	493	56.18	312.7	0.08	18.1	0.29
	PO	POCHARD...................	1.23	9.59	7.8	27	13	48	67.38	309.4	0.35	99.7	0.20
	SU	SHELDUCK..................	3.22	77.73	24.2	203	114	304	51.01	365.7	0.10	21.5	0.31
	SV	SHOVELER..................	0.78	2.86	3.7	14	11	43	69.23	191.8	0.37	108.2	0.22
	TU	TUFTED DUCK...............	3.13	55.75	17.8	103	122	313	49.65	397.0	0.10	21.8	0.29
Waders	CS	COMMON SANDPIPER..........	0.85	1.95	2.3	9	63	199	58.56	239.9	0.13	27.9	0.30
	CU	CURLEW....................	2.81	33.93	12.1	167	432	988	40.32	288.0	0.04	8.9	0.36
	DN	DUNLIN....................	2.35	90.63	38.6	130	26	82	57.21	1277.0	0.27	69.6	0.33
	GP	GOLDEN PLOVER.............	3.35	255.65	76.4	300	81	214	49.05	1288.9	0.13	27.8	0.35
	L.	LAPWING...................	3.43	70.64	20.6	182	541	1358	47.58	480.8	0.05	9.9	0.32
	OC	OYSTERCATCHER.............	3.27	72.29	22.1	251	231	514	39.27	436.4	0.05	11.2	0.35
	RK	REDSHANK..................	2.03	32.53	16.0	116	67	196	56.2	402.3	0.14	30.4	0.28
	RP	RINGED PLOVER.............	1.52	9.60	6.3	22	22	67	59.95	383.1	0.21	51.8	0.23
	WM	WHIMBREL..................	1.65	18.19	11.1	30	22	84	68.27	402.5	0.25	63.5	0.23
Colonial	CA	CORMORANT.................	0.94	5.93	6.3	48	140	482	62.98	158.9	0.09	19.9	0.27
	F.	FULMAR....................	3.33	41.41	12.4	40	20	47	43.9	432.3	0.20	47.1	0.34

Table 3.1.3 Basic descriptive statistics of the counts and statistics related to the BBS indexing model for count data from 1994-2000 for the 35 'target species'

For selected statistics, the top 10 values are highlighted in bold and the bottom 10 values are underlined.

species codes	Species	Mean	max	CV	no. 1km squares	yearly mean	% zero's	ratio total to mean squares	observations used	missing	Dispersion	StdErr	Min. effect size (%)	proportion missing
CN	COMMON TERN	1.52	**59**	**13.9**	140	44	59.18	3.18	752	228	261	0.17	40.5	0.30
CR	COMMON CROSSBILL	**2.05**	**108**	**21.2**	142	36	66.8	3.94	756	238	**787**	0.28	**73.8**	0.31
CS	COMMON SANDPIPER	0.85	9	2.3	199	63	58.56	3.16	1069	324	240	0.13	27.9	0.30
DI	DIPPER	0.55	5	1.1	153	45	58.97	3.40	775	296	199	0.20	47.2	**0.38**
DN	DUNLIN	**2.35**	**130**	**38.6**	82	26	57.21	3.15	430	144	**1277**	0.27	**69.6**	**0.33**
F.	FULMAR	**3.33**	**40**	**12.4**	47	20	43.9	2.35	246	83	**432**	0.20	47.1	**0.34**
FF	FIELDFARE	**5.12**	**301**	**92.0**	166	28	**79.17**	5.93	936	226	**1803**	0.44	**135.8**	0.24
GA	GADWALL	1.25	14	4.0	70	23	59.6	3.04	401	89	202	0.28	**71.9**	0.22
GB	GREAT BLACK-BACKED GULL...	1.28	**148**	**21.8**	**319**	**85**	64.63	3.75	1688	545	388	0.12	25.4	**0.32**
GD	GOOSANDER	0.69	31	5.0	139	32	**70.36**	4.34	749	224	277	0.24	58.7	0.30
GG	GREAT CRESTED GREBE	**1.79**	24	5.0	126	55	45.75	2.29	706	176	172	0.15	33.6	0.25
GH	GRASSHOPPER WARBLER	0.50	11	2.3	**264**	59	69.22	4.47	1345	503	171	0.19	45.4	**0.37**
GJ	GREYLAG GOOSE	**2.84**	**230**	**55.4**	**296**	**82**	64.89	3.61	1629	443	**851**	0.16	35.6	0.27
GP	GOLDEN PLOVER	**3.35**	**300**	**76.4**	214	**81**	49.05	2.64	1107	391	**1289**	0.13	27.8	**0.35**
HY	HOBBY	0.23	3	1.0	160	27	**79.52**	5.93	913	207	78	0.25	**61.7**	0.23
KF	KINGFISHER	0.35	4	1.0	171	39	**70.83**	4.38	936	261	84	0.22	54.3	0.28
LG	LITTLE GREBE	0.75	12	2.6	153	46	63.16	3.33	866	205	124	0.19	44.9	0.24
LO	LITTLE OWL	0.33	4	0.9	**389**	**89**	**71.05**	4.37	2162	561	71	0.14	30.5	0.26
LS	LESSER SPOTTED WOODPECKER.	0.30	5	1.2	123	23	**75.78**	5.35	669	192	66	0.30	**78.7**	0.29
N.	NIGHTINGALE	0.62	7	2.3	108	29	65.61	3.72	599	157	72	0.20	48.0	0.26
PE	PEREGRINE	0.33	5	1.1	138	27	**72.87**	5.11	704	262	170	0.24	**61.1**	**0.37**
PF	PIED FLYCATCHER	1.00	15	3.0	130	43	55.79	3.02	674	236	184	0.16	36.5	**0.35**
RK	REDSHANK	**2.03**	**116**	**16.0**	196	**67**	56.2	2.93	1073	299	**402**	0.14	30.4	0.28
RP	RINGED PLOVER	1.52	22	6.3	67	22	59.95	3.05	382	87	383	0.21	51.8	0.23
RW	REED WARBLER	**2.29**	35	7.3	205	**85**	46.79	2.41	1122	313	138	0.10	22.8	0.28
RZ	RING OUZEL	0.65	28	4.7	80	20	68.04	4.00	438	122	240	0.22	53.0	0.28
SC	STONECHAT	0.98	26	3.3	**249**	**74**	58.29	3.36	1237	506	309	0.16	36.0	**0.41**
SM	SAND MARTIN	**3.37**	**300**	**58.4**	**360**	**96**	65.9	3.75	1965	555	**832**	0.12	27.1	0.28
T.	TEAL	0.75	16	3.9	91	20	**71.11**	4.55	495	142	336	0.28	**74.5**	0.29
TO	TAWNY OWL	0.28	7	1.0	**385**	**77**	**75.07**	5.00	2166	529	85	0.15	33.3	0.24
TW	TWITE	1.31	16	4.9	75	23	61.46	3.26	410	115	**685**	0.32	**87.4**	0.28
WC	WHINCHAT	0.95	32	4.5	**279**	**80**	62.58	3.49	1499	454	245	0.13	29.3	0.30
WM	WHIMBREL	1.65	30	11.1	84	22	68.27	3.82	479	109	**402**	0.25	**63.5**	0.23
WO	WOOD WARBLER	0.70	17	3.4	**219**	58	64.05	3.78	1135	398	198	0.15	34.6	**0.35**
WT	WILLOW TIT	0.51	16	2.4	**256**	59	**70.77**	4.34	1406	386	135	0.18	41.4	0.27
	Range of the variables	0.23-5.12	3-301	0.9-92.0	47-389	20-96	43.9-79.52	2.29-5.93	246-2166	83-561	66-1803	0.10-0.44	22.8-135.8	0.22-0.41

Table 3.1.5 Spearman Rank correlation matrix of descriptive statistics with effect size (n=127)

	Yearly average no. squares	No. different squares	Percent zero	Over-dispersion	Effect size	Proportion missing
Yearly average no. squares	1	0.99***	-0.82***	-0.01 (0.96)	-0.99***	0.61***
No. different squares		1	-0.75***	-0.03 (0.69)	-0.97***	0.58***
Percent zero			1	-0.17 (0.06)	0.85***	-0.69***
Over-dispersion				1	-0.01 (0.93)	0.25 (0.01)
Effect size					1	-0.61***
Proportion missing						1

P value given in parentheses, otherwise *** = $P < 0.0001$

Table 3.2.1a Results of the simulation to assess power in detecting a 25 % decline over 25 years for the target species; using both the yearly average of squares seen in and the total number of 1 km squares seen in between the period of 1994-2000 for the number of sites in the model

Species are listed in descending order of yearly mean number of squares. The mean percent of zeros for the 100 simulation runs is nearly identical for both type of runs and so the results for the simulation using the yearly mean number of squares seen in is only given. The word 'actual' refers to the result from the true data collected between 1994-2000. For comparison the minimum effect size for the actual data is given.

species	Mean count actual data	Yearly Mean no. squares	no. 1km squares	power yearly mean (%)	power no. 1km squares (%)	% zero's actual	% zero's simulation mean	Min. effect size (%)
SAND MARTIN...............	3.37	96	360	57	100	65.9	23	71.9
LITTLE OWL................	0.33	89	389	10	24	71.05	87	61.7
REED WARBLER.............	2.29	85	205	27	79	46.79	57	63.5
GREAT BLACK-BACKED GULL...	1.28	85	319	45	76	64.63	37	51.8
GREYLAG GOOSE............	2.84	82	296	52	95	64.89	29	44.9
GOLDEN PLOVER............	3.35	81	214	57	93	49.05	24	135.8
WHINCHAT.................	0.95	80	279	25	55	62.58	66	33.3
TAWNY OWL................	0.28	77	385	8	19	75.07	88	33.6
STONECHAT................	0.98	74	249	24	54	58.29	65	30.5
REDSHANK.................	2.03	67	196	42	72	56.2	42	48.0
COMMON SANDPIPER..........	0.85	63	199	10	41	58.56	69	35.6
GRASSHOPPER WARBLER.......	0.50	59	264	14	35	69.22	81	41.4
WILLOW TIT................	0.51	59	256	9	35	70.77	80	53.0
WOOD WARBLER.............	0.70	58	219	11	32	64.05	74	30.4
GREAT CRESTED GREBE.......	1.79	55	126	29	55	45.75	46	54.3
LITTLE GREBE.............	0.75	46	153	5	31	63.16	73	22.8
DIPPER....................	0.55	45	153	11	26	58.97	78	87.4
COMMON TERN...............	1.52	44	140	14	43	59.18	52	27.1
PIED FLYCATCHER...........	1.00	43	130	19	39	55.79	65	74.5
KINGFISHER................	0.35	39	171	8	15	70.83	86	78.7
COMMON CROSSBILL..........	2.05	36	142	9	61	66.8	41	58.7
GOOSANDER.................	0.69	32	139	9	35	70.36	74	29.3
NIGHTINGALE...............	0.62	29	108	9	25	65.61	77	27.9
FIELDFARE.................	5.12	28	166	36	97	79.17	11	40.5
HOBBY.....................	0.23	27	160	76	17	79.52	90	73.8
PEREGRINE.................	0.33	27	138	25	17	72.87	86	25.4
DUNLIN....................	2.35	26	82	21	49	57.21	36	69.6
GADWALL...................	1.25	23	70	9	26	59.6	59	47.1
LESSER SPOTTED WOODPECKER.	0.30	23	123	43	6	75.78	88	36.5
TWITE.....................	1.31	23	75	4	23	61.46	56	34.6
RINGED PLOVER.............	1.52	22	67	10	28	59.95	52	27.8
WHIMBREL..................	1.65	22	84	13	35	68.27	49	61.1
FULMAR....................	3.33	20	47	17	36	43.9	24	45.4
RING OUZEL................	0.65	20	80	6	21	68.04	75	47.2
TEAL......................	0.75	20	91	4	24	71.11	72	36.0

Table 3.2.1b Results of the simulation to assess power in detecting a 25 % decline over 25 years for 10 selected target species using twice the total number of 1 km squares seen in between the period of 1994-2000 for the number of sites in the model

species	Mean count actual data	no. 1km squares	power (%)	% zero's actual	% zero's simulation mean
GREAT BLACK-BACKED GULL...	1.28	638	97	64.63	37
GOLDEN PLOVER............	3.35	428	100	49.05	24
WILLOW TIT................	0.51	512	56	70.77	80
GREAT CRESTED GREBE.......	1.79	252	87	45.75	46
LITTLE GREBE.............	0.75	206	37	63.16	73
DIPPER....................	0.55	306	49	58.97	78
COMMON TERN..............	1.52	280	76	59.18	52
PIED FLYCATCHER...........	1.00	260	52	55.79	65
KINGFISHER................	0.35	342	36	70.83	86
LESSER SPOTTED WOODPECKER.	0.30	246	18	75.78	88

Table 4.1a Species classed as category 2 and 3 under the protocol for reporting BBS indices

Category 2 : Species with a sample size of at least 40 and for which BBS trends should be reported with a caveat.

Species name	Category ; colonial/flocking (C) and nocturnal (N) species
Cormorant	C
Grey heron	C
Greylag goose	C
Canada goose	C
Oystercatcher	C
Golden plover	C
Lapwing	C
Curlew	C
Common tern	C
Feral pigeon	C
Wood pigeon	C
Swift	C
Sand martin	C
House martin	C
Rook	C
Crow	C
Jackdaw	C
Tawny owl	N

Category 3: Indices should not be produced for species with sample sizes less than 40 or for species whose counts are mainly non-breeding birds, wintering birds or those seen during migration.

