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Population trends of widespread woodland birds in Europe

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We explore population trends of widespread and common woodland birds using data from an extensive European network of ornithologists for the period 1980–2003. We show considerable differences exist in the European trends of species according to the broad habitat they occupy and the degree to which they specialize in habitat use. On average, common forest birds are in shallow decline at a European scale; common forest birds declined by 13%, and common forest specialists by 18%, from 1980 to 2003. In comparison, populations of common specialists of farmland have declined moderately, falling on average by 28% from 1980 to 2003. These patterns contrast with that shown by generalist species whose populations have been roughly stable over the same period, their overall index increasing by 3%. There was some evidence of regional variation in the population trends of these common forest species. The most obvious pattern was the greater stability of population trends in Eastern Europe compared with other regions considered. Among common forest birds, long-distance migrants and residents have on average declined most strongly, whereas short-distance migrants have been largely stable, or have increased. There was some evidence to suggest that ground- or low-nesting species have declined more strongly on average, as have forest birds with invertebrate diets. Formal analysis of the species trends confirmed the influence of habitat use, habitat specialization and nest-site; the effects of region and migration strategy were less clear-cut. There was also evidence to show that year-to-year variation in individual species trends at a European scale was influenced by cold winter weather in a small number of species. We recommend that the species trend information provided by the new pan-European scheme should be used alongside existing mechanisms to review the conservation status of European birds. The analysis also allows us to reappraise the role of common forest bird populations as a potential barometer of wider forest health. The new indicator appears to be a useful indicator of the state of widespread European forest birds and might prove to be a useful surrogate for trends in forest biodiversity and forest health, but more work is likely to be needed to understand the interaction between bird populations and their drivers in forest.

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Many studies have explored the population dynamics of woodland birds in Europe, with strong emphasis on the potential effects of forestry management on individual species (Järvinen *et al.* 1977, Järvinen & Väisänen 1978, Virkkala 1987, 1990, 1991, Angelstam & Mikusinski 1994, Fuller 1995, Kouki & Vaananen 2000). Work has typically focused at sites, or networks of sites, across relatively small geographical areas and rarely across national boundaries. Although this has provided invaluable insights into bird trends, ecological processes and their interaction with the local environment, it has often been difficult to generalize these findings beyond the scale of the study. There are some notable exceptions to this rule (Tucker & Heath 1994, Angelstam & Mikusinski 1994, Tucker & Evans 1997, Angelstam *et al.* 2004b, BirdLife International 2004), but such assessments and comparisons have by necessity often been rather crude.

In an attempt to increase the scale of study and to look at wider-scale patterns, we explore the population trends of widespread and common forest birds by using Europe-wide data collated by the Pan-European Common Bird Monitoring Scheme (PECBMS). The PECBMS is an association of experts and national organizations cooperating through the European Bird Census Council (EBCC) and BirdLife International (Gregory *et al.* 2005; www.ebcc.info), with technical assistance from Statistics Netherlands. This scheme collates population trend data from annually operated national breeding bird surveys from across Europe. The focus is on population trends of widespread birds and the scheme aims to promote the use of birds as 'bio-indicators' of the state of nature and of the health of the environment (Gregory *et al.* 2005). In the present paper, we first create pan-European indices for species by pooling information on their national trends and combining them statistically. Next, we create multispecies indices (= indicators) for groups of species. The species are grouped in various ways to help show the emergent patterns among these birds and to explore some of the potential ecological factors driving the changes. These indicators update those published by Gregory *et al.* (2005) with two improvements in the methods: one is a more tightly defined species selection, and the other is an improved computation procedure. A further change (beyond an extra year of data) is that the original set included Estonia but not Finland, and now the reverse is true (see Methods).

From previous assessments of species trends (Tucker & Heath 1994, BirdLife International 2004, Gregory *et al.* 2005), we would predict variation in trends between major habitat types and between the generalist and specialist species. We might also expect some degree of regional variation in trends across Europe, especially east to west, although such patterns may be complex, and some species may show uniform trends (BirdLife International 2004, Gregory *et al.* 2005). Previous work also suggests we might find long-distance migrants to be faring worse for a number of reasons, including the impacts of climate change (Böhning-Gaese 1992, Berthold *et al.* 1993, Böhning-Gaese & Bauer 1996, Berthold 2001, Flade & Schwarz 2004, Berthold & Fiedler 2005, Karlsson *et al.* 2005, Both *et al.* 2006, Sanderson *et al.* 2006). We might also expect a link between population declines and nest predation, nest availability (Donovan *et al.* 1995, Martin 1995, Martin & Clobert 1996, Chalfoun *et al.* 2002) and/or species' diet (Potts 1986, Wilson *et al.* 1999). Nest predation can be a strong selective force in bird evolution, and predation risk may be linked to management and other changes in the environment. For example, intensive forest management might also lead to a shortage of standing dead wood with knock-on negative effects for cavity-nesting birds. In the case of diet, we might expect birds reliant on insect food in particular to have declined most, given apparent declines at least in some taxa in some habitats (Gregory *et al.* 2005). We would also predict that annual variation around the trends might be explained by severe winter weather, particularly for small-bodied resident species (Greenwood & Baillie 1991, Peach *et al.* 1995).

Indicators, and biodiversity indicators specifically, are used to quantify and communicate complex information in a simple manner to target audiences (Bibby 1999, Angelstam *et al.* 2004a). Sophisticated trend analysis often underlies the indicator and intelligently combines the data. The output tends to be a single number, a simple graphic, or a mapped representation, to capture trends in the variable of interest. Indicators are often used as a proxy for ecosystem health because of the cost and considerable difficulty in measuring these processes directly. There are a number of different terms used under the heading of indicators and although these are often interchanged, they tend to have specific meaning (Lambeck 1997, Caro & O'Doherty 1998, Simberloff 1998, Hilty & Merenlender 2000, Roberge & Angelstam 2004). A large body of work has explored the development of indicators of forest health and forest biodiversity in northern Europe (Angelstam *et al.* 2004a, 2004b, Roberge & Angelstam 2006). Much of this work has attempted to identify individual species, or small sets of species, as umbrella indicators of the state of biodiversity and of forest condition (Mikusiński *et al.* 2001, Roberge & Angelstam 2006). An umbrella species is one whose conservation is expected to confer protection over a larger number of co-occurring species and the ecosystem they inhabit. Perhaps unsurprisingly, a recent review of the concept concluded that single-species umbrellas rarely worked to conserve co-occurring species because each species has individual ecological requirements not captured by the chosen umbrella (Roberge & Angelstam 2004). However, an attempt to extend the umbrella species approach by selecting multiple species, known as the focal species concept, has proved to be much more promising as an effective conservation tool (Lambeck 1997, Bani *et al.* 2002, Roberge & Angelstam 2004).

