**BTO Research Report No. 251**

# Statistical analysis of an indicator of population trends in farmland birds

S N Freeman, S R Baillie & R D Gregory

A joint report by BTO and RSPB to the
Ministry of Agriculture, Fisheries and Food

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## 1. EXECUTIVE SUMMARY

1. Methods for the statistical analysis of trends in a farmland bird indicator are developed in order to enable MAFF to make a more effective assessment of whether they are progressing towards their target of reversing the declines in farmland bird populations by 2020.

2. The indicator analysed here is based on 18 of the 20 farmland species included in an indicator published by DETR. Suitable data were not available for Rook and Barn Owl.

3. A smoothed indicator is produced by fitting generalized additive models to the individual species trends and then taking the geometric means of the resulting annual indices. Smoothing removes short-term fluctuations due to weather effects and sampling error.

4. The last point in such a time series is often a poor estimate, as can be demonstrated by comparing values of the indicator for the final year of a time series with those obtained for the same year once further years of data have been added into the analyses (Figure 3). We therefore recommend that the final estimate from any time series should not be used to assess the performance of farmland bird populations.

5. Confidence limits for the smoothed indicator and other statistics were calculated using a bootstrapping technique which avoids restrictive assumptions about the underlying distribution of the data. The indicator was measured with a high level of precision (Figure 5).

6. Estimates of rates of change of the smoothed indicator and their 95% confidence intervals provide a straightforward means of assessing trends in the indicator (Figure 4b).

7. An objective method of identifying turning points in the indicator is also presented. This will allow changes in the rate of change to be identified, and will thus provide a further aid to interpreting changes in the indicator.

8. The sensitivity of the indicator to individual species trends was examined. The indicator changed most when either Tree Sparrow or Whitethroat was omitted, dependent to a degree upon which year was chosen as a baseline for comparison. However, the indicator was not particularly sensitive to the omission of any of the 18 species used, despite the inclusion of species showing a wide range of population trends.

9. The Common Birds Census (CBC) will be replaced by the BTO/JNCC/RSPB Breeding Bird Survey (BBS) from 2001. CBC and BBS have both been operated between 1994 and 2000 providing 7 years of overlap between the two schemes. Methods of producing long-term population trends based on combining data from the two schemes are now being developed by the BBS partnership. Provided that this work is successful it will be straightforward to apply the techniques presented here to such a combined index.

## 2. INTRODUCTION

MAFF have adopted a target to reverse the long term decline in farmland birds by 2020, as measured annually against underlying trends. They have planned that this should be assessed using the headline farmland bird indicator produced by RSPB and BTO and published annually by DETR. The aim of this study was to develop statistical techniques that would provide MAFF with a more formal statistical analysis of trends in an indicator and hence allow them to make a more effective assessment of whether they were meeting their target.

We discuss the use of British Trust for Ornithology (BTO) census data to produce an indicator based on 18 common farmland species. These species are listed in an appendix to the report. Many of these species are declining and of great conservation concern. Census data used are taken from the Common Birds Census (CBC), which has provided the most important information on common terrestrial bird numbers (Marchant *et al*. 1990) for almost 40 years. CBC sites are selected by the volunteer observers themselves and not randomly distributed throughout the country, but the data are believed to be typical of lowland agricultural Britain (Fuller *et al*., 1985).

The government's headline farmland indicator includes data on two additional species, barn owl and rook, based on the extrapolation of regression models for the limited historical data available (Gregory *et al*. 1999). This procedure does not produce data that can be analysed using the rigorous statistical techniques used for this study (see also Zar, 1999, p.331, for discussion on the subject of extrapolation). As reliable, up-to-date annual data for these two species are not available they cannot be included in the analyses of this report, and to avoid bias these species are omitted. The prospects for including Rook and Barn Owl in future work are addressed in section 4.2.

Trends for individual species are developed using techniques developed by the BTO and annual species indices are combined into geometric means which are taken as the annual indicator values. Single-species models employed are from the Generalized Additive Model family (Hastie & Tshibirani, 1990), which calculate annual indices while controlling for the fact that the various CBC sites are not visited every year and tend to be widely variable in the numbers of territories held by any particular species. Annual site counts are assumed to follow a poisson distribution, and the resulting time-series of estimated annual counts used as an index of abundance for the species. This index can either be calculated without any imposed degree of smoothing (which amounts, in fact, to a Generalized Linear Model in which each annual index value is a free parameter), or under a built-in smoothing algorithm where the extent of smoothing is determined by the number of degrees of freedom set by the user. Here we shall use as the number of degrees of freedom n/3 (rounded to take an integer value), where n is the number of years in the survey. This procedure performed well in single species analyses (Siriwardena *et al.* 1998, Fewster *et al.* 2000), as it removes much of the noise from the time series yet is flexible enough to capture important population changes accurately.

The CBC has been active since 1962; here however we restrict analysis to data from 1966-99, since the earlier years may have been unreliable while the survey protocol was evolving. In due course, this will be replaced by the Breeding Bird Survey (Noble *et al*., 2000). Indices are presented relative to a baseline of 100% in 1970, except where otherwise specified. Further details of the CBC and BBS are provided in Appendix 1.

We consider the following main points:

i. The selection of end-points, with the intention of minimising bias while making the maximum informative use of the available data.
ii. The precision of the indices developed.
iii. Measures of proportional changes in the index, and the rates of such change.
iv. The sensitivity of the index to individual species trends

In ii) and iii) analysis is based on a programme of bootstrapping (Efron and Tibshirani, 1986). Random selections of sites are drawn, with replacement, from the available CBC data. Appropriate models are then fitted to the data in each sample and distributions of the various statistics of interest are stored and used to establish confidence limits and test hypotheses.

## 3. ANALYTICAL RESULTS

### 3.1 Production of smoothed indicators

Annual indices of avian abundance have long been published, based on a variety of BTO surveys. Presenting series of separate estimates for each year, however, can mean that any long-term, gradual change can be obscured by general year-to-year variability. Isolated low counts, for example, may merely reflect weather conditions in a particular year, and a drop in population that is soon reversed. Many bird populations are known to fluctuate markedly from year to year in relation to winter weather conditions. Fluctuations in annual indices may also reflect sampling error, particularly for species with low populations or that occur on only a small number of plots.

For these reasons, indices are now often presented after a process of 'smoothing', which identifies enduring trends and removes much of the short-term fluctuation. Simple moving-averages are an example of this; more sophisticated methods include smoothing Mountford indices using compound running medians (Mountford 1982, Siriwardena *et al.* 1998), applied to Common Bird Census data, and most recently the adaptation of Generalized Additive Models (GAM).

It is obviously desirable also to remove the effect of short-term variability from any indicator that is derived from a range of single-species census data. This is the subject of this section. We first note that this process can be carried out in two different ways:

(a) one can either produce smooth indices for each species, in the manner described above, and combine these to produce an indicator series.
(b) one can combine the species' indices in their unsmoothed form, and apply a smoothing algorithm to the resulting series.

For computational reasons, the former approach is the easiest to adapt to the existing BTO framework, but it is important to investigate the consensus between the two.

