BTO Research Report No. 244

Regional Indicators of Wild Bird Populations: An Exploratory Study

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A report for the Royal Society for the Protection of Birds

May 2000

British Trust for Ornithology
The Nunnery, Thetford, Norfolk, IP24 2PU, UK

Registered Charity No. 216652

GOVERNMENT OFFICE
FOR THE SOUTH EAST

Robinson, R.A. & Noble, D.G., 2000
Regional Indicators of Wildbird Populations:
An Exploratory Study.
BTO Research Report No. 244.
Thetford (BTO).

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Report dated May 2000 by the British Trust for Ornithology,
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ISBN No. 1-902576-26-8

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1. EXECUTIVE SUMMARY

This report is an exploratory study of the feasibility of generating regional wild bird indicators, in a similar way to the national headline wild bird indicator prepared annually for DETR. The approach taken was to produce sets of regional indicators for each of three sample English RDA regions, the north-east, the south-west and the south-east of England. Three main data sources are considered; the Breeding Bird Survey, the Common Birds Census, and the two UK breeding bird atlases. One set of indicators is based on the Breeding Bird Survey (BBS) and covers the five years since its inception in 1994, to 1998. The second set of indicators is based on the Common Birds Census (CBC) and covers the years 1970 to 1998.

A number of different versions of regional indicators are generated and evaluated with respect to the precision of the estimate, sample sizes and variance. There were few major differences in the pattern of change among BBS-based indices with different criteria for species inclusion, but species-specific BBS indices are vulnerable to small sample size and sparse data-set effects. Sample size appeared to have much less of an effect on equivalent sets of CBC-based indices for each of the three regions. Nevertheless, a number of species had to be excluded from the regional indicators because they did not occur there, or because of poor data. Whilst the CBC indices tended to be less variable, more species are monitored through the BBS.

In the headline indicator, annual indices for species not monitored by CBC or other monitoring schemes, are estimated from the estimates of occupancy in the two breeding bird atlases. Estimated changes in range appear to be positively related to changes in the CBC index between 1970 and 1990, but there is no relationship between the extrapolated changes in range from the atlases and the BBS indices between 1994 and 1998.

The report also examines the feasibility of indices for particular habitats. CBC-based farmland and woodland indices could be calculated for each of the three regions, using breeding bird atlas occurrence data in place of census data where necessary. Habitat specific BBS-based indices were also calculated for habitat specialists and by extracting bird data from particular habitats on BBS squares. Plots of different versions of BBS-based habitat-specific indicators revealed differences in population trends in different habitats as well as different regions.

2. GENERAL INTRODUCTION

Environmental indicators are measures of some component of an environmental system that are assumed to reflect (not necessarily directly) an underlying environmental condition of interest and which are usually simpler or cheaper to measure than the process itself (Rowell 1994). Indicators can vary in complexity from the simple presence of an organism indicating acidity to multi-species population indices that reflect the overall health of most populations in a particular biological system. The utility of an indicator depends critically on its being an accurate and meaningful synopsis of the underlying condition of interest. However, because indicators are used mainly as a tool for conveying important messages to the public, such as whether the state of the environment is improving or deteriorating in health, it is essential that the meaning of the resulting measure be easily understood.

The national wild bird indicator

In 1998, the Department of the Environment, Transport and the Regions (DETR)) funded work by the British Trust for Ornithology (BTO) and the Royal Society for the Protection of Birds (RSPB) to produce an indicator of wild bird populations (Gregory *et al.* 1999). Birds were chosen to signify biodiversity, and environmental health in general, because they are one of the best-monitored taxa in the UK and are readily identifiable to the public. Many are also relatively high up in the food chain, and can therefore be used as a proxy for changes lower down the food chain (Furness *et al.* 1993). The resulting indicator became one of 15 measures publicised as tools for the future monitoring of the sustainability of development.

The wild bird indicator published in the government's *Sustainability Counts* (Anon. 1998) represents summed population and change of range trends at a national (United Kingdom) level. The idea that national biodiversity can be summarised effectively in a single index number, such that future changes will be readily detected, is an attractive one. It also leads naturally to the suggestion that regional and habitat-specific information can be collated in a similar way to assist with management decisions at smaller spatial scales. The availability of a regional indicator would allow biodiversity indices to be promoted alongside the other, economic, social and environmental indices derived by DETR. These would be based on the 9 Regional Development Authority (RDA) regions in England, with Scotland, Wales and Northern Ireland probably best treated as equivalent to RDAs.

In this report, the feasibility of this approach is tested with three RDA regions: south-east and south-west England (for which data availability is likely to be good) and north-east England (for which data availability is likely to be poor). Throughout this report, we have followed much of the methodology of the national wild bird indicator (Gregory *et al.* 1999).

3. DATA SOURCES

The national wild bird indicator used two main sources of information: data on population trends, largely from the BTO's Common Birds Census but also other, more specialised surveys, and data on changes in range of distribution. Wherever possible, an indicator of the health of wild bird populations should be derived from data on population trends, as range change is a relatively crude measure, which may not reflect the underlying health of the populations (e.g. Morris *et al.* 1994). The two main sources for this are the Common Birds Census (CBC) which covers the period 1962 to the present (although it is gradually being phased out) and the Breeding Bird Survey (BBS), which covers 1994 to the present (Noble *et al.* 1999). Other sources of data are also available and those used to generate the national headline indicator include the Waterways Bird Survey (WBS), special surveys of particular species, Seabird Monitoring data for the colonial seabirds and terns (e.g.Thompson *et al.* 1999), the Rare Breeding Birds Panel data for scarcer species (e.g. Ogilvie *et al.* 1999) and Wetland Bird Survey counts (for a few species not monitored by other schemes, Cranswick *et al.* 1999). Data on range changes are taken from the two breeding atlases (Sharrock 1976; Gibbons *et al.* 1993). Further details of each of these sources are provided below and Appendix 1 lists the data sources for each of the 139 species included in the national indicator.

Common Birds Census

The Common Birds Census, currently funded by JNCC and operated by the BTO, has been running since 1962, and is the longest running terrestrial bird census in the world (Marchant *et al.* 1990). About 220 plots are surveyed annually, mainly in England with smaller numbers in Scotland, Wales and Northern Ireland. Plot turnover has been considerable since the inception of the survey, but without significant change in geographical or habitat coverage. Plots are selected by volunteers and categorised as either farmland, woodland or special (mainly heathland and wetlands). Volunteers make (ideally) ten visits to the plot to record the positions of all breeding birds seen or heard. The number of territories of each species is later calculated from the visit maps by trained BTO staff using standard procedures. Inter-year and long-term population changes are determined from the territory counts, using models that take missing data for some years into account.

Waterway Birds Survey

The Waterways Bird Survey (WBS) has been running since 1974, and is organised and funded by the BTO to monitor breeding birds along linear waterways; habitats not well-covered by the CBC (Marchant *et al.* 1990). Each year, more than 130 volunteers visit stretches of linear waterways they have selected to map breeding bird territories in a manner very similar to that of the CBC. The number of territories is determined from the visit maps by volunteers using standardised methods to identify clusters, and later verified by BTO staff. The geographical biases in the WBS data set are less severe than those for the CBC, but coverage of Northern Ireland is poor.

Breeding Bird Survey

The BTO/RSPB/JNCC Breeding Bird Survey was introduced in 1994 to monitor populations of breeding birds in the UK on an annual basis with equivalent precision to the CBC, but with fewer geographical and habitat biases, whilst allowing more species to be indexed and employing statistically more rigorous methods. Survey squares (1 km) are selected randomly within each sampling region according to available observer effort (differences in sampling intensity among regions are accounted for in the analyses). Bird counts are made along two parallel line transects in each 1k square, recording the numbers of each species detected in each of three distance categories. Only three visits per year (one to establish the transect route and two to count birds) are required and currently about 2300 BBS squares are surveyed annually. The rationale for, and development of, the

BBS is described and evaluated by (Field & Gregory 1999; Gregory & Baillie in press, Gregory *et al.* in press).

Seabird Monitoring Project

The Seabird Monitoring Project (SMP) is run by JNCC (together with the RSPB and the Shetland Oil Terminal Environment Advisory Group SOTEAG) and monitors seabird populations in Britain. The most detailed monitoring takes place at four 'key sites' Canna (in SW Scotland), Fair Isle, Skomer and the Isle of May. Long-term monitoring of colonies in Grampian, Orkney and St Kilda are also carried out. Numbers at these colonies are estimated from a random sample of small plot counts that can be extrapolated up to the entire colony area. Additional monitoring of other colonies is encouraged. The RSPB, for example co-ordinates the monitoring of tern colonies, many of which fall within their reserves. In addition to the more or less annual monitoring of selected colonies, complete counts of all colonies are undertaken at approximately 15 year intervals. The first of these occurred in 1969 (operation Seafarer) and the most recent in 1984-1987 (Lloyd *et al.* 1991). Another survey (Seabird 2000) is currently underway, with counts scheduled to be completed next year.

Rare Breeding Bird Panel

The RBBP is a collaborative body that collates records of rare breeding birds in the UK for monitoring purposes and publishes annual summaries (e.g. Ogilvie *et al.* 1999). The RBBP holds information on population sizes for more than fifty species. RBBP data covers the period from 1973 to the present, and is updated with the results of new surveys as data become available.

Wetland Bird Survey

The Wetland Bird Survey (WeBS, coordinated by BTO, RSPB, JNCC and the Wildfowl Wetlands Trust), together with its predecessors, has provided monitoring information for waterfowl and waders in Britain for over 50 years (Cranswick *et al.* 1999). WeBS aims primarily to monitor all non-breeding waterfowl populations in the Britain through complete counts and covers both a sample of inland sites and almost all the Britain's estuaries. Only wintering birds (counts from September to March) are routinely indexed, but a subset of survey sites is also counted in summer. Full details of the methods used and the background of the survey can be found in WeBS annual reports. Winter indices can be calculated for most species for the period 1974-1998; in summer, sufficient sites to allow indexing have been counted only since 1994.

Breeding Atlases

During the periods 1968-72 and 1988-91, detailed surveys of breeding birds were carried out in every 10k square in Great Britain. The results of these distributional surveys were published in two breeding bird atlases (Sharrock 1976 and Gibbons *et al.* 1993). Atlas data-sets are held by the BTO, RSPB and JNCC, and can be used to calculate changes in breeding distribution over the twenty year interval between the two atlases.

4. METHODS

For the purposes of this study three of the data sources outlined above are used; population trends derived from the CBC and BBS for population trends and the changes in range from the two breeding atlases. These will represent the majority of the species that are likely to be used in an indicator, for example of the 139 species included in the national indicator 66 (47%) were indexed on the basis of CBC trends and 36 (26%) by changes in range (Gregory *et al.* 1999). We also briefly comment on the suitability of the other data sources for their use with regional indicators.

Population trends for each species were calculated in a similar way for both data sources. First a site by year matrix of the available counts is constructed then a full site by year model is fitted, *i.e.* each site and year in the data was modelled by a separate parameter in the model. Models were fitted using the GENMOD procedure in SAS using a logarithmic link function and a Poisson error term (SAS Institute 1997). As birds are not distributed randomly, but aggregate in particular habitats, the distribution of count frequency is over-dispersed relative to the nominal Poisson distribution (more squares with zero counts and more squares with very high counts than expected). Consequently, the PSCALE option of GENMOD was used. This corrects the variances of the model parameters to take account of the over-dispersion in the data by multiplying the variances by a scaling parameter. This does not affect the estimated value of the parameter (only its variance) so is of limited practical significance in the present context.

Changes in range were measured by counting the total number of squares occupied in 1969-1972 (nominally 1970) atlas compared to second breeding atlas in 1988-1991 (nominally 1990). A linear change between the two periods was assumed and this linear trend was extrapolated forward to 1998 to provide index values for all years.

