Ornis Hungarica 12-13: 11-24. 2003

Using birds as indicators of biodiversity

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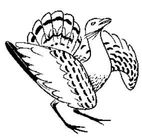
Gregory, R. D., Noble, D., Field, R., Marchant, J., Raven, M. and Gibbons, D. W. 2003. Using birds as indicators of biodiversity. – Ornis Hung. 12-13: 11-24.



Here we develop a new method for reducing information on population trends for a large number of bird species into a simple composite indicator. This approach standardises species trends and creates a mean index across species. The 'headline indicator', which incorporates information on all common native species in the UK, is then disaggregated by habitat to reveal the underlying trends. The purpose of this paper is to introduce the method, discuss the most desirable qualities of wildlife indicators, to illustrate the practical difficulties in bringing such information together, and to show how the method can be used and developed.

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1. Introduction

Composite indices or indicators have many desirable properties, foremost being the reduction of complex information into simple visual summaries. In the field of economics the stock market indices, such as the Dow Jones, FTSE 100 and Nikkei, are highly familiar. Experts and non-experts alike understand the trends in these indices, though they may be unaware of the complex patterns shown by the underlying data.

There are however, few examples of such high profile and widely accepted indicators for biodiversity, although there are encouraging signs of change. Catalysed by the Rio de Janeiro Earth Summit in 1992, which reinforced the importance of biodiversity monitoring, a range of organisations have been involved in the development of indicators. For example, the Secretariat of the Convention on Biodiversity, United Nations Environment Programme (UNEP), the UN Commission on Sustainability (CSD), the World Bank, the Organisation for Economic Co-operation and Development (OECD), European Environment Agency (EEA) and BirdLife International. A series of recent studies have sought to clarify the role of environmental indicators and generate new indices (Kuik & Verbruggen 1991, Ten Brink *et al*. 1991, Reid *et al*. 1993, van Strien 1997, 1999; Ten Brink 1997, Bell & Morse 1999).

First, it is important to distinguish between 'state', 'driving force' and 'response' indicators. The first describes the state of a variable, the driving force gauges a process that influences the state, and the response measures specific actions to return the state to a desired condition. In this paper, we restrict discussion to quantifying a state indicator, namely, the

Tab. 1. Some of the desirable features of a wildlife indicator.

Feature	Details
Representative	Includes all species in a chosen taxon, or a representative group
Immediacy	Capable of regular updating, *eg* on an annual basis
Transparency	Simple and easy to interpret
Assessment	Shows trends over time
Sensitivity	Sensitive to environmental change
Timeliness	Allows the timely identification of trends
Precision	Uses the raw data rather than categorical grouping of data
Cost	Does not require excessive financial resources to be produced
Available	Quantitative data are available
Indicative	Indicative of the more general situation among other taxa
Relevant	Policy and ecosystem relevant, relating to key sites and species; reflect main causes of biological change and conservation actions
Stability	Buffered from irregular, large natural fluctuations
Tractable	Susceptible to human influence and change

population trends of breeding birds in the United Kingdom (UK).

There are a number of key attributes to effective bio-indicators. They must be; quantitative, simplifying, user driven, policy relevant, scientifically credible, responsive to changes, easily understood, realistic to collect, and susceptible to analysis (see Tab. 1).

One basic approach to generating an indicator of the state of wildlife is to measure diversity through time. Species loss or gain could then be used to gauge the trends in biodiversity. A problem with this method is that abundance and range could be modified without a net change in species number (van Strien 1997). There is also the problem that species of conservation concern may be supplanted by less desirable species, but in the process no overall change occurs in species diversity.

A second approach would be to determine the passage of species through categories of conservation status, *e.g.* IUCN categories (IUCN 1996). Van Strien (1997, 1999, see Discussion) has developed a refined version of this approach. If one's interest is in rare or endangered species then this method may be appropriate, but there are limitations. For example, it does not relate to biodiversity targets and can only be updated at fixed time intervals. Clearly, it does not take account of the status of common and widespread species in the environment.

A third approach would be to use a mean index of change taken across species. This would fulfil several of criteria for a wildlife indicator (Tab. 1). However, by taking this inclusive approach there is the potential for the declines among threatened species to be balanced by population gains among commoner, 'less desirable' species (van Strien 1997). The advantage is that it is transparent, and beyond scaling the population trends, no further decisions need to be made about choosing species, deciding on conservation status, nor deciding on population targets or reference periods. Therefore, while this approach has its shortcomings, there is much to admire in its simplicity.

