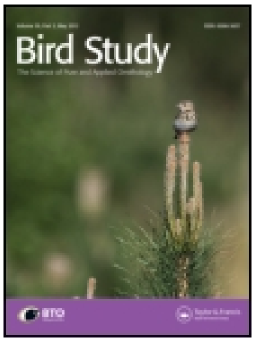

Bird Study

ISSN: 0006-3657 (Print) 1944-6705 (Online) Journal homepage: http://www.tandfonline.com/loi/tbis20

Indexing European bird population trends using results of national monitoring schemes: a trial of a new method

A.J. van Strien , J. Pannekoek & D.W. Gibbons

To cite this article: A.J. van Strien , J. Pannekoek & D.W. Gibbons (2001) Indexing European bird population trends using results of national monitoring schemes: a trial of a new method, Bird Study, 48:2, 200-213, DOI: 10.1080/00063650109461219

To link to this article: https://doi.org/10.1080/00063650109461219

Published online: 29 Mar 2010.

Bird Study (2001) **48,** 200–213

Indexing European bird population trends using results of national monitoring schemes: a trial of a new method

ARCO J. VAN STRIEN[1*], JEROEN PANNEKOEK[1] and DAVID W. GIBBONS[2]

[1]Statistics Netherlands, PO Box 4000, 2270 JM Voorburg, The Netherlands and [2]European Bird Census Council, c/o RSPB, The Lodge, Sandy, Bedfordshire, SG19 2DL, UK

Many European countries have annual breeding bird monitoring schemes based on nationwide samples; most are in northern and western Europe. We have developed a method to produce yearly population indices of bird species across countries by combining the results of existing national schemes. The method takes into account the differences in population sizes per country, as well as the differences in field methods, and the numbers of sites and years covered by the national schemes. In order to test the method, we collected raw data from a number of countries and applied an index method to produce scheme results per country. Data were collected for five farmland species (Lapwing Vanellus vanellus*, Linnet* Carduelis cannabina*, Skylark* Alauda arvensis*, Whitethroat* Sylvia communis *and Yellowhammer* Emberiza citrinella*), from seven countries (UK, Netherlands, Denmark, Germany, Finland, Latvia and Estonia) for a 20-year period (1978–97). The trial demonstrated that it was possible to combine national indices to provide supra-national yearly totals and their standard errors; the results were similar to those produced when the raw data were used. Thus, yearly European indices can be produced by exchanging only limited amounts of information, that is the national yearly indices of each species or, preferably, the yearly population numbers and their standard errors. At a European scale, the populations of the five species selected have changed considerably. In western Europe (UK, Netherlands, Denmark and former West Germany combined), Linnet, Skylark and Yellowhammer have declined and Whitethroat has increased. Most changes occurred during the first ten-year period (1978–88). The changes in eastern Europe (the remaining countries) were less clear, in part because the statistical power of the national schemes is as yet limited.*

The widespread changes in European land use which occurred during the last half of the 20th century have had an enormous impact on bird populations (Tucker & Heath 1994, Pain & Pienkowski 1997). Many of these changes were influenced by European, or at least European Union (EU), policies such as the Common Agricultural Policy, and their effects are likely to spread further east in Europe as former eastern-bloc countries join the EU. The impact that such changes will make on wildlife needs to be closely monitored by the scientific and conservation communities and its results made readily available to politicians, their advisors and the general public. To measure the impacts of policies that act over such a broad geographical scale, it is necessary to monitor wildlife at a similar scale, i.e. pan-European. Information on European population trends will also be invaluable in setting species' conservation priorities in Europe as a whole (thus ensuring

*Correspondence author.
Email: asin@cbs.nl

that scarce resources are directed at the priority species) and in assessing the success of conservation action.

Many European countries have annual breeding bird surveys, but no scheme exists to monitor common and widespread breeding birds at a pan-European scale. Tucker & Heath (1994) documented highly summarized trends of all breeding species in each European country during 1970–90 using a simple scoring system based on expert judgements (population increase or decrease >50%, 20–50% or <20%). The data took several years to collect, were sometimes based on no more than informed guesswork and gave trends over only a single, long time period. These data are becoming out-of-date. Annual index values would be preferable to a periodic repeat of the questionnaire approach used by Tucker & Heath (1994), though the latter could itself be based on the annual data.

About 15 European countries have annual breeding bird surveys based on nation-wide samples; most are in northern and western European countries (Hustings 1992, Kwak & Hustings 1994, Marchant *et al.* 1997). A consortium of organizations from many countries, co-operating through the European Bird Census Council (EBCC), has proposed a pan-European volunteer-based breeding bird monitoring scheme ('Euromonitoring') (European Bird Census Council 1997, Gibbons 2000). This would give species-by-species annual European population trends. It could also allow comparisons between trends in different regions of Europe or between different habitats, which could illuminate the causes of the population changes. Such information already exists for a small number of species (mainly rare or threatened ones), but not for common and widespread breeding birds.

One way to run pan-European monitoring would be to set up an entirely new scheme, with survey sites scattered at random throughout Europe, taking no account of existing national schemes. The main advantage of this would be that it could have a unified formal sampling design. The major disadvantages are that it would be hard to impose on individual nations, particularly those with existing schemes, and it ignores the large amounts of long-term national data that are already collected, which are necessary to put the current trends into context. In addition, it may well be better to allow each country to use its own methods adapted to its own circumstances rather than to apply a uniform system.

An alternative approach is to base an international scheme upon the data already collected by national schemes in European countries. This would make best use of existing data, but needs to deal with the many differences between national schemes.

Combining national schemes

National schemes differ in many respects, particularly field methods (territory mapping, point counts, line transects), number of sites covered, manner of site selection, indexing methods used and years covered (Table 1). The differences in field method and the number of sites involved will mainly lead to differences in precision of the results, i.e. in standard errors of the yearly indices. In addition, different field methods may, in principle, monitor slightly different sections of the population, but it has been assumed that this hardly influences the yearly index values. Of greater concern is the manner of site selection as this is often non-random and may lead to biases at the national, and thus European, level. In most cases field

Table 1. Differences between monitoring schemes and their consequences at a national and European level. See text for explanations.