Having computed the indices (of population or range change) for each species, all indices were standardised to a value of 1 in 1970 and subsequent index values re-scaled accordingly. In each case the indicator is the geometric mean of the contributing species indices, *i.e.* the index values for all species in a given year are multiplied together and the nth root taken. This accounts for the fact that proportional population changes are not symmetric (on an arithmetic scale, a 20% increase followed by a 20% decrease, results overall in a 4% decrease).

5. SUITABILITY OF DATA

Breeding Bird Survey

For future indexing purposes the BBS obviously represents the major source of data, being based on a regionalised random selection sampling regime. A SAS program has been written which will allow the index to be calculated on a regional basis (either RDA or some other regional grouping) each year straightforwardly, with a minimum of modification to the code. The number of squares surveyed in each of the ten mainland RDAs in England, together with Scotland and Wales, for each year is given in Table 1. As can be seen, BBS survey squares are not distributed evenly across the country, and for some regions data are rather sparse, notably the north-east of England and London, reflecting observer availability and the relatively small size of the regions. (Note that these totals exclude squares counted in one year only (which cannot be used for indexing purposes) and hence differ slightly from those presented in the annual BBS reports.) The three sample regions selected represent the regions with the greatest (south-east and south-west England, with over 200 squares/year) and the least (north-east England, with under 50 squares/year) amount of data available.

At the UK level, the BBS reports on population trends for species that occur in fifty or more squares each year. With this criterion applied to the regional analyses there will clearly be some regions for which producing a bird indicator would be impossible (*e.g.* the north-east). However, Field and Gregory (1999) analysed the data for eight species that are detected on 30-50 BBS squares, on average, and found that Pied Flycatcher could be indexed with sufficient reliability with a mean sample of only 39 squares. Recently, separate country summaries for Scotland and Wales have been produced, which rely on species occurring in only 20 squares, with appropriate caveats concerning the precision of estimated changes (Noble *et al.* 1999). This criterion might also be appropriate for the regional indicators. A habitat-based sustainability index produced for the water industry used species counted in at least 30 squares per year (Siriwardena *et al.* in prep.).

The precision with which changes in population are measured will be dependent on the sample size. This can be estimated roughly by looking at the average 95% confidence limits of the annual indices (= 1.96 * standard error). This was estimated by looking at an (arbitrary) range of 15 species, from widespread to relatively rare (Table 2). The precision of the estimates depends strongly on the sample size (amongst other factors, such as geographic dispersion) and for species with very small samples (less than about 20) the indices fluctuated markedly (with apparent population size changing by a factor of 2 or more between consecutive years). This indicates their unreliability for annual indexing and sets a minimum threshold for species suitable for inclusion in the indicator index. The relationship between sample size and confidence in the population index is plotted graphically in Figure 1. Clearly, reducing the sample size reduces the reliability of the species index. However, increasing the sample size beyond about 30-40 doesn't affect the confidence limit markedly. It would probably be a good idea to include another region with moderate amounts of data to confirm the robustness of this, as the maximum sample size for the north-east is 33.

From the information above, the minimum sample size for a species' inclusion in the indicator index should be between 20 and 40. The number of species this would allow for each region is detailed in Table 3. For the relatively data rich South-east and South-west the precise value of the threshold for inclusion makes little difference to the sample size (of 50-60 species, compared to around 100 species indexed annually on a national scale). However, for the north-east the effect is much greater, although in any case, the number of species included is rather small. These numbers would be further constrained if the indicators should contain a similar set of species for each region. A full list of species used for each region is included as Appendix 1. In the indices only those (101 in 1998) species indexed nationally by the BBS are considered, although six introduced species are excluded (as with the national indicators).

Common Birds Census

BBS data are only available from 1994, thus any historical index will have to be based largely on CBC survey data. However, the number of plots covered by this method is relatively small, for example, in 1999 there were 212 plots in the United Kingdom, though nearer 300 have been surveyed in recent years (Table 4), though including plots no longer being counted will increase these sample sizes. These are not evenly distributed throughout the country, but tend to be concentrated in the south and east of England.

Unlike the BBS indices, variability in the indices produced using CBC methods does not appear to be consistently related to sample size, although a few species have very high variances, reflecting the highly aggregated nature of their distribution (Figure 2). This probably reflects the differences in recording methodology of the two surveys. CBC fieldwork is relatively intensive, based on a number of visits throughout the breeding season and would be expected to give a good estimation of the number of birds present on a plot (at least for generally territorial species, which the CBC was designed to survey effectively). BBS fieldwork, in contrast, involves only two relatively short visits, thus error attributable to the estimation of numbers present will be much greater than for CBC. Of course, habitat variability across CBC plots will also be much less than across BBS squares, though this will bias the estimates of population size produced because of uneven habitat representation (Marchant *et al.* 1990).

The national headline indicator only includes species for which more than half the year-to-year changes are based on more than 20 plots. (An additional four species are included using WBS data, based on similar criteria.) Based on the lack of a relationship between variability and sample size, our approach was to first generate indices for all (66) species that were included in the national headline indicator on the basis of their CBC trends and to later exclude species if the indexing process proved unsatisfactory.

Atlas data

The national headline indicator also included figures for changes in range, based on the two breeding atlases, for those species for which there was no other data. This was done simply by drawing a straight line between the two estimates of population range (number of squares occupied) and extrapolating backwards and forwards the required number of years. The validity of this practice depends on it being a reasonable surrogate for changes in population size for the species concerned. Obviously it is not possible to test this for the species for which we do not have population data (and hence for which using atlas data is necessary). However, if using range change as a surrogate for population change, we would expect there to be a relationship between population change and range change for the (common/widespread) species for which we do have data (on the assumption that similar relationships are likely to be evident in the scarcer species).

For the period covered by the CBC index, there does appear to be a relationship between population change and range change, although there is a fair degree of scatter in the relationship (Figure 3). For this comparison, populations were indexed between 1970 and 1990 to ensure compatibility with the atlas data, which covered this period. Relating range changes from the atlas to the full run of CBC data (1970-1998), if anything yields a better relationship (atlas change = 4.65 – 0.22 CBC change, R^2 = 0.42). Thus for the historical index, broadening the species base by including range changes seems to have reasonable validity (at least on this basis). However, comparing range change and population change between 1994 and 1998, the period covered by the BBS, shows there is no relationship between the two indices. This is despite the fact that we might expect a better correlation, because the composition of habitat in the BBS survey (which is a random selection of that present overall in the landscape) is likely to be more similar to that contributing to the atlas data than the highly biased selection of CBC plots (which are restricted largely to farmland or woodland habitats). This shows the

dangers of extrapolating range changes based on only two sampling points. For this reason, atlas data will not be considered when generating indices based on BBS data.

Other Sources of Data

The Waterway Birds Survey data is produced and indexed in almost exactly the same manner as the CBC data. Thus, incorporating this data, which was used for four species: Dipper, Grey Wagtail, Common Sandpiper and Kingfisher in the national indicator, will be easy (although subject to the same caveats applying to the CBC).

A number of sources of data included in the national sustainability index could also potentially be included. The Seabird Monitoring Program yields population indices, based on counts at a sample of seabird colonies, which could readily be incorporated into a sustainability index (Thompson *et al.* 1999). These counts are already indexed regionally, to almost the same boundaries. Fourteen regions are used (three of which are in Eire). Scotland, Wales and Northern Ireland form discrete groupings for which data could be summed across the constituent SMP regions. England is divided into five regions, of which four follow RDA boundaries, the SMP's NE England includes counties from three RDA regions (NE England, Yorkshire & Humberside and East Midlands. With the exception of gulls and terns (some which are also indexed, though perhaps not optimally, by CBC and BBS), most seabirds occur in Scotland and Wales, so including SMP data in the regional indicators should prove relatively straightforward.

WeBS counts may be used for some species not adequately monitored by other schemes. These counts are mainly from the non-breeding period and hence their use in the national indicator for Mute Swan, Red-breasted Merganser and Goosander seems dubious (particularly for regional indicators) since there is marked population movement between seasons (*e.g.* Lack 1986). However, some counts are made throughout the year and the use of specific months may be possible (and necessary for a regional breakdown), for example, March for Goosanders and April/May for mergansers (M. Armitage *pers. comm.*).

Rare Breeding Birds Panel data could be included; they are used in the national indicator for two species (Woodlark and Dartford Warbler) that have populations exceeding 500 pairs. Species with fewer pairs are excluded (Gregory *et al.* 1999). Because of the small size of some of the populations monitored, the indices are likely to be erratic from year to year, which may adversely influence the overall index (particularly on a regional basis, where the number of species included is likely to be small). Extracting this data on a regional basis may prove time-consuming. On the other hand, many rare birds are high profile components of the avifauna of particular regions. Examples include stone curlews in East Anglia and upland species such as Ptarmigan and Dotterel, in Scotland. Whilst it may be necessary to exclude these species from a headline regional indicator, it might be useful to include them in a separate 'rare birds' indicator for each region. This may also give a better indication of the success of conservation measures, which are generally successful for rarer species, but tend to be less so for more widespread species (Gregory *et al.* 2000).

Similarly, inclusion of other species covered by specific surveys may be possible, depending the methodology for the species concerned, though breaking down the data regionally may be more or less time consuming. Many of the concerns relating to atlas data also apply to extrapolating between these occasional surveys with no explicit annual component. The BTO Heronries Census is a notable exception to this, and colonies are indexed by county and grid reference making production of regional summaries straightforward.

6. THE REGIONAL INDICATORS

A Current Index based on the Breeding Bird Survey

The headline indicator included all species (except those that are introduced, or have a breeding population of less than 500 pairs) that are monitored in some way. However, this is not possible to use the BBS for all of these species, because a number of species are not monitored by the BBS and for some (generally scarce) species the indexing process fails for various technical reasons. For some species, the modelling process does not converge, resulting in invalid indices being produced and for others, there are simply insufficient data to calculate an index. Additionally, a few species had highly variable indices (yielding index values of > 10) which were likely to be due to small sample sizes, these have also been excluded. Note some species may have had similarly large index values because of large-scale expansion (e.g. Siskin) or highly variable population sizes (e.g. Goldcrest) and some thought will need to be given to how these may be identified. Figure 4 depicts an index based on all species for which a valid index could be produced. Indices are also presented for those species that occur in greater than 20 BBS squares in the region (index TSq) for which the indices are likely to be most reliable and for a common set of 25 species that occur in at least 20 squares in all three regions (index ATSq). The regional CBC 'All' index (based on the longer-running CBC and defined later) is included for comparison.

In general, the three indicators based on the BBS data yield similar indices, at least over the short period covered here (Figure 4). Given the nature of the indicators, there seems little reason, at the moment not to choose the 'All' indicator. However, care needs to be taken in future as some species included in the index presented here may yield poor estimates in future years. Some thought could be given to which these species might be and excluding them at the outset, to maximise comparability between years. Comparison with the CBC index (discussed below) suggests the two methods yield roughly comparable results, with the north-east performing poorest in this respect (it is an area traditionally poorly covered by the CBC). These issues are particularly important if some estimate of variation (or confidence) in the indices are to be produced.

The national indicators produced habitat-specific population indices for farmland by selecting a list of habitat indicator species (20 on farmland and 41 for woodland, see Appendix 2). Indices for these species were then produced for CBC plots across all habitats. One of the major benefits of the BBS, in addition to the greatly enhanced habitat coverage it provides, is the ability to split the data by habitat, which is recorded according to a standard set of criteria by individual transect sections. Thus habitat-specific indicators could be produced in a three ways. Firstly, analogous to the national indicators using the habitat indicator species (BBS-C), secondly by indexing a wider suite of species in particular habitats (BBS-H), and thirdly by indexing habitat-specific indicators in particular habitats (BBS-S). Thus for the farmland indicator species indices were produced based on transect sections where both the primary and secondary (Level 1) habitats were noted as farmland or where the primary habitat was coded as farmland and the secondary habitat code was not used (BBS-S). Similarly, the woodland indicator was based on transect sections where woodland was recorded. These indicators were produced for two sets of species (Appendix 2), a general list of around 50 reasonably common species likely to occur in the habitats in sufficient numbers to be indexed (BBS-H) and the list of habitat specialists currently used in the national habitat indicators (BBS-C and BBS-S).