Here we use birds as exemplar taxa to illustrate some of the issues in developing meaningful indicators for wildlife. We describe a new method for creating indicators based on the mean index.

Tab. 2. Sources of data for the indicators.

Data source	Partners	No of spp	Units used
ATLAS	BTO/SOC/IWC	42	10-km squares in UK
CBC	BTO/JNCC	69	CBC index 1970-97
WBS	BTO/JNCC	4	WBS index 1974-96
RBBP	BB/JNCC/RSPB/BTO	51	Mostly max total pairs 1973-95
RBBP/SURVEY	RBBP/RSPB/EN	4	Mostly max total pairs 1973-95
SCR	JNCC/SEABIRD GROUP	9	Pairs
SCR/SURVEY	SCR/RSPB/SNH	3	AOTs/pairs
SCR/SMP	JNCC/RSPB/SOTEAG	4	Mostly Thompson index
SURVEY	RSPB/JNCC/BTO/+	14	Various
OTHER	BTO/RSPB/SNH/WWT/+	9	Various
OTHER/SMP		2	Various
OTHER/SURVEY		1	Breeding pairs
WEBS	WWT/BTO/JNCC/RSPB	6	WeBS index, 1970/71-1996/97
GAME BAG	GCT	1	Bag / 100ha
NONE		10	

Acronyms of data sources explained in text.
BTO = British Trust for Ornithology. SOC = Scottish Ornithologists' Club. IWC = Irish Wildbird Conservancy (now BirdWatch Ireland). JNCC = Joint Nature Conservation Committee. BB = *British Birds*. RSPB = Royal Society for the Protection of Birds. EN = English Nature. SNH = Scottish Natural Heritage. SOTEAG = Shetland Oil Terminal Environmental Advisory Group. WWT = Wildfowl and Wetlands Trust. GCT = Game Conservancy Trust. + = various other sources. AOT = apparently occupied territories.

2. Methods

2.1. Data sources

Taking an inclusive approach to producing a wild bird indicator, we first interrogated all of the long-term bird data sets to obtain information on population trends or range changes for as many species as possible. Because the dates of the first breeding atlas for Britain and Ireland and for the start of a number of the more important surveys were in 1970, it was decided to obtain information from 1970 to the most recently available data (1999 in this report). Hence the index is based on breeding bird populations for the period 1970-99. Approximately 230 species bred in the UK during this period. Data were available for 219 species. These data come from a wide variety of sources (Tab. 2). Wherever possible, an annual measure of population size (either absolute, *e.g*. pairs, or relative, *e.g*. an index) for 1970-99 was sought. There were eight main data sources:

2.1.1. Common Birds Census (CBC) and Waterways Bird Survey (WBS)

CBC and WBS are long-running mapping surveys of breeding birds (Marchant *et al*. 1990, Crick *et al*. 1998, Baillie *et al*. 2001). CBC indices were calculated for each year for 69 species using a general additive model (GAM) with degrees of freedom set to the full span of years in each data set. This is equivalent to a log-linear regression model with a full annual effect (*ie.* without smoothing). Indices were generated using data from all CBC plot types (*ie.* farmland, woodland and special plots; see Marchant *et al*. 1990). CBC data were available mostly for the period 1970-99, although for House Sparrow *Passer domesticus* they were available only from 1975. Data from the Waterways

Bird Survey (WBS) - (the riparian equivalent of the CBC) were calculated in exactly the same way for four specialist waterside species; Common Kingfisher *Alcedo atthis*, Dipper *Cinclus cinclus*, Common Sandpiper *Actitis hypoleucos* and Grey Wagtail *Motacilla cinerea*, and began in 1975. Indices were not calculated if sample sizes had fewer than twenty plots in more than half the years with data.

2.1.2. Rare Breeding Bird Panel (RBBP)

The RBBP reports several population estimates for each species. The lowest is based on proven breeding pairs, the highest is the maximum total number of pairs. Because proof of breeding is difficult to obtain for many species, the latter is more likely to reflect the true breeding population and is used in creating indices. The run of RBBP data covers the period 1973-98, though with some exceptions. For example, RBBP only included a few species in their reports some years after the instigation of the scheme (*e.g*. Common Quail *Coturnix coturnix*). For some, the panel ceased to report national populations during the time period (*e.g.* Common Goldeneye *Bucephala clangula*). Occasional years of data are missed for some species (*e.g*. Snow Bunting *Plectrophenax nivalis*, Black Redstart *Phoenicurus ochruros* and Marsh Warbler *Acrocephalus palustris*). For a few species, such as Cirl Bunting *Emberiza cirlus* and Dartford Warbler *Sylvia undata*, data from the panel are enhanced by full national surveys at decadal intervals. These are listed as RBBP/SURVEY in Tab. 2.