**Figure 1. Farmland Indicator, based on unsmoothed spp. trends**

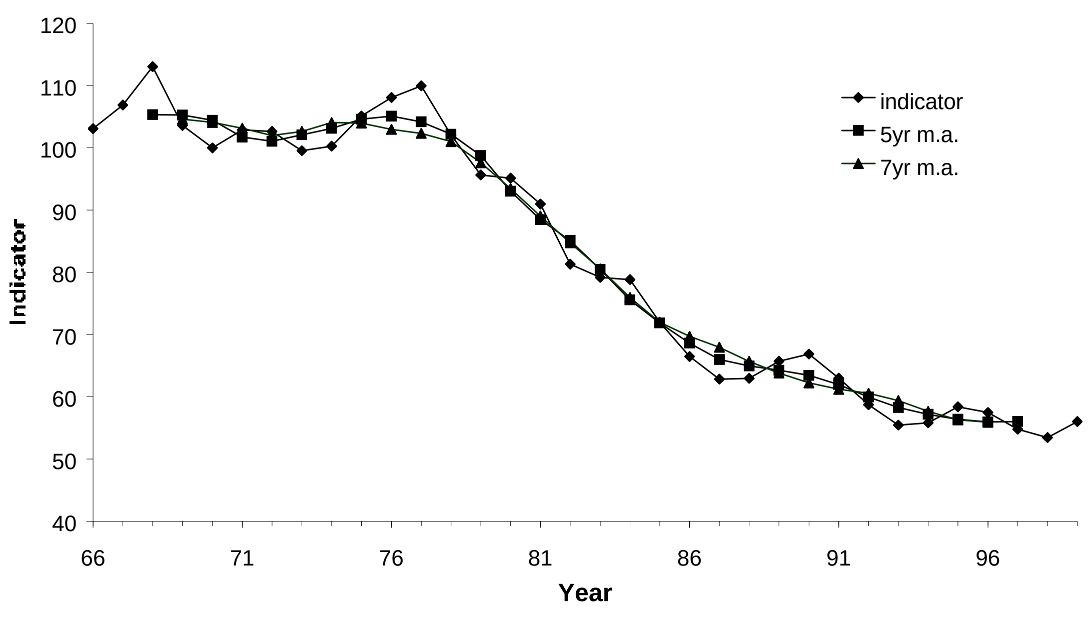



Figure 1 shows an indicator derived by combining unsmoothed data for the separate species. Evidently, along with the long-term downward trend, there is considerable year-to-year short-term variability, the influence in part of sampling error and natural factors such as weather. This is emphasised when a simple smoother, such as a simple 5 or 7 point moving average is applied.

The indicator derived using method (a) is shown in Figure 2a. It can be seen that the general appearance mimics that of Figure 1, with a period of approximate stability (1966-1978) followed by a period of decline, albeit at a slowing rate. For consistency with method (a), we also applied a GAM to the unsmoothed index of Figure 1, employing assumptions identical to those of the single-species analyses underlying Figure 2a, except that a normal distribution was assumed for the (now non-integer) data. The results, in fact, show a curve declining to 52.95% in 1999, virtually indistinguishable from that of method (a) which declines to 53.53% (Figure 2b). Hereafter all analyses are derived using method (a).

**Figure 2a. Farmland indicator, based on smoothed spp. trends**

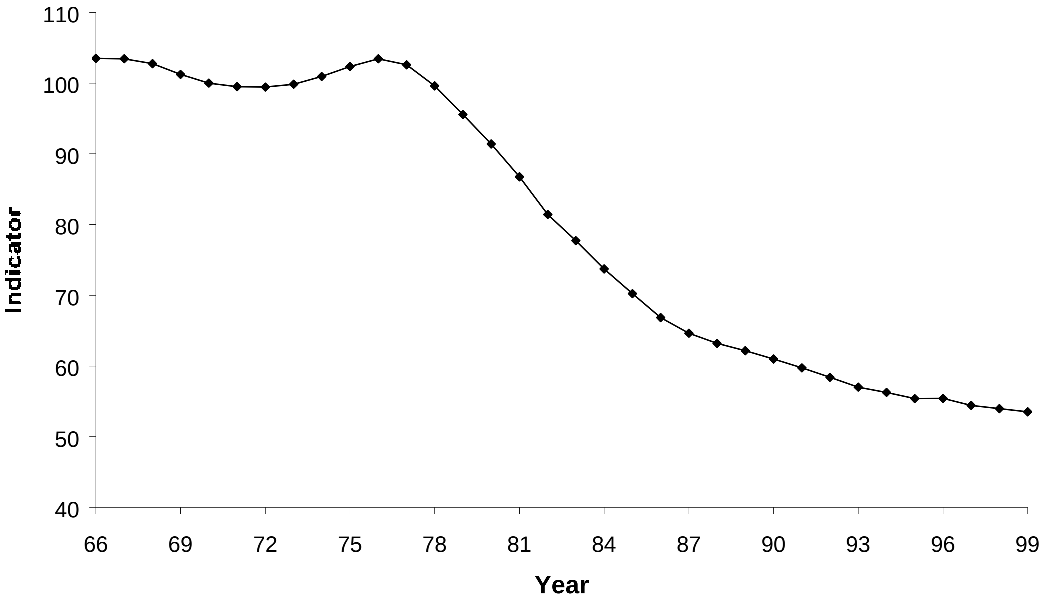
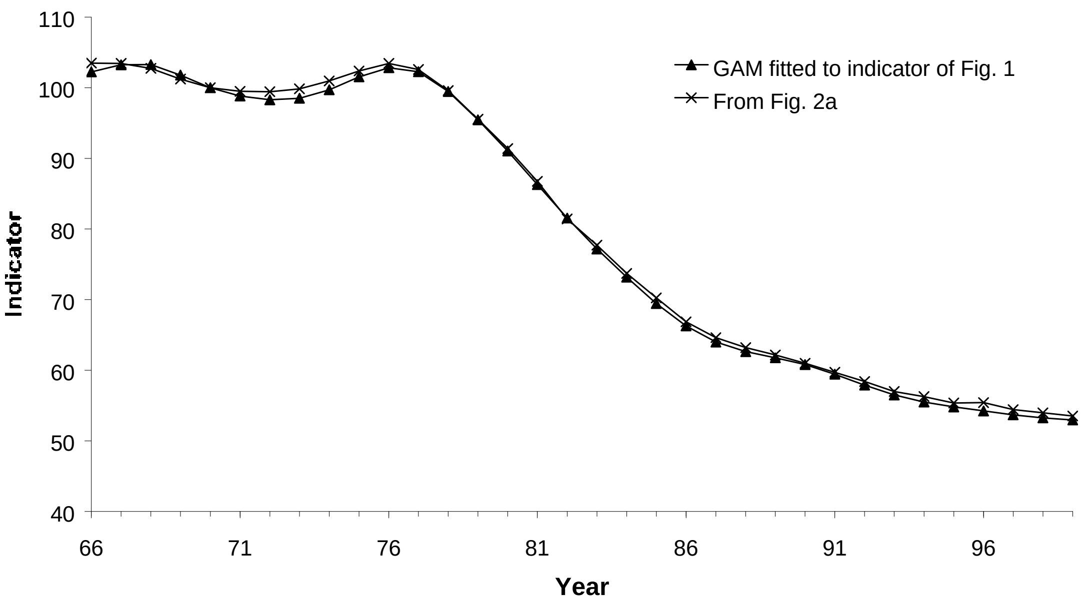