Here, we use groups of widespread species as barometers of the general health of the environment. In a sense, this represents a further extension of the umbrella species concept to include multiple species, although our selection criteria differ from those described above. Our indicators are designed to capture the overall, average changes in population levels (resulting from several contemporarily measured changes in population size) to reflect the health and functioning of ecosystems. By doing this, we focus attention on the population trends of a relatively large group of abundant European species associated with woodlands or forests of different kinds. We also make comparisons with birds associated with other habitats to set these trends in context. We then explore the influence of region and aspects of ecology on the pan-European trends. It is important to recognize that these indicators provide only the big picture and not all the biological answers or detail. Considerable work is likely to be needed to disaggregate and explore the species trends and their drivers in order to understand fully the underlying ecological processes, and thus promote an environmental indicator that is fit for purpose (Gregory *et al.* 2005).

The work we describe forms one part of a three-pronged approach advocated by BirdLife International for delivering biodiversity indicators of sustainability in Europe, which also includes monitoring the status and trends of threatened bird species and Important Bird Areas (IBAs).

METHODS

Species selection

Population trend information was collected from a sample of 77 moderately widespread and abundant European species, predominantly birds of farmland or forest. These two broad habitats were chosen both because they dominate the European landscape (agricultural land and grassland make up *c.* 50%, and boreal and temperate forest *c.* 30%, of the land surface of Europe; Tucker & Evans 1997) and because of their policy relevance for bird conservation. The species had large European ranges, were abundant enough to be monitored accurately in the majority of countries by common bird monitoring schemes, and were well monitored by standard field methods. Within this large group, we identified 57 common birds associated with trees (Appendix 1: 'Use of forest'). These are birds using trees in copses, shelterbelts, gardens, parklands and forests of various kinds at least at certain times of the year for feeding and/or nesting. Within this group, we also identified a subset of 33 species of common birds more closely associated with forest (Appendix 1: 'Habitat specialization'). The classification of forest specialists was derived from the assessment of Tucker and Evans (1997). These are birds using and having a high dependence or specialization on forest of various kinds in the nesting season, and for feeding during most of the year. For convenience, we term the first larger group of species 'common forest birds' and the second subset 'common forest specialists'. Within the dataset, there were in addition 19 farmland specialists, three inland wetland specialists and one Mediterranean specialist (Appendix 1).

We define a 'specialist' simply in terms of how the European population of each species is distributed across major habitats according to a review led by BirdLife International (Tucker & Evans 1997). This is a simplification because some species that inhabit woodlands in certain parts of Europe occur in semi-open and varied habitats in other parts. Specifically, species with more than 75% of their population occurring in boreal and temperate forest types were classified as specialists of forest. In addition, species with 10–75% of their population using forest only and no other habitats were classified as specialists, according to Tucker and Evans (1997) for Species of European Conservation Concern (SPECs), and Snow and Perrins (1998) for non-SPECs. Finally, species with 10–75% of their population in three or more forest categories in Tucker and Evans, and 10–75% in only one other habitat were also classified as forest specialists. Specialist birds of other habitats, for example farmland birds, were defined in the same manner. The remaining species with more than 10% of their population occurring across a range of habitats were classified as 'generalists' (Appendix 1).

We defined migration strategy of our species as the predominant behaviour across the European range (as resident, partial resident, long-distance migrant; Appendix 1). The location of the nest-site (tree or shrub, on or near the ground, otherwise), and nest type (open, closed) were taken from Ehrlich *et al.* (1994; Appendix 1). Closed nesting species include cavity-nesting birds along with those nesting in crevices, and pendant and sphere-shaped nests. Diet was classified following Ehrlich *et al.* (1994) and Wilson *et al.* (1996, 1999), updated for forest birds by the authors and J.D. Wilson (pers. comm.). This describes food taken by adult and young birds through the year (as omnivore, herbivore or invertebrate feeder; Appendix 1). We repeated the analyses using 'morphological' diet, i.e. the diet to which the species' beak morphology is adapted, which most often reflects the staple diet. We also checked for the potentially confounding effects of species body size given its influence on aspects of ecology and life history (Peters 1983). Such classifications of ecology are necessarily coarse grained and we use them to explore broad-scale patterns among European woodland birds.

Data

Some 18 countries contributed to the PECBMS (Table 1). The field methods differed between countries and varied from spot/territory mapping to line or point transects, each with between one and 12 visits to each site per year (see Bibby *et al.* 2000, Szép & Gibbons 2000, Vorisek & Marchant 2003, Gregory *et al.* 2004, Lindström & Svensson 2006). These sample surveys record all bird species encountered, but by their nature, they are unlikely to cover very rare species, and so the trends represent the more widespread birds in the environment.

National indices

For each country, the national organizations that co-operated in the PECBMS produce indices for each species using the programme TRIM, which is the standard tool used by the scheme (available at www.ebcc.info). The annual indices are measures related to the total number of birds counted, but anchored to an arbitrary year (often 100 in the first year) to show relative change (Gregory *et al.* 2003).

Table 1. European data sources contributing species indices. The table lists the regional grouping used in indicator construction, country/subnational region covered, field methods used to survey birds, and the time period involved.