Since the monitoring of most rare breeding birds by the RBBP began in 1973, the indicator for rare breeding species was started at, and indexed to that year.

2.1.3. Seabird monitoring

Seabirds are monitored by two separate schemes. The Seabird Colony Register (SCR) is a complete census of British and Irish seabirds every 15 years. In practice this has been in 1969-70 (Cramp *et al*. 1974) and 1985-87 (Lloyd *et al*. 1991). The Seabird Monitoring Programme (SMP) has counted a sample of plots throughout Britain and Ireland since 1986. For most seabirds therefore, population sizes are known for the two complete censuses, and trends are known for a number from 1986 onwards. Unfortunately, truly national post-1986 trends are available only for a small number of species (there are many regional trends). For Common Guillemot *Uria aalge*, Northern Fulmar *Fulmarus glacialis* and Sandwich Tern *Sterna sandvicensis*, a chain index was produced from 1986 to 1999 (see Upton *et al*. 2000). These species are listed as SCR/SMP in Tab. 2. Annual trend data were available for Little (*Sterna albifrons*) and Roseate Terns (*S. dougallii*). For some species (*e.g*. skuas), full national surveys have been undertaken since 1985-87. Such species are listed as SCR/SURVEY in Tab. 2.

2.1.4. Wetland Birds Survey (WeBS)

For a small number of waterfowl, the best information on annual breeding population levels is available from the WeBS scheme (see Pollitt *et al*. 2000). Although this monitors mainly the non-breeding population, the WeBS trend can be taken as the breeding trend for sedentary species; ie those whose UK wintering population is made up solely of UK breeding birds. Such species were, *e.g*. Mute Swan *Cygnus olor* and Ruddy Duck *Oxyura* *jamaicensis*. Although year-to-year variations in trend will also be related to productivity in the previous breeding season, these are small compared to the overall trend. WeBS produces indices for winter months, which span the end of one year and the beginning of the next. The winter 1970/71 index was taken as the 1970 breeding season value, 1971/72 taken as 1971 value, and so on. The indices were generated using the Underhill method (Underhill 1989, Underhill & Prys-Jones 1994), with 1970 set to an index of 100.

2.1.5. Single-species survey data

A number of species, though not monitored annually, are monitored intermittently on longer time scales; most commonly every ten years at a national scale. In recent years, much of this has been undertaken within the Statutory Conservation Agencies/RSPB annual breeding birds scheme (SCARABBS), although other organisations have also been involved. Such species are listed as SURVEY in Tab. 2.

2.1.6. Other population monitoring data

Information on trends for a variety of other species was extracted from the scientific literature (OTHER); for Red Grouse (*Lagopus lagopus scoticus*) game-bags were used as the best index of the species population trend.

2.1.7. Distributional data

For a number of species, some 42 out of the total of 219 (=19%) there were no data available on population size during the time period. For these species a change in range, rather than population, over a twenty-year period was used. These data were obtained by comparing the results of the breeding atlases of 1968-72 (Sharrock 1976) and 1988-91 (Gibbons *et al*. 1993). Data on population trends (rather than changes in range) were always used wherever available, even if they were for a shorter time period than that spanned by the atlases (Red-throated [*Gavia stellata*] and Black-throated [*G. arctica*] Divers). Wherever a population or range estimate was collected from a survey spanning more than one year, the value was allocated to the middle year(s) of the range of survey years. For example, values from the 1968-72 atlas were allocated to its mid year, 1970, while data from the SCR collected during 1985-87 were allocated to 1986.

The geographical scope of the data for each species is summarised in Tab. 3. In most cases (86%), the data are of change in population or range for the UK. This is because most of the major schemes (*e.g.* CBC and RBBP) cover the UK. In practice, some of these schemes yield trends that may be a biased representation of the true UK trends, largely because some have no formal sampling design. Data for half

Tab. 3. Geographical scope of the species data.