These indicators for the five years indexed by BBS data are graphed in Figure 5, together with the equivalent trend based on CBC data). The table below may help in interpreting the similarities and differences between the indices.

	Wider Spp List	Habitat specialists
All Habitats	-	BBS C
Farm/Wood Habitat only	BBS H	BBS S

Obviously, the general list of species included here could be refined to exclude some of the species less tied to a specific habitat (such as gulls) whilst retaining a wider suite of species typical of a habitat. A technical consideration ignored in this preliminary analysis is that by selecting squares of specific habitat, the weighting factors used in producing the BBS indices of the individual species (based on relative coverage in each BTO region) may be slightly out as not all squares are being used. This should be easy to rectify for the production of the final indices. (The number of transect sections contributing form each square are included as an offset in the linear modelling procedure, to account for unequal survey effort caused by different amounts of habitat in each square).

Historical Index based on Common Birds Census and Atlas data

The range of species covered by the CBC is generally less than for the BBS (because of the restricted range of habitats comprising CBC plots and their distribution), however atlas data could be substituted for those species not indexed by the CBC and species whose indices were deficient in some way (based on the modelling output). In addition to the problems noted with the BBS data (estimates not converging and insufficient data) there was a problem with the presence of zero indices for some species, at least partly because of the longer run of data available with the CBC. This may represent poor data (zero indices occurring in only one or two years, *e.g.* Redstart), or the consequence of a large population decline (*e.g.* Tree Sparrow). Since the overall indicator is based on the geometric mean of component indices, it cannot be calculated if any of the component indices are zero. For these species atlas data has been used, though this seems slightly inefficient, particularly for species with only a single zero value, perhaps some form of imputation should be considered. Alternatively, a better of way dealing with these species might be to set the index value to 1 which effectively makes the species 'disappear' in the index (because it is multiplicative) and still taking the *n*th root.

An additional problem in a very few cases was created by the extrapolation of range change creating a negative index (the extrapolation covers 29 years, compared to the 20 years between atlases). These species: Black Grouse which became extinct in the south-west, Barn Owl (which underwent a large population decline) and Dotterel (very scarce) in the north-east, have been excluded from the indices, but it may be possible to include them by arbitrarily re-assigning negative range estimates. Extrapolating the atlas data for a longer period will inevitable lead to more of this type of problem.

As might be expected from an index that has no explicit annual component and which is based on a relatively crude measure of change, the index based on the atlas data alone shows rather little variability (Figure 6). Consequently, the overall index based on both CBC and atlas indexed species largely reflects the CBC index. However, encouragingly, the two indices do seem broadly comparable in terms of the changes they index.

The national indicator tracks populations of farmland and woodland species separately, with 20 species described as farmland species and 41 woodland species (though two of these, Crested Tit and Capercaillie only occur in Scotland); these are indexed with counts from all plots (Appendix 2). The indices can also be produced regionally (Figure 7). Virtually all species included in the national indices could be included in their regional counterparts (because those species not sufficiently common to be censused properly, could be included using range changes, see Appendix 2).

7. DISCUSSION

The main conclusion of this report is that extending the national wild bird indicator to use for the English RDAs (and by extension Scotland and Wales) is certainly possible, even for data poor areas such as the north-east (although London and Northern Ireland may prove problematical). Also CBC is, in some ways, more suited for this purpose than BBS, reflecting the difference in methodological design: the extra variability inherent in BBS was designed to be counterbalanced by larger sample sizes. Using regional samples means indices for some species based on BBS data are unsuitable for indexing purposes, though they will be much less biased than their CBC counterparts. Whilst it has been possible to construct regional indicators, some external validation of the method would be useful to assess its utility in measuring changes in biodiversity (Siriwardena *et al.* in prep.).

Indicator Trends

The general pattern of the indices is similar to the national pattern, farmland species are declining, but in general there has been little overall change in population trends. However, there are intriguing regional differences between the (long-term CBC) indices; BBS has yet to run for a sufficient length of time to detect meaningful trends. The headline indicator for the north-east, seems more or less stable; the other two indices show some evidence of declining overall bird numbers, with a shallow decline in the south-east since 1980 and a steeper, more sustained decline in the south-west. Populations of both farmland and woodland birds in the south-west have shown a consistent decline over the last thirty years. These declines are not confined to any particular species, but seem to be fairly general (Table 7). The steep decline of the woodland indicator, in particular, merits further investigation. This decline seems not be based on (apparent) large declines in a few species, but rather a general decline across all species, though some species (e.g. tits, Chaffinch) are increasing much as one would expect. This, could, for example, be related to some change in climatic conditions (the amount of warm, wet westerly airflow over Britain has increased dramatically over the last 20 years for instance) or, more likely, the increasing trend for intensive pastoral farming to dominate land use in this region.

Species Inclusion

Although there are issues of increased variability with small sample sizes (primarily with BBS data) these do not seem to have affected the annual pattern in a significant way. The headline indicator for each region, encompassing all species except those for which the modelling did not converge, is rather similar to those based on a more restricted suite of species. Some thought needs to be given to handling species for which the log-linear models did not converge, those with rather variable estimates (*e.g.* Sand Martin) and those which yield a zero index in one or more years. These reflect lack of data, poor model fits or a large decline in numbers, depending on the species.

At present, the indicator is summed over all species, each contributing equally. This makes the implicit assumption that the value of each species is equal, both as a monitor of the environment and as a cue to trigger appropriate management action. In fact, neither of these assumptions may be true. For example, the long life-spans of many seabirds means that their population trends are to some extent buffered from the effects of environmental change. This compromises their utility as short-term monitors of the environment (Furness *et al.* 1993). On farmland, much conservation concern has focussed on the declines of certain granivorous passerines (Krebs *et al.* 1999). Including species such as Magpie, widely considered a pest species, and whose population has more than doubled since the start of the CBC, effectively cancels out the effect of a halving in Skylark numbers. This may undermine the indicator's utility for monitoring deterioration of farmland habitats.

Scarcer species (which are not currently well-monitored) may be included with greater confidence in future indicators through the introduction of new surveys designed specifically to assess their

population status (e.g. recent surveys of Twite and Barn Owl). However, this relies on a previous comparable survey against which population trends can be assessed. Alternatively, the number of BBS squares in which a species is present might be utilised as a measure of range change. Whilst this suffers from some of the drawbacks of atlas data, such as an unknown relationship between population and range changes, it does have the benefit of an annual component.

Rare species, which were not included in the national indicator can form an important part of the fauna of particular regions, particularly in Scotland, which has many unique habitats within the UK. Whilst it may be necessary to exclude these species from the headline regional indicators, it should be possible to generate a separate 'rare birds' indicator for each region, which would reflect conservation priorities unique to each region. This would resemble the rare species indicator that shows increases in populations of rare species at a national level between 1970 and 1998 (Gregory *et al.* 2000).

Assessing Confidence in the Changes

A major question for the future development of these indices is the ability to ascribe statistical confidence limits to the indices, thus allowing some degree of significance to be ascribed to the observed changes. Currently, if the value of the indicator changes up or down, little can be said as to whether this represents a real change or whether it can be attributed to sampling error. This obviously compromises the use of such indicators in decision-making processes. If measures of reliability are required, then the issues of variability discussed above will become much more pressing, as inclusion of too many species may yield confidence limits so wide that there is little power to detect any changes. It is not immediately clear how such confidence limits would be calculated, though some form of boot-strapping is likely to be the most plausible way forward, although likely to be very computer-intensive.

An alternative approach would be to take the analytical estimates of the variances of each annual population index value for each species that are provided by packages such as SAS and to combine them using standard formulae (Siriwardena *et al.* in prep.) to estimate the variance of a multi-species indicator. Although this approach would allow variances to be combined across survey schemes, it is less sound statistically than bootstrapping, because of the inherent assumption of a Poisson distribution of the count data. As indicated by high over-dispersion coefficients (Table 2), this is usually not the case.

Habitat specific Indicators

Habitat-based regional indices from both the long-term dataset (which includes atlas data for species not well-indexed by CBC) and the shorter-term BBS dataset seem to be reasonably viable (though the BBS-based woodland index for the north-east is based on only thirteen species, Figure 4). There is less concordance between different indices over the shorter time-span covered by the BBS index, particularly in the north-east (where the data are poorest). One particularly interesting development of a BBS-based indicator would be the use of the habitat recorded during the survey to index populations of species occurring in specific habitats. For woodland species, this index (BBS-C) is not particularly similar to the index based on all habitats (BBS) suggesting there may be different population processes occurring in preferred and non-preferred habitat. Ideally, a rather longer run of data would be required.

A major benefit of the BBS is the ability to assign counts to habitats at either square level (by looking only at squares with more than a certain amount of a given habitat) or in finer detail (by considering counts from transect sections (200m in length) of a given habitat). For greatest utility, indicators are best based on populations from specific habitats, when they are likely to give a clearer indication of the environmental conditions involved, than from an all habitats nation-wide index, which is likely to reflect many, perhaps confounding, factors. For example, the farmland CBC indicator for the south-

east (and to a lesser extent, the south-west) is almost identical to the BBS-C indicator (Figure 5), which comprises the same species, but on farmland habitat only. This is probably because farmland dominates the landscape in these two regions. In contrast, the two indicators for the north-east show very different trends, presumably reflecting processes in farmland species on non-farmland habitat (farming land being less prevalent in the north-east). Currently only indicators for farmland and woodland species are produced, although these are not tied specifically to these habitats. Use of a BBS-based indicator should make it possible to measure habitat-based processes much more closely, and to calculate indicators for other habitats, such as wetlands, uplands and urban areas – that were not covered by the CBC.

8. CONCLUSIONS AND RECOMMENDATIONS

It is possible to generate regional wild bird indicators, derived largely from the CBC and BBS, which incorporate the majority of species included in the national headline indicator. Due to differences in distribution and sparse data for uncommon species in some regions, the derived regional indicators will necessarily include a smaller number of species, with the north-east performing poorest in this regard. The exclusion of species due to poor data is likely to change over time, and some thought needs to given to do this in a sufficiently flexible manner, for future development of the indices.

The utility of regional indicators is highlighted by the regional differences in the trends reported here. Populations in the north-east of England appear to be declining to a lesser extent, but populations in the south-west have undergone severe and sustained declines. The causes of these declines should be investigated as a matter of priority.

Indicators based on a subset of approximately 20-25 widespread species common to all regions can be produced. This would enable a straightforward comparison of trends between regions, but is rather restrictive in terms of the number of species included, particularly when all nine RDAs are considered.

An additional indicator, based on scarce species (which are often restricted to particular regions) should be developed to highlight regional conservation priorities.

It may be possible in the future to analyse datasets to generate estimates of the precision of multiple-species indicators, although confidence intervals are likely to be very broad for other than a subset of widespread and common species. Such measures should be considered to enable the development of criteria that could, reliably, trigger necessary action. This may be possible only for some indicators, e.g. farmland birds.

Estimates based on extrapolated changes in distribution from the atlas data are unreliable for current indexing and should be avoided where possible. Using a BBS-based indicator minimises the number of species for which atlas data must be used, and with additional recent or current special surveys, better data should become available for some of these species (e.g. Hen Harrier, Capercaillie, Barn Owl).

Habitat-based indicators are readily produced and are more useful than all-species all-habitats indicators because they reflect changes in a particular habitat. These should be developed in two ways: by extending coverage to other habitats, *e.g.* uplands, wetlands, and by including counts only from BBS squares largely comprised of a particular habitat.

Acknowledgements

Thanks to Gavin Siriwardena, Steven Freeman, Humphrey Crick and Richard Gregory for much useful discussion, to Gavin for his contribution to the report, and to Jackie Coker and Susan Waghorn for helping to prepare the final report. This work was funded by the Royal Society for the Protection of Birds, with additional support from the South East England Development Agency (SEEDA), the Government Office for the South East (GOSE) and English Nature (EN). We are also extremely grateful to the many volunteer fieldworkers and regional organisers who collected the data for all of the schemes used here.