Difference	Influence on national indices	Consequences for pan-European monitoring
Field method	Precision	Include standard errors of indices/total numbers
Number of sites	Precision	Include standard errors of indices/total numbers
Site selection method	Bias	Remove bias at national scheme level prior to assessing European indices
Index method	Bias/precision	Avoid inferior methods and standardize method
Years covered	Missing yearly indices	Estimate missing indices by using information from other countries

workers are free to choose their own monitoring site, so particular habitats and regions will be oversampled and others undersampled. In addition, even within a particular habitat field workers may choose non-random (e.g. better than average) sites. As a result, many national schemes are likely to be non-representative.

Yearly indices also depend to a considerable extent on the index method applied, especially when many missing counts are present in the data (Ter Braak *et al.* 1994). Due to a considerable turnover of sites, many scheme results contain a large percentage of missing counts, up to 60–70%. The chain method is commonly used to calculate indices for data with missing values (Table 2) (Marchant *et al.* 1997), but may produce spurious results (Crawford 1991). Better index methods are now available, which can overcome this risk, for example the Underhill index (Underhill & Prys-Jones 1994), the Mountford index (Siriwardena *et al.* 1998) and, particularly, methods based on loglinear models (Ter Braak *et al.* 1994, Pannekoek & van Strien 1998). Finally, schemes differ in the years covered because they have different starting points, leading to missing indices in earlier years. These missing indices need to be estimated in one way or another, otherwise European indices can only be produced for those years that all schemes have in common. Ultimately, when schemes are well established in all European countries, this problem will disappear.

At the outset there is a choice between combining the raw data (e.g. site counts) or the scheme results (e.g. national indices). Although combining the raw data would allow more detailed statistical analyses to be undertaken, there are considerable difficulties inherent in this. If raw data were used many data would need to be collected, processed and analysed; varying national field methods would lead to analytical complications; and problems of data ownership might be greater. These difficulties would be partly overcome if the scheme results calculated by the national organizations were combined, instead of the underlying raw data. If scheme results were combined it would be necessary to take into account the standard errors of these results, in order to allow for differences in number of sites and field method. Information on standard errors is necessary to allow the combined results to be correctly interpreted. Furthermore, standardization of the index method used is desirable when combining the scheme results.

The aim of this study was to develop a method to provide European indices based on national scheme results, such as national indices or equivalent figures. We performed a trial of the method using the raw monitoring data from a number of countries.

MATERIAL AND METHODS

Data

Raw data for five species were obtained from seven countries, from western to eastern Europe: UK, Netherlands, Denmark, Germany,

Table 2. Characteristics of the schemes in 1997/1998 involved in the study (Hustings, 1992, Kwak & Hustings 1994, Marchant *et al.* 1997, Flade & Schwarz 1996).

Country	Field method	No. of sites	Site selection	Index method	Years covered
United Kingdom	Mapping method	300	Free choice	Various	1963–97
The Netherlands	Mapping method	400	Free choice	Loglinear	1984–97
Denmark	Point counts	350	Free choice	Chain method	1975–97
Germany	Point counts + mapping method	400	Free choice	Chain method	1989–97
Finland	Point counts + line transects	150	Free choice	Chain method	1978–97
Latvia	Point counts	20	Free choice	Chain method	1983–94
Estonia	Point counts	50	Free choice	Chain method	1983–97

Only data from the UK Common Birds Census were included in this study. No. of sites refers to the current number of sites (plots or routes) counted annually in all habitats combined. Index method refers to that currently used by the national organizations; in this study loglinear regression was used for all data.

Finland, Latvia and Estonia. The five species were Lapwing *Vanellus vanellus*, Linnet *Carduelis cannabina*, Skylark *Alauda arvensis*, Whitethroat *Sylvia communis* and Yellowhammer *Emberiza citrinella*. All are widespread across Europe, although their density differs considerably between countries. Their numbers were expected to have changed in time, in large part because of the considerable changes in agriculture in Europe (Tucker & Heath 1994, Pain & Pienkowski 1997). The data were counts (numbers of breeding pairs or individuals) per site (plot or route) and per year for each species on farmland sites for as many years between 1978 and 1997 as available. Data from Denmark, Germany, Estonia and Finland included not only pure farmland sites, but also sites that cover other habitat types such as woodland. Despite this, we believe that the great majority of the data for these species selected came from farmland areas because the bulk of their populations breed in farmland. Several of the countries included have extensive monitoring schemes with numerous sites; others have schemes with relatively few (Table 2). The length of the time series covered also varied considerably between countries. The data were collected using a variety of field methods (mapping method, line transects and point counts with one to ten visits per year).

Information on species-specific population sizes was also obtained for each country for a particular year. Approximate population sizes for farmland were estimated from several sources, including the European Bird Database (Table 3) (Tucker & Heath 1994, Hagemeijer & Blair 1997). We have assumed that two-thirds of the populations of each species of German breeding birds occur in the former West Germany and one-third in the former East Germany.

Indices and trends for each country

We applied the freeware program TRIM to produce annual indices based on loglinear models (McCullagh & Nelder 1989, Pannekoek & van Strien 1998). By using TRIM, we applied a standard index method to the data from each country. In addition to annual indices, TRIM allows the estimation of trends over the whole period.[a]

In assessing the importance of a population trend it is necessary to consider both the significance of the trend and its magnitude. After all, a significant trend may be precisely known but biologically unimportant. Therefore it is useful to assess whether a significant change has a substantial magnitude. Following Tucker & Heath (1994), we consider a substantial change to be larger than 20% in a 20-year period. This corresponds to trends of less than 0.988 (leading to a decline from 100 to 80 in 20 years) and more than 1.010 (leading to an increase from 100 to 120 in 20 years). Furthermore, if a trend is not significant, it is important to know if the species population is stable or whether substantial changes may remain unnoticed due to the large standard errors of the trend estimate. For clarity we have distinguished five categories of changes here (see Appendix 1).

Combining total numbers across countries

Rather than combining indices, we combined total population estimates for each country to obtain supra-national yearly indices. Population sizes were not estimated in this study, but derived from other sources (see Data

Table 3. Estimates of farmland populations (no. of breeding pairs) of five bird species for a given year (Hagemeijer & Blair 1997, Gibbons *et al.* 1993, pers. comms).