Geographical scope	No of spp	Notes
UK	188	*e.g.* CBC, WBS and RBBP data
GB	16	*e.g.* WeBS wildfowl indices
UK coast	5	Only coastal part of seabird populations monitored
Northern Isles	3	Skuas and Arctic Tern *Sterna paradisaea*; bulk of populations are in the Northern Isles
Shetland	2	Whimbrel *Numenius phaeopus* and Red-throated diver
Other	5	Various

of the remaining species are representative of Great Britain (GB) rather than UK (GB plus Northern Ireland); thus for example the WeBS trends used for a few wildfowl are indices for GB not UK. The remaining species data are from yet more restricted geographical scales. However, in all of these cases, the bulk of the UK population for that species lies within these areas. Thus, for example, for five species of seabird the UK coastal population is monitored, even though a small part of the population may nest inland.

2.2 Dealing with missing values

Ideally, one would have measures of population (or failing that, range) for all 219 species for each of the 30 years, 1970-99. In practice, this was not the case and there were many missing species-year values. These missing values were either of data that has never existed, or which have been collected but not reported at the time of the analysis. Wherever possible missing values were estimated by interpolation (ie in years between known values) or by extrapolation (ie in years beyond known values) in the following manner.

To interpolate missing values a constant annual rate of change (C) in between the intermittent surveys was calculated as:

$$C=(value_n/value_1)^{1/(n-1)}$$

Where: $Value_n$=value (e.g. population size or index) in yr_n, and $value_1$=value in yr_1.

Knowing C and $value_1$, it was possible to estimate the values for yr_2, yr_3, yr_4 etc up to yr_{n-1}. For species with several intermittent surveys, C was estimated for each intervening time period separately. The approach taken to deal with missing values at the beginning and ends of data series was to extrapolate forwards or backwards based on the species trend over the previous or following periods. No data were extrapolated (forwards or backwards) over more than a nine-year period. This period is almost certainly too long (see Discussion) and in subsequent versions of the indicator the period is likely to be reduced. Instead, alternative data sources will be sought, or the species may be excluded from the indicator.

Extrapolations were either from intermittent surveys or annual monitoring data. The method of extrapolation was subtly different for these two sorts of data. An explanation of forwards extrapolation is given here, but the principle is the same for backwards extrapolation.

For intermittent surveys, the interpolation formula (above) was used for forward extrapolation beyond the last survey. Where there were several intermittent surveys, the most contemporary value of C was used. The manner in which missing values were extrapolated for annual data was similar to the forward extrapolation from intermittent surveys, but with C calculated from the mean of the first and last three years of data in the monitoring string.

One drawback with this approach is that it assumes a linear change from beginning to end of the data string, and this cannot always be justified. Annual monitoring data were only rarely extrapolated forwards by more than two years.

2.3. Calculation of the mean index

Since population size is measured in a variety of units (e.g. pairs or indices, often with different base years for indices), it is necessary to standardise all figures to a base year. We chose to use 1970 (the first year in the index) as the base year. This may give the impression that the 1970 value was some kind of target to be regained, particularly with an index that declines from 1970, but this was not the intention. Species for which no data for 1970 were available or where they cannot be extrapolated from later years (because of incompatible survey techniques, for example) were excluded.

The mean index was calculated as an average index of population trend taken across species (or various groupings). One cannot take a simple arithmetic average of indices. Instead, for each year separately, the log of each species index value was taken, this was then averaged across species and the exponential of the result calculated. Hence, each indicator is simply the average population trend of the species that it includes.

2.4. Groupings of species prior to index calculation

Each species was classified in three separate ways, by native or introduced status, by habitat and by abundance class. These classifications allowed the calculation of across-species indices for different groupings. Each species was categorised as native or introduced/feral following the definitions used by Gibbons *et al*. (1993). Re-introduced, or part-re-introduced species (Capercaillie *Tetrao urogallus*, Osprey *Pandion haliaetus* and Red Kite *Milvus milvus*) were included as native species.

Each species was allocated to one of seven habitat categories. These categories, which reflect the main habitat used for foraging during the breeding season, were: coastal, farmland, woodland, wetland, urban, upland and 'not classified'. The classification follows Gibbons *et al*. (1993), parts of which were taken from Ratcliffe (1990, for uplands) and from Fuller (1994, for woodland). Twenty additional species were allocated to their preferred habitat because they were too rare or had too restricted a distribution to be categorised by Gibbons *et al*. (1993).

In this situation, a species can be included in only one habitat, even though it may occur in many different habitats. There is no reason why species could not be included in the different habitats they occupy (with an indicator for each), but this would slightly alter the nature of the indicator.