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Table 1 Number of Breeding Bird Survey Squares within each of the English Regional Development Authorities and the other countries for each year. Squares are only included if they are surveyed in at least two of the five years (and hence can be used for indexing purposes). Total refers to the number of plots counted at least twice in the five-year period.

	1994	**1995**	**1996**	**1997**	**1998**	**Total**
Scotland	238	274	296	297	274	359
South-west England	223	261	283	321	309	348
South-east England	227	261	273	320	308	342
Eastern England	211	250	258	295	274	319
North-west England	124	141	170	183	168	197
East Midlands	117	130	140	152	141	172
Wales	121	122	116	131	142	172
Yorkshire & Humber	87	92	107	133	129	147
West Midlands	73	86	83	124	117	134
Northern Ireland	23	17	62	68	74	81
London	34	36	43	47	48	55
North-east England	41	42	46	48	46	54
Total	1519	1712	1877	2119	2030	2380

Table 2 Summary index statistics for a range of species in each of the three sample RDA regions. For each region is given the sample size (number of BBS squares used to create the index), deviance: degrees of freedom ratio and the 95% confidence interval of the index (a mean of the four annual parameters calculated, the first being zero because the index is scaled to 1). The deviance:degrees of freedom statistic is a measure of the overdispersion, or aggregation of the data, which takes the value of 1 for data which are randomly (*i.e.* Poisson) distributed; the variances, and hence the confidence interval are inflated by this factor.

		South-East			**South-West**			**North-East**		
	Total N	**N**	**Dev:df**	**95% CI**	**N**	**Dev:df**	**95% CI**	**N**	**Dev:df**	**95% CI**
Blackbird	1572	274	92.3	0.057	274	114	0.057	33	245	0.162
Skylark	1239	197	81.9	0.075	188	89.7	0.075	35	419	0.202
Jackdaw	978	190	349	0.128	209	411	0.128	30	898	0.240
Blackcap	879	196	73.7	0.111	184	77.9	0.111	18	105	0.255
Mallard	803	125	125	0.145	119	123	0.145	13	252	0.411
Cuckoo	712	147	63.7	0.137	120	70.8	0.162	*13*	*135*	*0.387*
Meadow Pipit	520	34	34.9	0.170	35	48	0.165	27	243	0.162
Stock Dove	519	117	109	0.170	104	119	0.178	10	207	0.387
Black Head Gull	400	46	124	0.153	26	127	0.210	18	617	0.387
Nuthatch	260	85	44.5	0.145	51	34.9	0.158	*2*	*23.2*	*0.445*
Corn Bunting	145	27	18.2	0.153	*21*	*14.4*	0.145	*2*	*27.8*	*0.324*
Sand Martin	83	*7*	*33.3*	*0.283*	*6*	*12.6*	0.225	*6*	*102*	-
Tawny Owl	70	*13*	*11*	*0.255*	*11*	*13.4*	0.324	*3*	*27.1*	*0.586*
Kingfisher	56	*8*	*4.97*	*0.225*	*7*	7.6	0.255	*0*	-	-
Barn Owl	13	*1*	*0.67*	-	*1*	*1.1*	-	*0*	-	-

Note: Italics indicate species whose indices fluctuate markedly between years and sample sizes (N) are the average number of squares a species was recorded in over the 5 years.

Table 3 Number of species in each of the three sample RDAs occurring in at least the number of BBS squares given in the first column.

Sample Size	North East	South East	South West
20	27	63	65
22	23	63	65
24	19	63	65
26	15	63	60
28	13	61	59
30	12	60	57
32	9	58	56
34	7	56	56
36	5	56	53
38	3	54	53
40	3	54	53

Table 4 Number of currently surveyed Common Birds Census plots in each of the 10 mainland RDA regions. For comparison the number of CBC plots in the (more or less) equivalent RSPB regions is also given. Note blank lines are used where more than one RSPB region corresponds to a single RDA or *vice versa*.

RDA	Number	RSPB Region	Number
South-east England	83	South East	60
London	5		
South-west England	44	South West	38
Eastern England	35	East Anglia	32
North-west England	26	North-west	43
Scotland	25	East Scotland	4
		South & West Scotland	18
		North Scotland	3
Yorkshire & Humber	18	North England	28
North-east England	13		
East Midlands	17	Central England	53
West Midlands	13		
Wales	10	Wales	10
Northern Ireland	3	N Ireland	3
Total	292	**Total**	292

Table 5 Results from the BBS indexing for each region. Of the 101 species indexed by the BBS in 1998 (Noble *et al.* 1999), six species (greylag and Canada goose, red-legged partridge, pheasant, feral pigeon and little owl) are introduced so are not used for the indicators, leaving 95 species to be considered. These are included in the 'All' Index, unless the data caused problems, indicated below. Only species occurring in more than 20 squares in a given RDA region are included in the TSq index (see Figure 3).

	North-east	South-east	South-west
Species in 'All' Index	81	87	90
Species doesn't occur	1	1	0
Index didn't converge	7	4	1
Bad variance estimates	5	3	2
Variable estimates	1	0	2
Total BBS Species	95	95	95
Species in 'TSq' index	27	62	64

Table 6 Results of the CBC indexing for each region. Of the 66 species indexed by the CBC nationally, some could be indexed regionally using CBC data, others required to be indexed using atlas data (either because of convergence problems or the presence of zero index values). An additional 36 species are included in the national index using atlas data, regionally some of these could not be included because extrapolating the change indicated by the atlas data gave negative indexes or because the species did not occur in the region.

	Northeast	Southeast	Southwest
Indexed by CBC nationally	66	66	66
Regions Index CBC	38	58	52
Regions Index Atlas (poor data)	17	3	5
Regions Index Atlas (zeroes)	11	5	9
Indexed by Atlas nationally	36	36	36
Regions Index Atlas	29	25	29
Not Indexed (negative range)	2	0	1
Not Indexed (not present)	5	11	6
Total in 'CBC' Index	38	58	52
Total in 'Atlas' Index	57	33	43
Total in 'All' Index	95	91	95

Table 7 Population Indices for habitat indicator species in the south-west in 1998. Indices for all species were set to 1 in 1970, thus these indices measure population change in the period 1970-1998, *e.g.* Yellowhammer has declined by 61%. The CBC was used to index all species with sufficient data, the rest were indexed using atlas data.

Farmland Species			**Woodland Species**		
Greenfinch	CBC	3.62	Siskin	Atlas	5.20
Jackdaw	CBC	1.52	Pied Flycatcher	Atlas	1.81
Kestrel	CBC	1.05	Gt Spotted Woodpecker	CBC	1.50
Stock Dove	CBC	1.02	Nuthatch	CBC	1.38
Woodpigeon	CBC	0.98	Coal Tit	CBC	1.23
Goldfinch	CBC	0.84	Blackcap	CBC	1.16
Linnet	CBC	0.74	Great Tit	CBC	1.14
Yellow Wagtail	Atlas	0.70	Blue Tit	CBC	1.10
Lapwing	CBC	0.63	Robin	CBC	1.09
Reed Bunting	CBC	0.63	Chaffinch	CBC	1.08
Whitethroat	CBC	0.49	Wren	CBC	1.05
Grey Partridge	CBC	0.47	Green Woodpecker	CBC	1.04
Tree Sparrow	CBC	0.47	Lesser Redpoll	Atlas	0.84
Corn Bunting	CBC	0.45	Wood Warbler	Atlas	0.84
Skylark	CBC	0.45	Chiffchaff	CBC	0.73
Turtle Dove	Atlas	0.45	Treecreeper	CBC	0.70
Barn Owl	Atlas	0.43	Jay	CBC	0.69
Yellowhammer	CBC	0.39	Blackbird	CBC	0.67
Starling	CBC	0.30	Tree Pipit	Atlas	0.64
			Nightingale	Atlas	0.61
			Redstart	Atlas	0.56
			Dunnock	CBC	0.55
			Long-eared Owl	Atlas	0.52
			Garden Warbler	CBC	0.49
			Hawfinch	Atlas	0.45
			Song Thrush	CBC	0.40
			Woodcock	Atlas	0.39
			Tawny Owl	CBC	0.38
			L. Spotted Woodpecker	CBC	0.37
			Goldcrest	CBC	0.37
			Bullfinch	CBC	0.37
			Spotted Flycatcher	CBC	0.36
			Lesser Whitethroat	CBC	0.33
			Long-tailed Tit	CBC	0.33
			Willow Warbler	CBC	0.32
			Mistle Thrush	CBC	0.28
			Sparrowhawk	CBC	0.20
			Willow Tit	CBC	0.02

Figure 1 Confidence intervals for the annual index for the species listed in Table 2 in relation to the number of squares used in calculating the index. Each point represents a species and each species appears up to three times (once for each region).

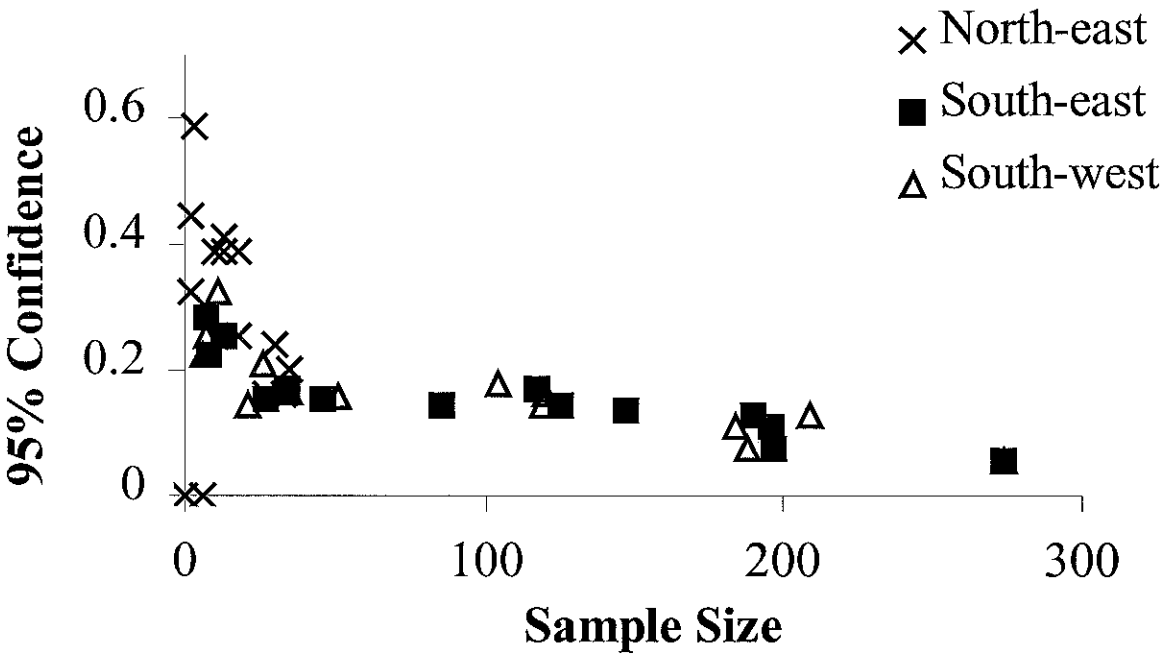
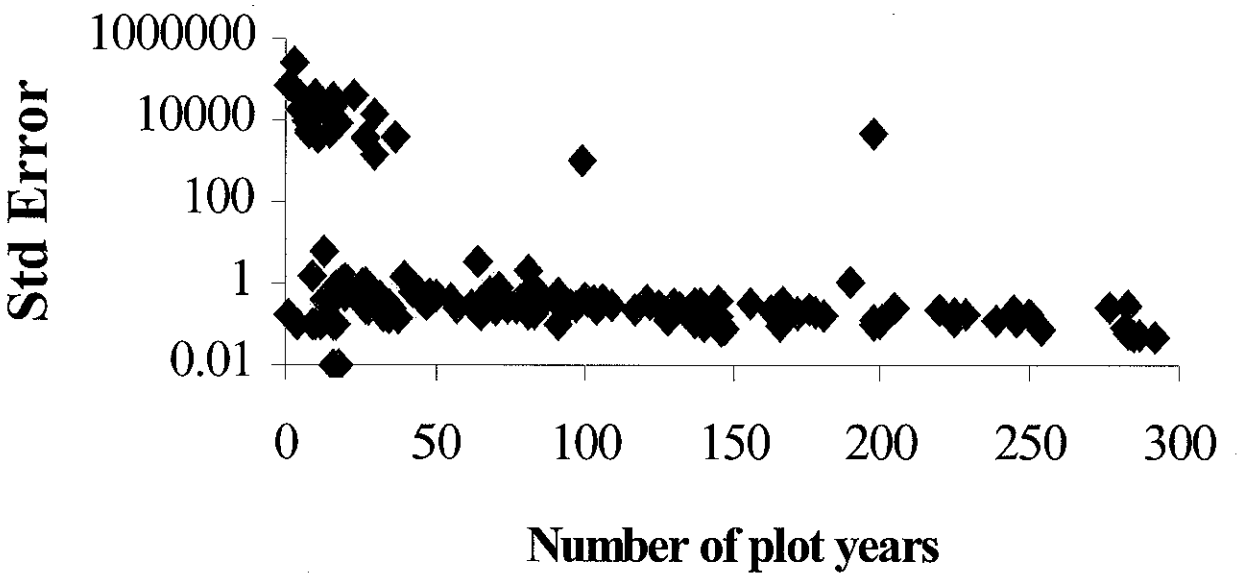