Country	Year	Lapwing	Linnet	Skylark	Whitethroat	Yellowhammer
UK	1990	210 000	520 000	2 000 000	660 000	1 200 000
The Netherlands	1990	235 000	66 000	120 000	66 000	12 500
Denmark	1995	40 000	250 000	1 360 000	350 000	560 000
Germany	1995	100 000	500 000	3 000 000	250 000	1 500 000
Finland	1992	63 000	17 000	346 000	240 000	900 000
Latvia	1988	13 000	16 000	1 400 000	300 000	85 000
Estonia	1988	7 000	32 000	140 000	100 000	100 000

section). We first converted the national yearly indices into national yearly total population sizes in that country. If, for some year, an estimate E of the total population size is available (see Table 3), a weighting can be calculated as the quotient E/T of the population size E and the estimated all-sites total T in that year. Subsequently, this weighting was applied to all years of the scheme, so that the weighted year totals may be considered as the yearly total population sizes in that country. If the weight is treated as a known constant, estimates of the variances of these weighted year totals can be obtained by multiplying the variances of the estimated unweighted year totals by the square of the weight.

The second step was to combine the yearly totals from each country. Combining total numbers across countries is straightforward in cases where we restricted the analysis to a time period for which data were available for all countries. The most obvious method is to simply add the estimated totals for each country. Since the estimates of the year totals are independent between countries, the variance of each combined total is the sum of the variances of the corresponding country totals.

Alternatively, one could first collect the raw data for all sites from all countries in one large data set. The same model could be applied to this combined data set, but now with country as a covariate. This means that the indices are allowed to differ between countries, but not between sites within countries. Because this method is essentially the same as applying separate models to each country, it results in the same estimates of the combined year totals as the previous method and the standard errors will also be equal. In other words, the analysis of the raw data produces exactly the same results as combining the scheme results.

Unfortunately, the monitoring schemes differ in years covered (Table 2) and the missing year totals for certain countries make combination of year totals more complicated. The missing year totals were estimated by TRIM in a way equivalent to imputing missing counts for particular sites (Pannekoek & van Strien 1998), but the estimation procedure was slightly different and incorporated the standard errors and covariances of the year totals per country. We pooled countries in order to derive the missing year totals from the other countries within the same group. Groups of countries were formed such that (i) for each group in each year there was at least one country with an estimated total available, and (ii) all countries within the group were likely to have had similar changes in population numbers during those years in which pooling was needed. This latter criterion was assessed using information on population trends from the European Bird Database (EBD) (Tucker & Heath 1994, Hagemeijer & Blair 1997) and from the major driver of these trends, agricultural intensification (Siriwardena *et al.* 1998), taking nitrogenous fertilizer applications as a measure of the latter. The EBD suggested (Table 4) that most changes occurred in the Netherlands and Germany (four and five species, respectively, declined). Latvia was at the other extreme, with only two declining species. Changes in other countries were in between. In the UK, Netherlands, Denmark and former West Germany yearly nitrogen inputs were

Table 4. Trends during 1970–90 in populations of five bird species based on expert judgements and average use of nitrogenous fertilizer in agricultural areas in 1980–90 (Hagemeijer & Blair 1997, European Commission for Europe 1992).

Country	Lapwing	Linnet	Skylark	Whitethroat	Yellowhammer	Fertilizer (kg N ha^{-1})
United Kingdom	–1	–2	–2	0	0	200
The Netherlands	0	–2	–2	–1	–2	500
Denmark	–1	+1	–1	–1	0	140
Germany*	–1	–1	–2	–2	–1	200 (W) <100 (E)
Finland	–1	–2	–1	0	0	80
Latvia	–2	0	0	0	–1	<100
Estonia	–2	–1	–1	+1	0	<100

+2, –2, increase and decrease, respectively, >50%; +1, –1 , increase and decrease, respectively, 20–50%; 0, increase or decrease <20%.
*No separate estimates of trends are available for W Germany and E Germany.

more than 100 kg N ha^{-1}, whereas those in the other four countries were probably less than 100 kg N ha^{-1} (Table 4) (European Commission for Europe 1992). Taking into account EBD trends, fertilizer use and also geographical similarities (e.g. climate), we placed UK, Netherlands, Denmark and West Germany in one group and East Germany, Finland, Latvia and Estonia in another group. We assessed total numbers for both groups of countries.

The results of trends of individual species shown below need to be treated with caution. They are not yet pan-European trends, being based on data from only a few countries within Europe. The results presented should be seen as a trial of the method, rather than as definitive trends for these species across Europe, and should give a feel for the sort of information that could be produced if data were available from more European countries. Despite this, some interesting species-specific results do emerge.

RESULTS

Many national trends were significant and most significant changes were substantial (Table 5). Almost all non-significant changes were in fact poorly known trends, so changes, even substantial ones, cannot be excluded in these cases.

The Skylark was the most abundant species on farmland of the five selected (Table 3). In western Europe, the Skylark declined significantly in UK, Netherlands and, to a lesser extent, Denmark (Fig. 1; Table 5). The trend estimate for West Germany suffered from a large standard error (Table 5) so that inferences from the time series are unreliable. Taking all western countries used in this study together, the total number of Skylarks dropped from more than eight million pairs in 1978 to about five million in 1997 (Fig. 2). The decline happened during the first ten-year period: in 1978–88 numbers declined with a trend value of 0.952 ($P < 0.01$), whereas in 1988–97 there was even a slight increase (trend value 1.006; $P < 0.01$; Wald-test for change-point in 1988 = 542; $P < 0.01$ [b]).

Across the eastern European countries used in this study, Skylark numbers also declined (Figs 1 & 2; Table 5). Again, the decline occurred during the first ten-year period (trend value 0.927; $P < 0.01$), after which the species increased (trend value 1.058; $P < 0.01$; Wald-test

Table 5. Trend estimates and standard errors in farmland populations of five bird species, and diagnosis of the trend.