Each species was classified as rare (<500 breeding pairs in UK) or not rare (>500 breeding pairs) at the time of the most recent population estimate included in Stone *et al*. (1997). For a few species, it was necessary to convert into pairs the unit in which population size was reported (*e.g.* adults or individuals), following Heath *et al*. (2000).

2.4. Rare bird indicator

The rare bird indicator follows the methodology of the headline indicator but there are important differences due to data availability and quality. Thus, the index runs 1973-1998, the period for which these data were available. In calculating a mean index, a five-year running mean was used as the species-year value, instead of the real count value. This not only allowed smoothing of the sometimes large fluctuations in yearly counts of some very scarce species (through variations in observer effort and the difficulties inherent in surveying scarce animals), but also the inclusion of some very scarce, colonising or

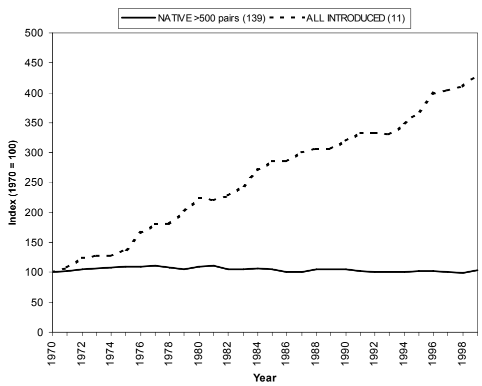

Fig. 1. UK Headline wild bird indicator for 139 common (more than 500 pairs) native species and indicator for 11 introduced species.

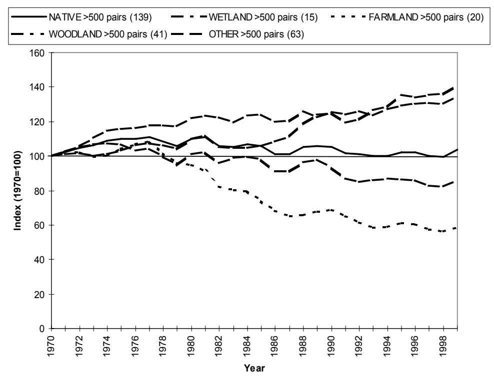

Fig. 2. UK Headline wild bird indicator for 139 common (more than 500 pairs native species and indicators for species of woodland, wetland, farmland and for unclassified species with populations greater than 500 pairs.

declining species that would have otherwise been excluded from the mean index. Species with an index of zero in any year were set to an arbitrary index value of 1 (van Strien, pers comm).

3. Results

Annual population indices (both real and estimated values) were available for 198 species for the period 1970-99. Of these, 11 were of introduced or feral origin and their overall populations have increased strongly (Fig. 1). Populations of some other groups of species, most notably wetland birds, increased during 1970-99 (Fig. 2). Among the remaining 187 native species, 42 had populations of fewer than 500 pairs. Populations of these rare species have increased substantially, rising by over 260% between 1973 and 1998, as shown in the separate rare species indicator (Fig. 3). Rarities were excluded from the final headline indicator because their population trends were not representative of the wider environment, most having increased because of direct conservation action. The final headline indicator was thus based on trends of the remaining 139 common native species, indices being produced for all 139 species combined, and for farmland and woodland birds (subsets of the 139) separately (Fig. 4). While the overall line has remained relatively constant, the woodland and farmland indices have fallen by approximately 20 and 40% respectively since the mid-1970s. Farmland and woodland account for about 85% of the UK land surface and are home to many of the UK's most abundant species. Declines of species in these habitats are probably a sign of general environmental change or deterioration.

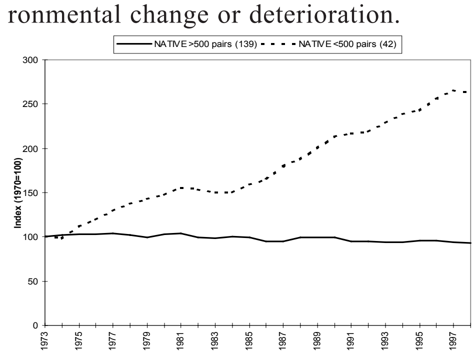

Fig. 3. UK Headline indicators for 139 common (more than 500 pairs) native species and 42 rare (fewer than 500 pairs) species.

It has also been possible to produce headline and rare species indicators for specific regions and countries within the UK, following methods similar to those used above. These are currently under development, but examples are given in Figs. 5 and 6. It can be seen that there are considerable differences in the indicator trends in different regions and habitats, which are only partly due to the differences in species composition of the regional avifauna.