European region	Country/region	Field method(s)	Period
West Europe	Austria	Point counts	1998–2003
West Europe	Belgium (Brussels)	Point counts	1992–2003
Central & East Europe	Czech Republic	Point counts	1982–2003
West Europe	Denmark	Point counts	1976–2003
North Europe	Finland	Point counts & line transects	1983–2003
West Europe	France	Point counts	1989–2003
West Europe/	Germany	Point counts & line transects	
Central & East Europe	West	& territory mapping	1989–2003
	East		1991–2003
Central & East Europe	Hungary	Point counts	1999–2003
West Europe	Ireland	Line transects	1998–2003
	Italy	Point counts	2000–2003
Central & East Europe	Latvia	Point counts	1995–2003
West Europe	Netherlands	Territory mapping & species-specific surveys	1990–2003
North Europe	Norway	Point counts	1996–2003
Central & East Europe	Poland	Line transects	2000–2003
South Europe	Spain	Point counts	1996–2003
North Europe	Sweden	Point counts	1975–2003
West Europe	Switzerland	Territory mapping	1999–2003
West Europe	UK	Line transects & territory mapping	1966–2003

TRIM (TRends and Indices for Monitoring data – Pannekoek & van Strien 2001) is a program designed to analyse time-series of counts with missing observations using Poisson regression (log-linear models; McCullagh & Nelder 1989). Missing counts from particular sites were estimated ('imputed') from changes in all other sites, or sites with the same characteristics, by using covariates. In addition, serial correlation was taken into account. The program produced imputed yearly indices and scheme totals for each species. These yearly scheme totals, together with their standard errors and covariances, were collated by the PECBMS.

Supranational indices

National indices were combined to produce supranational indices. Data were weighted to allow for the fact that different countries hold different proportions of a species' European population (van Strien *et al*. 2001). The yearly scheme totals were first converted into yearly national population sizes, using the latest information on national population sizes from *Birds in Europe* (BirdLife International 2004). These population sizes were assumed to reflect the situation in or around the year 2000. A weighting factor was calculated as the national population size divided by the average of the estimated yearly scheme total for 1999–2001. This weighting factor was applied to all other years of the scheme in order to obtain yearly national population sizes for each year.

Because national schemes have run for different lengths of time, there are missing year totals for particular countries. These were estimated using TRIM in a way equivalent to imputing missing counts for particular sites within countries (van Strien *et al*. 2001). Missing year totals of particular country sites were estimated from other countries of the same European region, assuming that all countries within the same region have had similar changes in population numbers. Furthermore, we have prevented any estimation of missing year totals in the original 15 European Union (EU) countries using information from the ten new EU countries (those joining in 2004) by applying a hierarchical procedure to estimate missing years. First, we assessed separate yearly totals for North, West, South, and Central & East Europe. Then, the regions North, West and South were combined to impute remaining missing yearly totals. Finally, missing years for Central & East Europe were estimated from the combination of North, West and South Europe. In addition to yearly indices, overall trend slopes for 1980–2003 were calculated (Pannekoek & van Strien 2001).

Multispecies indicators

The individual European species indices were combined (averaged) to create multispecies supranational indicators for Europe and European regions. We averaged indices rather than bird abundance in order to give each species an equal weight in the resulting indicators. If more species decline than increase, each at the same rate, then the mean should go down and vice versa. We used geometric means rather than arithmetic means because we consider an index change from 100 to 200 equivalent, but opposite, to a decrease from 100 to 50. Trends of the indicators were smoothed using the program TrendSpotter, which is based on structural time series analysis and the Kalman filter (Visser 2004).

Analysis of drivers of changes

We used multispecies indicators to illustrate the patterns among species grouped in various ways at a pan-European level. To assess the potential drivers of changes in the bird populations, analysis of variance was applied to the overall slopes per species grouped in various ways (see Julliard *et al*. 2003). We explored the influence of region, habitat, migration strategy, nest-site, nest type, diet, body size and winter weather. Specifically, we used generalized linear modelling (GLM) to analyse the European species trend slopes for 1980–2003, weighted by the inverse of their standard error, with species grouped by the particular factors in question. Slopes were normally distributed and no transformation was required. In each case, we conducted analyses for all species (77), common forest birds (57) and common forest specialists (33). We also built models including all relevant factors and then used backward stepwise exclusion of factors with $P > 0.1$ to come to a final minimum adequate model (MAM). We repeated the analyses including body mass (log10-transformed mass in grams) as a nuisance variable, and repeated the process with minimal models.

We explored the influence of winter weather on the trends by correlating year-to-year changes in species indices or multispecies indicators with the preceding European winter temperature anomaly, using Pearson correlation. Winter anomaly data are the averaged mean European land temperature