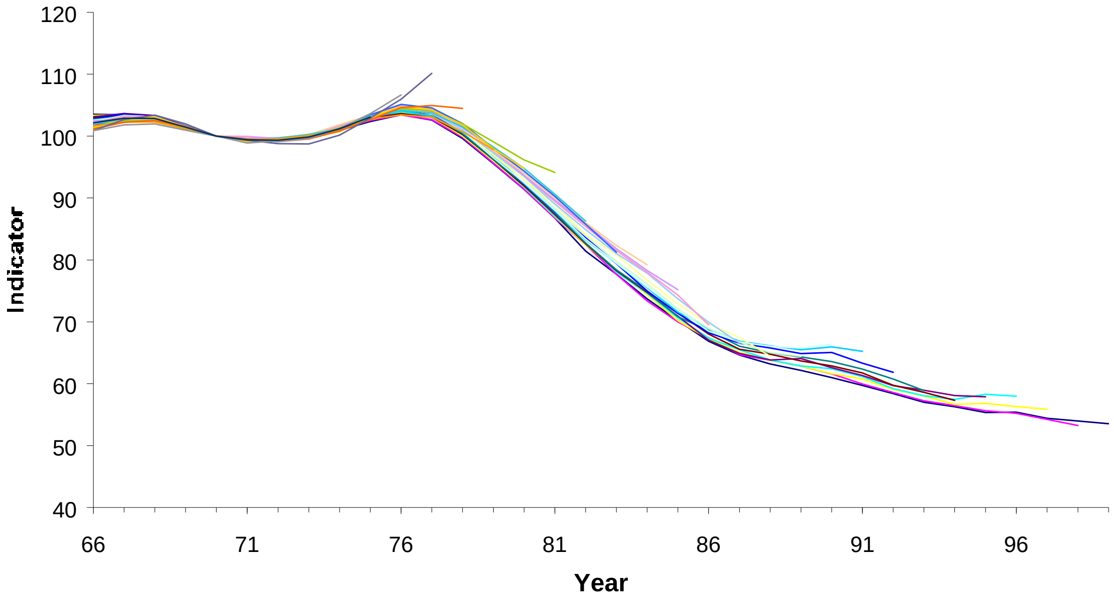

**Figure 2b. Two forms of smoothed indicator**



## 3.2 Endpoints

Single-species analyses have shown that smoothing algorithms of the kind employed here can produce erratic values at the end of the time-series. Such analyses are therefore routinely truncated for presentation. We investigated the behaviour of endpoints in the multispecies indicator by comparing the results of an analysis based on the full 34 years of census data with similar analyses based on shorter runs of data, that is in turn 33,32,31 ... years of data. The shortest period of time considered this way is ten years (1966-1975), as inspection of very short runs of data is clearly pointless. Trends derived in these cases are combined in Figure 3, where it is seen that although the final observation can be erratic, especially in 1977 when the steepest descent began, the trends are broadly consistent. Certainly there appears no reason to disregard more than the final year in presenting an indicator produced in this manner.

**Figure 3. End point analysis**




## 3.3 Identification of turning points

It is important to assess whether apparent changes in the rate of increase or decrease in the indicator are merely due to chance (sampling error), or whether we can be confident that they represent a real change in the behaviour of the indicator. We consider here a method developed for single species trends by Siriwardena *et al.* (1998). Mathematically, this amounts to identifying those years at which the second derivative of the indicator is significantly different from zero. The second derivative is a measure of the extent to which the rate of a population increase (or decline) is itself changing, analogous to an "acceleration". If it is zero, the population may be changing (increasing or decreasing), but it is doing so at a constant rate. Statistically significant second derivatives then imply a varying rate of population change.

This is done by bootstrapping; the distribution of the second derivatives is estimated by repeatedly resampling from the CBC counts for each species. The significance of the second derivative in a given year, at a chosen significance level, is ascertained by whether or not zero is contained between the relevant percentiles. Significant observations may reflect either a period of decline after a period of increase (or vice-versa), or merely a change in the *rate* of increase or decrease. Clearly the nature of these turning points means that they cannot be identified right at the end of a series.

Second derivatives significant at the 1% (filled circles) level, and additional ones significant at the 5% (open circles) level are shown in Figure 4a. It is perhaps surprising that there are so many of these, both at the 5% level conventionally taken to indicate significance and at the more restrictive 1% level, which is indicative of a high level of precision in the estimator (see also point 4 below). Use of any significance levels represents an arbitrary choice of probability values.  On the basis of our experience of identifying turning points in population trends, we recommend that most emphasis should be placed on results that are significant at the 1% level.  The most significant trend changes occur, predictably, in the mid-1970s (where an increase gives way to a steep decline) and the mid-1980s, when this steep decline becomes noticeably shallower.

**Figure 4a. Significant 2nd derivatives**

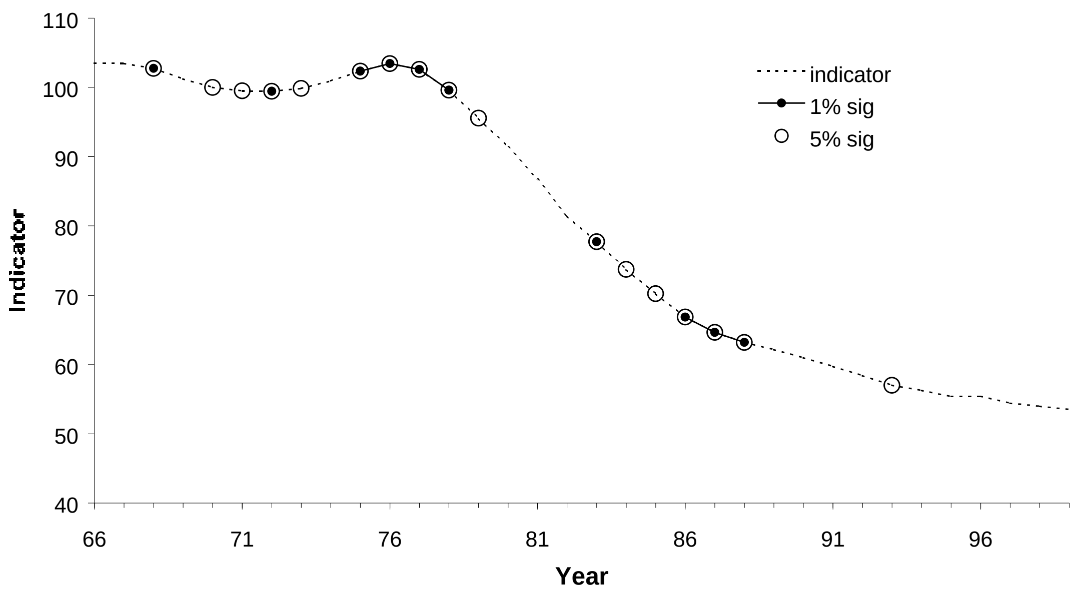



**Figure 4b. Index as a proportion of previous year's index**

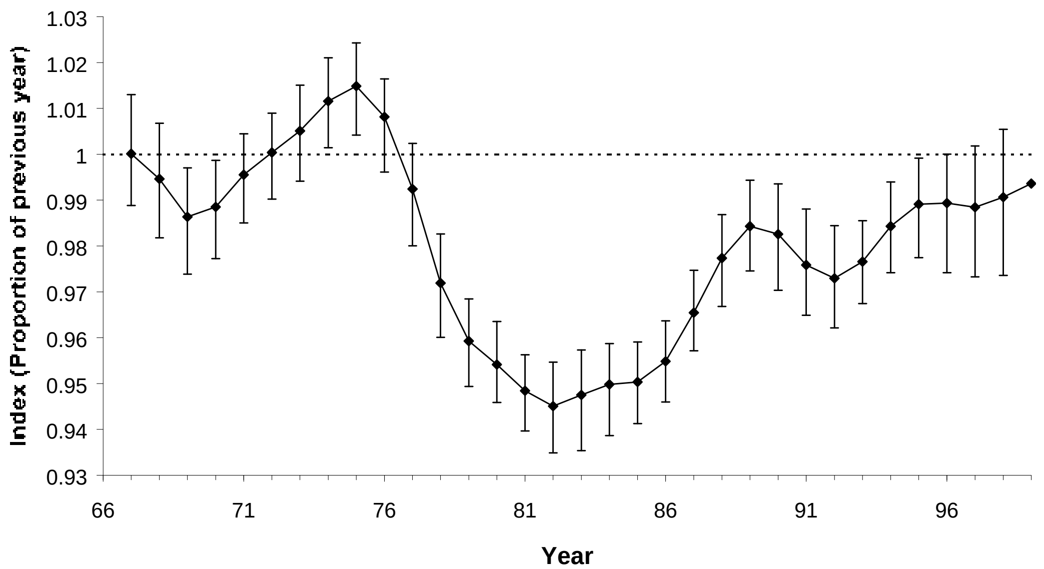


Table 1. Percentage change in the index, compared to the previous year's index.