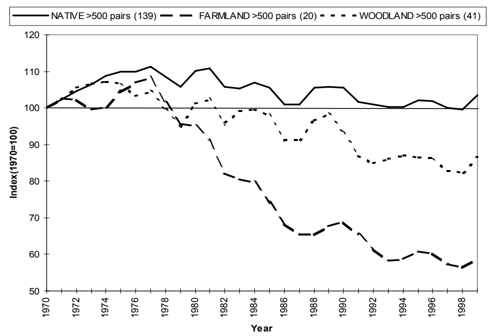

Fig. 4. UK Headline wild bird indicators for 139 common species and for common woodland and farmland species, as accepted by the UK Government as one of its 15 Quality of Life Indicators.

4. Discussion

4.1. General remarks

Here we describe a new method for producing wildlife indicators based on an average index across all species. A version of this mean index, representing the commoner native bird species (Fig. 4) has been adopted by the UK Government as one of its 15 headline indicators, the so-called Quality of Life Indicators, out of a set of 150 core indicators of sustainable development (Anon 1998, 1999). It shows unequivocally, that on average, common birds of both farmland and woodland are in sharp decline. It is recognised that such an index has resonance with policy makers, politicians and the public alike. The UK Government is committed to publishing annual updates of the headline indicator, its goal being to reverse the long-term trends. Furthermore, the Ministry for Agriculture Fisheries and Food has pledged to reverse the decline of farmland birds by 2020, using the headline indicator to measure their progress. There is mounting evidence that farmland birds are threatened in the UK (Marchant *et al*. 1990, Gibbons *et al*. 1993, Marchant and Gregory 1994, Fuller *et al*. 1995, Baillie *et al*. 1997, Siriwardena *et al*. 1998) and in Europe (van Strien 1997), and that the driver of these changes

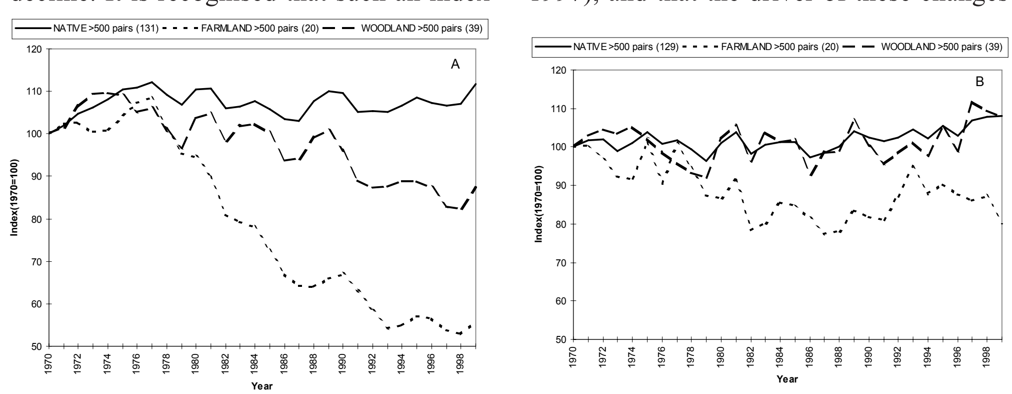

Fig. 5. Examples of regional Headline indicators currently under development (a) England, (b) Scotland.

Tab. 4. A comparison of the properties of different wildlife indicators.

(a) A mean index approach	(b) AMEOBA approach	(c) Red List Index	(d) Ecological Capital Index
All widespread species are included	Indicator species are selected	Rare species included	Species indicative of habitats are chosen
All species are weighted equally	All species are weighted equally	Influenced by changes in status of species of high conservation concern	All the included species are weighted equally
Underlying model is simple	Underlying model is simple	Underlying model is simple	Underlying model is complex
There is no reference state/period	A reference state/period must be chosen	A reference state/period must be defined	A reference state/period must be defined
Require high quality data	Require high quality data	Require lower quality data i.e. categorical data on rare birds	Require high quality data for chosen species
All species need to be monitored	Indicator species need to be monitored	Rare species need to be monitored	Indicator species need to be monitored
Sensitive to change	Sensitive to change	Relatively insensitive to change	Sensitive to change

is agricultural intensification (Krebs *et al*. 1999, Donald *et al*. 2001).