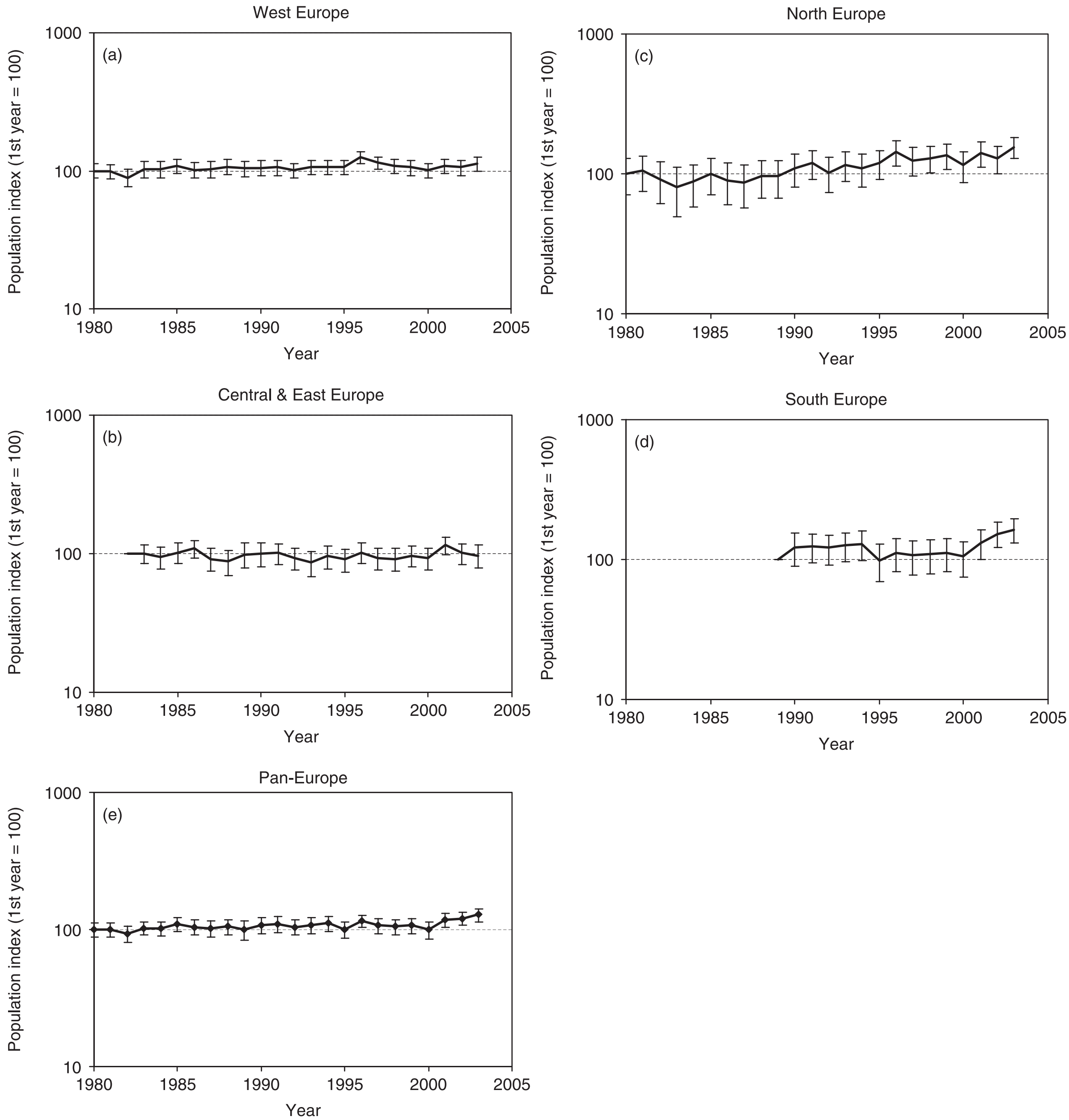

Figure 1. An example of pan-European indices (± 1.96 se) for the Blue Tit *Cyanistes caeruleus* for the four regions used to produce the indices, (a) West, (b) Central & East, (c) North, (d) South, and for (e) Europe as a whole. The pan-European index for Blue Tit has increased by 28% from 1980 to 2003.

anomalies (relative to the 1901–95 calibration average), derived from Luterbacher *et al.* (2004).

RESULTS

Figure 1 shows population trends of Blue Tit *Cyanistes caeruleus* for the four regions used in the production of the indices, and the resultant pan-European index. Note that not all the indices start in 1980 because of a lack of data (Central & Eastern trends commence in 1982, and Southern trends in 1989), and that the confidence limits on the trends vary by region, but overall trends are measured with some precision (Fig. 1). To illustrate this further, the

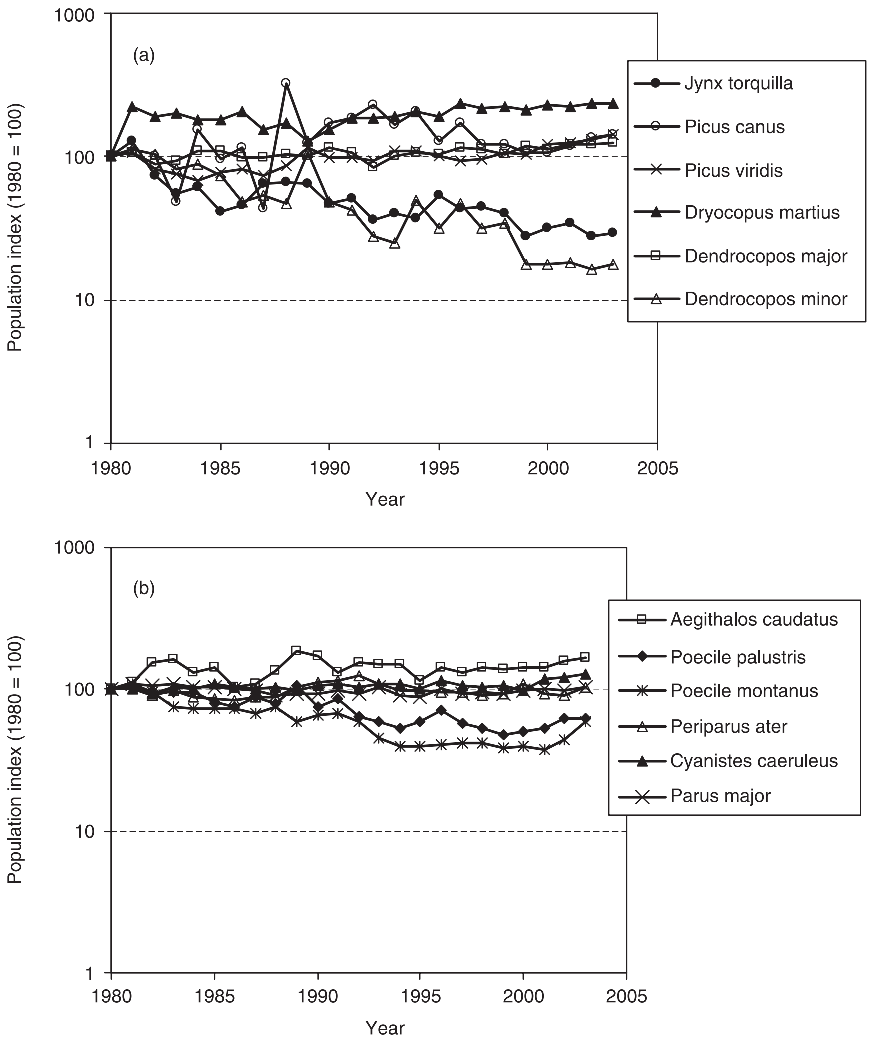

Figure 2. Examples of pan-European species trends for the (a) woodpeckers, (b) tits, (c) thrushes and (d) warbler species.