Figure 2 Relationship between standard error of the annual CBC index (averaged across the 28 years the CBC index was calculated) and the number of CBC plots used to calculate the index, for all species indexed. Note each species appears three times in each graph, once for each region. (A) All data (B) Only those species with a standard error < 10 ($y = 0.65 - 0.002x$, $R^2 = 0.09$).

(A)



(B)

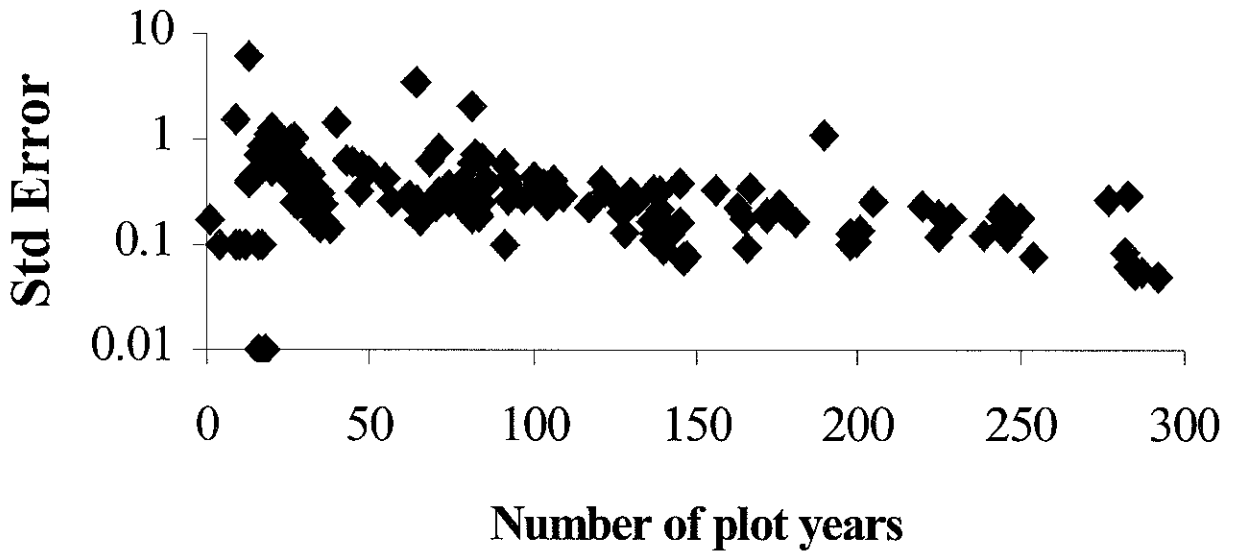
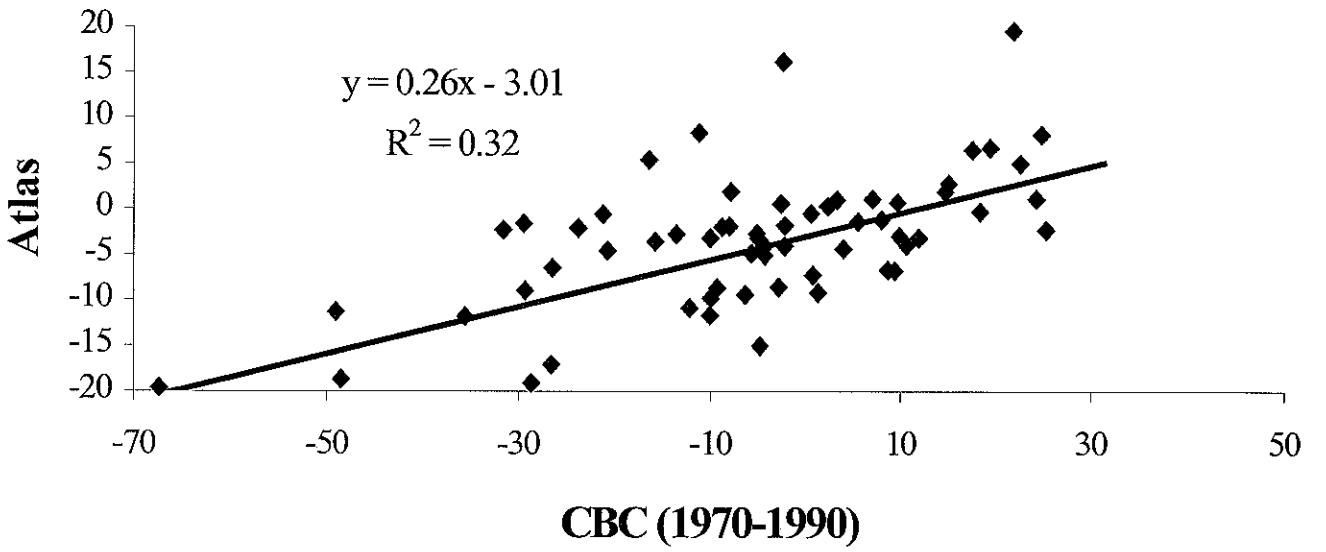


Figure 3 Relationships between change in population index and changes in range. Change in range was measured using the two breeding atlases (Sharrock 1976; Gibbons *et al.* 1993, see text). Population trend measured using (A) Common Birds Census (B) Breeding Bird Survey. Note The CBC was indexed between 1970 and 1990 to match the period covered by the atlas data (extending the period to 1998 yields essentially the same pattern).

(A)



(B)

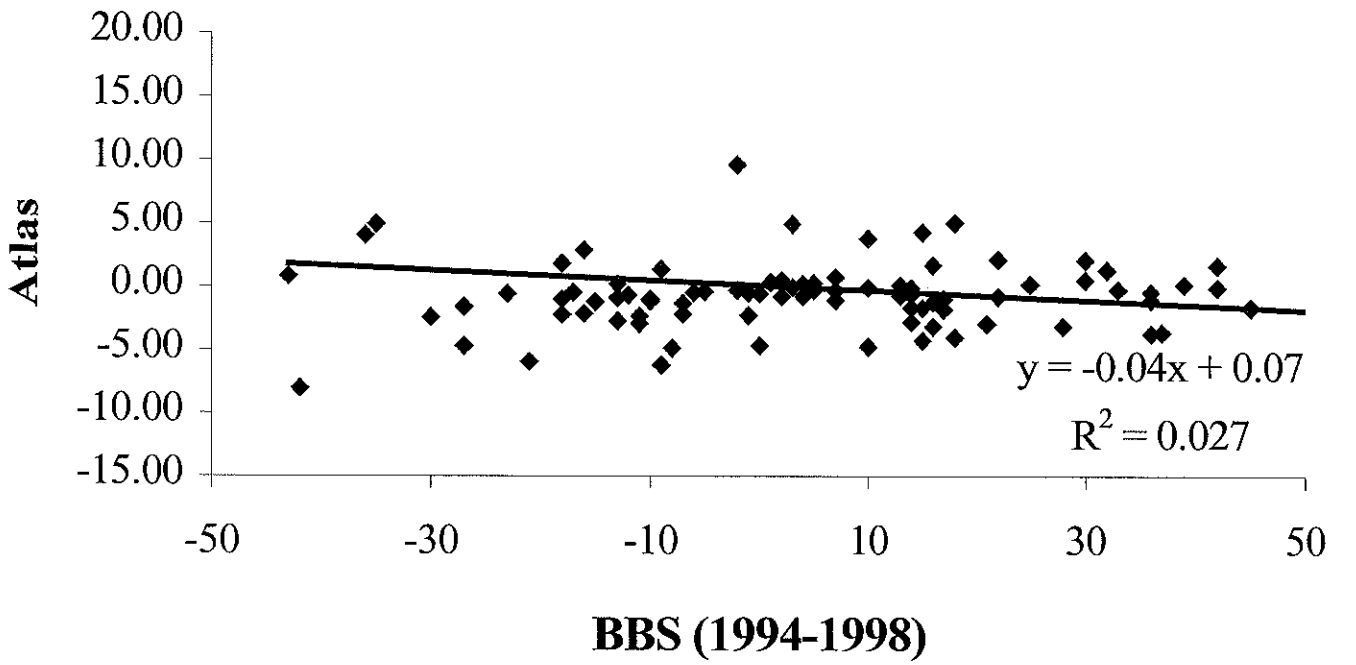


Figure 4 Regional indicators based on BBS population trends for the three sample regions. For each region three indices are given (the number of species included in each is given in the parentheses in the legend). 'All' is based on all species indexed by the BBS that could be indexed regionally (i.e. species for which there were no technical problems with the modelling procedure). 'TSq' includes those species that were present in at least twenty BBS squares in a given region. 'ATSq' includes the 25 species that were present in at least 20 BBS squares in all three sample regions. For comparison the CBC index (see Figure 5) for each region is also shown.