Country (years)	Lapwing	Linnet	Skylark	Whitethroat	Yellowhammer
UK	0.948 ± 0.006	0.981 ± 0.004	0.962 ± 0.002	1.040 ± 0.005	0.972 ± 0.003
(1978–97)	sub. dec.	sub. dec.	sub. dec.	sub. inc.	sub. dec.
Netherlands	0.991 ± 0.003	1.021 ± 0.008	0.967 ± 0.004	1.053 ± 0.006	1.078 ± 0.010
(1984–97)	decline	increase	sub. dec.	sub. inc.	sub. inc.
Denmark	0.989 ± 0.007	0.997 ± 0.006	0.995 ± 0.002	0.997 ± 0.003	0.982 ± 0.002
(1978–97)	poorly known	poorly known	non-sub. dec.	stable	sub. dec.
West Germany	0.986 ± 0.039	0.976 ± 0.031	1.022 ± 0.013	1.029 ± 0.021	1.008 ± 0.016
(1989–97)	poorly known	poorly known	poorly known	poorly known	poorly known
East Germany	1.126 ± 0.293	0.947 ± 0.107	1.071 ± 0.078	0.889 ± 0.043	1.186 ± 0.108
(1989–97)	poorly known	poorly known	poorly known	sub. dec.	poorly known
Finland	0.970 ± 0.009	1.042 ± 0.033	0.971 ± 0.005	1.017 ± 0.006	0.987 ± 0.005
(1978–97)	sub. dec.	poorly known	sub. dec.	increase	decline
Latvia	0.930 ± 0.023	1.002 ± 0.137	1.013 ± 0.010	1.003 ± 0.017	1.052 ± 0.020
(1983–94)	sub. dec.	poorly known	poorly known	poorly known	sub. inc.
Estonia	0.991 ± 0.021	0.974 ± 0.029	0.998 ± 0.009	1.053 ± 0.012	1.011 ± 0.011
(1983–97)	poorly known	poorly known	poorly known	sub. inc.	poorly known
Western Europe	0.977 ± 0.003	0.990 ± 0.003	0.984 ± 0.001	1.011 ± 0.002	0.975 ± 0.001
(1978–97)	sub. dec.	decline	sub. dec.	increase	sub. dec.
Eastern Europe	0.969 ± 0.009	0.975 ± 0.028	0.977 ± 0.005	1.018 ± 0.006	0.992 ± 0.001
(1978–97)	sub. dec.	poorly known	sub. dec.	increase	non-sub. dec.

Sub. dec., substantial decline; sub. inc., substantial increase; non-sub. dec., non-substantial decline. The estimates are a measure of the overall yearly rate of change (<1, decline; >1, increase). See Appendix 1 for details on the diagnosis of trends.

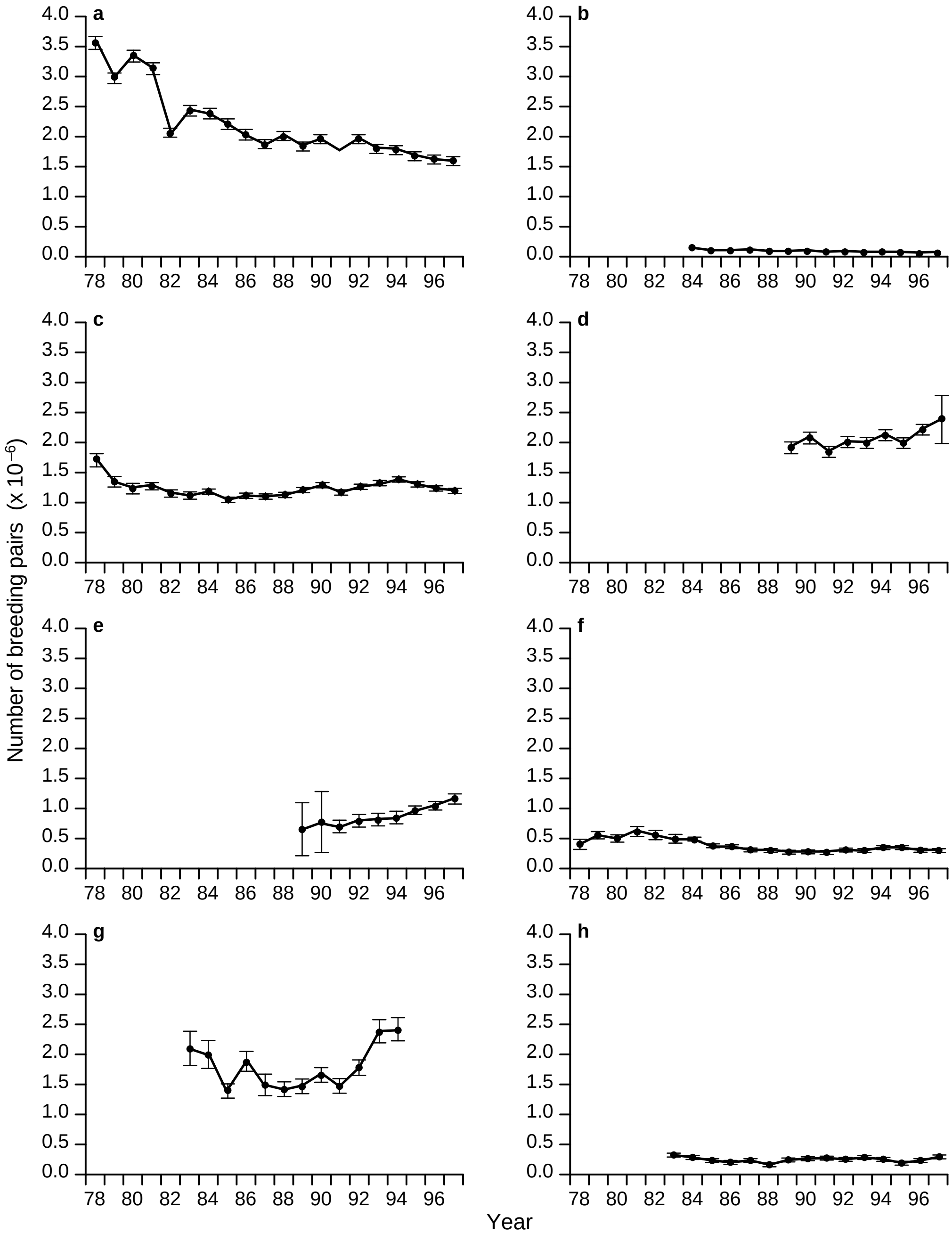

Figure 1. The number of breeding pairs (in millions) and standard errors of Skylark in (a) UK, (b) Netherlands, (c) Denmark, (d) West Germany, (e) East Germany, (f) Finland, (g) Latvia and (h) Estonia. The high standard error of the index in 1997 in West Germany was because we received less data for that particular year.

for change-point in 1988 = 870; $P < 0.01$). However, the index for eastern Europe for 1978–82 was based entirely on Finnish data and these data showed a significant decline in numbers. Combining western and eastern Europe revealed a loss of about one-third of the total breeding Skylark population across the seven countries involved (Fig. 2).