pan-European species trends of woodpeckers, tits, thrushes and warblers all show a degree of interspecific variation and fluctuation (Fig. 2). Among woodpeckers, Black Woodpecker *Dryocopus martius* has increased very strongly, while Lesser Spotted Woodpecker *Dendrocopos minor* and Eurasian Wryneck *Jynx torquilla* have crashed in numbers from 1980 to 2003. Amongst the tits, Blue Tit and Long-tailed Tit *Aegithalos caudatus* have done well, while Willow Tit *Poecile montanus* and Marsh Tit *Poecile palustris* have shown declines. Common Nightingale *Luscinia megarhynchos* stands out in the thrushes as a species that has declined, particularly in the 1980s, while other species such as European Robin *Erithacus rubecula* and Blackbird *Turdus merula* have maintained their numbers at the European scale (Fig. 2c). Finally, the warblers show a mixture of population trends. Blackcap *Sylvia atricapilla* and Common Chiffchaff *Phylloscopus collybita* have increased very strongly in Europe, while Icterine Warbler *Hippolais icterina*, Willow Warbler *Phylloscopus trochilus* and Wood Warbler *Phylloscopus sibilatrix* have declined moderately from 1980 to 2003 (Fig. 2d). Interestingly, in each taxonomic group some species appear to be faring well, while close relatives are faring poorly in terms of their population trends. Each of the individual pan-European trends for the 77 species is available via the EBCC website (www.ebcc.info).

A pan-European common bird indicator based on all species within the sample (i.e. a composite species

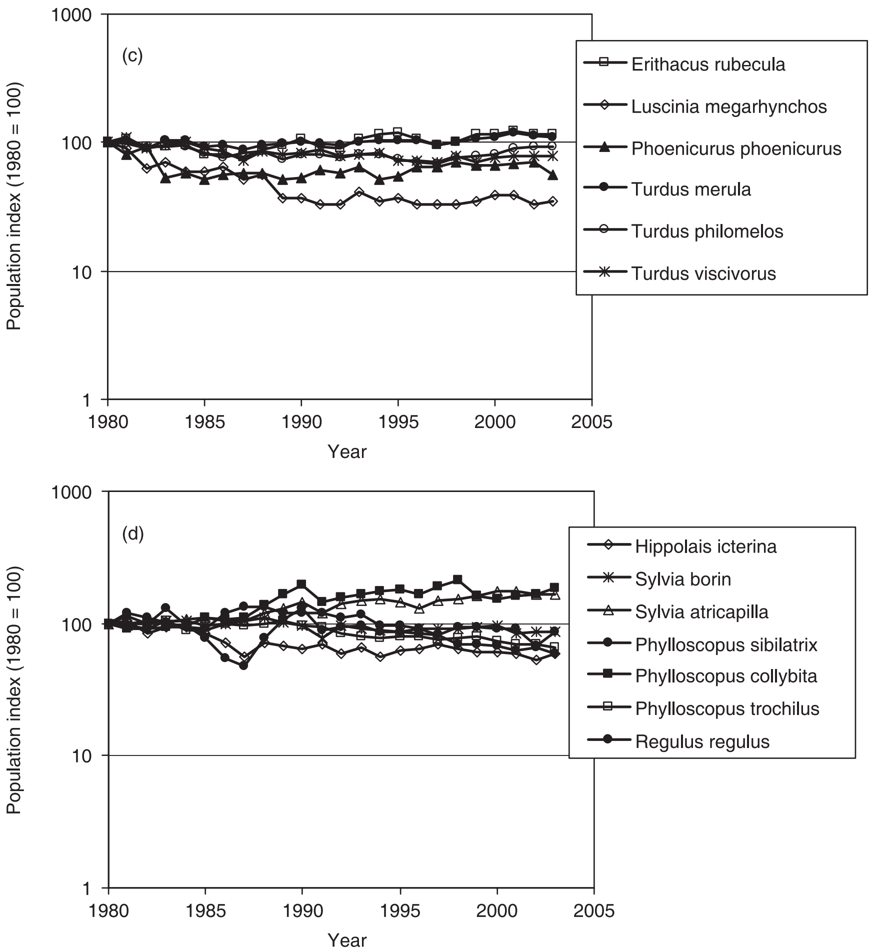

Figure 2. *Continued.*

index) shows a small decline over the period of study (Fig. 3a). Separating the species into their main habitat preference is instructive, showing that common forest birds have declined by 13% while common forest specialists (a subset of the latter) have declined by 18% from 1980 to 2003. This can be compared with a sharp decline in common farmland birds, down by 28% from 1980 to 2003, with the steepest rate of decline in the early 1980s followed by relative stability (Fig. 3b). Patterns of decline among the forest and farmland specialists contrast with the apparent stability of those species that occur across a range of habitats, which we term generalists (Fig. 3b). Exploring the patterns more formally using analysis of variance shows that species trends differed significantly, whether we compared main habitat choice or habitat specialists vs. generalists (Table 2a).

Looking in detail at the common forest specialists (33 species) for the period 1980–2003, their population trends showed marked differences when grouped by geography (Fig. 4). [Note that the patterns we show were almost exactly mimicked among the wider group of 57 common forest birds, suggesting some generality for these birds as a whole.] At a regional scale, common forest birds have on average showed much greater stability in Central & Eastern Europe over the last 20 years than in the other regions, where modest declines were evident (Fig. 4a). However, species trends across the four regions were not statistically different despite this trend (Table 2a). This contrast is even more marked if we compare common forest specialist trends in the new and old EU countries over this period (Fig. 4b). Trends in the new EU countries were on average markedly more positive than those in the