Species name	Category ; colonial/flocking (C) and nocturnal (N) species
Black-headed gull	C
Common gull	C
Lesser black-backed gull	C
Herring gull	C
Great black-backed gull	C
Fieldfare	C

Note: adjustments are already made for large counts for waders under the standard BBS method. Colonial/flocking species include counts that are likely to be made away from colonies. Nocturnal species are poorly covered by the BBS method. Large counts of the winter migrants are likely to be from the early visit from the BBS and do not represent part of the British breeding population.

Table 4.1b Category 2 & 3 species which are currently included on the list for reporting the BBS trends and would be excluded if the protocol were adopted for the UK as a whole and the four countries (total number of species excluded for each of the nine RDAs are reported at the foot of the table)

Species	Reporting level	Reason for exclusion: sample size <40 (S), colonial/flocking (C)
Black-headed gull	UK	C
Common gull	UK	C
Lesser black-backed gull	UK	C
Herring gull	UK	C
Great black-backed gull	UK	C
Little grebe	England	S
Red grouse	England	S
Golden plover	England	S
Common sandpiper	England	S
Great black-backed gull	England	S (C)
Kingfisher	England	S
Whinchat	England	S
Stonechat	England	S
Wood warbler	England	S
Siskin	England	S
Black-headed gull	England	C
Common gull	England	C
Lesser black-backed gull	England	C
Herring gull	England	C
Grey heron	Wales	S
Curlew	Wales	S
Feral pigeon	Wales	S
Stock dove	Wales	S
Green woodpecker	Wales	S
Tree pipit	Wales	S
Grey wagtail	Wales	S
Wood warbler	Wales	S
Spotted flycatcher	Wales	S
Pied flycatcher	Wales	S
Treecreeper	Wales	S
Yellowhammer	Wales	S
Lesser black-backed gull	Wales	C
Herring gull	Wales	C
Grey partridge	Scotland	S
Redshank	Scotland	S
Common sandpiper	Scotland	S
Great black-backed gull	Scotland	S (C)
Collared dove	Scotland	S
Swift	Scotland	S
Tree pipit	Scotland	S
Grey wagtail	Scotland	S

Note includes those species currently reported with a caveat due to small sample size (italicised).

Table 4.1b continued

Species	Reporting level	Reason for exclusion: sample size <40 (S), colonial/flocking (C)
Whinchat	Scotland	S
Blackcap	Scotland	S
Chiffchaff	Scotland	S
Spotted flycatcher	Scotland	S
Treecreeper	Scotland	S
Raven	Scotland	S
Lesser redpoll	Scotland	S
Bullfinch	Scotland	S
Reed bunting	Scotland	S
Black-headed gull	Scotland	C
Common gull	Scotland	C
Lesser black-backed gull	Scotland	C
Herring gull	Scotland	C
Skylark	Northern Ireland	S
House martin	Northern Ireland	S
Pied wagtail	Northern Ireland	S
Mistle thrush	Northern Ireland	S
Sedge warbler	Northern Ireland	S
Chiffchaff	Northern Ireland	S
Goldcrest	Northern Ireland	S
Coal tit	Northern Ireland	S
Great tit	Northern Ireland	S
House sparrow	Northern Ireland	S
Greenfinch	Northern Ireland	S
Linnet	Northern Ireland	S
Reed bunting	Northern Ireland	S

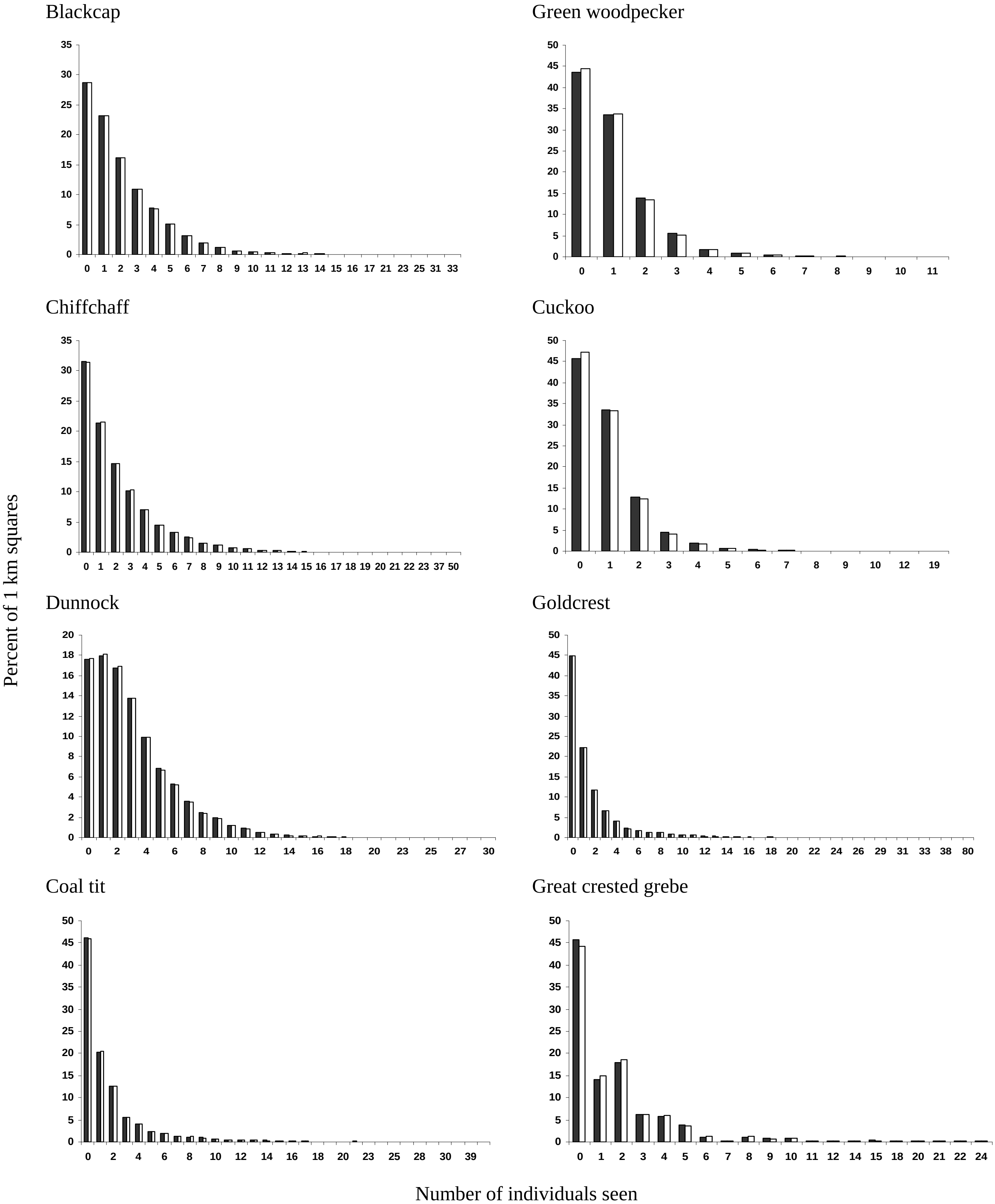
The following number of species would have to be excluded from the list for each of the nine RDAs (in parentheses) if the protocol were adopted; 14 (S. West), 12 (S. East), 10 (London), 9 (E. England), 17 (E. Midland), 15 (W. Midlands), 12 (N. West), 11 (Yorks & Humb) and 25 (N. East).

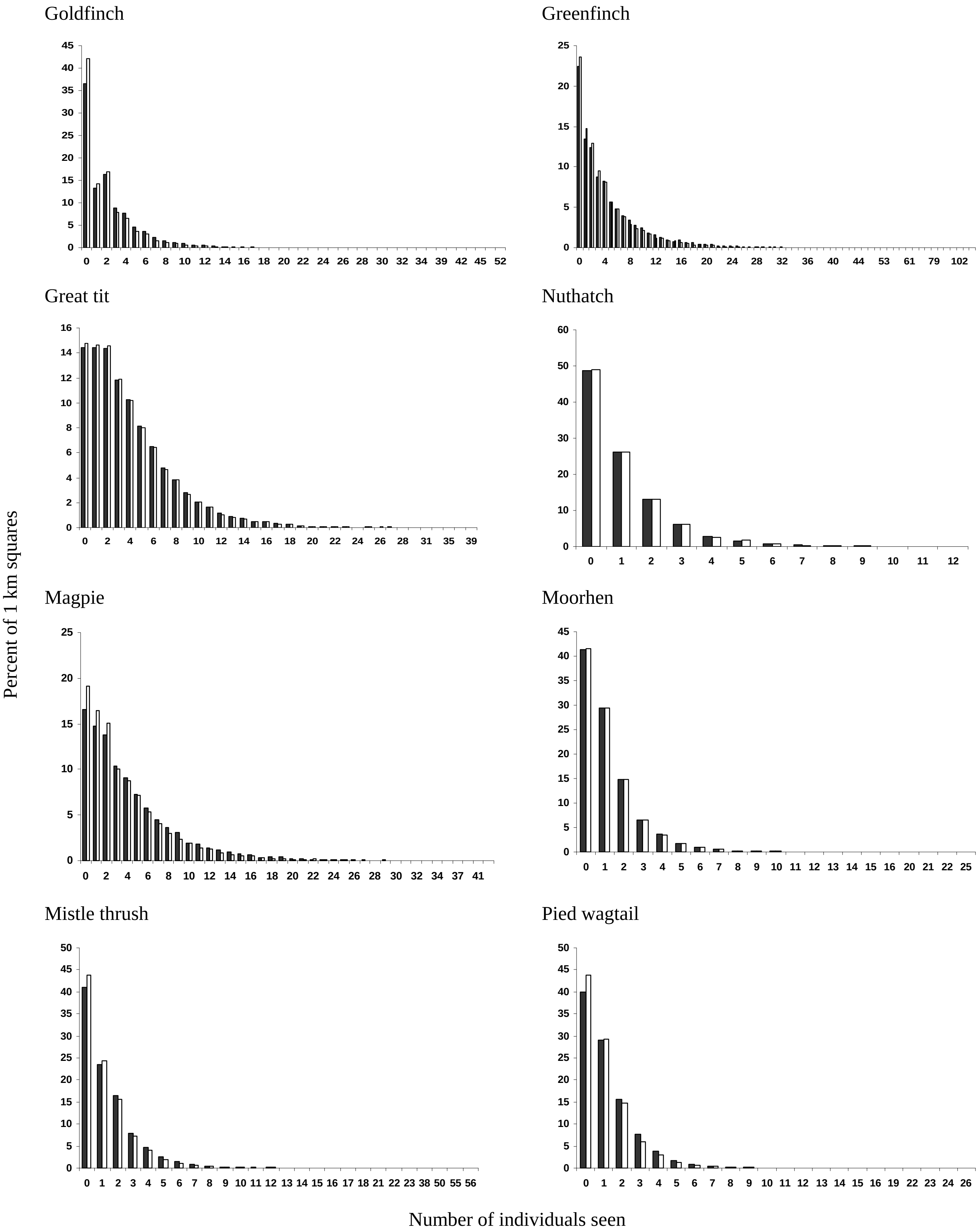
Note includes those species currently reported with a caveat due to small sample size (italicised).