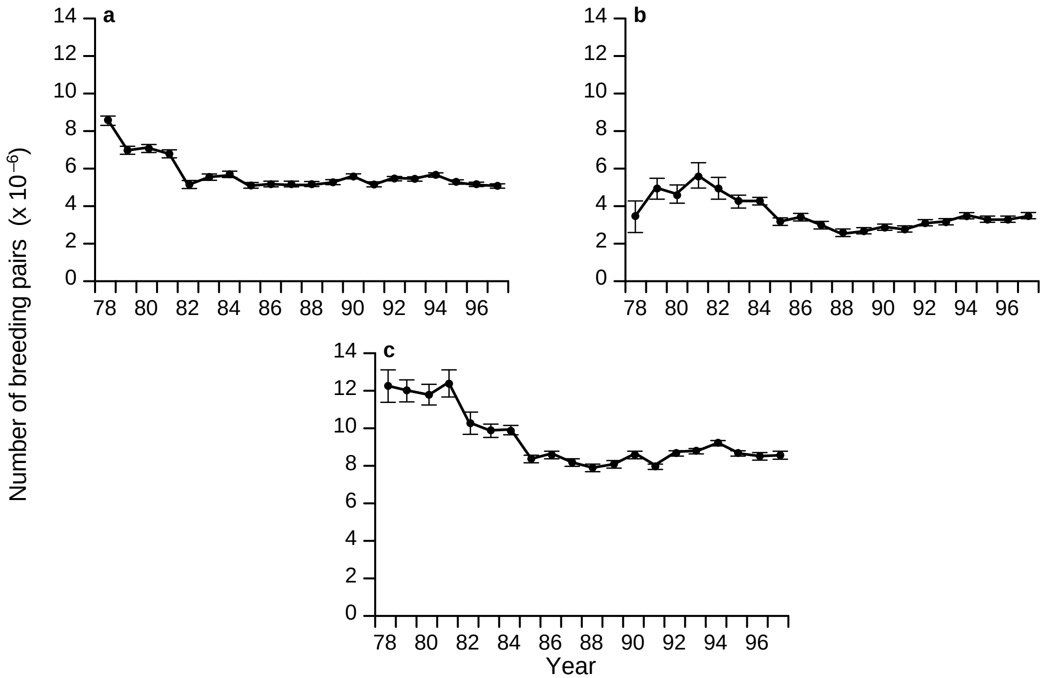

Figure 2. The number of breeding pairs (in millions) and standard errors of Skylark in (a) western Europe (UK, Netherlands, Denmark and West Germany pooled), (b) eastern Europe (East Germany, Finland, Latvia and Estonia pooled) and (c) Europe (all seven countries combined).

Most breeding pairs of Lapwing from the countries studied were in the UK and the Netherlands (Table 3). In western Europe, numbers dropped considerably, due to significant declines in the UK and, to a lesser extent, the Netherlands (Fig. 3; Table 5). The decline in western Europe during 1978–83 was entirely caused by that in the UK. Eastern Europe holds much lower numbers of Lapwing. Numbers dropped significantly in Finland and Latvia, but for East Germany and Estonia the information on change is, as yet, insufficient (Table 5).

The Linnet mainly breeds in the UK, Denmark and West and East Germany; numbers in the other five countries are insignificant for European indices (Table 3). In western Europe, its numbers dropped significantly over the 20-year period, mainly due to a decline in 1978–82 in the UK (Fig. 3; Table 5). The figures for eastern Europe did not allow any conclusions to be drawn on changes in Linnet numbers because of the limited statistical power of the monitoring schemes there. The standard errors of the population numbers are especially large in the early years of the time series. Even if all four eastern countries are combined, the overall population change for this species remains poorly known (Table 5).

The Whitethroat is a common species in most countries (Table 3). In western Europe its numbers increased (Fig. 4) due to an increase in the UK and the Netherlands (Table 5). On the whole, population numbers also increased in eastern Europe, although the trajectory of the changes varied considerably across time and countries.

The trends in Yellowhammer varied widely. In western Europe populations steadily declined, mainly driven by the UK and Denmark, even though the species increased in the Netherlands (Fig. 4; Table 5). In eastern Europe numbers fluctuated considerably, though overall there was a slight decline.

DISCUSSION

Method to combine national scheme results

Combining scheme results produced exactly the same European indices and trends as would have been produced by the raw national data.