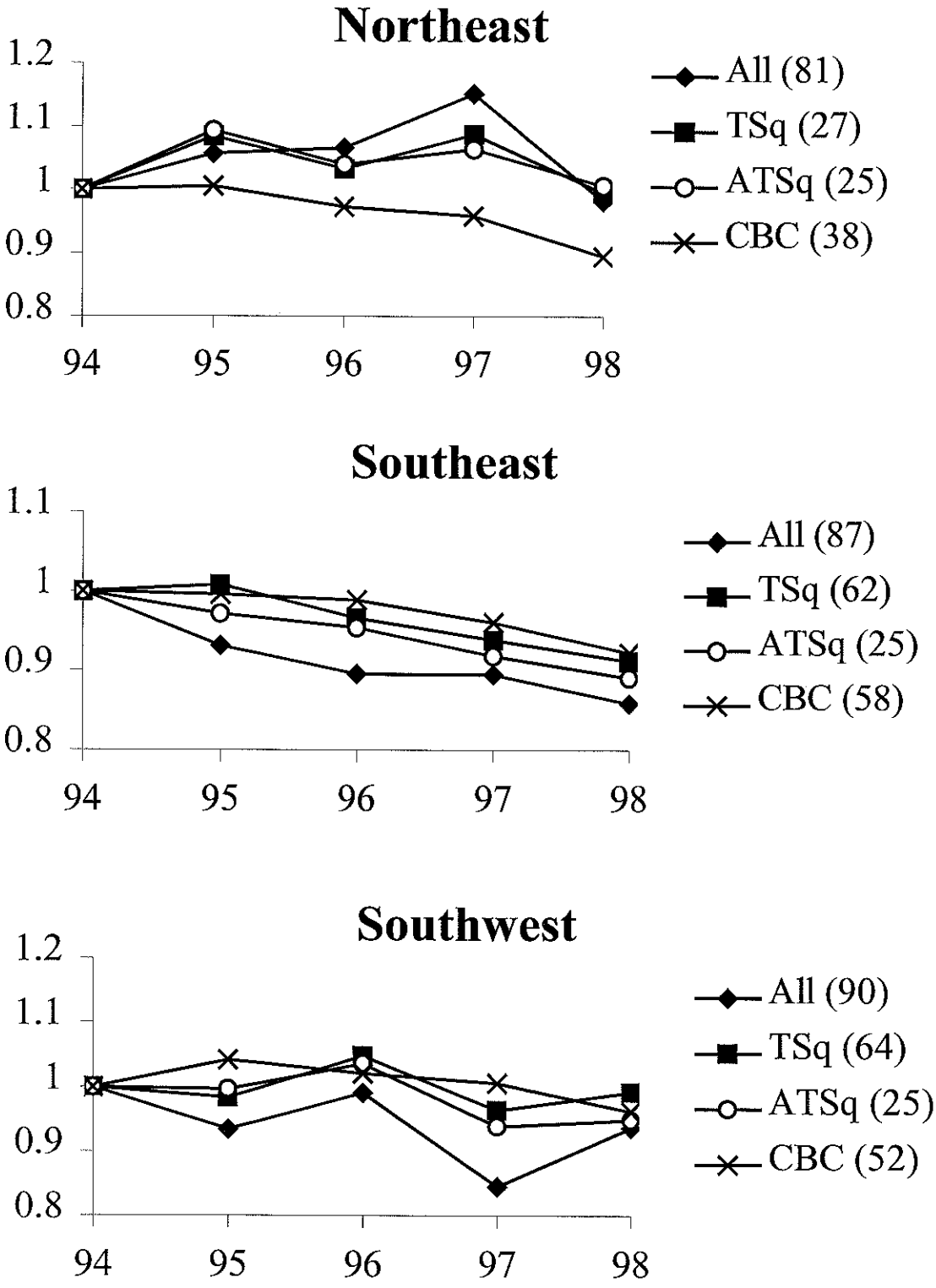
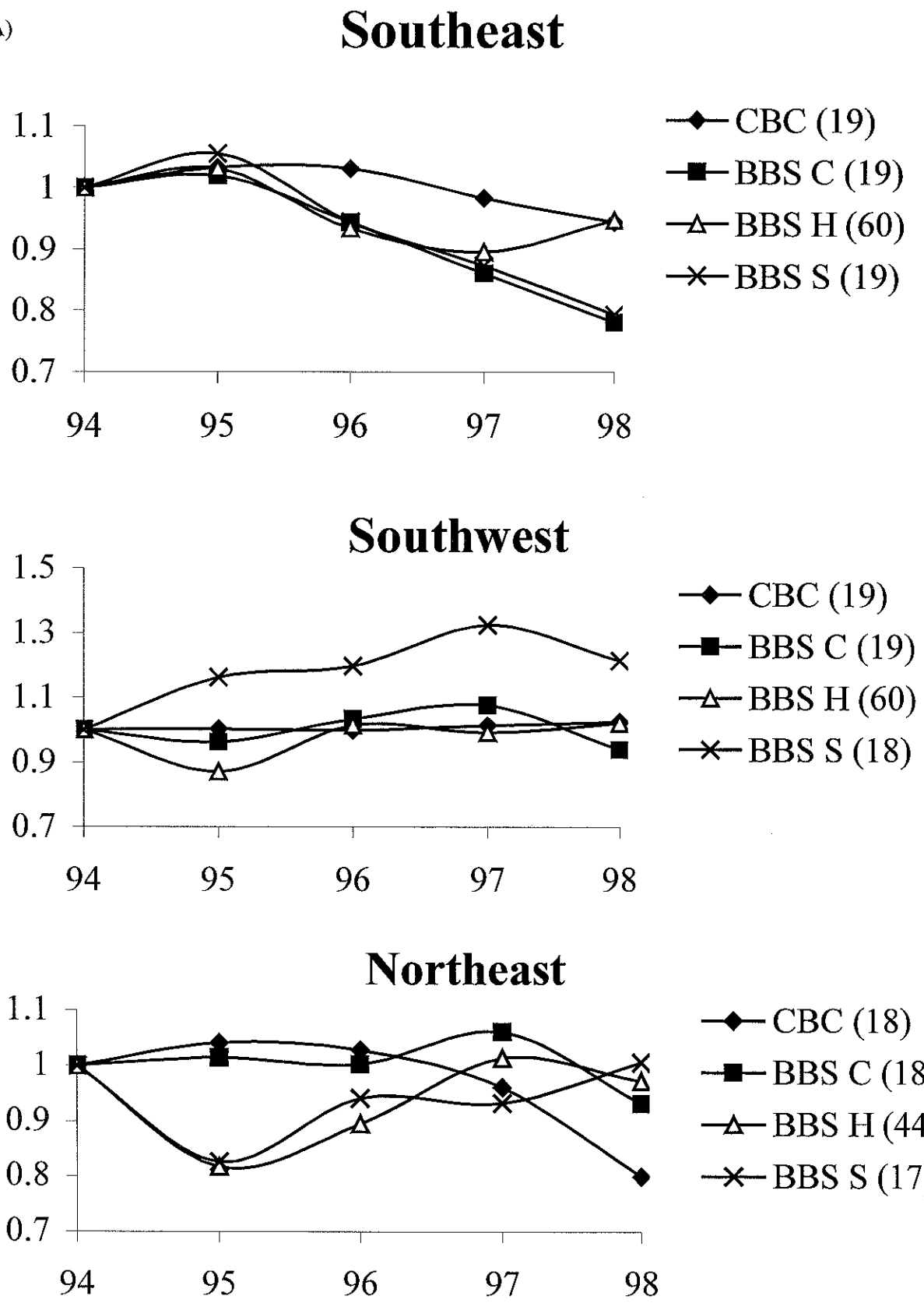
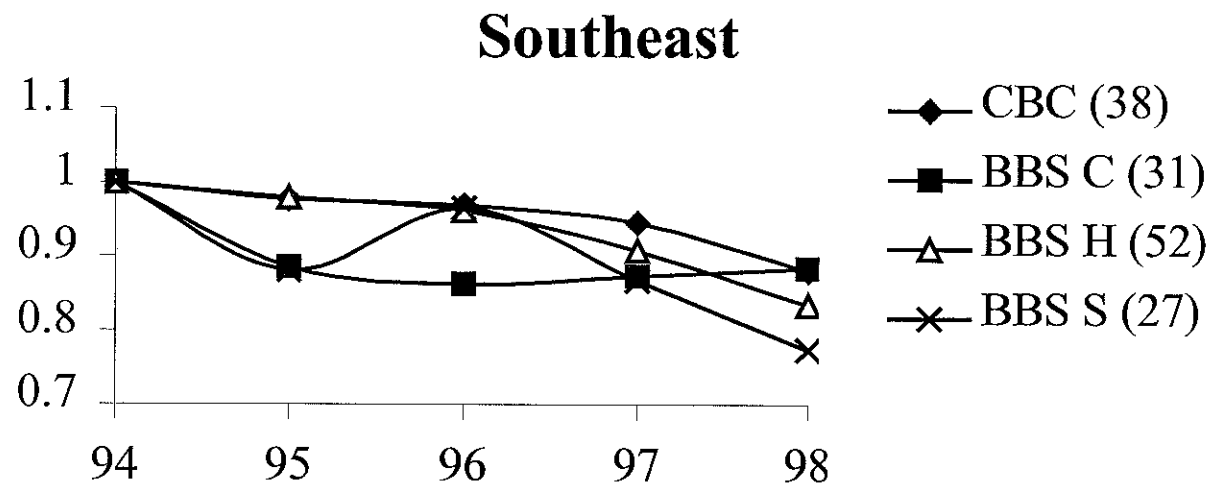


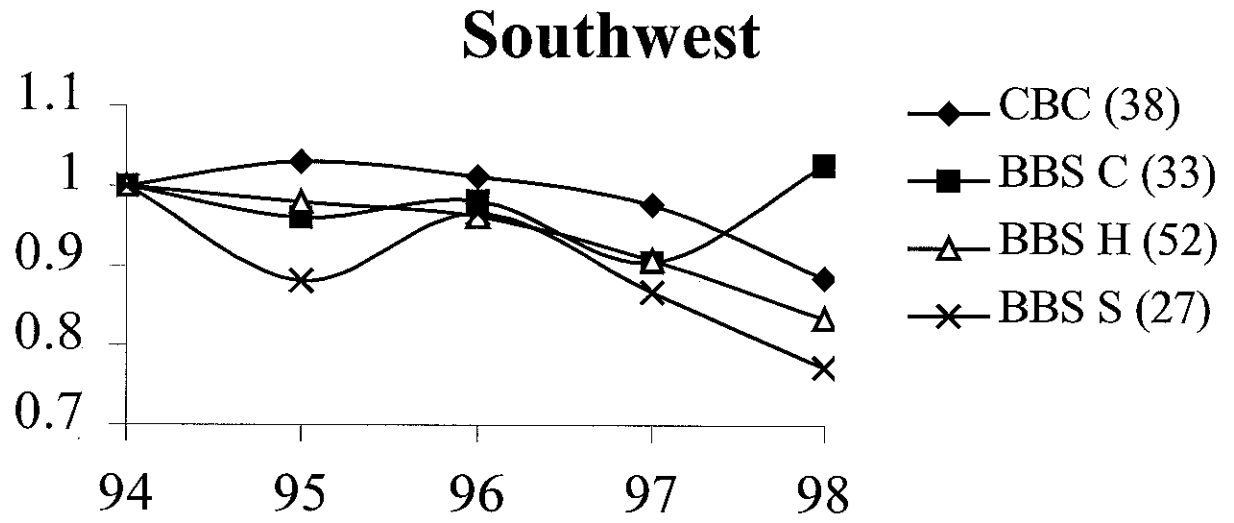
Figure 5 Habitat based indicators generated using BBS data for (A) Farmland and (B) Woodland. Number of species included in each index is indicated in parentheses. BBS C uses habitat indicator species from all habitats, BBS S uses habitat indicator species from specific transects only; BBS H uses a wider list of species from specific transects. The CBC habitat index is included for comparison, see text for details.

(A)



(B)


Southeast
1.1
1
0.9
0.8
0.7
94
95
96
97
98
CBC (38)
BBS C (31)
BBS H (52)
BBS S (27)


Southwest
1.1
1
0.9
0.8
0.7
94
95
96
97
98
CBC (38)
BBS C (33)
BBS H (52)
BBS S (27)

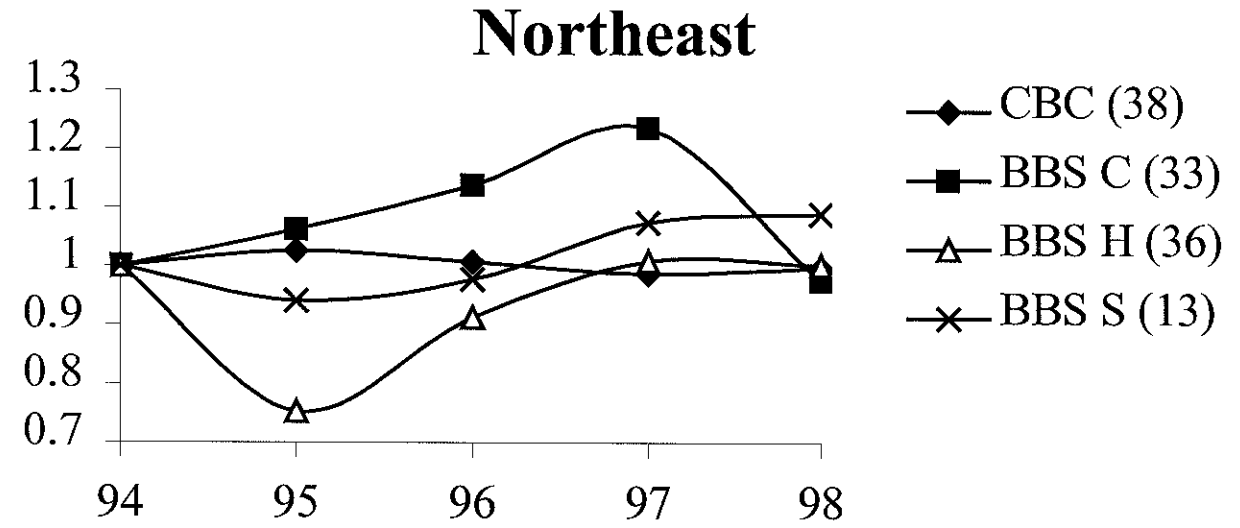

Northeast
1.3
1.2
1.1
1
0.9
0.8
0.7
94
95
96
97
98
CBC (38)
BBS C (33)
BBS H (36)
BBS S (13)

Figure 6 The influence of species indexed using atlas on the CBC regional indicators. CBC indexes species on the basis of CBC data alone ATLAS indexes on the basis of atlas data alone and the ALL index includes both groups of species. Numbers of species included in each index is given in parentheses in the legend (see Table 6).