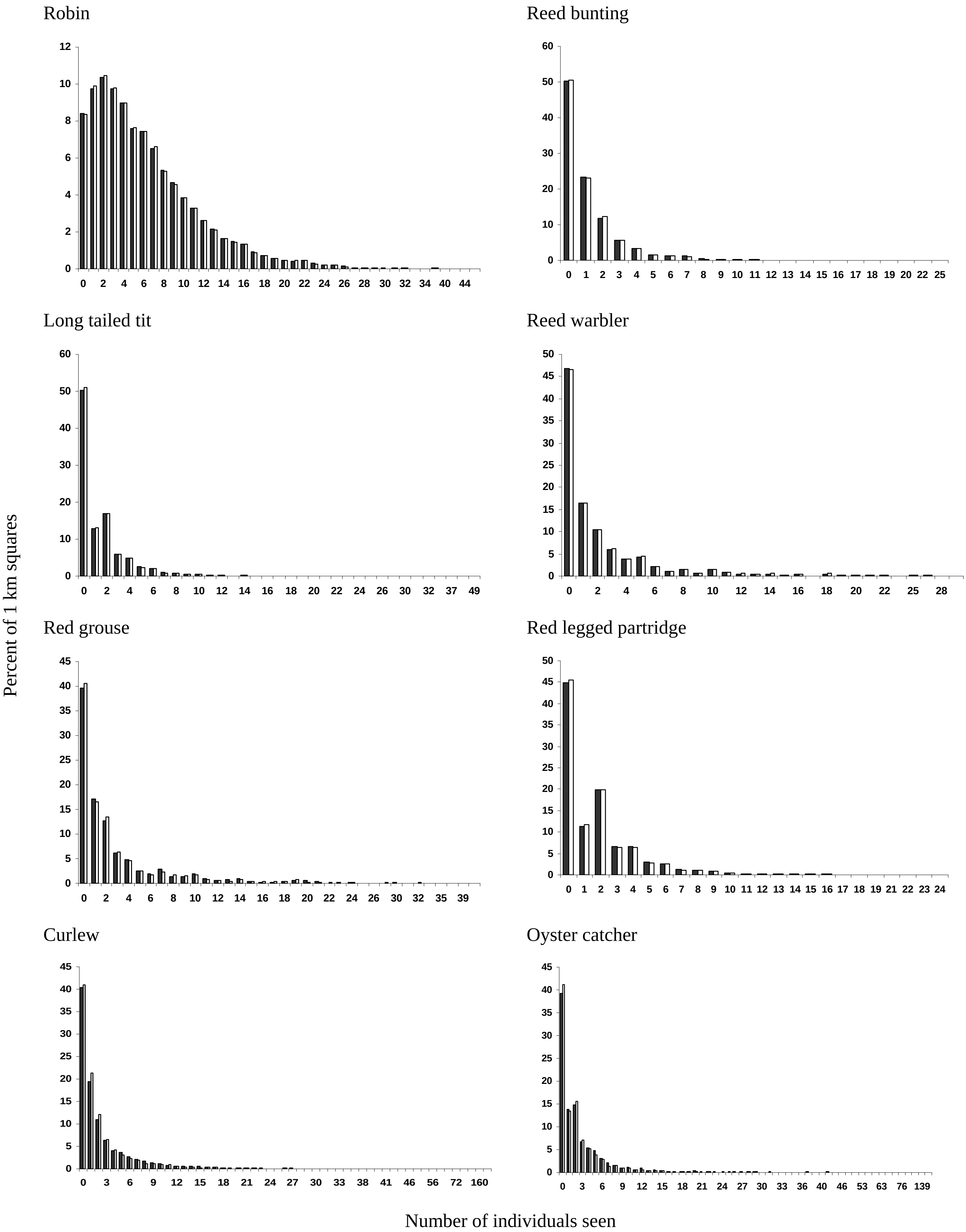
Figure 3.1.4 Comparison of frequency of counts (percent) between the sum of the three distance bands and birds in flight (dark) and the sum of the three distance bands alone (light) excluding the flight category. Restricted to selected species from those seen in greater than 50 1 km squares in the UK.

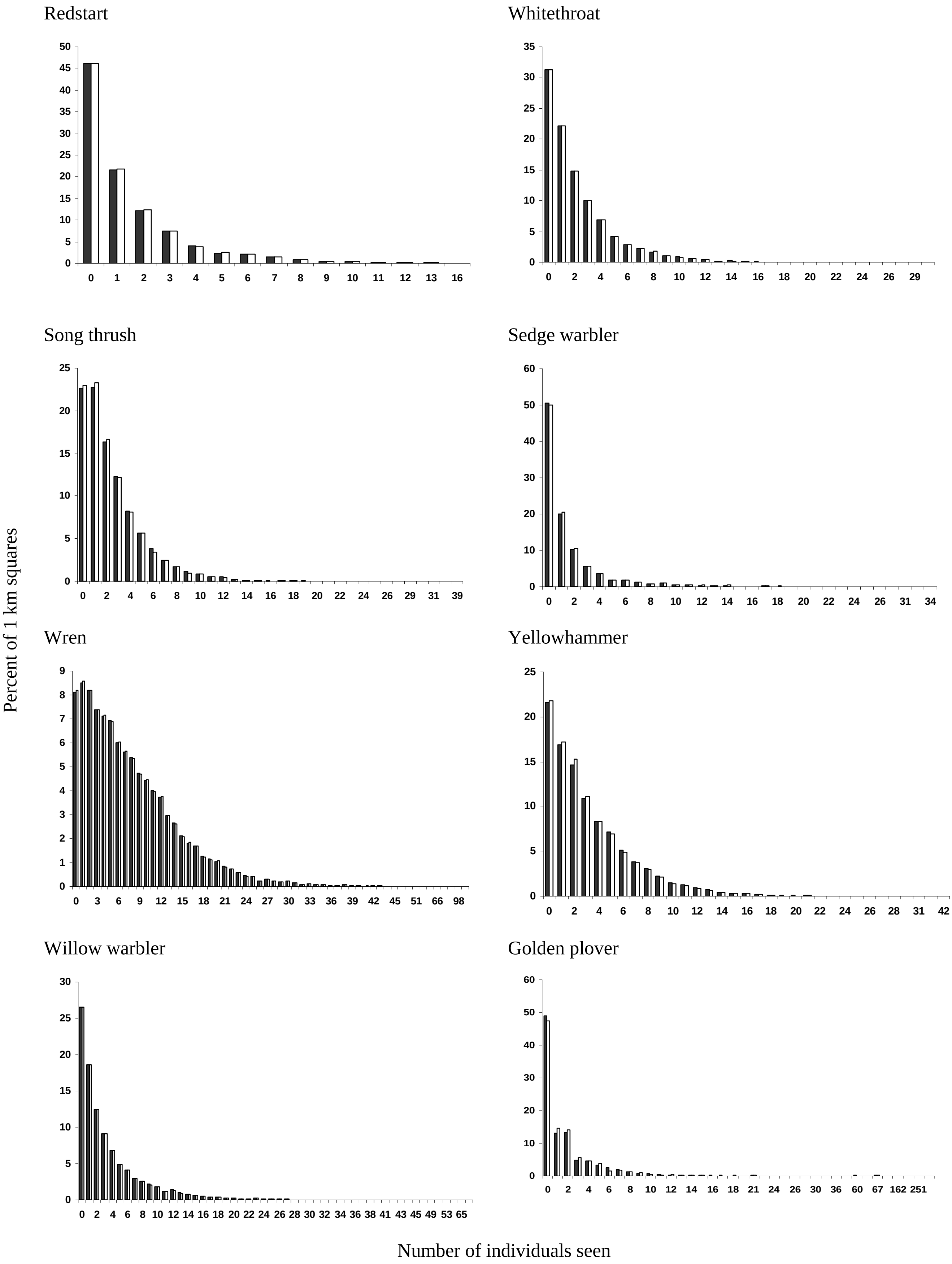
Species are ordered according to the proportion of zeros: part A includes all those with less than 50% zero counts; part B includes all the species with greater than 50 % zero counts.

Part A




Goldfinch
Greenfinch
Great tit
Nuthatch
Magpie
Moorhen
Mistle thrush
Pied wagtail
Percent of 1 km squares
Number of individuals seen

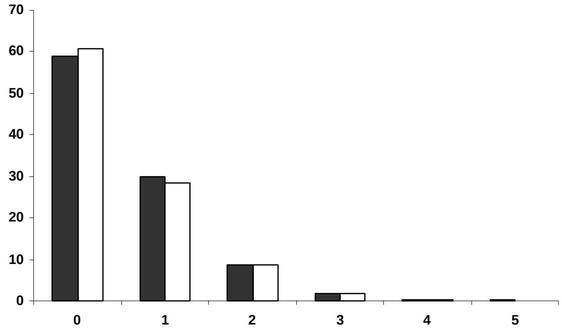

Robin
Reed bunting
Long tailed tit
Reed warbler
Red grouse
Red legged partridge
Curlew
Oyster catcher
Percent of 1 km squares
Number of individuals seen


Redstart
Whitethroat
Song thrush
Sedge warbler
Wren
Yellowhammer
Willow warbler
Golden plover
Percent of 1 km squares
Number of individuals seen