| Year | Proportion of previous year | Percentage change | % change, 95% CI | |
|---|---|---|---|---|
| | | | Lower | Upper |
| 1966 | | | | |
| 1967 | 1.00012 | 0.012 | -1.252 | 1.505 |
| 1968 | 0.99463 | -0.537 | -1.664 | 0.753 |
| 1969 | 0.98633 | -1.367 | -2.654 | -0.151 |
| 1970 | 0.98852 | -1.148 | -2.396 | -0.077 |
| 1971 | 0.99553 | -0.447 | -1.575 | 0.566 |
| 1972 | 1.00038 | 0.038 | -1.015 | 0.93 |
| 1973 | 1.00508 | 0.508 | -0.509 | 1.363 |
| 1974 | 1.01158 | 1.158 | 0.06 | 2.156 |
| 1975 | 1.01484 | 1.484 | 0.468 | 2.432 |
| 1976 | 1.00816 | 0.816 | -0.25 | 1.761 |
| 1977 | 0.99242 | -0.758 | -1.962 | 0.071 |
| 1978 | 0.97193 | -2.807 | -4.045 | -1.814 |
| 1979 | 0.95926 | -4.074 | -5.258 | -3.005 |
| 1980 | 0.95415 | -4.585 | -5.573 | -3.665 |
| 1981 | 0.94843 | -5.157 | -5.985 | -4.222 |
| 1982 | 0.94505 | -5.495 | -6.372 | -4.71 |
| 1983 | 0.94751 | -5.249 | -6.267 | -4.291 |
| 1984 | 0.94978 | -5.022 | -6.238 | -4.042 |
| 1985 | 0.95034 | -4.966 | -6.081 | -4.074 |
| 1986 | 0.95485 | -4.515 | -5.423 | -3.641 |
| 1987 | 0.96543 | -3.457 | -4.345 | -2.575 |
| 1988 | 0.97735 | -2.265 | -3.097 | -1.342 |
| 1989 | 0.98428 | -1.572 | -2.627 | -0.623 |
| 1990 | 0.98255 | -1.745 | -2.719 | -0.738 |
| 1991 | 0.97586 | -2.414 | -3.635 | -1.318 |
| 1992 | 0.97294 | -2.706 | -3.803 | -1.487 |
| 1993 | 0.97658 | -2.342 | -3.421 | -1.193 |
| 1994 | 0.98428 | -1.572 | -2.486 | -0.676 |
| 1995 | 0.98912 | -1.088 | -2.099 | -0.119 |
| 1996 | 0.98933 | -1.067 | -2.235 | -0.062 |
| 1997 | 0.98842 | -1.158 | -2.674 | -0.087 |
| 1998 | 0.99065 | -0.935 | -2.451 | 0.403 |
| 1999 | 0.99362 | -0.638 | -2.345 | 0.84 |

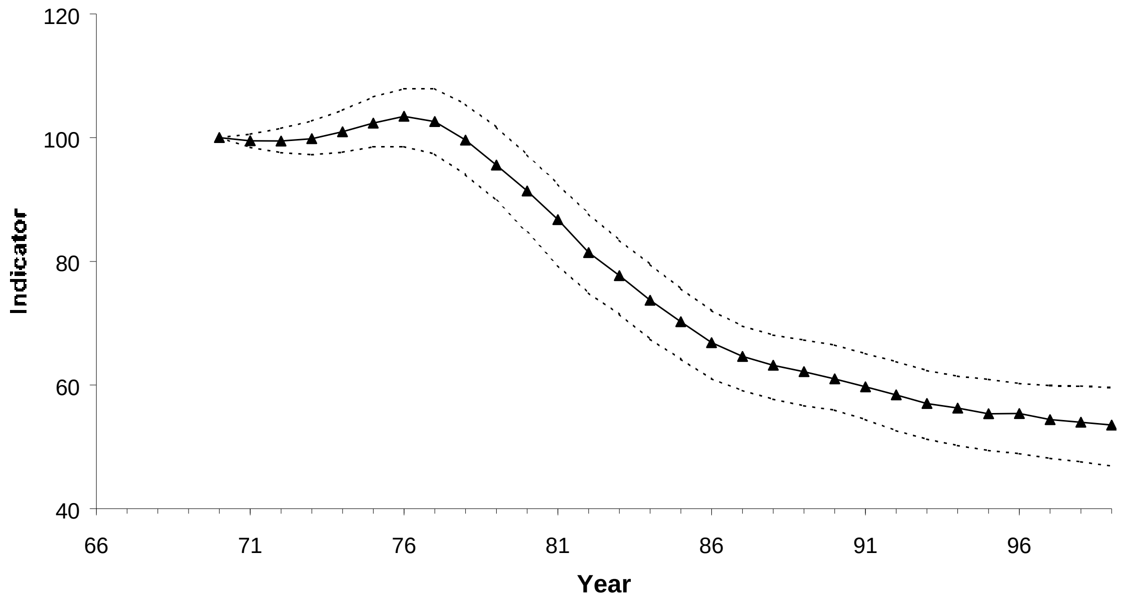
### 3.4 Rates of change in the smoothed indicator

To complete the examination of change-points in the indicator we derived confidence limits also for the proportional change between each pair of consecutive years. Such limits are again derived by bootstrap resampling from the individual species' CBC data, and are shown (using a 95% confidence interval) in Figure 4b and Table 1. Here a score of one indicates no change, and a lower score a decline. Declines whose confidence limits do not overlap unity are therefore statistically significant; in keeping with the appearance of Figure 1 most years come into this category, although it is notable that by the end of the series the change, though still negative, has ceased to be significant.

### 3.5 Precision of the smoothed indicator

Precision of the smoothed indicator estimates is also obtained by bootstrapping. 95% confidence limits are shown in Figure 5 and are found to be narrow. No doubt this accounts for the high power observed to detect significant changes in both annual decreases in the index (Figure 4b) and non-zero second derivatives (Figure 4a).

**Figure 5. Farmland Indicator with 95% Confidence Limits**




### 3.6 Influence of individual species trends

We conclude analyses of the indicator by considering the relative influence of the various 18 species from which it is derived upon its final form. We began by repeating the calculations omitting each species in turn. That is, we produced 18 alternative indicators, each of which contains data on 17 species, 16 of which are common to any other such indicator. The results are shown in Figure 6. Generally, all of these subset-based indicators bear the same shape, little different to the ‘full’, 18 species indicator of Figure 2a. The most influential species appear to be Tree Sparrow and Whitethroat. With the former species discarded the indicator shows a decline since 1970 that is much reduced, compared to the full indicator. This is due to the sheer scale of the disappearance of the species, which has been much the most marked of the species considered (Figure 7). The influence of the Whitethroat data is more interesting; in Figure 6 it appears to influence only the few years either side of 1970, and this influence is due to the widely-known crash experienced in the late 1960s, since when it has been largely stable (Figure 7). This crash is attributed to unfavourable conditions in the Sahel region (Winstanley *et al.* 1974). However, if we consider the formation of an indicator using 1966 (before the Whitethroat crash) as the base year, rather than 1970, this produces an indicator much more sensitive to the presence or absence of the species (Figure 8). Without the Whitethroat contributing to the indicator, the decline from 1975 to the present day is much more pronounced. As this sort of effect cannot be ruled out for any other species in future years, it is important in interpreting the indicator to carry out sensitivity analyses of this kind.

It is notable that, just as Tree Sparrow and Whitethroat are in some way distinctive due to the nature or extent of their decline, so the index for Stock Dove is also unique in having undergone a massive, almost four-fold increase since 1966 (Figure 9). It is interesting then that this species still has relatively little influence upon the shape of the entire indicator (Figures 6, 8).