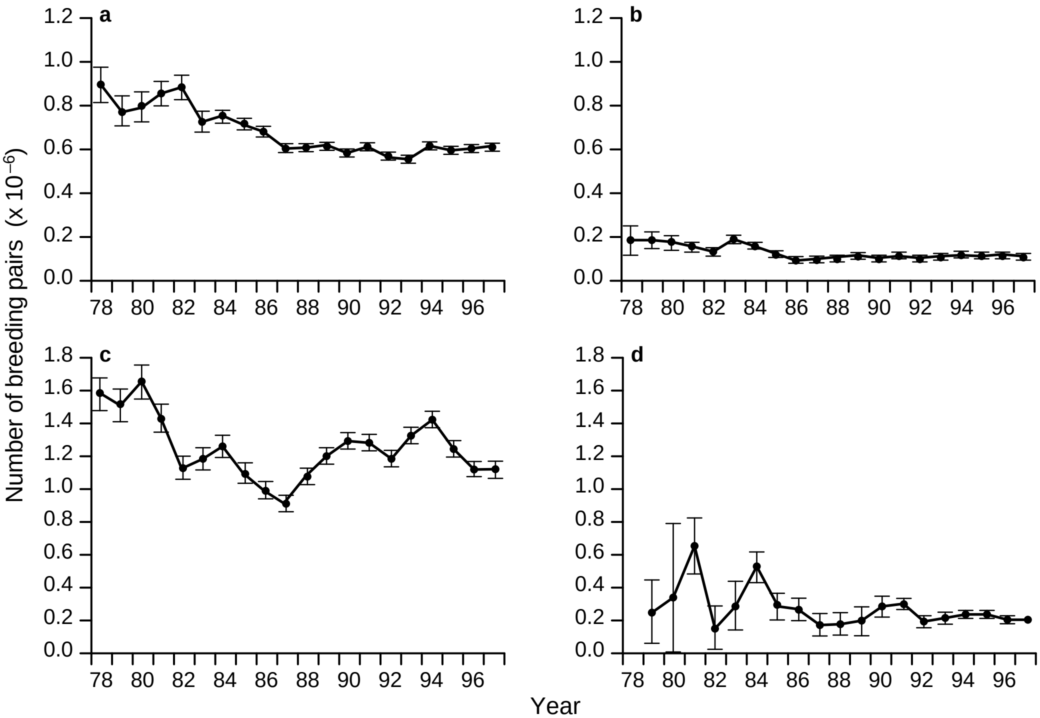

Figure 3. The number of breeding pairs (in millions) and standard errors of Lapwing in (a) western Europe (UK, Netherlands, Denmark and West Germany pooled) and (b) eastern Europe (East Germany, Finland, Latvia and Estonia pooled); and Linnet in (c) western Europe and (d) eastern Europe, though with Latvia excluded because of convergence problems in computing indices.

Thus, the time-consuming process of collating and analysing raw data, which is done nationally, does not have to be repeated at the European level. Annual European indices could be produced by collecting and combining limited amounts of information provided by national monitoring organizations. A central organization would need to collect the national yearly indices per species (or preferably the yearly population numbers), and their standard errors, and also the covariances between the year figures. Ideally these would be estimated by the participating countries, preferably using a standard index method. National yearly indices alone, without information on standard errors and covariances, could still be combined, but would restrict opportunities for statistical testing and limit interpretation of the results.

Reliability of the European results

The method developed here allows the creation of a combined index based on the results of national schemes. However, there is much room for improvement.

The precision of the European trends does not only depend on the national scheme results, but also on the precision of the national population estimates. These (Table 3) were not always accurate (Hagemeijer & Blair 1997), and were converted to approximate farmland population sizes (although for some countries we used data for all habitat types on the assumption that the bulk of the population lived in farmland). As a result, the European results cannot be considered very precise. More accurate estimates of population size per country and per habitat type are needed. It would also be helpful to incorporate the precision of the population size estimates in the method developed.

The pooling of countries to estimate missing year values has important consequences for the results. The combined year totals for a group of countries can be dominated by one single country for those years for which no information is

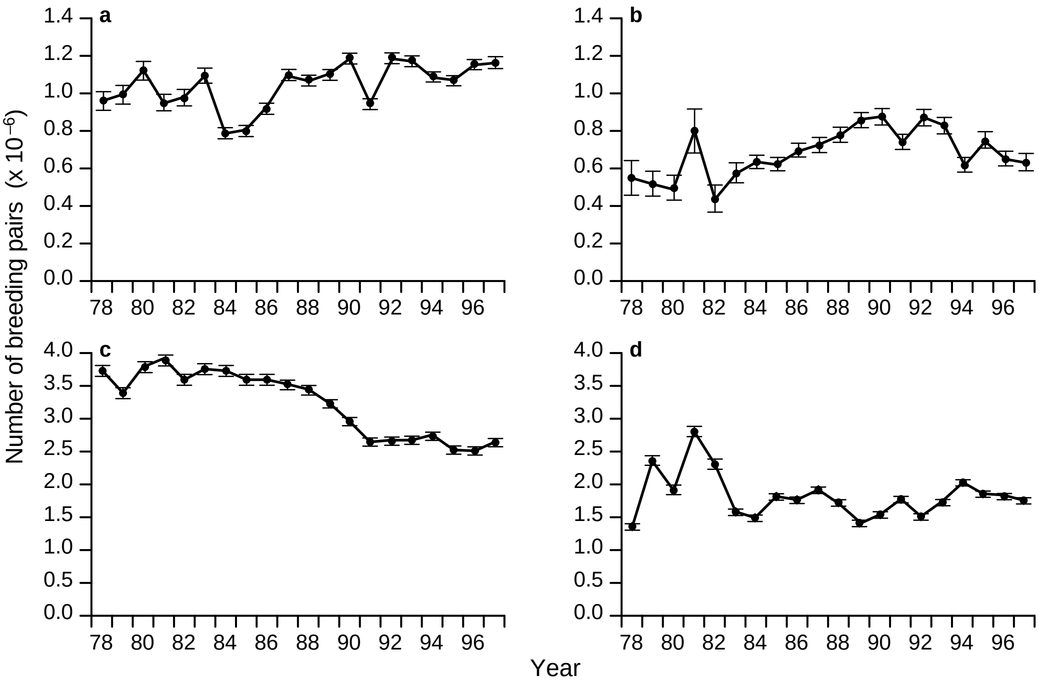

Figure 4. The number of breeding pairs (in millions) and standard errors of Whitethroat in (a) western Europe (UK, Netherlands, Denmark and West Germany pooled) and (b) eastern Europe (East Germany, Finland, Latvia and Estonia pooled); and Yellowhammer in (c) western Europe and (d) eastern Europe.

available for the other countries. For the period 1978–82, the eastern European totals were determined entirely by the Finnish totals. Whether or not the changes in Finland in those years were indeed representative of the other countries in the group is unknown; possibly the changes in agriculture in the other eastern countries were more limited. As a result, the overall declines of Lapwing, Skylark and Yellowhammer in eastern Europe might have been overestimated by the pooling procedure, or may even be artefactual. The trajectories of the western European totals were more robust, because in the early years of the time series (1978–83) two countries provided information (UK and Denmark), and agricultural developments in all four countries were similar over the period.

Clearly, the procedure to estimate year totals for years not covered by each scheme can be improved further. The pooling of countries needs to be undertaken carefully and would be helped if earlier population estimates were available for each country, even if these estimates were very crude. In addition, it might be better to combine regions within countries, rather than individual countries, because regions could be more easily matched than countries as a whole. An alternative to pooling could be to estimate missing indices by extrapolating trends beyond the years covered by a scheme. However, this may lead to unrealistic values, because trends are rarely constant for many consecutive years.