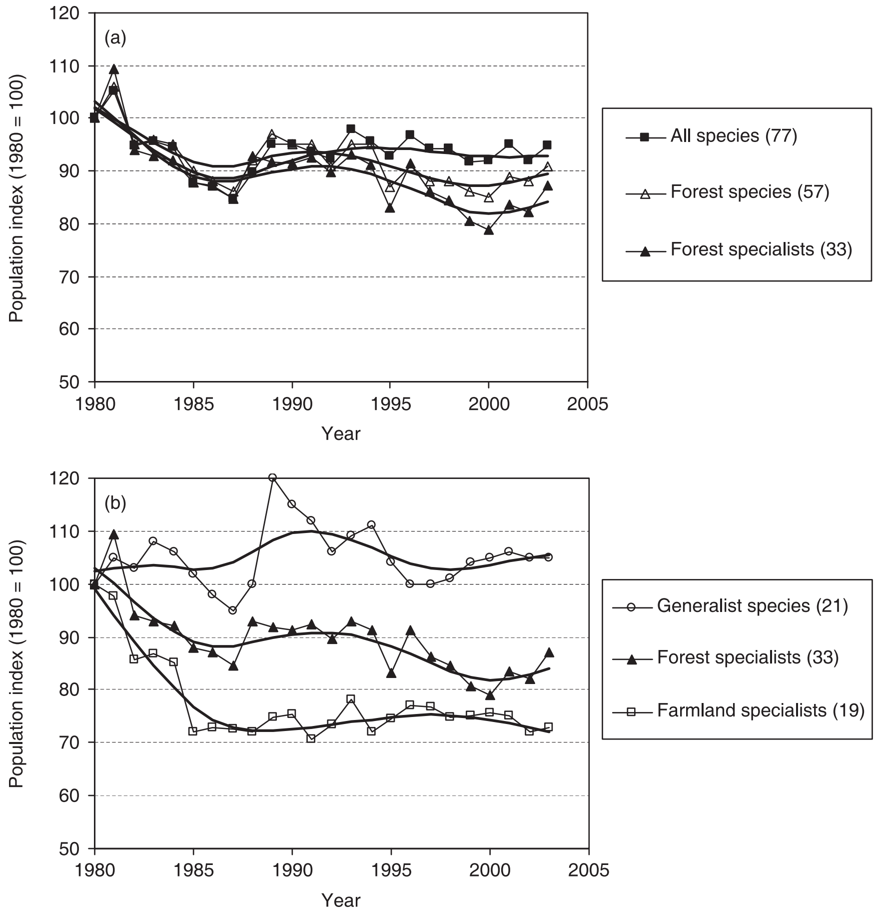

Figure 3. Pan-European multispecies wild bird indicators for various groupings for the period 1980–2003. Patterns among all species are contrasted with trends among forest birds (a) and generalist species are contrasted with specialists of forest and farmland (b). The heavy lines show the smoothed indicator, the lighter lines with symbols show the annual indicator values. Overall trends measured as the percentage change in the smoothed indicators from 1980 to 2003: –9% all species, –13% species using forest, –18% forest specialists, +3% generalist species, –28% farmland specialists. The heavy lines show the smoothed indicator values, the lighter lines with symbols show the indicator values. The figures in parenthesis show the number of species contributing to each indicator line.

old EU countries, although there was no significant difference in trends, except that forest specialists in the new EU countries showed more positive trends (Table 2a).

A consistent pattern emerged in relation to migration strategy, with long-distance migrants and resident birds declining somewhat among forest birds and forest specialists, but partial migrants on average showing slightly positive trends (Fig. 5a), but this effect was only statistically significant among the wider group of 57 birds using forest (Table 2b). There was a tendency for birds nesting on the ground or in low vegetation to have declined more than those nesting higher up in shrubs and trees (Fig. 5b), and nest-site had a significant influence on species trends among all species and among common forest birds (Table 2b). Closed nesters appeared to have declined more than open nesters, but the differences were slight and non-significant (Fig. 5c, Table 2b). Finally, there was a suggestion that diet may also be linked to the trends, as invertebrate feeders declined more than omnivores and herbivores, but these differences were non-significant (Fig. 5d, Table 2b). Of course, interpreting these broad trends is difficult because they are closely interrelated and they conceal much underlying variation.

We repeated the analyses combining factors into the same model to test for their independent effects and interactions. The final minimal models for all species and for common forest birds retained only

Table 2. Generalized linear modelling (GLM) analysis of species trend slopes for 1980–2003 exploring the potential influence of (a) habitat and region on the indicators, and then (b) the influence of ecology on the species trends. Specifically, we used GLM to analyse the European species trend slopes for 1980–2003 weighted by the inverse of their standard error. The table presents results from single factor ANOVA. Values in bold type represent the minimal adequate models (MAM) derived from backward selection of models starting with a full model (for 'all species' containing habitat, migration strategy, nest-site, nest type and diet, otherwise, containing migration strategy, nest-site, nest type and diet). We also repeated the analyses correcting for species body mass (see Results). Note that the species groups are subsets of each other and statistically non-independent.

Species grouping:	All Species (77)	Forest birds (57)	Forest specialists (33)
(a) Exploring indicators			
Habitat (forest, farmland & all others)	$F_{2,76} = 3.95$ $P = 0.02$*	–	–
Habitat specialization (forest, farmland & generalists)	$F_{2,72} = 4.0$ $P = 0.02$*	–	–
Region (North, South, Central & East, West)	$F_{3,235} = 1.20$ $P = 0.31$	$F_{3,201} = 0.91$ $P = 0.43$	$F_{3,115} = 0.24$ $P = 0.14$
Region (old EU vs. new EU Countries)	$F_{1,154} = 1.37$ $P = 0.24$	$F_{1,111} = 1.33$ $P = 0.25$	$F_{1,63} = 4.30$ $P = 0.04$*
(b) Exploring ecology:			
Migration (long-distance, partial migrants & residents)	$F_{2,76} = 2.43$ $P = 0.10$†	$F_{2,56} = 3.62$ $P = 0.03$*	$F_{2,32} = 0.23$ $P = 0.79$
Nest-site (tree/shrub vs. ground/low vegetation)	**$F_{2,76} = 4.80$ $P = 0.01$***	**$F_{2,56} = 4.65$ $P = 0.01$***	$F_{2,32} = 0.01$ $P = 0.90$
Nest type (open vs. closed)	$F_{1,76} = 0.27$ $P = 0.61$	$F_{1,56} = 0.08$ $P = 0.78$	**$F_{1,32} = 3.42$ $P = 0.07$**
Diet (Omnivore, Herbivore, Invertebrate)	$F_{2,76} = 0.12$ $P = 0.89$	$F_{2,56} = 0.11$ $P = 0.89$	$F_{2,32} = 0.19$ $P = 0.99$

†$P < 0.1$ *$P < 0.05$.