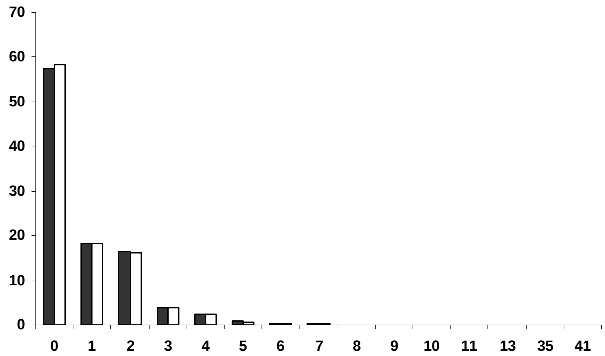
Part B

Percent of 1 km squares

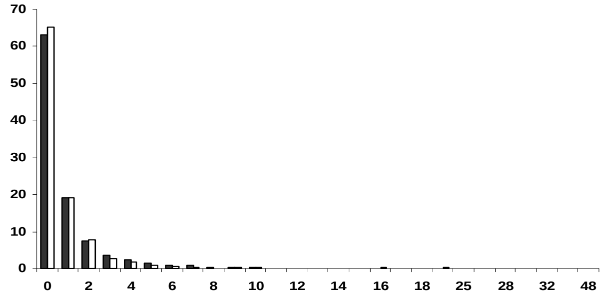
Dipper



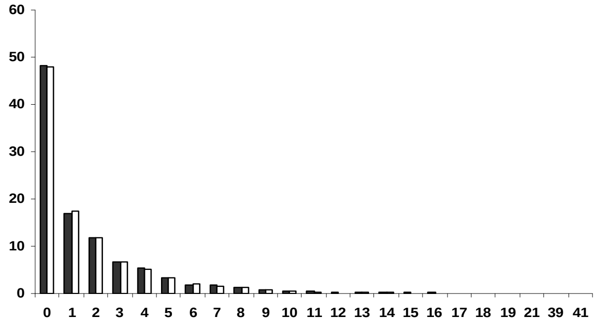
Bullfinch



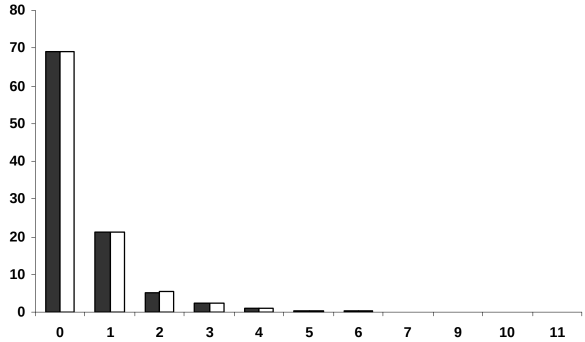
Cormorant



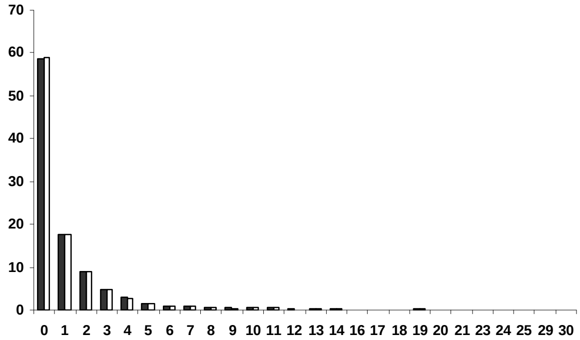
Corn bunting



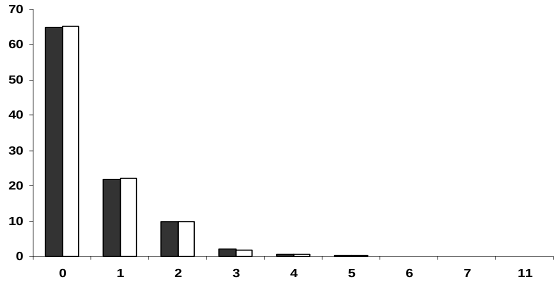
Grasshopper warbler



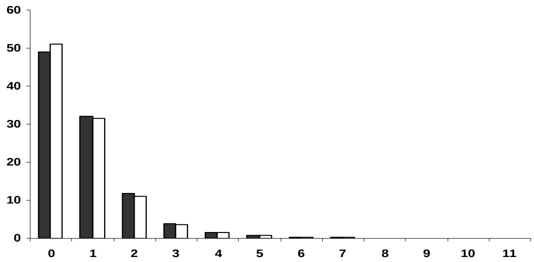
Wheatear



Grey wagtail

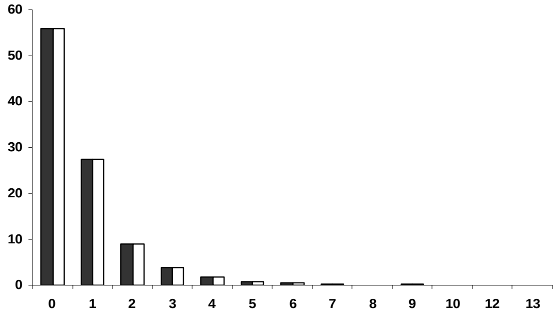


Great spotted woodpecker

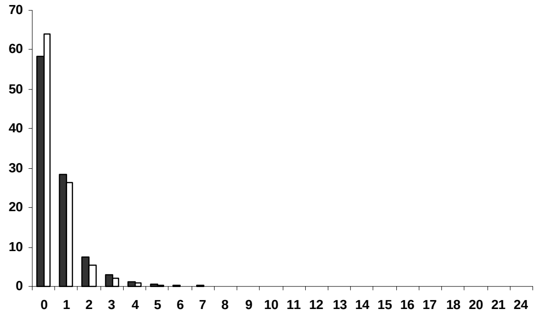


Number of individuals seen

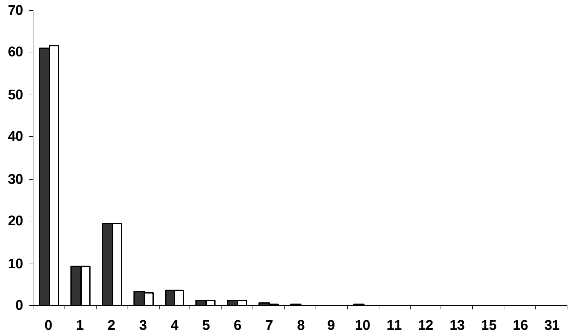
Garden warbler



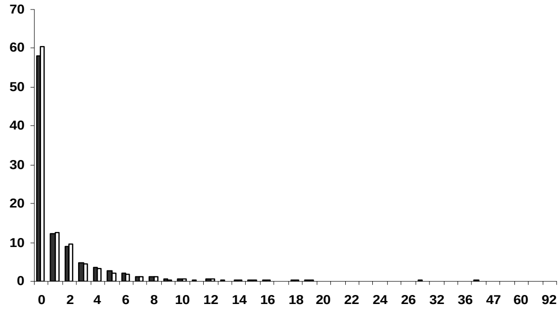
Grey heron



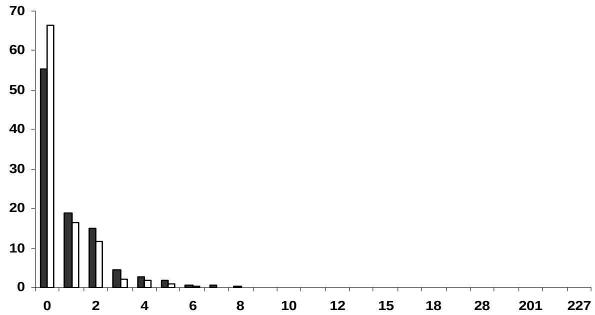
Grey partridge



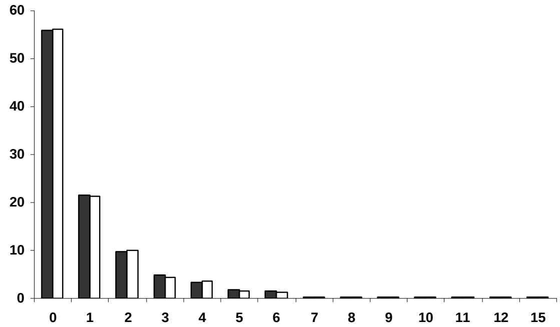
Siskin



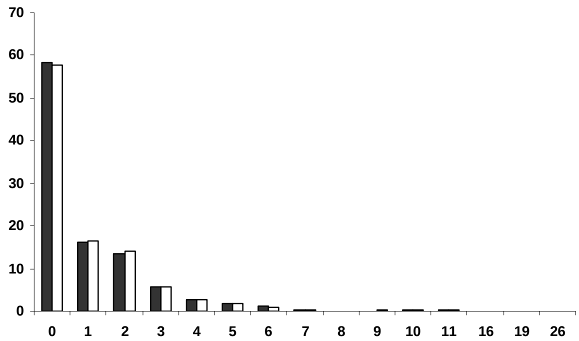
Raven



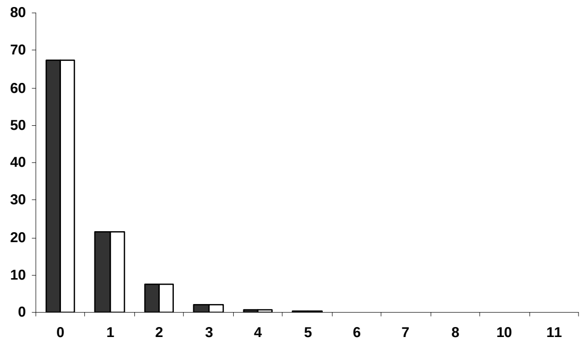
Pied flycatcher



Stonechat



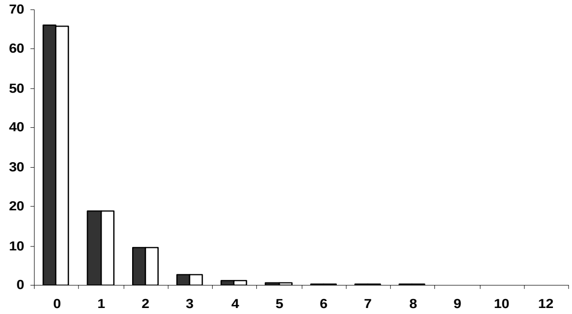
Spotted flycatcher



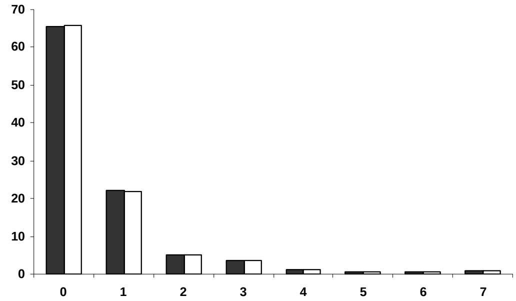
Number of individuals seen

Percent of 1 km squares

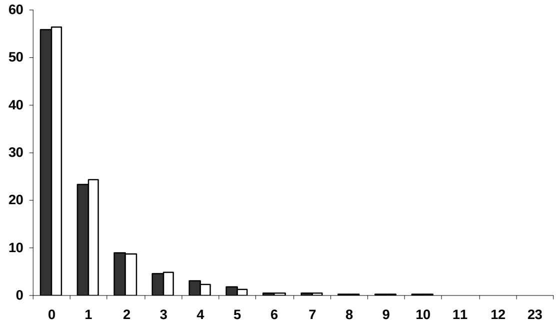
Marsh tit



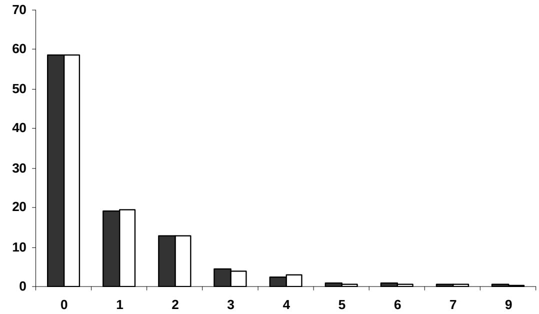
Nightingale



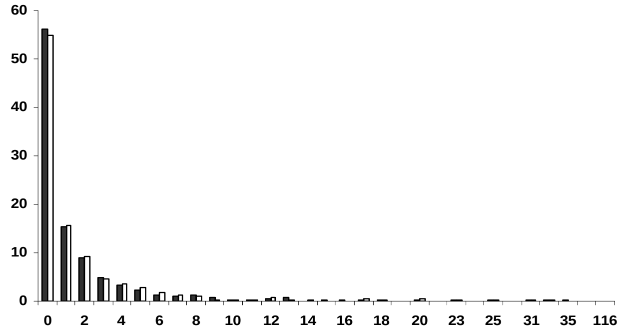
Snipe



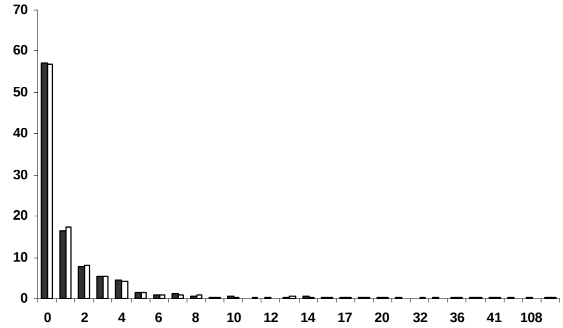
Common sandpiper



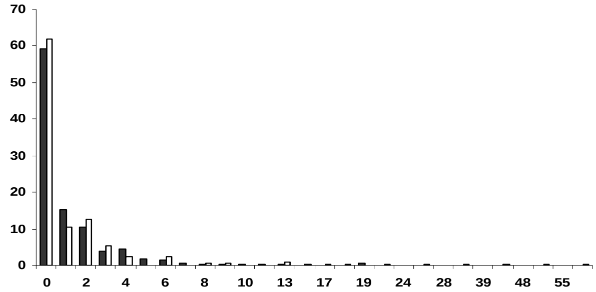
Redshank



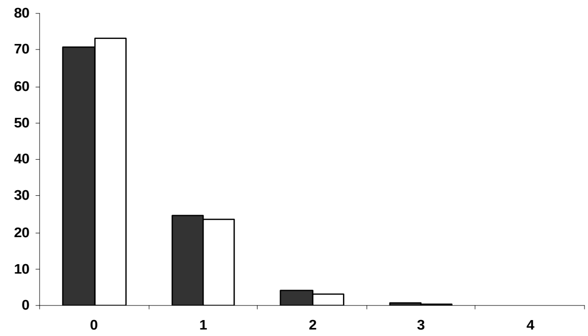
Dunlin



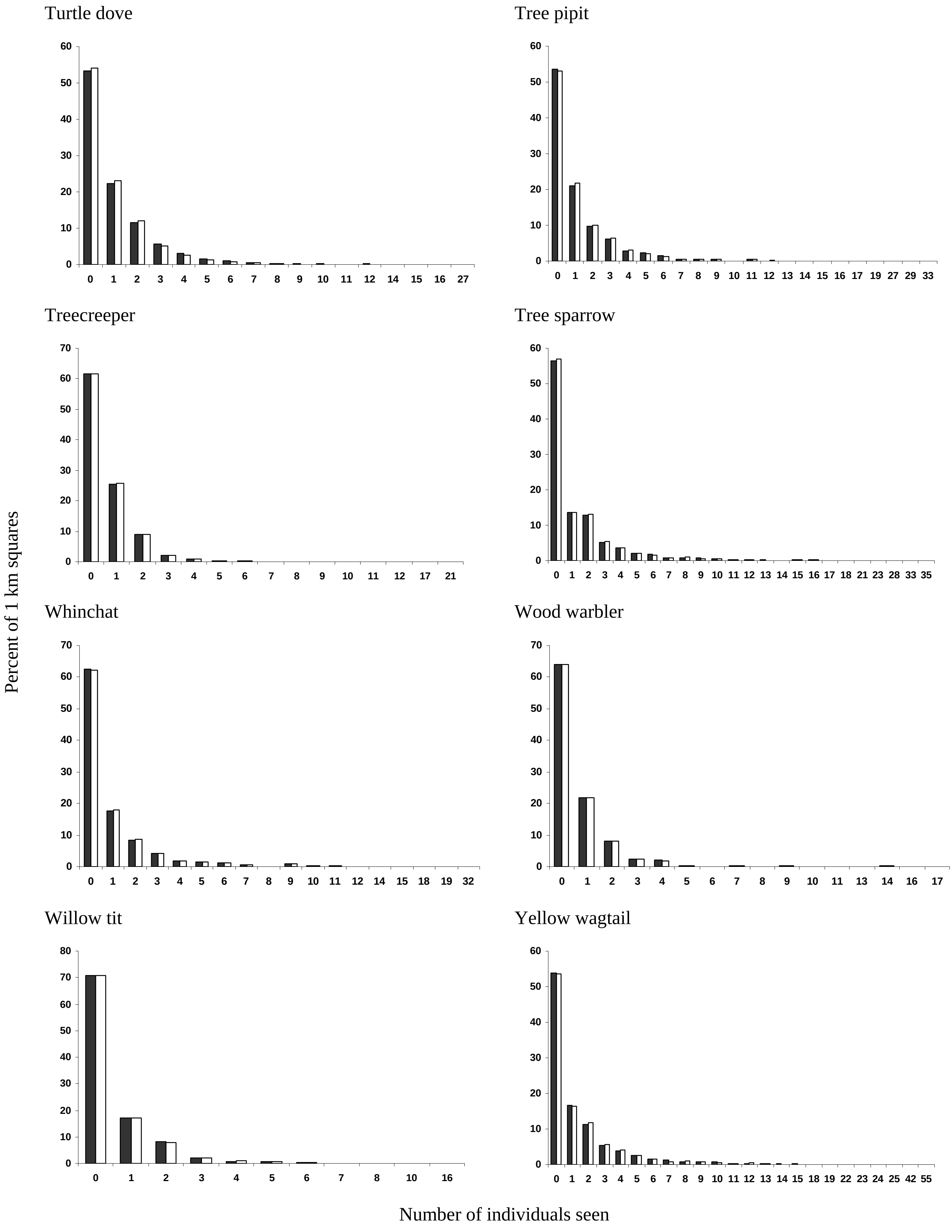
Common tern



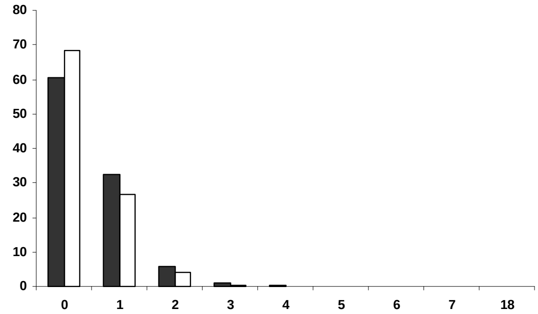
Kingfisher



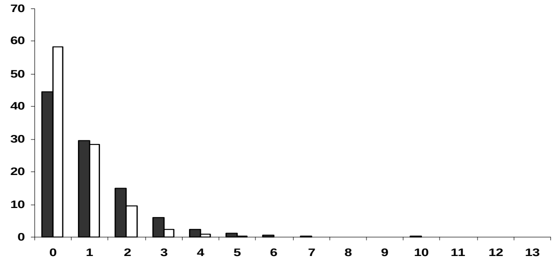
Number of individuals seen


Turtle dove
0 10 20 30 40 50 60
0 1 2 3 4 5 6 7 8 9 10 11 12 14 15 16 27
Tree pipit
0 10 20 30 40 50 60
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 19 27 29 33
Treecreeper
0 10 20 30 40 50 60 70
0 1 2 3 4 5 6 7 8 9 10 11 12 17 21
Tree sparrow
0 10 20 30 40 50 60
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 21 23 28 33 35
Whinchat
0 10 20 30 40 50 60 70
0 1 2 3 4 5 6 7 8 9 10 11 12 14 15 18 19 32
Wood warbler
0 10 20 30 40 50 60 70
0 1 2 3 4 5 6 7 8 9 10 11 13 14 16 17
Willow tit
0 10 20 30 40 50 60 70 80
0 1 2 3 4 5 6 7 8 10 16
Yellow wagtail
0 10 20 30 40 50 60
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 18 19 22 23 24 25 42 55
Percent of 1 km squares
Number of individuals seen