Recent work has extended the general methodology presented here to examine regional variation in common and rare breeding bird populations within the UK, and to produce regional headline and habitat-based indicators (Figs 5 and 6.). The methodologies of the UK-wide survey schemes from which constituent data are drawn lend themselves to collation of data on a regional basis. Regional wild bird indicators are currently being developed as one type of a number of indicators of regional sustainability in conjunction with the UK Government.

Data on non-breeding bird populations were available for many (but not all) species, but they were not incorporated in the index. These may be incorporated at a future date, with the possibility of including an indicator of wintering bird populations in the UK, because the UK is globally important as a wintering site for many wildfowl and wader species.

4.2. Conceptual issues

The wild bird indicator is the average trend of a group of species found in a particular country, region or habitat, and the degree to which this indicates changes in

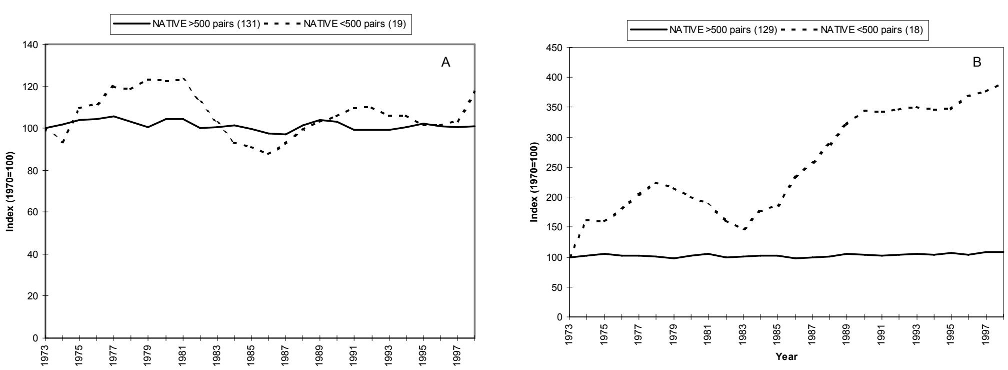

Fig. 6. Examples of regional rare species indicators currently under development (a) England, (b) Scotland.

the landscape or biodiversity in general remains open to question. In the case of UK farmland, declines in bird populations have been mirrored by declines in populations of many specialised invertebrates and plants, declines driven mostly by similar changes in land use (Donald 1998, Sotherton & Self 2000). Whether birds can act as bio-indicators in other ecosystems and in other situations is less clear. In some, perhaps rare, cases, population gains among birds could reflect habitat degradation *e.g.* mild eutrophication, rather than any genuine improvement in habitat quality. This reinforces the need to be cautious in promoting birds as indicators of other wildlife.

4.3. Statistical issues

The use of atlas range change in the place of abundance data (for 42 out of 139 species in the headline indicator) is contentious and its use in future breeding bird indicators is under review. Range change, based on two widely spaced surveys, is a relatively insensitive measure of trends in bird populations. First, the use of atlas data assumes that changes in range and abundance are analogous. This may not always be true and the degree to which the two are linked may be species specific. Second, extrapolation of these data assumes a linear consistent change over the entire period, including after 1990. In the absence of any evidence that this assumption is justified, we should be aware that these extrapolations may differ considerably from actual changes. It seems likely that the atlas information will not be used in future updates of the headline indicators.

In this work, no assessment of the precision of the indicator has been made. Some measure of statistical confidence would be desirable if trends shown by the indicator are to be ascribed to real processes, rather than to chance fluctuations. When dealing with single species population indices derived by GAMs or similar, this can be achieved by calculating confidence intervals by bootstrapping on survey sites (Buckland *et al*. 1992, Siriwardena *et al*. 1998). The bootstrapping approach could also be adapted for use in a multi-species indicator. It is not possible to estimate the precision of data from some of these sources, and hence the average trend may incorporate these 'unknown' errors. However, it may be possible to use analytical solutions to approximate errors of the mean index (van Strien, pers comm).

4.4. Alternative indicator models

The development of sustainable indicators in the UK parallels work elsewhere. In the Netherlands, for example, three separate indices have been developed, termed the AMOEBA approach (Ten Brink 1991), the Red List Index and the Ecological Capital Index (van Strien 1997, 1999). The general properties of these indicators (and the mean index) are given in Tab.4.