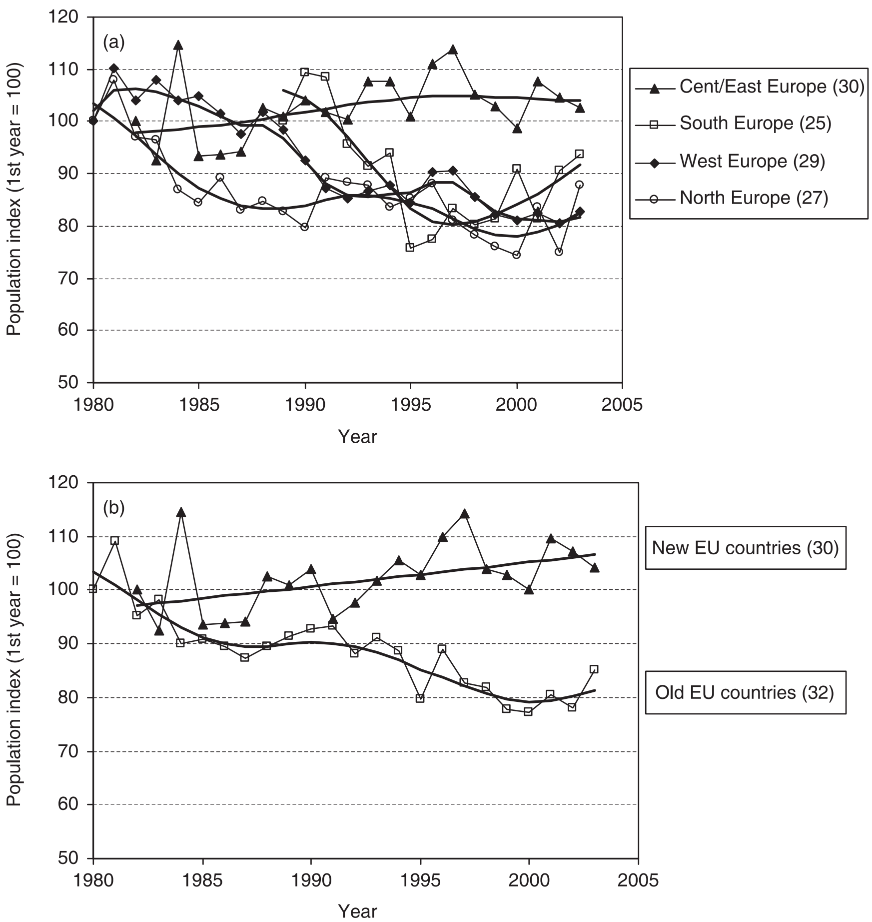

Figure 4. Pan-European multispecies wild bird indicators for common forest specialists (33 species) for the period 1980–2003 grouped (a) by four geographical regions and (b) by two geopolitical regions, new EU and old EU countries. The heavy lines show the smoothed indicator values, the lighter lines with symbols show the indicator values. The figures in parentheses show the number of species contributing to each indicator line.

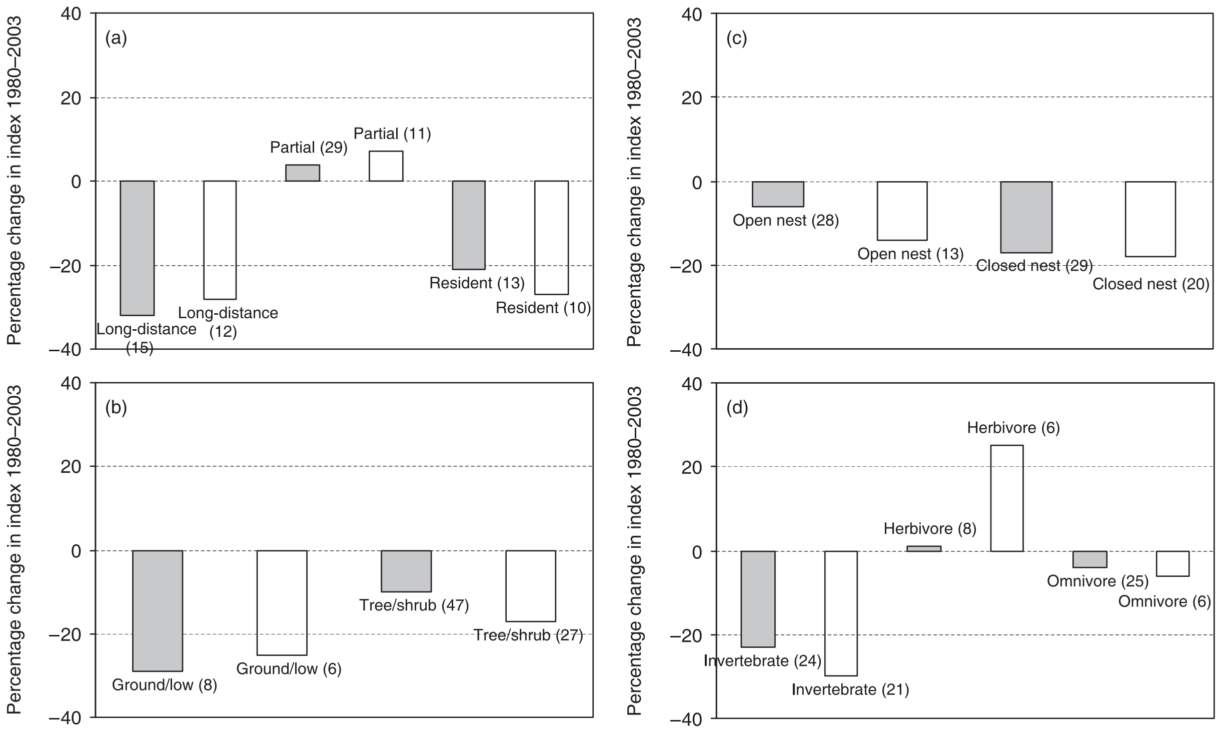

Figure 5. Percentage changes in the smoothed indices for species grouped by ecology from 1980 to 2003: (a) by migration strategy, (b) nest-site, (c) nest type and (d) diet. Filled bars are birds associated with forest and open bars are the subset of forest specialists. Numbers in parenthesis are the number of species in each group.

nest-site as a significant explanatory variable (P = 0.01 in both cases, Table 2b). The equivalent model for common forest specialists retained only nest type at a non-significant level ($P = 0.07$). We also looked at the potential influence of body size on these relationships. Overall, there was no correlation between body mass and species trend in our dataset ($n = 77$, $r = -0.04$, $P = 0.74$); however, we re-ran the analyses to check for any effects. The results were virtually identical and exactly the same minimum models, with body mass forced into each model, were retained. As before, for all species and for common forest birds, nest-site was retained as a significant explanatory variable ($P = 0.01$ in both cases), and for specialist forest birds, nest type was retained at a statistically significant level ($P = 0.05$).