**Figure 6. Indicators based on 17-species subsets (1970=100)**

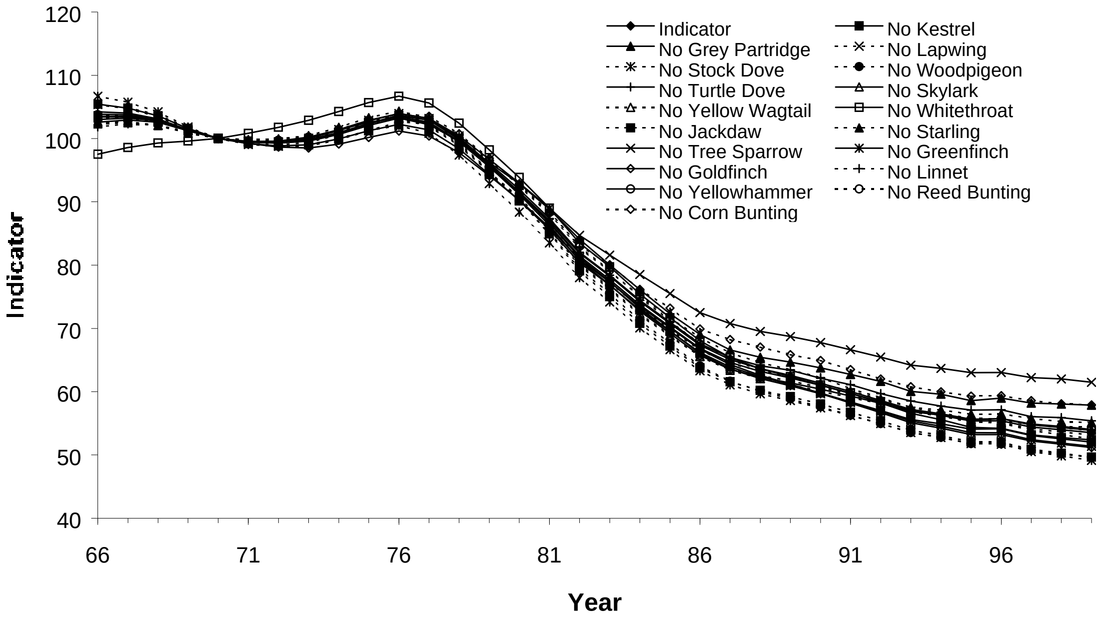



**Figure 7. Individual species smoothed trends (1970=100)**

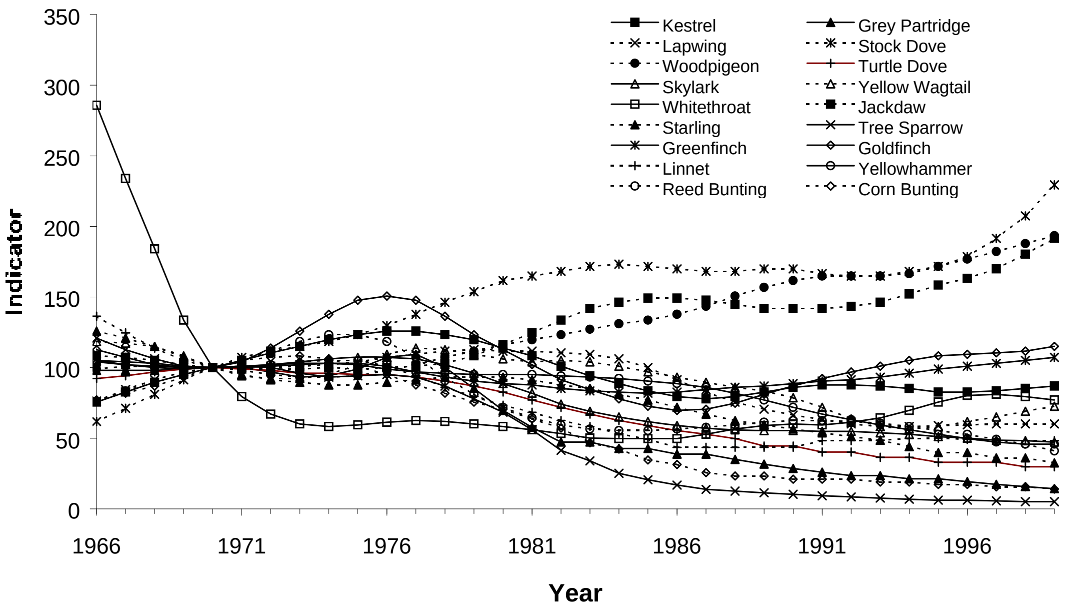


**Figure 8. Indicators based on 17-species subsets (1966=100)**

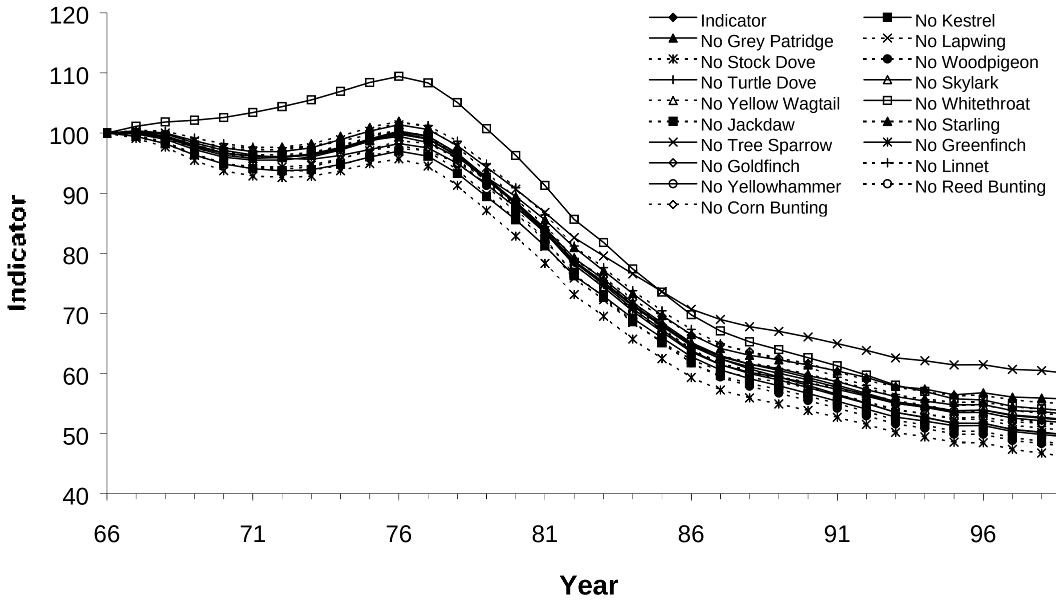
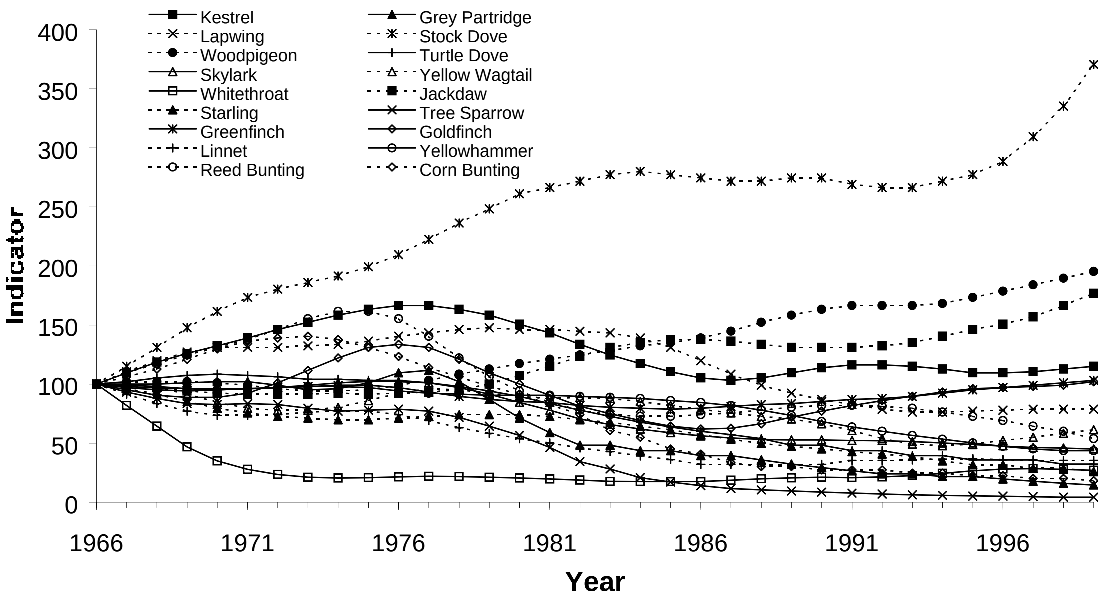