The AMOEBA approach is an innovative method that compares the status of a number of species at some recent point in time with a previous reference point, the latter being chosen to represent an ideal state (Ten Brink 1991, Ten Brink *et al*. 1991). This approach can also compare two systems separated in space where, again, one is chosen to represent an idealised state. The index can include a range of species, although there is some preselection. The visual presentation of the indicator is one of its key characteristics and was developed with non-specialists in mind. The outputs show the difference between the present and the reference situation, and their amoeba-like form gives the indicator its name. A further product of this diagram is termed an 'ecological Dow Jones Index' that is the summed numerical difference between the reference points and the observed data for all the species. The smaller the difference, the closer the system is to a desirable state. This approach can be criticised because different taxa are included with equal weighting, although they may have different values to some users and there is subjectivity in choosing the species and the reference condition.

In the Red List Index, the rarity of a species is classified into one of five groupings, which have different associated scores linked to range or numbers at several time points. The scores are then summed across species for each period and expressed in relation to the reference period. Van Strien (1997, 1999) was able to calculate indices for eight taxa, and in all cases but one, the index showed biodiversity to have declined in the Netherlands since 1900. Curiously, the exception was birds; overall, rare breeding birds had increased. This result thus parallels our own findings for the UK (Fig. 3). Rare birds have increased in both countries because of concerted conservation actions to protect and enhance the species and their habitats. Clearly, the Red List index is not designed to deal with common species, rather it is designed for use alongside the Ecological Capital Index (see below). A further criticism is that the classification of species into broad classes of rarity may be too crude, and so species can move between classes only rather slowly.

The Ecological Capital Index (ECI) is arguably the most sophisticated of the methods considered here. This habitat-based approach combines the quality and quantity of a habitat into a single figure. Quality is taken to be the density of a number of habitat-specific species, and quantity is the area of that habitat. Both rare and common species can be included and their contemporary densities are contrasted with a reference situation in the past. Habitat quantity comes from land cover statistics and is expressed in relation to the reference period. The ECI is the product of quality and quantity. Using birds as an exemplar taxon, van Strien (1997, 1999) showed a decline in habitat quality and quantity in the Netherlands, using the 1950s as the reference period. Overall, farmland and heathland habitats had deteriorated to the greatest extent. This basic framework has also been used with slight modification in the Natural Capital Index that is again based on concepts of ecosystem quality and quantity (Ten Brink 1997). One of the difficulties of this approach is that it concatenates two fundamentally different but related processes; the loss of habitat area and the loss of biodiversity inhabiting that habitat. One could have a situation where the area of a habitat declined rapidly but the biodiversity of the remaining patches was unaltered, or a situation where the habitat area remained constant but the biodiversity declined rapidly, yet both might have the same ECI. Disaggregating the index into its component parts provides better understanding of the ECI. As van Strien is careful to stress, there are two main practical difficulties; they are the choice of the reference period and the selection of the habitat-specific species. While the selection procedures have been based on expert advice, it is still arguable whether they can be considered strictly objective. The choice of species is akin to defining 'keystone species' (Paine 1969), a concept that is generally considered unworkable (Scott Mills *et al*. 1993). However, by taking a relatively wide group of species for each habitat, the amount of subjectivity is minimised. Future editions of the ECI are likely to take a broader group of species, thus increasing its similarity with the UK index (van Strien pers comm).

One of the main differences between the mean index approach and the other biodiversity indicators (Tab. 4) is that the former treats all species equally, regardless of conservation status, and does not include conservation targets. This may be seen as a strength or a weakness. On the positive side, there is no subjectivity in the choice of species to be included or the relative importance they may have because it covers all species for which data are available. However, since all species are weighted equally, 'desirable' rare or vulnerable species are treated equally with 'less desirable' common, or even pest species. This reinforces the point that indicator information needs careful thought and interpretation. Disaggregating the trends is an important step in understanding the underlying patterns. The method we present allows the simple presentation of large amounts of ecological data, making it available to a diverse non-expert audience. While our method has some inherent limitations (and should be regarded as a simplistic summary of a complex situation), it has proved to be an effective tool in communicating information about biodiversity to the public, policy makers and to Government in the UK.

Acknowledgements. We thank the many volunteer and professional ornithologists who are responsible for the data collection over many years. The authors are grateful to the UK Department for the Environment, Transport and the Regions (DETR) for funding and in particular to John Custance, Liz Aldous and Alan Brown. We thank Malcolm Ogilvie and the Rare Breeding Birds Panel for assistance. Arco van Strien provided constructive comments on the manuscript. We thank Mark Avery, Colin Bibby and Jeremy Greenwood for helpful discussion.

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