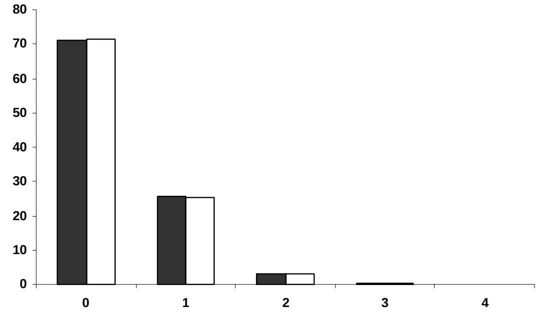
Kestrel



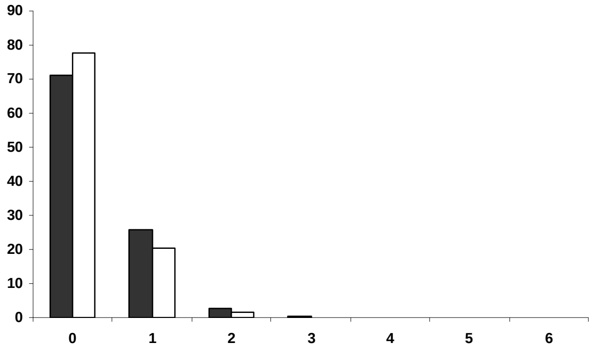
Buzzard



Little owl

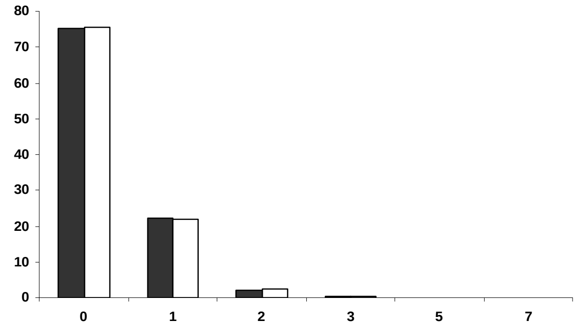


Sparrowhawk

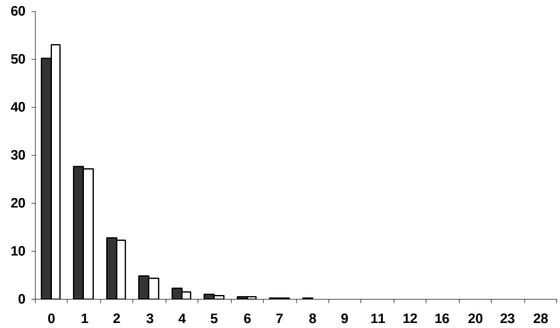


Percent of 1 km squares

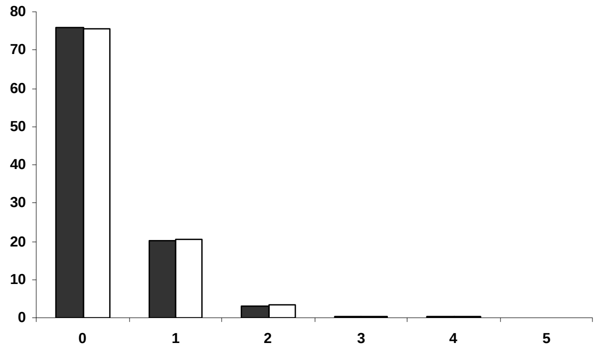
Tawny owl



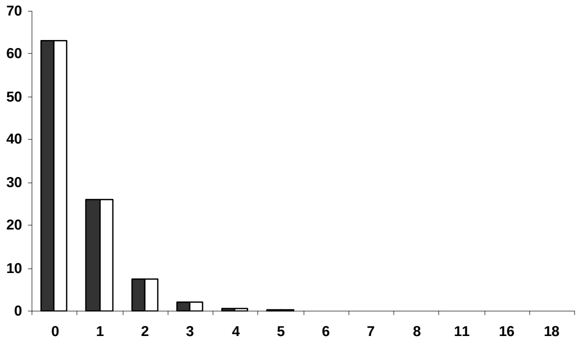
Jay



Lesser spotted woodpecker

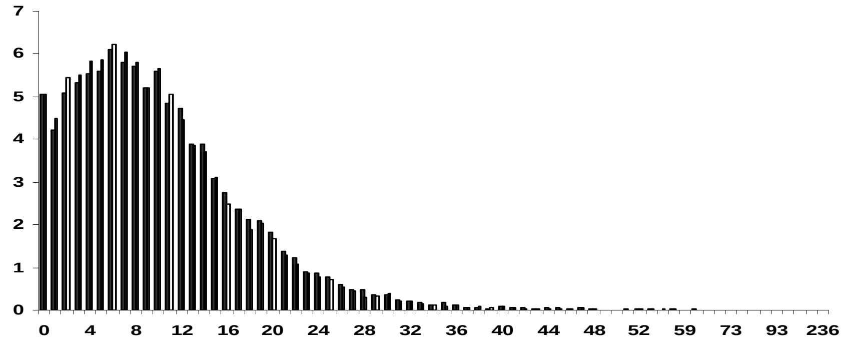


Lesser whitethroat

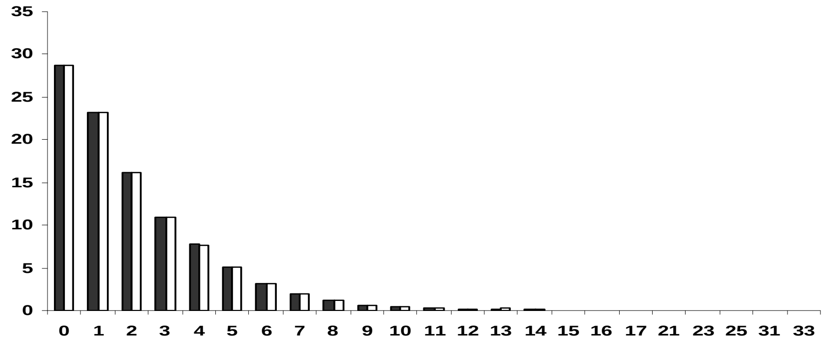


Number of individuals seen

Chaffinch

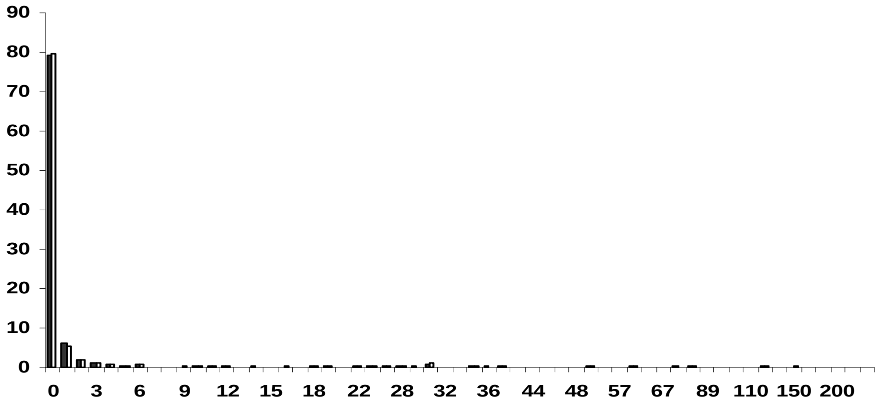


Blackbird

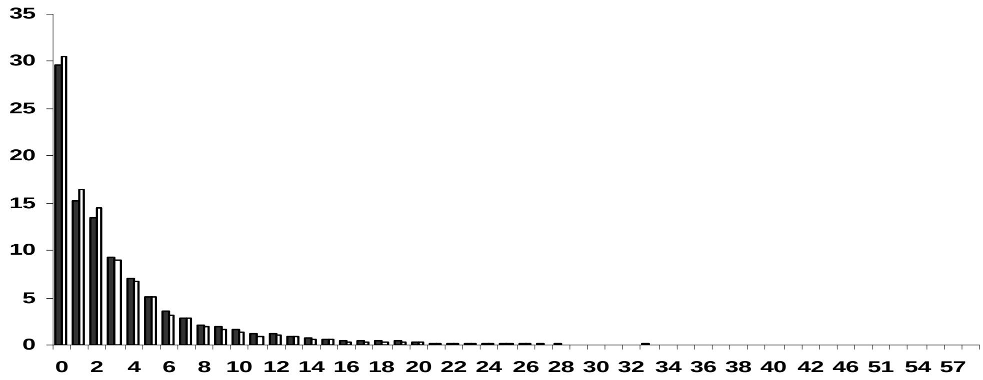


Percent of 1 km squares

Fieldfare



Collared dove



Number of individuals seen

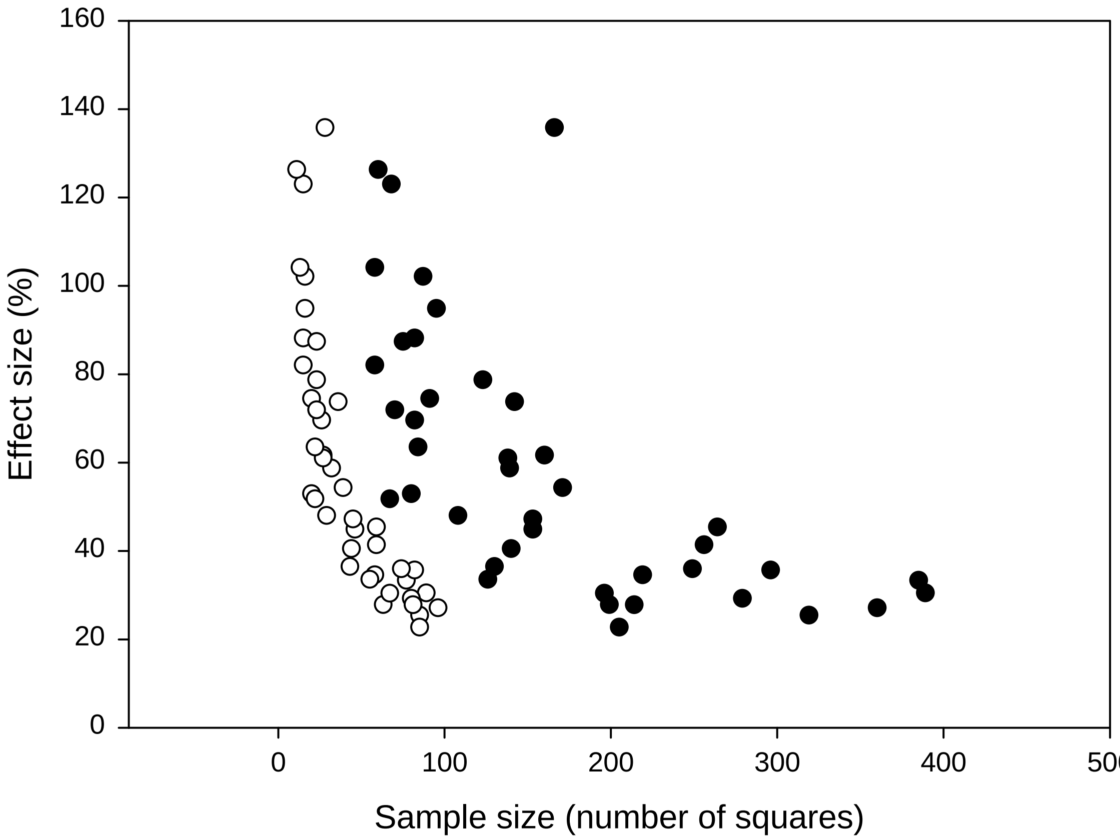
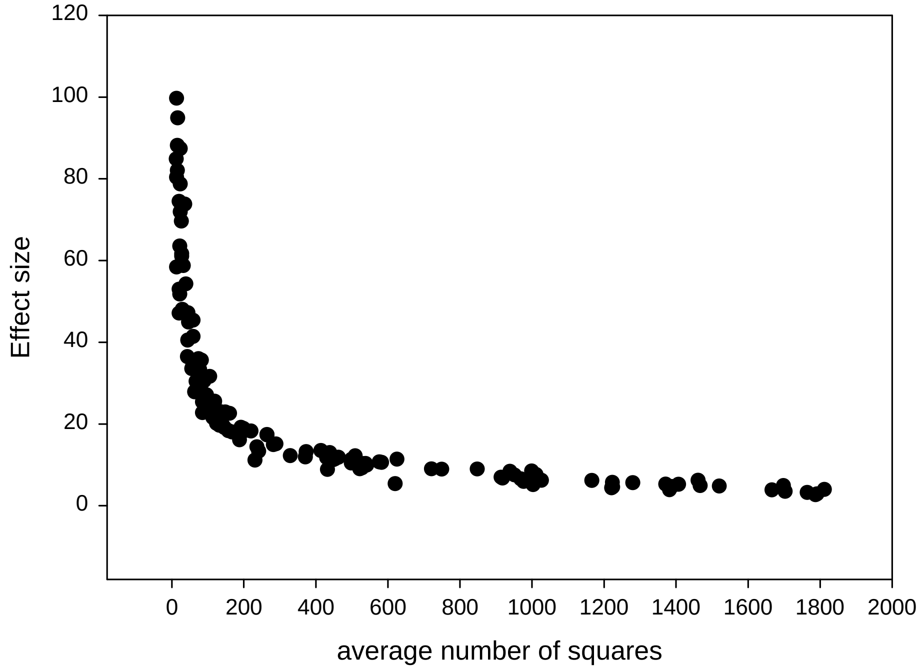