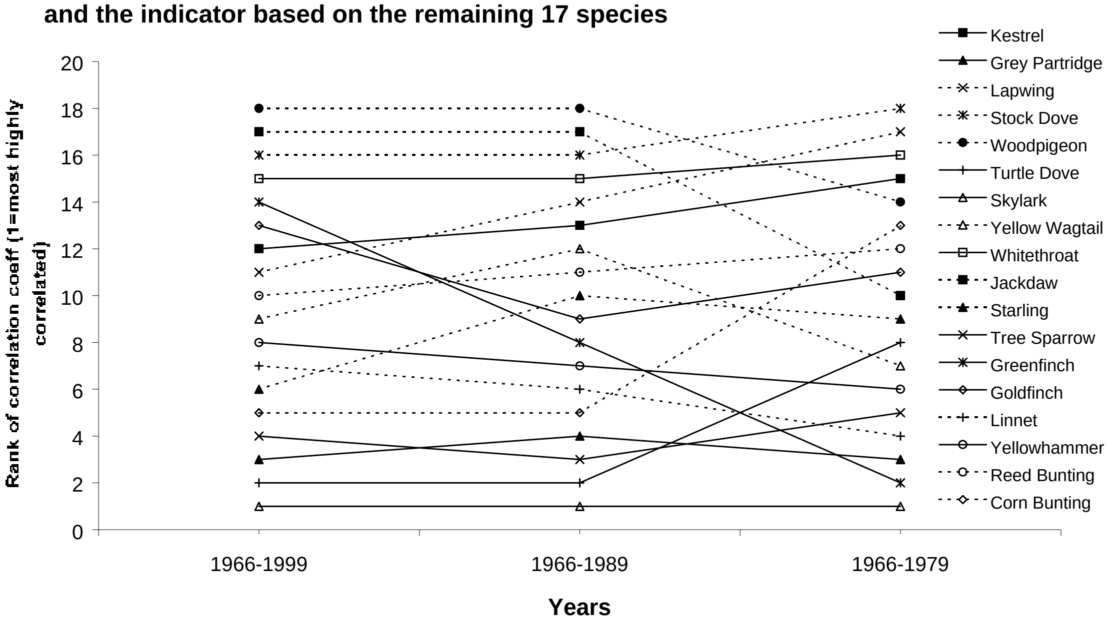

**Figure 9. Individual species smoothed trends (1966=100)**




Having estimated the indicators for sets of 17 species, i.e. with one species omitted in turn, it is of interest to consider the relationship between these indices and the single-species index for the discarded species. We computed correlation coefficients between the abundance of each species in turn and the corresponding indicators based on the remaining species. This forms a simple picture of the (linear) relationship between each species and the indicator based on the remainder of the set. Based on the entire 1966-99 data, the strongest positive correlations relate to the most declining species, Skylark, Grey Partridge, Turtle Dove, Tree Sparrow and Corn Bunting ($\rho > 0.95$ in each case). Similarly the few increasing species, Stock Dove, Jackdaw and Woodpigeon register highly negative correlations.

We repeated this procedure based on two reduced periods of time, 1966-89 and 1966-79 for comparison with the full series 1966-99. Care is needed in comparing correlations between samples of different sizes but what is notable is that the high correlations disappear once the data set is reduced until the period of decline is removed; full results are shown in Appendix 2. Further, once the period is restricted to 1966-1989 or 1966-79, there can be pronounced differences in which species are least correlated with the indicator. Skylark is most positively correlated with the index in all three cases considered; Turtle Dove however is initially second but drops to eighth when the years 1966-79 alone are used; the Jackdaw, which had a high negative correlation initially is essentially uncorrelated in the third analysis. The behaviour of the correlation coefficients for all species is shown in Figure 10.

**Figure 10. Ranks of correlation coefficients between species abundance and the indicator based on the remaining 17 species**



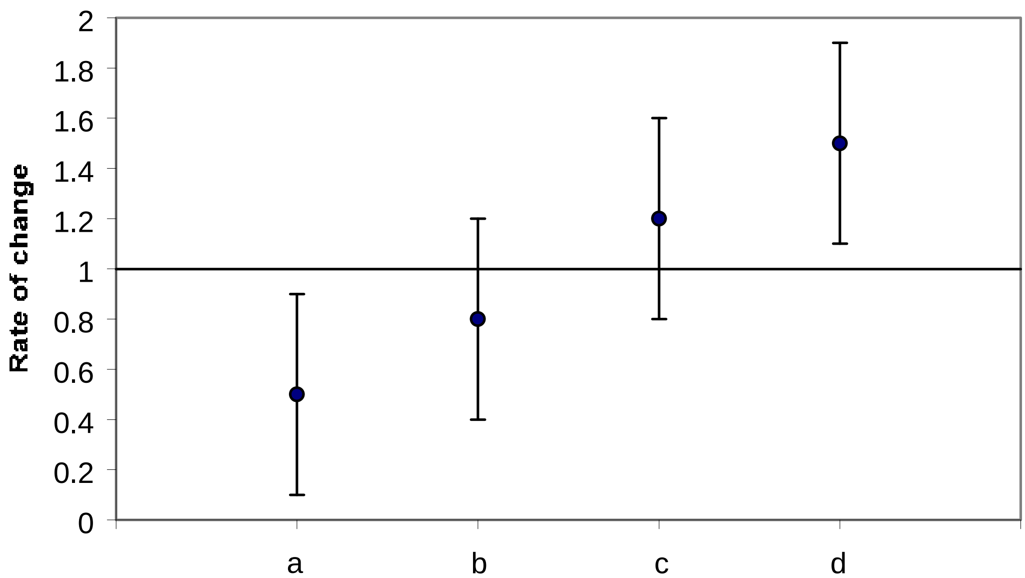
# 4. DISCUSSION

## 4.1 Interpreting changes in the farmland bird indicator

MAFF have a target to reverse the decline in the farmland bird indicator by 2020. They therefore need to be able to assess the rate of change of the indicator and the precision with which that rate of change can be measured. We recommend that this assessment should be based on the smoothed indicator presented here as this provides the best measure of the underlying trend from which most short-term fluctuations due to weather and sampling error have been removed. The last year of data should not be used in such assessments as it may be unreliable due to endpoint effects (section 3.2, Figure 3). Precision should be assessed by bootstrapping because this avoids any restrictive assumptions concerning the underlying distribution of the CBC data.