Pooling will become increasingly unnecessary with time, when more countries have monitoring schemes. For the time being, however, pooling is needed to compute the indices in earlier years so that a reasonable time series can be generated. Information on population levels in former years could help to set current trends into a proper conservation perspective (Ten Brink 1997, Van Strien 2000).

For species other than the five studied here, other country groupings could be more appropriate. Therefore, for each species or species group it would be necessary to identify the environmental factors that have (probably) driven their population trends in the past, for example changes in agriculture, forestry, water management or on their wintering grounds. In addition, it might be helpful to group countries according to their EBD trends and on similarities in trend over the years they share in common, although the latter does not prove that trends were similar in other years.

Many national year totals had larger standard errors in the earlier years of the scheme (Figs 1 & 2). This was caused mainly by the low number of sites counted in these years. The standard errors of the trend estimates were much larger for Latvia, Estonia and Germany than for the other countries, where longer and larger schemes exist. In several countries the standard errors of the trends were so large that the statistical power of the scheme for particular species was limited (Table 5). Despite this, European yearly totals and trends can be assessed sufficiently accurately, even when based on countries with relatively small schemes (Table 5). The only exception here was the Linnet for which no accurate eastern European trend could be estimated. East Germany is especially important for this species and we may expect that the eastern European estimates will improve as the East German scheme develops.

In this study, we have produced western and eastern European trends from data for seven countries. True European trends require the involvement of many more countries. Ideally, each country would have its own scheme, so that one could also compare countries to identify possible causes of change. In the absence of schemes in every country it would be worthwhile to promote a few 'Euro-sites' in each country without a national scheme. These would be sample plots which would provide data direct to the European scheme and thus improve estimates of pan-European trends, even though they would probably be too few in number to provide reliable estimates of national trends. One downside of this approach is that it might lead to relatively imprecise European trends for those species that inhabit such countries in large numbers. In addition, by investigating the standard errors of year totals and trends, it is possible to identify the countries where extensions of schemes are most needed.

Apart from a number of non–farmland sites being included in the data set, the national organizations involved may have used different definitions of farmland. As a result, the estimated totals may be a mix of farmland and other habitat types, such as a patchy landscape of farmland and woodland. Still, the totals presented are expected to reflect changes in farmland, because the bulk of the populations of these species breed in farmland. For species that breed in a variety of habitat types, a clear definition of these would be needed to obtain comparable information from each country.

Finally, the European trends might be biased due to bias present in the national schemes, mainly a consequence of the free choice of sites by fieldworkers. Because we selected mainly farmland sites, this bias might have been limited. Nevertheless, it is necessary to remove such national bias in the future, either by adapting the sampling design or by using retrospective weighting to adjust statistically for deviations from representativeness. This should be done by the national organizations themselves, because they are the best informed about any deviations from representativeness. This is a further argument for exchanging scheme results rather than raw data.

European trends in farmland birds

Despite these flaws, it is obvious that the five species selected showed considerable changes in western Europe. Four out of the five species (Lapwing, Linnet, Skylark and Yellowhammer) declined from 1978 and only the Whitethroat increased. The decline of these species is a consequence of the considerable changes in agricultural practices across Europe, which have affected nesting and foraging opportunities (Pain & Pienkowski 1997). The changes in eastern Europe were less clear, because the impact of pooling was great and the statistical power of the national schemes is as yet limited.

In western Europe the decline of the Lapwing, Linnet and Skylark was greater in the first ten years of the period studied than in the last ten years, while the Yellowhammer declined in the late 1980s and early 1990s. Changes in the future will depend largely on the changes to agricultural policy in these countries and in Europe as a whole, much of it brought about by changes in the Common Agricultural Policy. The increase of the Whitethroat is probably a recovery from an earlier decline due to severe drought in Africa in the late 1960s (Siriwardena *et al.* 1998).

These results correspond more or less with the trends reported by Tucker & Heath (1994) which are available in the European Bird Database (Hagemeijer & Blair 1997). But there are also marked differences, caused by a variety of reasons, most notably the different time periods covered (1970–90 and 1978–97 respectively). This study shows that for several species the trends in the 1980s were different from those in the 1990s, thereby demonstrating that the trends documented by Tucker & Heath (1994) may be becoming out-of-date.

ACKNOWLEDGEMENTS

This paper was written on behalf of the European Bird Census Council (EBCC). Richard Gregory (BTO, United Kingdom), Erik Mandrup Jacobson (Ornis Consult, Denmark), Johannes Schwarz (Dachverband Deutscher Avifaunisten, Germany), Risto Väisänen (Zoological Museum, University of Helsinki, Finland), Janis Priednieks and Elmars Peterhofs (University of Latvia, Latvia), and Andres Kuresoo and Arne Ader (Estonian Ornithological Society, Estonia) kindly provided the raw monitoring data from their respective organisations. Chris van Turnhout and Henk Sierdsema helped to estimate total populations on farmland. Thanks are also due to Adriaan Gmelig Meyling for processing the raw data and to Stephen Baillie, Lodewijk van Duuren, Jeremy Greenwood, Richard Gregory, Ward Hagemeijer, Luc Schifferli, Sören Svensson, Tibor Szep, Risto Väisänen and Niklaus Zbinden for their comments on an earlier draft and for their encouragement.

ENDNOTES

a. The trend is measured as an average yearly change, b; $b = 1.00$ implies no change; $b = 1.02$ would imply an average increase of 2% per year (which over 20 years multiplies to 1.45, or a 45% increase over the whole 20 years); $b = 0.98$ would imply a 2% decrease per year (leading to a value of 0.68 or a 32% overall decline over 20 years).

b. The Wald-test for a change point is a statistical test for the significance of the difference between the trends before and after the change point. It is equal to the square of the difference divided by the variance of the difference. Larger values of the Wald-test indicate more significant differences. In large samples, the Wald-test is approximately chi-squared distributed on one degree of freedom. The square root of the Wald-test is equal to the t-test for the difference between the trends.