Figure 3.1.5a Effects of total number of different 1 km squares and yearly average of number of squares species seen in between 1994-2000 on minimum detectable effects size restricted to species with a yearly average of less than 100 squares

Solid black circles are total number of squares and solid open circles are yearly average number of squares.

i) Yearly average of number of squares and effect size



ii) % of zeros and effect size (species codes are listed in Table 3.1.1)

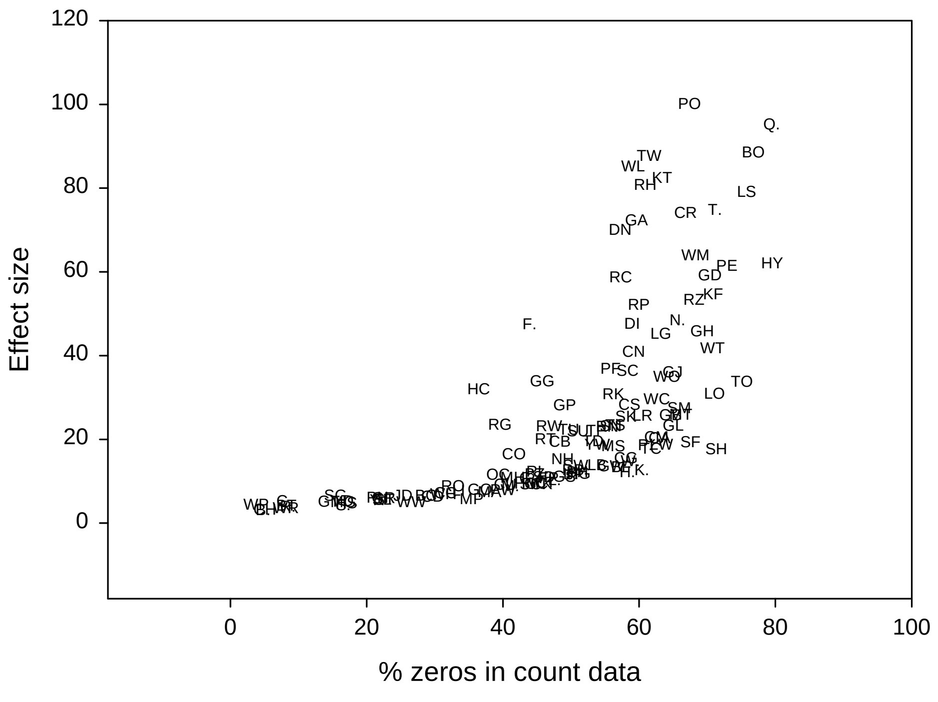
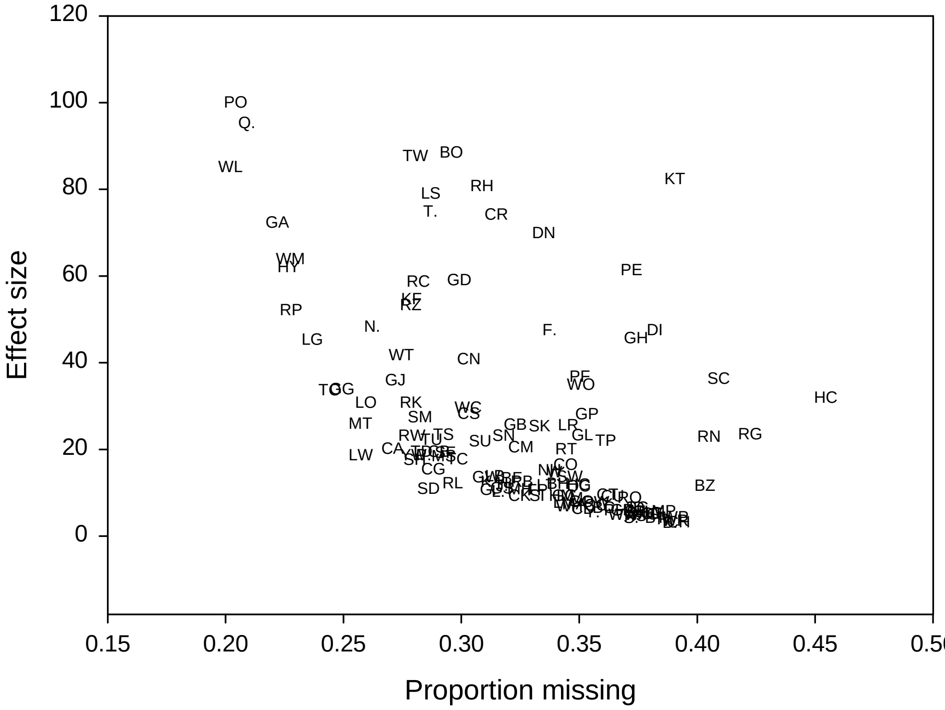


Figure 3.1.5b Relationships of descriptive statistics of count data with effect size for period 1994-2000 for species with ≤100 % effect size at the UK level

iii) Proportion missing (sites by year combinations) and effect size



iv) Mean count and effect size

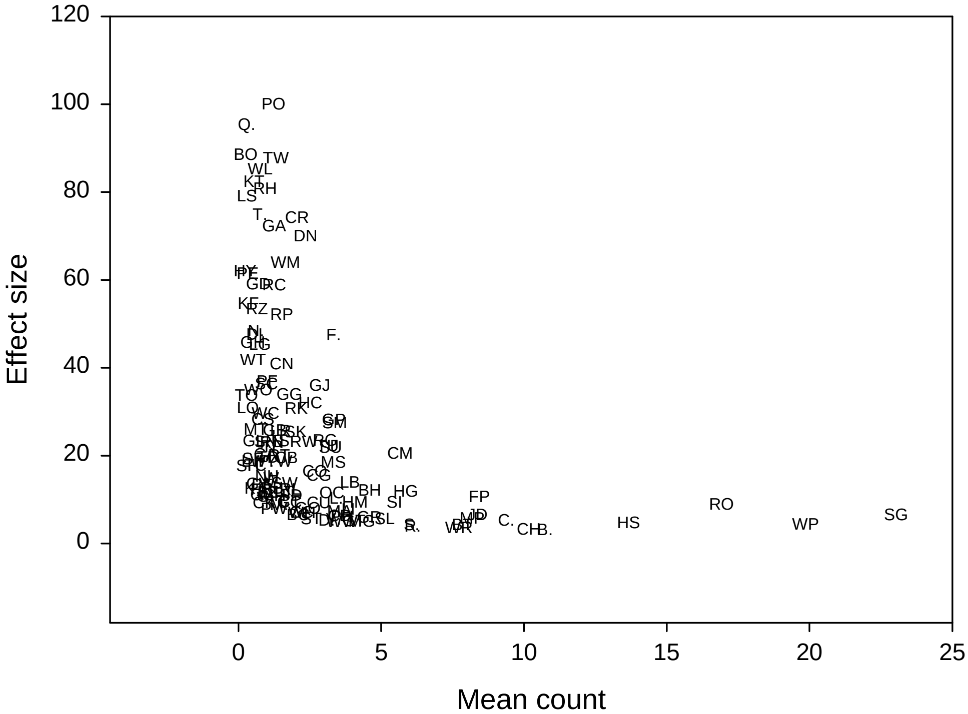


Figure 3.1.5b continued

v) Value of over-dispersion (deviance/degrees of freedom) and effect size

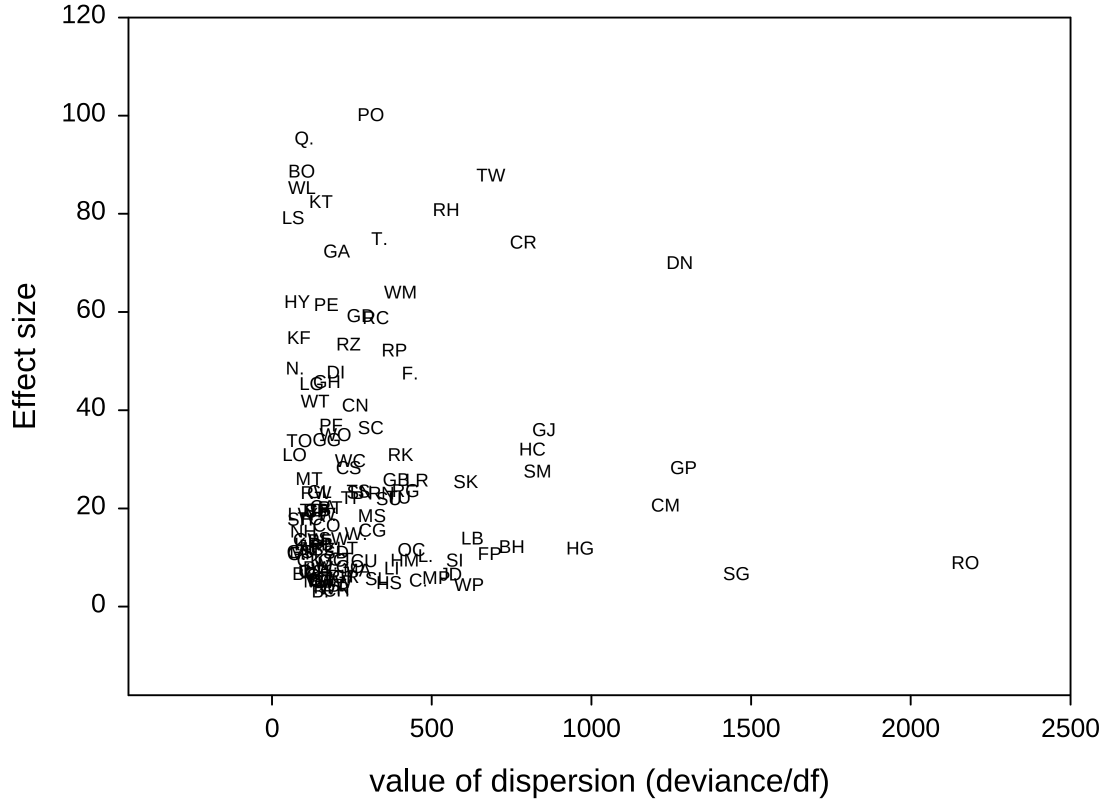
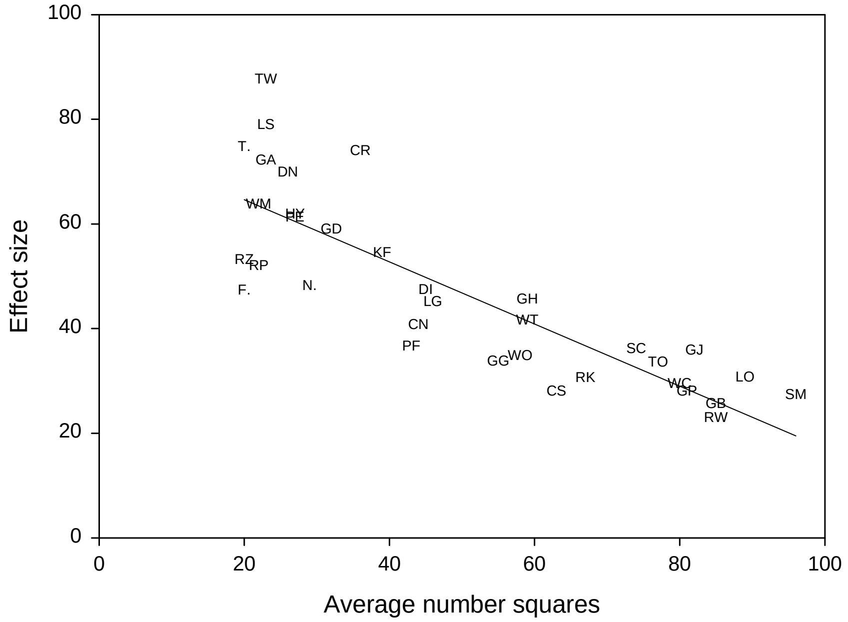