The rate of change in the smoothed indicator provides a straightforward measure of whether the indicator is decreasing, stable or increasing (Figure 4b). A schematic representation of some possible change measures and their interpretation is presented in Figure 11. Throughout the following discussion it is assumed that use of a two-tailed test with a 5% probability of a type I error is considered appropriate, as is generally the case in population biology. Interpretation of the data based on this widely accepted convention is recommended. If the change measure is less than one and the upper 95% confidence limit is also less than one then the indicator should be regarded as declining (Figure 11 point a). If the change measure is greater than one and the lower 95% confidence limit is also greater than one then the indicator should be regarded as increasing (Figure 11, point d). Greater difficulties of interpretation arise if the confidence limits of the change measure overlap one. If the rate of change is less than one but the upper 95% confidence limit is greater than one then the population is most likely to be decreasing or stable (Figure 11, point b) while if the rate of change is greater than one but the lower 95% confidence limit is less than one than the population is most likely to be stable or increasing (Figure 11, point c). However, the degree of uncertainty means these cases should be viewed with caution. Where confidence limits overlap one, medium-term changes in the indicator should be inspected to assess whether there is any consistent pattern of increase or decline.

**Figure 11. Schematic representation of some possible change measures and their interpretation: (a) Decreasing, (b) Stable/decreasing, (c) Stable/increasing, (d) Increasing.**



It should be noted that there is some indication that the confidence limits of the change measures have become wider towards the end of the time series (Figure 4b). This may result partly from lower precision in the recent indices for individual declining species. When species become less abundant fewer individuals are present on the sample plots, resulting in less precise measures of change.

The turning point analysis provides a further indication of the ways in which the indicator is changing. Significant positive turning points in the mid-1980s and in 1993 show that the rate of decline in the farmland bird indicator has slowed. Further positive turning points should be detected as progress towards the intended reverse of the decline is achieved.

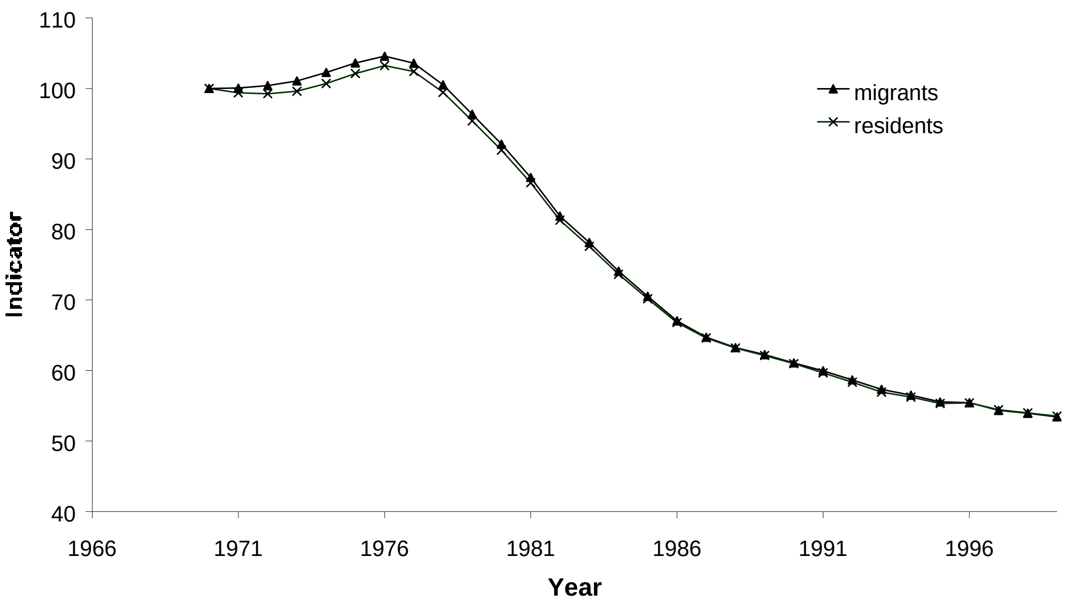
The conclusions are summarised as follows:

- An indicator should be smoothed, in a manner of the kind described here, to reduce the influence of sampling variation and short-term natural fluctuations.
- The final year in such a series acquires the most unreliable index value. It should be omitted from any assessments. There is, however, no reason to remove more than one such year at the end of the series.
- Rates of change in the smoothed index can be used to assess whether the indicator is moving in the desired direction.
- Analyses of turning points should be used as an additional aid to the interpretation of trends in the indicator.
- Bootstraps can be made to estimate the precision of the indicator and to assess the significance of the estimated rates of change, and turning points in the index trajectory.

## 4.2 The selection of species

Certain individual species, based on data available so far, can influence the estimated index more than others. Most notable in this respect are Whitethroat and Tree Sparrow (Figures 6 and 8). Any effect of this kind is dependent also upon the choice of the base year for comparison. Most of the species analysed have little effect, on their own, upon the form of the indicator. There is, for instance, little difference between indicators based only on the three migrant species (Whitethroat, Yellow Wagtail and Turtle Dove) and on the remaining resident species (Figure 12). Therefore there is presently no case for removing any of these 18 species from the indicator. However, it is always desirable to interpret the indicator with respect to the individual species trends that contribute to it, particularly where individual species have shown unusually large increases or declines.

**Figure 12. Farmland Indicators for migrant and resident birds**



Two species, Rook and Barn Owl, were not included in the present study due to a lack of suitable data. These species are included in the DETR indicator on the basis of atlas data (Gregory *et al.* 1999). However, for inclusion in the more rigorous statistical approach adopted here we require annual census data from which we can estimate a reliable smoothed population trend and its confidence limits. Rooks are not censused by the standard CBC territory mapping method because their highly clumped distribution makes this inappropriate (Marchant *et al.* 1997). Since 1987 Rook nests have been counted on most CBC plots where the species is present. However the number of CBC plots supplying analysable data for this species remains small (range 17-30 plots). The BBS will provide data for this species and it may eventually be possible to provide an annual rook index form 1987 onwards based on combined CBC and BBS data (below). Such an index could contribute to the type of statistical analysis presented here.

There is no immediate prospect of producing an annual population index for Barn Owls. This species is extremely difficult to count and there has only been one census providing a national population estimate (Toms *et al*. 2001). The species is not monitored by the CBC. It is included in the BBS but only a small number of individuals are recorded during these counts each year (18 birds in 2379 squares in 1999; Noble *et al.* 2000)

### 4.3 Implications of the change from the Common Birds Census to the Breeding Bird Survey

The breeding season of 2000 is the last one in which a full Common Birds Census will be operated. From 2001 annual monitoring of terrestrial breeding birds will be based on results from the BTO/JNCC/RSPB Breeding Bird Survey. The BBS has been in operation since 1994 so there will be 7 years of overlap between the CBC and the BBS. This will allow joint long-term population indices based on data from the two schemes to be produced. Such joint indices are currently being developed by the BBS partnership. Preliminary results indicate that for most species there is no substantial difference in the trends shown by the BBS and the CBC. It is planned to produce combined, smoothed indices based on data from both schemes by the end of 2001 but some computing issues concerned with fitting Generalized Additive Models to these very large combined data sets remain to be resolved. Provided this can be done then the results from these single species analyses could be used to produced a smoothed indicator with confidence limits using the methods presented in this report.

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## Appendix 1 - Methods used by the Common Birds Census and the Breeding Bird Survey

### Common Birds Census

The results from the Common Birds Census (CBC) provide estimates of population trends for almost all of the commoner breeding species in Britain. Annual counts of birds during the breeding season on between 200 and 300 plots around the country allow comparisons of population levels on a year-to-year basis. Focusing on farmland and woodland habitats, the CBC provides indices of population change for around 75 species.

The CBC has been running since 1962 and was instigated to provide sound numerical information on farmland bird populations in the face of rapid changes in agricultural practice. Fieldwork is carried out by a team of dedicated volunteers. The same observers survey the same plots using the same methods year after year. On average, plots are censused for around seven consecutive years but some observers have surveyed the same sites since the CBC's inception in the early 1960s.