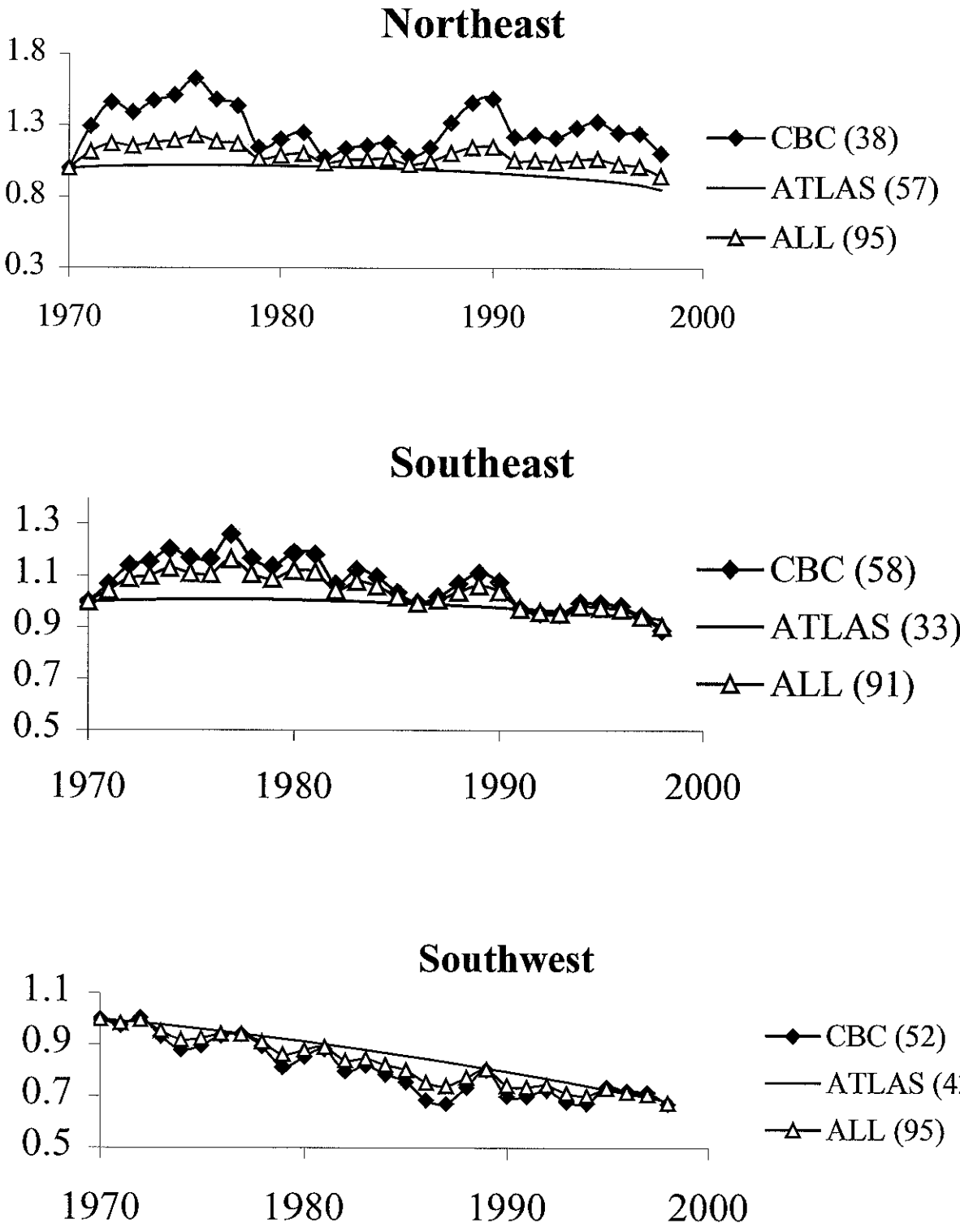
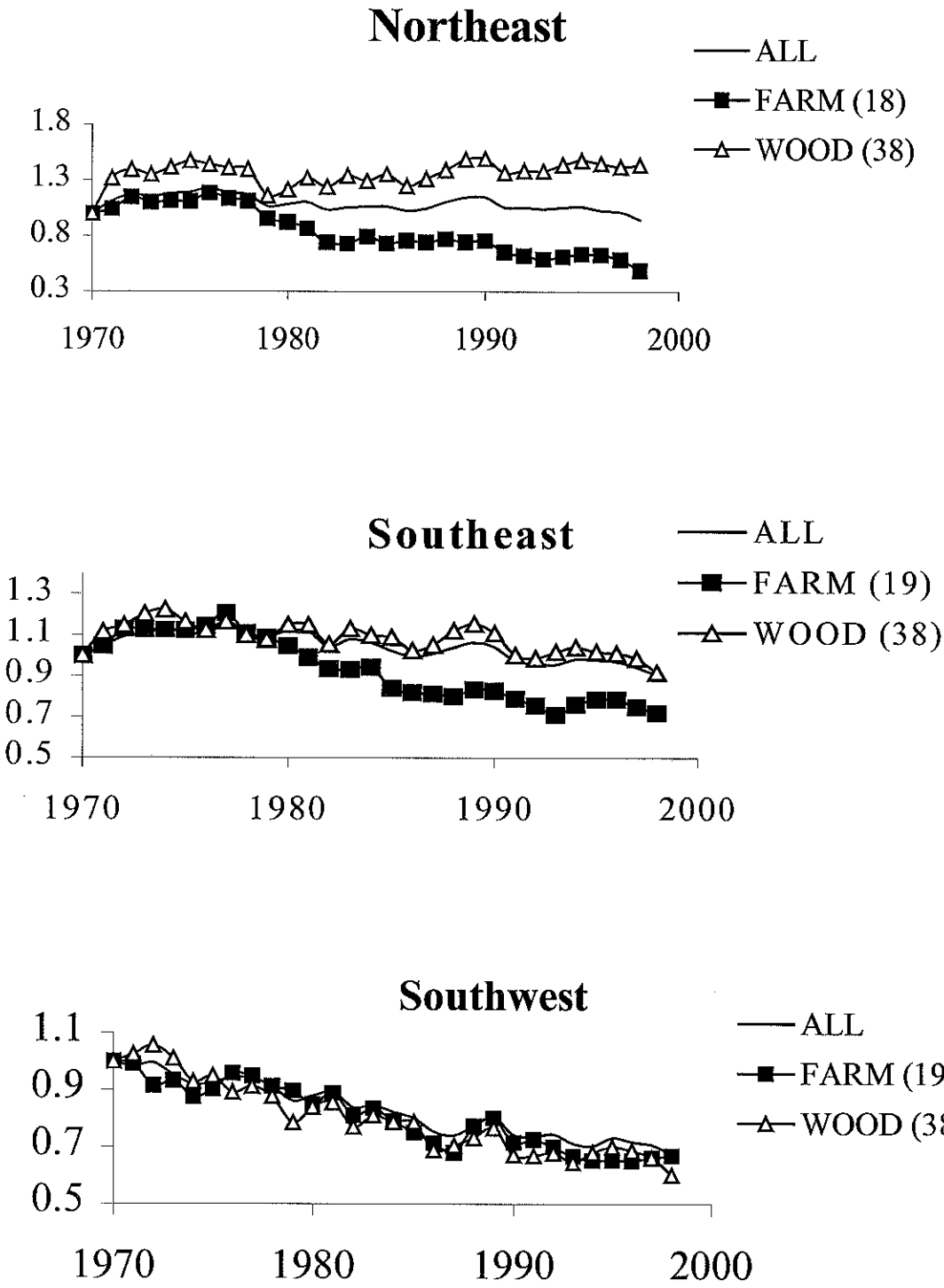


Figure 7 Habitat specific regional indicators based on CBC data. Indices are constructed from all plots of the trends in the habitat indicator species used for the national habitat indicators. Number of species contributing to the index is given in parentheses in the legend (see Appendix 2).



Appendix 1

List of species included in national headline indicator, and their inclusion in CBC-based and BBS-based regional indicators. Codes for CBC refer to index methodology (census or atlas based), species in italics are generally censused by special surveys (which were beyond the scope of this report), codes for BBS to presence in the index (see footnotes).

Species	CBC-based indicator				BBS-based indicator			
	National	SE	SW	NE	National	NE	SE	SW
Little Grebe	A	A	A	A				
Great-crested Grebe	S				X	nc	X	X
Gannet	M							
Fulmar	M							
Cormorant	M				X	nc	X	20
Shag	M							
Grey Heron	S				X	X	20	20
Greylag Goose	S							
Mute Swan	E				X	var	20	20
Gadwall	S							
Teal	A	A	A	A				
Mallard	C	C	C	C	X	X	20	20
Shoveller	A	A	A	A				
Tufted Duck	A	A	A	A	X	X	X	X
Shelduck	S				X	var	X	X
Eider	S							
Red Breasted Merganser	E							
Goosander	E							
Hen Harrier	A	-	A	A				
Sparrowhawk	C	Az	C	Az	X	X	20	20
Buzzard	C	Ad	C	Ad	X	nc	X	20
Kestrel	C	C	C	Az	X	X	20	20
Peregrine	S							
Red Grouse	S				X	X	var	var
Ptarmigan	A	-	-	-				
Black Grouse	A	-	(A-)	A				
Capercaillie	A	-	-	-				
Grey Partridge	C	C	Az	C	X	X	20	X
Water Rail	A	A	A	A				
Moorhen	C	C	C	C	X	X	20	20
Coot	C	C	C	Ad	X	nc	20	20
Oystercatcher	A	A	A	A	X	X	X	X
Golden Plover	A	-	A	A	X	X	nc	var
Little Ringed Plover	S							
Ringed Plover	A	A	A	A				
Dotterel	A	-	-	(A-)				

Species	CBC-based indicator				BBS-based indicator			
	National	SE	SW	NE	National	NE	SE	SW
Lapwing	C	C	Az	C	X	C	C	C
Snipe	A	A	A	A	X	20	X	X
Woodcock	C	C	Ad	Az				
Curlew	C	Ad	Ad	C	X	20	X	X
Greenshank	A	-	-	-				
Redshank	A	A	A	A	X	X	X	X
Whimbrel	S							
Common Sandpiper	W				X	nc	X	X
Arctic Skua	S							
Great Skua	S							
Black-headed Gull	M				X	X	20	20
Common Gull	M				X	X	X	Vest
Herring Gull	M				X	X	20	20
Great Black-backed Gull	M				X	X	var	X
Lesser Black-backed Gull	M				X	X	X	20
Kittiwake	M							
Sandwich Tern	M							
Common Tern	M							
Arctic Tern	M							
Little Tern	M							
Guillemot	M							
Stock Dove	C	C	C	Ad	X	X	20	20
Woodpigeon	C	C	C	Ad	X	C	C	C
Collared Dove	C	C	C	C	X	X	20	20
Turtle Dove	C	C	Az	Ad	X	var	20	X
Cuckoo	C	C	C	Az	X	X	20	20
Barn Owl	A	A	A	(A-)				
Tawny Owl	C	C	C	Az	X	X	X	X
Long eared Owl	A	A	A	A	X			
Short-eared Owl	A	A	A	A				
Swift	A	A	A	A	X	X	20	20
Kingfisher	W							
Green Woodpecker	C	Ad	C	Ad	X	X	20	20
Great Spotted Woodpecker	C	C	C	Az	X	X	20	20
Lesser Spotted Woodpecker	C	C	Ad	Ad				
Skylark	C	C	C	C	X	C	C	C
Woodlark	S							
Sand Martin	A	A	A	A	X	Vest	X	X
Swallow	C	C	C	C	X	C	C	C
House Martin					X	X	20	20
Tree Pipit	C	Az	Az	Az	X	X	X	X
Meadow Pipit	C	C	Az	C	X	C	C	C