Figure 3.1.5b continued

i) Yearly average number of squares and effect size (with linear regression line)



ii) % zeros and effect size

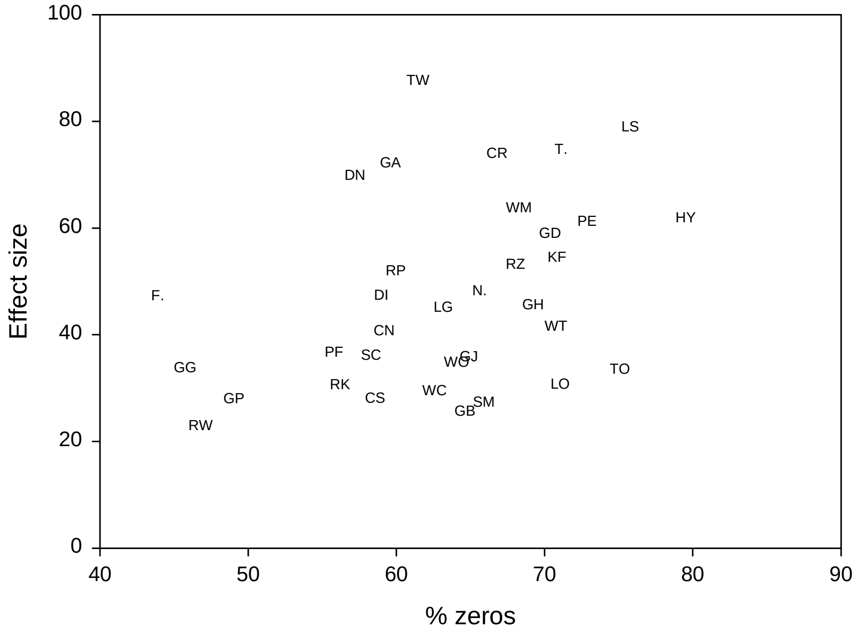


Figure 3.1.5c Relationships of descriptive statistics of count data with effect size for period 1994-2000 for target species (≥20 and ≤100 yearly average no. squares seen in) at the UK level.

Fieldfare is excluded from the plots as it seems an outlier and may represent a non-breeding population.
For ii and iii the x axis does not start as 0 to allow a better interpretation of the associations with effect size. Species codes are listed in Table 3.1.3.

iii) Proportion missing (sites by year combinations) and effect size

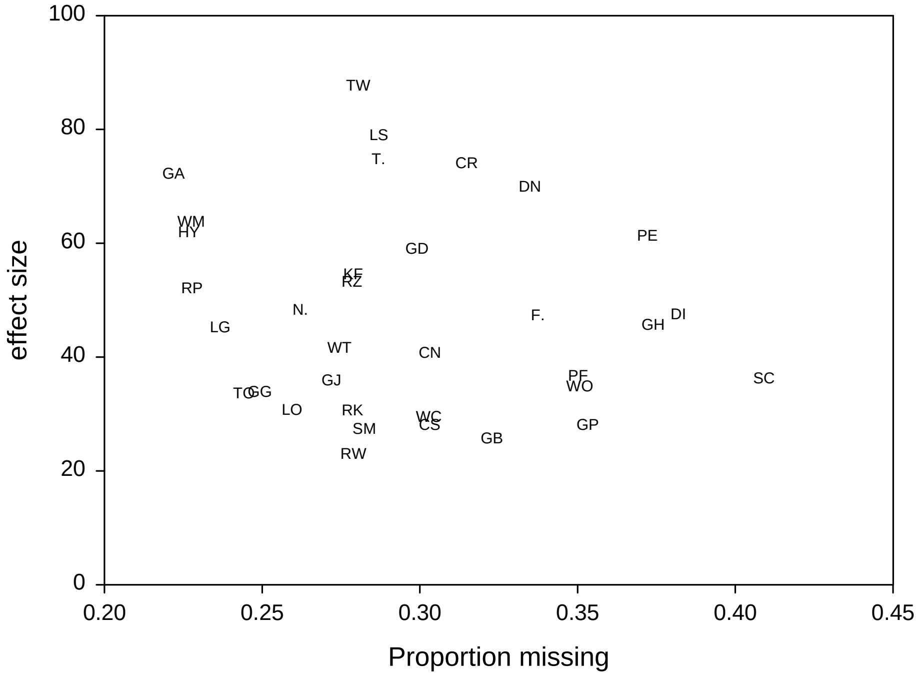
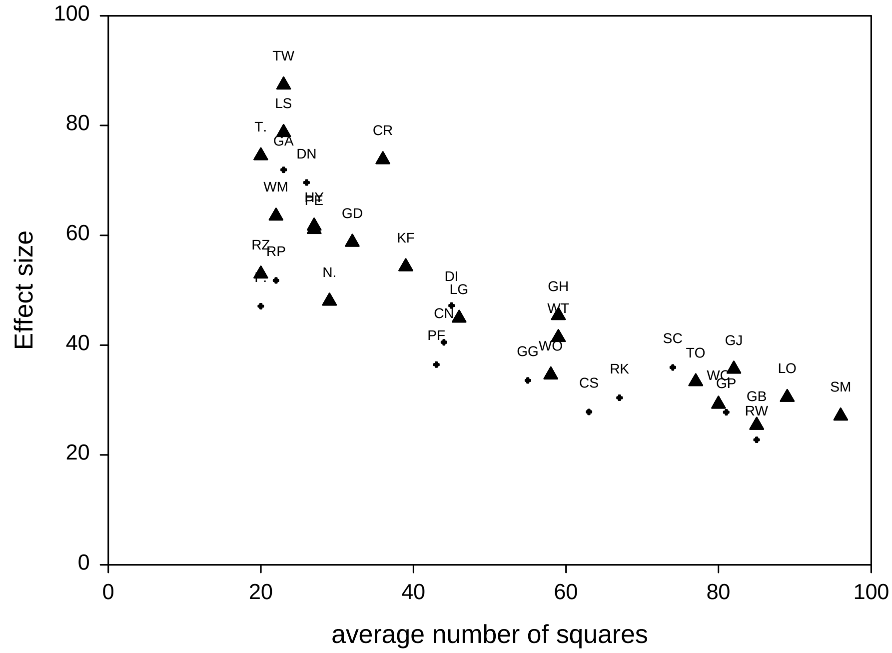


Figure 3.1.5c continued

i) Symbols relate to percent of zeros; cross-hairs represent low values for % of zeros (43 - 61) and solid triangles represent high values for % of zeros (62 - 80)



ii) Symbols relate to proportion missing; cross-hairs represent low values for proportion missing (0.22 - 0.30) and solid triangles represent high values for proportion missing (0.31 -0.41)

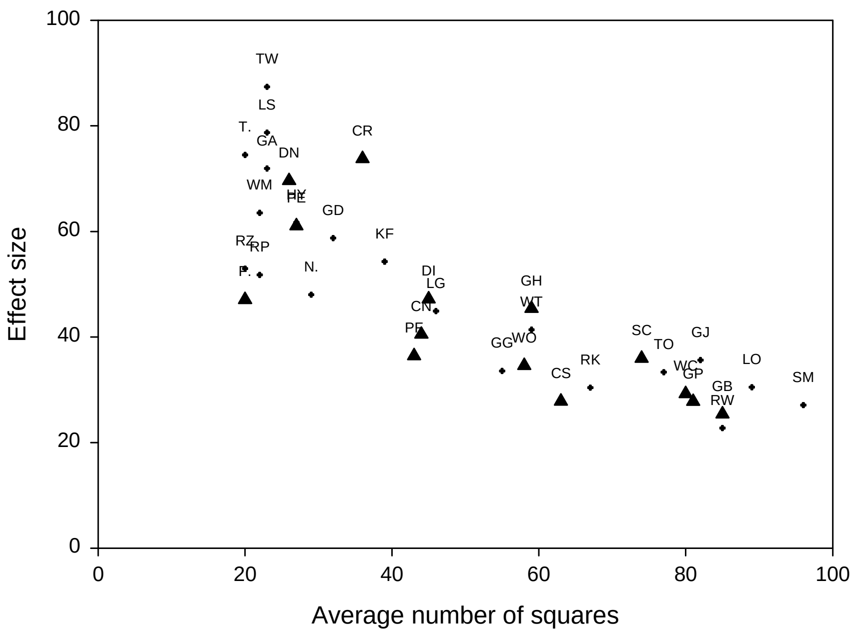
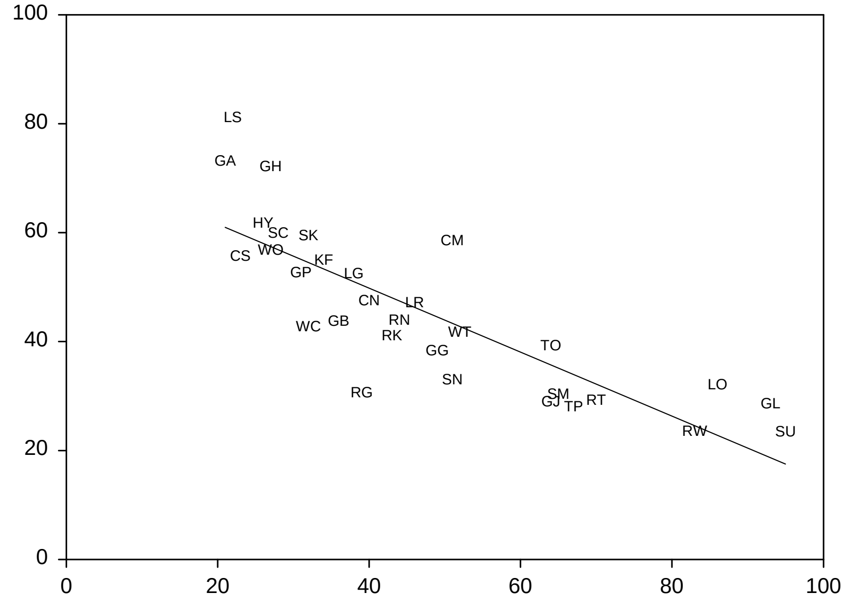


Figure 3.1.5d Relationship of effect size with yearly mean number of squares for the target species (n = 34); excluding fieldfare to allow better interpretation of the relationships

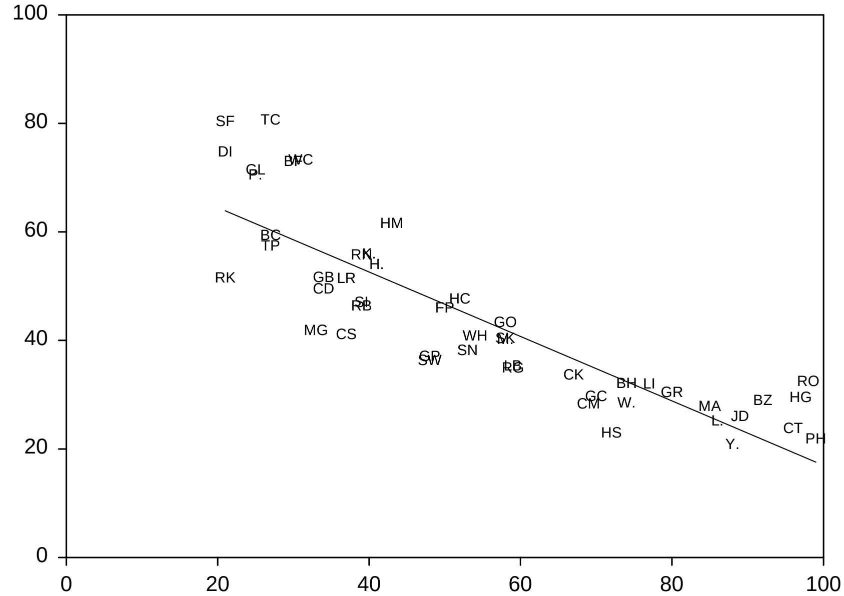
Points are labelled according to species and symbols represent low and high values for percent of zeros (i) and proportion missing (ii). Species codes are listed in Table 3.1.3.

i) England



Effect size (%)

ii) Scotland

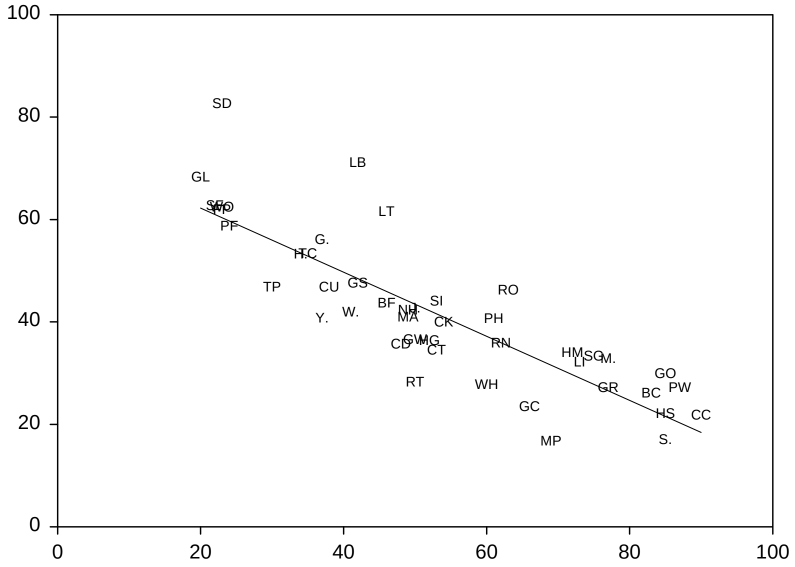


Yearly mean number of squares seen between 1994-2000

Figure 3.1.5e Relationship of yearly mean number of squares with effect size for the target species (>20 and <100) within each of the four countries