Originally, emphasis was on farmland plots but other habitats including woodland were added shortly afterwards. The sample of farmland plots contains most of the main agricultural land-uses, with plots averaging around 80 hectares in extent. Woodland plots are generally smaller, averaging just over 20 hectares. A small number of plots of other habitats are surveyed annually, including heathlands and small wetlands.

A territory-mapping approach is used to estimate the number and positions of territories of each species present on each survey plot during the breeding season. Volunteers visit their survey plot ten times between late March and early July and all contacts with birds, either by sight or sound, are plotted on large-scale maps. Codes are used to identify the birds' species, sex and age where possible, and also to record activity such as song or nest-building. The registrations are then transferred to species maps, which are returned to the BTO for analysis.

The pattern of registrations reveals the numbers of territories for each species. By applying rigorous rules while analysing the species maps, we can be sure that there is consistency between our estimates from year to year. Comparison of territory totals with those for the same plots in previous years gives estimates of change between years and allows the production of a long-running population index for each species. In 1990, the results from the Common Birds Census were brought together in the book *Population Trends in British Breeding Birds* (Marchant *et al.* 1990). This landmark publication discussed long-term population trends for the years 1962 to 1988 for 164 species, with graphs showing CBC population indices for around two-thirds of these. More recent analyses of population trends on farmland have been published in the refereed scientific literature (Siriwardena *et al.* 1998, Fewster *et al.* 2000) and are included in a report and web site that is published periodically by BTO in partnership with JNCC (Baillie *et al.* 2001). Some results are also summarised in *The State of the UK's Birds 2000* (Gregory *et al.* 2001).

Observers also provide detailed habitat maps and information from their plots. This makes it possible to match the distribution of bird territories with habitat features, providing the potential for detailed studies of bird-habitat relationships.

The CBC was the first national breeding bird monitoring scheme of its kind anywhere in the world and has become the standard by which other schemes and surveys are compared. The territory mapping method adopted by the CBC is acknowledged as the most efficient way of estimating breeding bird numbers in small areas. As the CBC is often regarded as the benchmark by which other survey methods are compared, it is important that its validity and limitations are understood. There have been many validation studies of the CBC, mainly by the BTO itself. Snow (1965) compared CBC mapping and intensive nest-finding, concluding that mapping censuses are good indicators of breeding population size for 70% of species. Experiments to test differences between observers' abilities to detect birds found that although there was considerable variation between individual abilities, the observers were consistent from year to year (O'Connor & Marchant 1981). As the CBC relies on data from plots covered by the same observer in consecutive years, this source of bias will not have implications for the CBC's ability to identify population trends. It has also been found that the sample of plots from which CBC results are drawn has not changed in composition or character over the years (Marchant *et al.* 1990) and similarly that the results of territory analysis are not affected by changes in analysts, once trained (O'Connor & Marchant 1981). Fuller *et al.* (1985) found that farmland CBC plots were representative of ITE land-classes and cropping patterns in lowland England. Work by Moss (1985) examined the extent to which spurious random fluctuations can develop within CBC indices. It was concluded that such changes were small in relation to levels of population change estimated by CBC data.

The CBC is recognised as having many strengths and has been a keystone of bird population monitoring within the United Kingdom for more than three decades. However, all monitoring programmes are subject to compromises between the theoretical ideal and what is practicable and cost-effective. The weaknesses of the CBC are largely related to the fact that both fieldwork and analysis are very time-consuming. This inevitably limits the numbers of volunteer birdwatchers who are able to participate in the scheme with the result that areas of low human population density (and therefore density of birdwatchers) are under-represented. The constraints imposed by the relatively small sample size mean that it was felt necessary to concentrate on farmland and woodland habitats, with the results that bird population trends in built-up areas and the uplands are little known. As the plots are chosen by the observers, it may be that plots are not always representative of the surrounding countryside and there may be some bias towards bird-rich habitats. It is for these reasons that the Breeding Bird Survey was introduced in 1994 and both surveys will continue for several years in order to allow calibration between the schemes.

**Breeding Bird Survey**

In 1994 the BTO/JNCC/RSPB Breeding Bird Survey (BBS) was launched following two years of extensive pilot work and a number of earlier desk-based studies. The introduction of the BBS was a response to the limitations of the Common Birds Census (CBC), which has monitored bird populations since 1962. It was recognised that there was a need to improve the geographical representation of UK bird monitoring and, thereby, both species and habitat coverage. The BBS uses line transects rather than the time-consuming territory mapping method used by the CBC. This makes the survey relatively quick and convenient to undertake, thereby encouraging a larger number of volunteers to take part.

Survey squares are 1 x 1 km in size. They are selected using a stratified random sample from within 83 sampling regions. In most cases, these are standard BTO regions based on membership distribution. BBS regions with larger numbers of potential volunteers are allocated a large number of squares enabling more birdwatchers to become involves in these areas. Note that this does not introduce bias in the results because the analysis takes each region separately in drawing up national statistics. The BBS requires a relatively large sample of survey squares and the aim is to maintain coverage of between two and three thousand squares in the UK. Fieldwork is co-ordinated through a network of BBS Regional Organisers.

Fieldwork involves three visits to each survey square each year. The first is to record details of habitat and to establish the survey route, the second and third to count birds. A survey route is made up of two parallel lines, each 1 km in length, although for practical reasons routes typically deviate somewhat from the idea. Each of these lines is divided into five sections, making a total of ten 200m sections, and birds and habitats are recorded within these units. The two bird-count visits are made about four weeks apart (ideally early May and early June), ensuring late migrants are recorded. Volunteers record all the birds they see or hear as they walk along their transect routes. Birds are noted in three distance categories (within 25m, 25-100m or more then 100 m either side of the line) measured at right angles to the transect line, or as in flight. Recording birds within distance bands is important because it provides a measure of bird detectability in different habitats and allows population densities to be estimated. The average time observers spend per visit is around 90 minutes. The number of squares surveyed within the BBS has increased from 1569 in 1995 to 2378 in 1999.

**Appendix 2 – Correlation coefficients showing the effects of omitting individual species from the indicator**

Correlation coefficients between population indices derived for 18 species from CBC data, and the smoothed farmland indicator based on the remaining 17 species, for each species in turn. Coefficients are calculated using three periods of years a) 1966-1999 b) 1966-1989 c) 1966-1979.

| **SPECIES** | **CORRELATION COEFFICIENT BASED ON YEARS** | | |
|---|---|---|---|
| | **a) 1966-99** | **b) 1966-89** | **c) 1966-79** |
| Kestrel | 0.66 | 0.57 | -0.63 |
| Grey Partridge | 0.98 | 0.97 | 0.56 |
| Lapwing | 0.76 | 0.32 | -0.70 |
| Stock Dove | -0.86 | -0.83 | -0.83 |
| Woodpigeon | -0.97 | -0.98 | -0.51 |
| Turtle Dove | 0.99 | 0.98 | 0.16 |
| Skylark | 0.99 | 0.99 | 0.78 |
| Yellow Wagtail | 0.84 | 0.62 | 0.24 |
| Whitethroat | 0.27 | 0.29 | -0.68 |
| Jackdaw | -0.95 | -0.97 | -0.06 |
| Starling | 0.91 | 0.79 | 0.15 |
| Tree Sparrow | 0.98 | 0.98 | 0.49 |
| Greenfinch | 0.28 | 0.88 | 0.63 |
| Goldfinch | 0.50 | 0.79 | -0.25 |
| Linnet | 0.91 | 0.92 | 0.50 |
| Yellowhammer | 0.89 | 0.91 | 0.38 |
| Reed Bunting | 0.83 | 0.78 | -0.31 |
| Corn Bunting | 0.96 | 0.93 | -0.37 |