REFERENCES

Crawford, T.J. 1991. The calculation of index numbers from wildlife monitoring data. In Goldsmith, B. (ed.) *Monitoring for Conservation and Ecology:* 225–248. Chapman & Hall, London.

European Bird Census Council 1997. Report on the workshop on monitoring birds in Europe. *Bird Census News* **2**: 81–95.

European Commission for Europe 1992. *The Environment in Europe and North America. Annotated Statistics 1992.* United Nations, New York.

Flade, M. & Schwarz, J. 1996. Stand und aktuelle Zwischenergebnisse des DDA-Monitorprogramms. *Die Vogelwelt* **117**: 235–248.

Gibbons, D.W. 2000. Pan-European breeding bird monitoring. In Bischoff, C. & R. Dröschmeister (eds) *European Monitoring for Nature Conservation*: 173–178. Schriftenreihe für Landschaftsplege und Naturschutz, Vol 62. Bundesamt für Naturschutz, Bonn-Bad Godesberg.

Gibbons, D.W., Reid, J.B. & Chapman, R.A. 1993. *The New Atlas of Breeding Birds in Britain and Ireland: 1988–1991.* Poyser, London.

Hagemeijer, E.J.M. & Blair, M.J. (eds) 1997. *The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance.* Poyser, London.

Hayes, J.P. & Steidl, R.J. 1997. Statistical power analysis and amphibian population trends. *Conserv. Biol.* **1**: 273–275.

Hustings, F. 1992. European monitoring studies on breeding birds: an update. *Bird Census News* **2**: 1–56.

Kwak, R.G.M. & Hustings, M.F.H. 1994. National common birds census projects in Europe: an overview. In Hagemeijer, W. & Verstrael, T. (eds) *Bird Numbers 1992. Distribution, Monitoring and Ecological Aspects. Proceedings 12th International Conference of IBCC and EOAC*: 347–352. Statistics Netherlands, Voorburg & SOVON, Beek-Ubbergen, Netherlands.

Marchant, J.H., Forest, C. & Greenwood, J.J.D. 1997. A review of large-scale generic population monitoring schemes in Europe. *Bird Census News* **2**: 42–80.

McCullagh, P. & Nelder, J.A. 1989. *Generalized Linear Models,* 2nd edn. Chapman & Hall, London.

Pain, D.J. & Pienkowski, M.W. 1997. *Farming and Birds in Europe.* Academic Press, London.

Pannekoek J. & van Strien, A. 1998. *TRIM 2.0 for Windows (Trends & Indices for Monitoring data)*. Statistics Netherlands, Voorburg.

Siriwardena, G.M., Baillie, S.R., Buckland, S.T., Fewster, R.M., Marchant, J.H. & Wilson, J.D. 1998. Trends in the abundance of farmland birds: a quantitative comparison of smoothed Common Birds Census indices. *J. Appl. Ecol.* **35**: 24–43.

Ten Brink, B.J.E. 1997. *Biodiversity Indicators for Integrated Environmental Assessments.* Technical Report United Nations Environment Program & RIVM, Bilthoven, Netherlands.

Ter Braak, C.J.F., van Strien, A.J., Meijer, R. & Verstrael, T.J. 1994. Analysis of monitoring data with many missing values: which method? In Hagemeijer, W. & Verstrael, T. (eds) *Bird Numbers 1992. Distribution, Monitoring and Ecological Aspects. Proceedings 12th International Conference of IBCC and EOAC*: 663–673. Statistics Netherlands, Voorburg & SOVON, Beek-Ubbergen.

Tucker, G.M. & Heath, M.F. 1994. *Birds in Europe – their Conservation Status.* Birdlife International Series No. 3. Birdlife International, Cambridge.

Underhill, L.G. & Prys-Jones, R.P. 1994. Index numbers for waterbird populations. I. Review and methodology. *J. Appl. Ecol.* **31**: 463–480.

Van Strien, A.J., van de Pavert, R., Moss, D., Yates, T.J., van Swaay, C.A.M. & Vos, P. 1997. The statistical power of two butterfly monitoring schemes to detect trends. *J. Appl. Ecol.* **34**: 817–828.

Van Strien, A.J. 2000. From monitoring data to policy- relevant summary statistics. In Helbig, A.J. & Flade, M. (eds) *Bird Numbers 1998. Where Monitoring and Ecological Research Meet; Proceedings 14th International Conference of EBCC. Die Vogelwelt (*suppl.) **120**: 67–73.

(MS received 12 December 1999; revised MS accepted 4 October 2000)

APPENDIX 1

Categories of trend estimates

The procedure to characterize the trends to five categories was as follows (see also Hayes and Steidl 1997 and Appendix 2).

(a) The 95% confidence interval of a trend estimate was computed by multiplying the standard error by 1.96. If this interval does not include the value 1, then the trend is statistically significant.

(b) The lower and upper limit of the confidence interval was converted into the corresponding magnitudes of change in a 20-year period, using the lower and upper limits of the interval as factors.

(c) If the trend was significant and the magnitude of change was significantly greater than 20% in a 20-year period, then the trend was considered as (1) a *substantial decline* or *increase*.

(d) If the trend was significant, yet the change was significantly less than 20%, the trend was classified as (2) a *non-substantial decline* or *increase*.

(e) If the trend was significant, but not significantly different from a 20% change, the trend was classified as (3) a *decline* or *increase*.

(f) If the trend was not significant and the confidence limits were sufficiently small that the trend was significantly less than 20% in a 20-year period, the species was classified as having a (4) *stable* population.

(g) If the trend was not significant and the confidence limits were so large that the trend could be larger than 20%, the population trend was classified as (5) *poorly known*, which implies that the statistical power of the scheme for that particular species was too limited to detect a change of less than 20% in 20 years. In such cases, the scheme could still be useful to detect very large changes (Van Strien *et al.* 1997).

APPENDIX 2

Classification of the trend estimates as used in Table 5. See Appendix 1 for details on the diagnosis of trends.

	Greater than 20% change in a 20-year period		Less than 20% change in a 20-year period	
	Significantly so	Not significantly so	Not significantly so	Significantly so
Significantly different from one	Substantial decline or increase	Decline or increase	Decline or increase	Non-substantial decline or increase
Not significantly different from one	(Impossible)	Poorly known	Poorly known	Stable