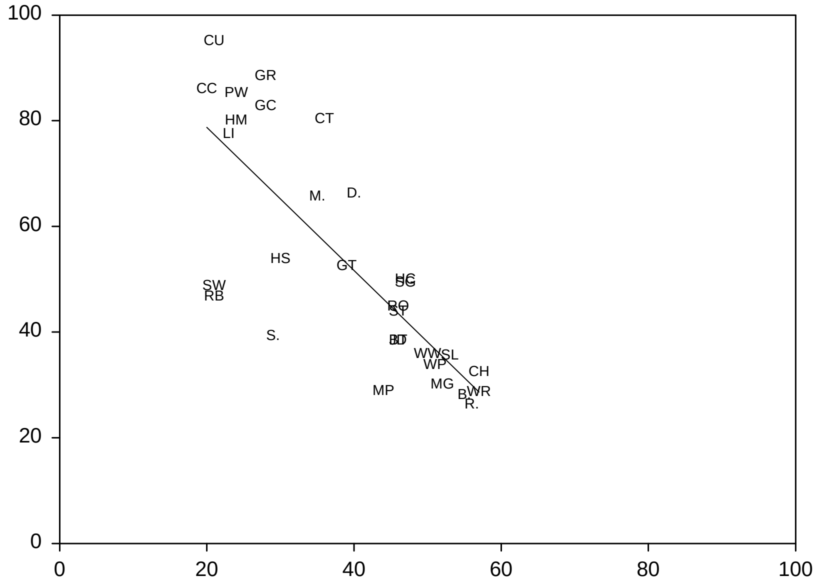
Note that exact target species and the number of species will differ from country to country as they are selected within each of the countries separately. Species codes are listed in Table 3.1.3. Fieldfare is excluded from the plot for England.

iii) Wales



Effect size (%)

iv) Northern Ireland



Yearly mean number of squares seen between 1994-2000

Figure 3.1.5e continued

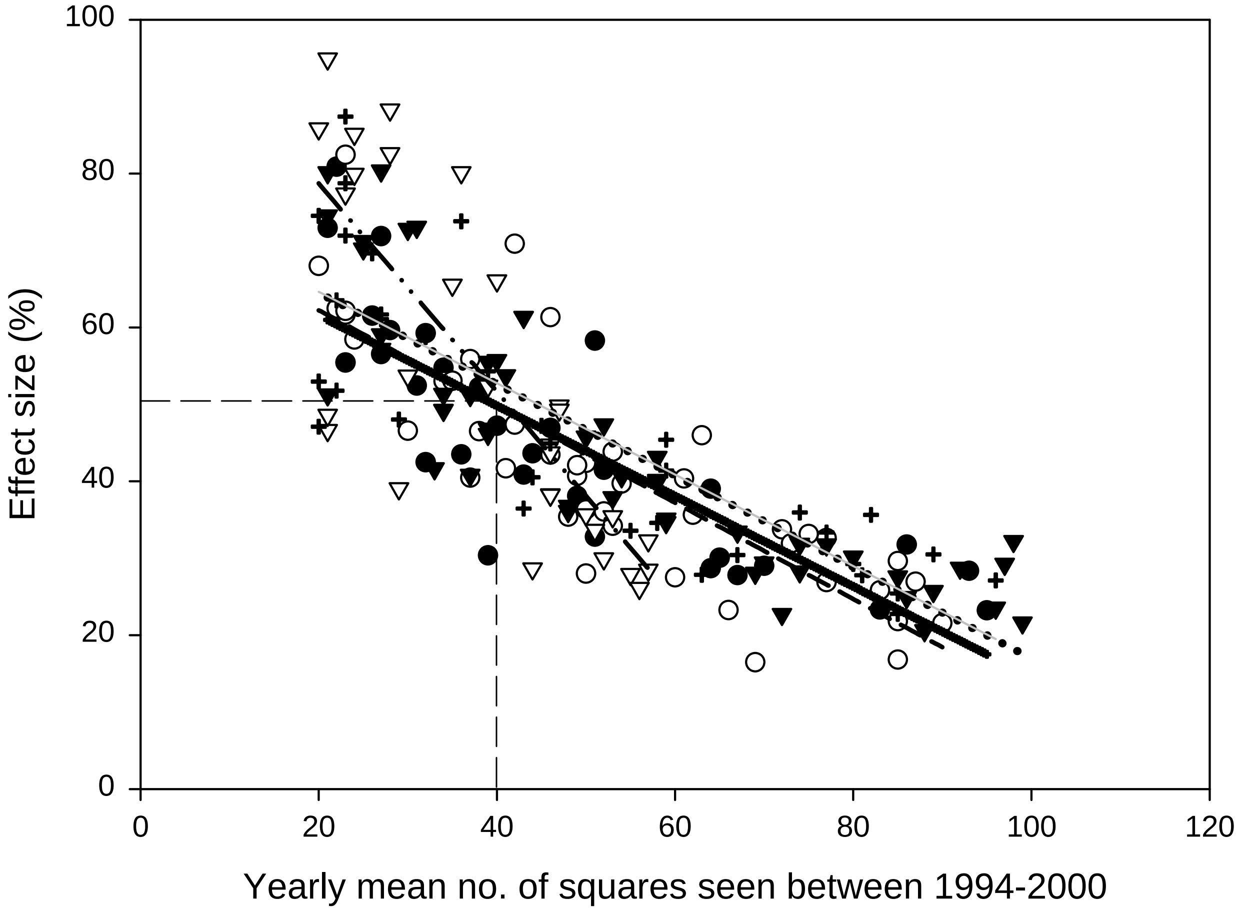
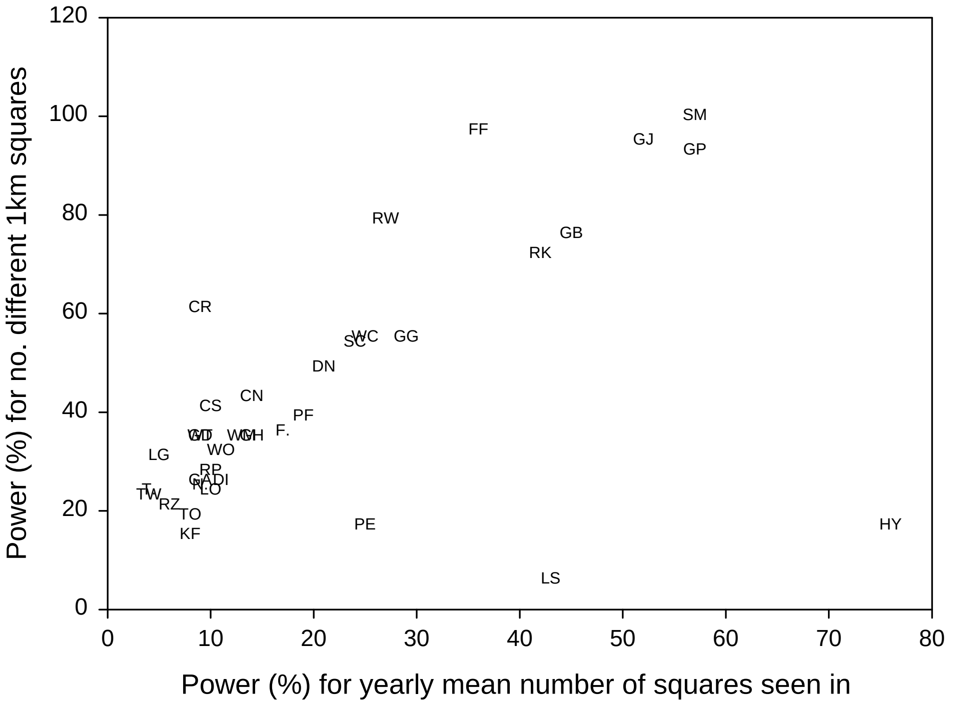


Figure 3.1.5f Relationship of yearly mean number of squares with effect size for the different target species (>20 and <100) for the UK and within each of the four countries

Linear regression lines are plotted for the UK and for each of the 4 countries. UK target species are crosshairs (+) with a solid grey line (—), English target species are solid circles (●) with a solid regression line (—), Welsh species are open circles (**O**) with a dashed black line (---), Scottish species are solid triangle (▼) with dotted line (·····) and Northern Irish species are open triangles (∇) and dash-dotted line (–··–··). Note that the grey regression line for the UK is almost identical and obscured by the regression line for Scotland. R^2 for the regression lines for the UK, England, Wales, Scotland and Northern Ireland are 0.70, 0.68, 0.71, 0.75 and 0.62 respectively.

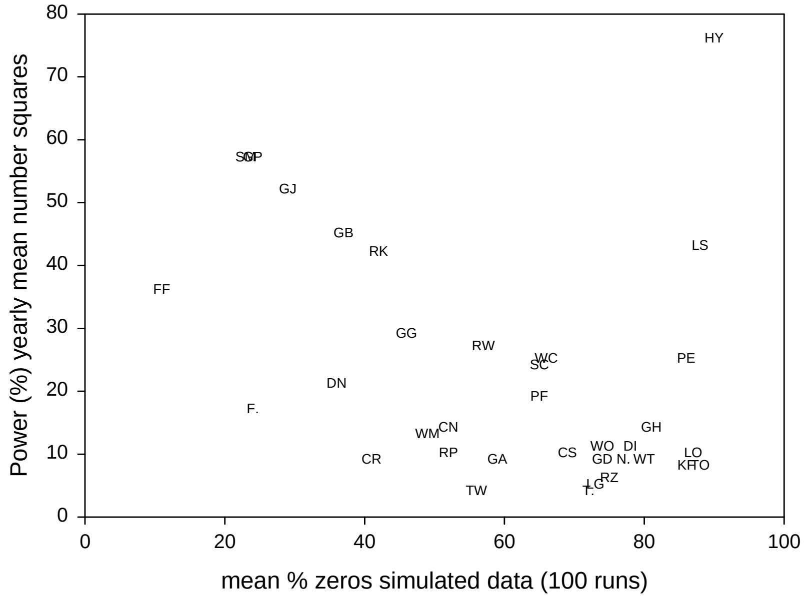


($r_s = 0.54$, $P = 0.001$, n = 35)

Figure 3.2.1 Association between power (%) from the two methods using the different species samples sizes; the first using the yearly mean number of squares seen in for the sample size and the second the number of different 1km squares seen in between 1994-2000

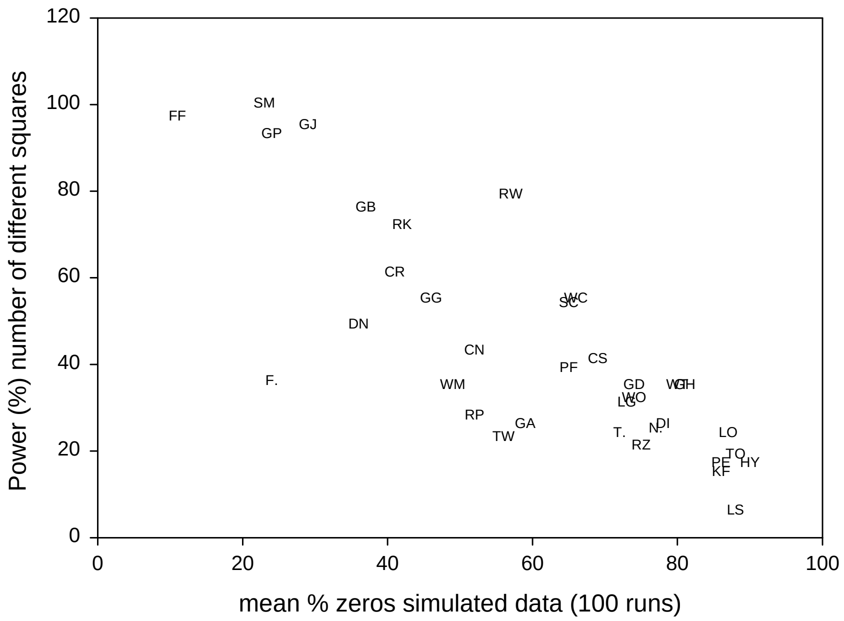
Species are labelled according to the BTO codes. Spearman Rank correlations are given at the base of the Figures.

i) Power of the program using the yearly mean number of squares seen in as the sample size for the species



(r_s = -0.38, P = 0.02, n = 35)

ii) Power of the program using the number of different 1km squares seen in as the sample size for the species



(r_s = -0.82, P < 0.0001, n = 35)

Figure 3.2.2 Association between the mean % of zeros in the simulated data and the power of the monitoring program for the two sample sizes; one using the yearly mean number of squares seen in for the sample size and the other the number of different 1 km squares seen in between 1994-2000

Species are labelled according to the BTO codes. Spearman Rank correlations are given at the base of the Figures.