Species	CBC-based indicator				BBS-based indicator			
	National	SE	SW	NE	National	NE	SE	SW
Rock Pipit	A	A	A	A				
Yellow Wagtail	C	C	Az	Ad	X	X	20	X
Grey Wagtail	W				X	X	X	20
Pied Wagtail	C	C	C	C	X	C	C	C
Dipper	W							
Wren	C	C	C	C	X	C	C	C
Dunnock	C	C	C	C	X	C	C	C
Robin	C	C	C	C	X	C	C	C
Nightingale	A	A	A	-				
Redstart	C	C	Az	Az	X	nc	nc	X
Whinchat	A	A	A	A	X	X	X	X
Stonechat	A	A	A	A	X	var	X	X
Wheatear	A	A	A	A	X	X	X	X
Ring Ouzel	A	-	A	A				
Blackbird	C	C	C	C	X	C	C	C
Song Thrush	C	C	C	C	X	C	C	C
Mistle Thrush	C	C	C	C	X	C	C	C
Grasshopper Warbler	A	A	A	A	X	X	X	nc
Sedge Warbler	C	C	C	Ad	X	X	20	20
Reed Warbler	C	C	C	Ad	X	var	X	X
Dartford Warbler	S							
Lesser Whitethroat	C	C	C	Ad	X	X	20	20
Whitethroat	C	C	C	C	X	X	20	20
Garden Warbler	C	C	C	C	X	X	20	20
Blackcap	C	C	C	C	X	X	20	20
Wood Warbler	A	A	A	A	X	X	-	X
Willow Warbler	C	C	C	C	X	C	C	C
Chiffchaff	C	C	C	Ad	X	X	20	20
Goldcrest	C	C	C	C	X	X	20	20
Spotted Flycatcher	C	C	C	C	X	X	20	20
Pied Flycatcher	A	A	A	A	X	-	nc	X
Marsh Tit	C	C	C	Az	X	X	20	20
Willow Tit	C	Az	C	Az	X	X	X	X
Crested Tit	A	-	-	-				
Coal Tit	C	C	C	C	X	C	C	C
Blue Tit	C	C	C	C	X	C	C	C
Great Tit	C	C	C	C	X	C	C	C
Long-tailed Tit	C	C	C	C	X	X	20	20
Nuthatch	C	C	C	Ad	X	X	20	20
Treecreeper	C	C	C	C	X	X	20	20
Jay	C	C	C	Ad	X	X	20	20
Magpie	C	C	C	C	X	X	20	20

Species	CBC-based indicator				BBS-based indicator			
	National	SE	SW	NE	National	NE	SE	SW
Jackdaw	C	C	C	C	X	C	C	C
Rook	S				X	C	C	C
Carrion Crow	C	C	C	C	X	C	C	C
Raven	A	A	A	A	X	nc	nc	20
Starling	C	C	C	C	X	C	C	C
House Sparrow	C	C	Az	Ad	X	X	20	20
Tree Sparrow	C	Az	Az	C	X	X	X	X
Chaffinch	C	C	C	C	X	C	C	C
Greenfinch	C	C	C	C	X	C	C	C
Goldfinch	C	C	C	Ad	X	C	C	C
Siskin	A	A	A	A	X	X	X	X
Linnet	C	C	C	C	X	C	C	C
Twite	A	-	-	A				
Lesser Redpoll	C	Az	Ad	Az	X	X	X	X
Crossbill	A	-	A	A	X	X	var	Vest
Bullfinch	C	C	C	C	X	X	20	20
Hawfinch	A	A	A	A				
Yellowhammer	C	C	C	C	X	C	C	C
Reed Bunting	C	C	C	C	X	X	20	20
Corn Bunting	C	C	Ad	Ad	X	X	20	20
Total Species	139	91	95	95	95	81	87	90

CBC-based indicator: C – Census; A – Atlas; Ad – Atlas (because poor census data); Az – Atlas (because zero estimate in ≥ 1 year); (A-) – Atlas, but negative range estimate prevented inclusion; E - WeBS count; M – Seabird Monitoring Project; S – Special Survey; W – Waterways Bird Survey; '-' – Species not Present.

BBS-based indicator: X – Species indexed; 20 – Occurs in at least 20 squares; C – Occurs in at least 20 squares in all regions; nc – Index did not converge; var – bad variance estimates; Vest – Variable estimates.

Appendix 2

Inclusion of species in farmland and woodland indices

FARMLAND	CBC-based indicator				BBS-based indicator		
Species	All	SE	SW	NE	NE	SE	SW
Sparrowhawk						H	H
Buzzard						H	H
Kestrel	C	C	C	A	CHS	CHS	CHS
Grey Partridge	C	C	A	C	CHS	CHS	CHS
Lapwing	C	C	A	C	CHS	CHS	CHS
Snipe					H		
Black-headed Gull					H	H	H
Common Gull						H	
Herring Gull					H	H	H
Great Black-backed Gull							H
Lesser Black-backed Gull						H	H
Collared Dove					H	H	H
Stock Dove	C	C	C	A	CHS	CHS	CHS
Turtle Dove	C	C	A	A		CHS	C
Woodpigeon	C	C	C	A	CHS	CHS	CHS
Cuckoo					H	H	H
Barn Owl	C	A	A	A			
Swift					H	H	H
Skylark	C	C	C	C	CHS	CHS	CHS
Swallow					H	H	H
House Martin					H	H	H
Meadow Pipit					H	H	H
Grey Wagtail						H	H
Pied Wagtail					H	H	H
Yellow Wagtail	C	C	A	A	C	CHS	CHS
Wren					H	H	H
Dunnock					H	H	H
Robin					H	H	H
Wheatear					H	H	H
Blackbird					H	H	H
Mistle Thrush					H	H	H
Song Thrush					H	H	H
Sedge Warbler					H	H	H
Lesser Whitethroat						H	H
Garden Warbler						H	H
Whitethroat	C	C	C	C	CHS	CHS	CHS
Blackcap					H	H	H
Willow Warbler					H	H	H

FARMLAND	CBC-based indicator				BBS-based indicator		
Species	All	SE	SW	NE	NE	SE	SW
Chiffchaff						H	H
Goldcrest						H	H
Spotted Flycatcher						H	H
Willow Tit							H
Marsh Tit						H	H
Coal Tit					H	H	H
Blue Tit					H	H	H
Great Tit					H	H	H
Long-tailed Tit						H	H
Jay						H	H
Magpie					H	H	H
Jackdaw	C	C	C	C	CHS	CHS	CHS
Rook	S				CHS	CHS	CHS
Carrion Crow					H	H	H
Raven							H
Starling	C	C	C	C	CHS	CHS	CHS
House Sparrow					H	H	H
Tree Sparrow	C	A	A	A	CHS	CHS	CHS
Chaffinch					H	H	H
Greenfinch	C	C	C	C	CHS	CHS	CHS
Goldfinch	C	C	C	A	CHS	CHS	CHS
Linnet	C	C	C	C	CHS	CHS	CHS
Lesser Redpoll						H	
Bullfinch						H	H
Yellowhammer	C	C	C	C	CHS	CHS	CHS
Corn Bunting	C	C	A	A	CHS	CHS	CHS
Reed Bunting	C	C	C	C	CHS	CHS	CHS
Total Species	20	19	19	19	44	60	60

Codes for CBC-based indicator: C – included as CBC data; A – included as atlas data; S – indexed by special survey.
Codes for BBS-based indicator: C – habitat indicator species in all transects (BBS C); H – wider species list in transects of given habitat only (BBS H); S – Habitat indicator species in transects of given habitat only (BBS S).

WOODLAND	CBC-based indicator				BBS-based indicator		
Species	All	SE	SW	NE	NE	SE	SW
Sparrowhawk	C	A	C	A	C	CHS	CHS
Buzzard						H	H
Kestrel					H	H	H
Capercaillie	A	-	-	-			
Woodcock	C	C	A	A	C		
Collared Dove					H	H	H
Stock Dove					H	H	H
Turtle Dove						H	H
Woodpigeon					H	H	H
Cuckoo					H	H	H
Long-eared Owl	A	A	A	A			
Tawny Owl	C	C	C	A	C	CHS	CHS
Swift					H	H	H
Green Woodpecker	C	C	C	A	C	CHS	CHS
Great Spotted Woodpecker	C	A	A	A	CHS	CHS	CHS
Lesser Spotted Woodpecker	C	C	A	A			
Swallow					H	H	H
House Martin					H	H	H
Tree Pipit	C	A	A	A	C	C	C
Wren	C	C	C	C	CHS	CHS	CHS
Dunnock	C	C	C	C	CHS	CHS	CHS
Robin	C	C	C	C	CHS	CHS	CHS
Nightingale	A	A	A	-	C	C	
Redstart	C	C	A	A	CHS	C	C
Blackbird	C	C	C	C	CHS	CHS	CHS
Mistle Thrush					H	H	H
Song Thrush	C	C	C	C	CHS	CHS	CHS
Sedge Warbler					H	H	H
Lesser Whitethroat	C	C	C	A	C	CHS	CHS
Whitethroat					H	H	H
Garden Warbler	C	C	C	C	C	CHS	CHS
Blackcap	C	C	C	C	CHS	CHS	CHS
Wood Warbler	A	A	A	A	C		C
Willow Warbler	C	C	C	C	CHS	CHS	CHS
Chiffchaff	C	C	C	A	C	CH	CHS
Goldcrest	C	C	C	C	C	CHS	CHS
Pied Flycatcher	A	A	A	A	C	C	C
Spotted Flycatcher	C	C	C	C	C	CHS	CHS
Blue Tit	C	C	C	C	CHS	CHS	CHS
Crested Tit	A	-	-	-			
Coal Tit	C	C	C	C	CHS	CHS	CHS

WOODLAND	CBC-based indicator				BBS-based indicator		
Species	All	SE	SW	NE	NE	SE	SW
Great Tit	C	C	C	C	CHS	CHS	CHS
Marsh Tit	C	C	C	A	C	CHS	CHS
Willow Tit	C	A	C	A	C	C	C
Long-tailed Tit	C	C	C	C	C	CHS	CHS
Nuthatch	C	C	C	A	C	CHS	CHS
Treecreeper	C	C	C	C	C	CHS	CHS
Jay	C	C	C	A	C	CHS	CHS
Magpie					H	H	H
Jackdaw					H	H	H
Rook					H	H	H
Carrion Crow					H	H	H
Starling					H	H	H
House Sparrow					H	H	H
Tree Sparrow					H	H	H
Chaffinch	C	C	C	C	CHS	CHS	CHS
Greenfinch					H	H	H
Goldfinch					H	H	H
Siskin	A	A	A	A	C	C	C
Linnet					H	H	H
Lesser Redpoll	C	A	A	A		CHS	CHS
Crossbill	A	-	-	A			
Bullfinch	C	C	C	C	C	CHS	CHS
Hawfinch	A	A	A	A			
Yellowhammer					H	H	H
Reed Bunting					H	H	H
Total Species	41	38	38	38	56	58	58