Winter weather was only weakly associated with year-to-year variation in the European indicators. In general, and as expected, warmer winters were associated with more positive population changes and vice versa, but none of the correlations reached statistical significance (Fig. 6). This was the case when we divided the species into long-distance migrants, partial migrants and residents (Fig. 6). However, when we examined the species trends of small-bodied birds susceptible to the cold winter weather, we saw an effect at a European scale in a small number. Among the smallest 18 resident or partial migrant species of forest, we found significant correlations with winter weather in just five (Winter Wren *Troglodytes troglodytes* $r_{23} = 0.46$, $P = 0.03$; European Robin $r_{23} = 0.61$, $P = 0.002$; Goldcrest *Regulus regulus* $r_{23} = 0.43$, $P = 0.04$; Hedge Accentor *Prunella modularis* $r_{23} = 0.46$, $P = 0.03$; and European Goldfinch *Carduelis carduelis* $r_{23} = 0.43$, $P = 0.04$). Interestingly, and as we might have expected, the first four of these are insectivorous birds.

DISCUSSION

Trends among forest birds

Combined analyses of breeding bird data from 18 European countries suggest that common forest birds have on average declined in number from 1980 to 2003 (Fig. 3). The average population trend for common forest birds over this period was –13%, compared with –18% for common forest specialists.

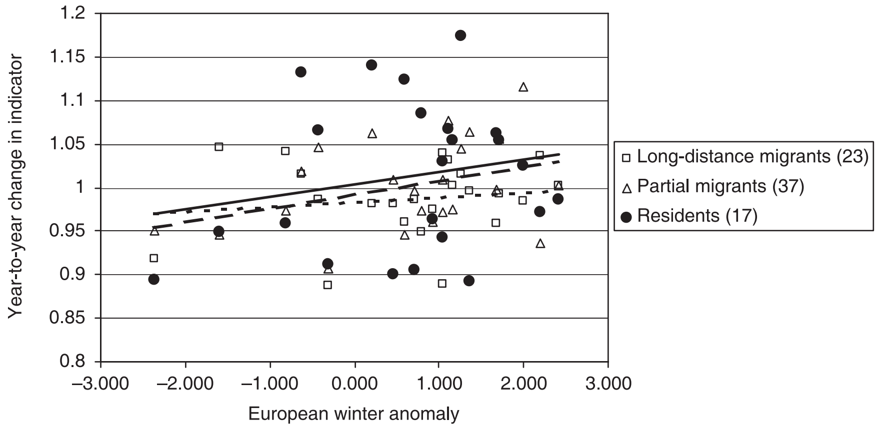

Figure 6. Relationship between year-to-year changes in the population indices and winter weather based on all species in the data set. Long-distance migrants (open squares & light dashed line), partial migrants (open triangles & heavy dashed line) and resident birds (solid circles & solid line) are shown separately. Numbers in parentheses are the number of species in each group. Lines are drawn for illustration by linear regression. All three correlations were non-significant at the 5% level.

These trends contrast with those of common generalist birds, up slightly by 3%, and common farmland specialists, down moderately by 28% from 1980 to 2003. It is difficult to make independent comparisons with other studies, but interestingly *Birds in Europe* showed that 16% of species primarily associated with boreal and temperate forests were declining, 1% were increasing, 61% were stable and 22% had unknown trends from 1990 to 2000 (BirdLife International 2004). Among common forest birds, our equivalent figures (the species are not matched) for 1990–2003 were 33, 23, 39 and 5%, respectively (and among common forest specialists 39, 12, 43 and 6%, respectively). The comparison suggests that our methods may have revealed declines undetected by the coarser resolution of *Birds in Europe*, but equally we must recognize that our study considered mostly passerines from a subset of European countries, excluding many in the east and southeast of Europe where monitoring schemes do not exist or have only recently begun. That said it is somewhat alarming that around one-third of the forest species we considered were declining. Over the longer period 1980–2003, the figures are even higher, with 47% of common forest birds and 46% of common forest specialists declining. A number of other studies have revealed declines among forest birds in northern Europe (Angelstam *et al.* 2004b). Evidence shows that some forest specialists, particularly birds associated with old-growth stands, have declined severely and some are threatened by modern commercial forestry practice (Virkkala 1991, Angelstam & Mikusinski 1994, Tucker & Heath 1994, Kouki & Vaananen 2000). A large body of work has focused on (hemi-)boreal forest and forestry, and our knowledge of other forest types in Europe is less well advanced.

The wild bird indicators we present show a degree of variation across Europe (Fig. 4), the most marked pattern being a difference in trends in Central & Eastern Europe compared with the rest. The same pattern was identified by Gregory *et al.* (2005), who suggested that land-use changes associated with the post-1990 collapse of the state farming system in the Eastern Bloc might be at least partially responsible for the differences, especially for farmland birds. Angelstam *et al.* (2004b) reported a similar contrast in the population trends of forest birds in northern Europe, when comparing east with west, which they linked to more intensive forest management in the latter. Certainly, abandonment and scrubbing up of agricultural land is likely to be linked to a short-term surge in the populations of some farmland birds, which we predict to be short-lived as habitat succession proceeds rapidly to exclude the species within a few years. Furthermore, we would predict that farmland birds with a particular tie to arable systems might actually respond negatively to abandonment (Robinson *et al.* 2001). In contrast, we would expect a sustained and strong increase in some forest birds as scrub and then forest encroaches onto farmed land. Again, it is likely to be a subset of forest species pre-adapted to succession stages of forest that benefit most from these changes in the short to medium term. The habitat requirements of many specialist forest birds are more demanding and they require older, more mature stand types. Migration strategy of individual species may also be relevant to the east–west difference in trends. Eastern populations of many species migrate along different routes (primarily an eastern vs. western or central Mediterranean route) and winter in different parts of Africa. These differences may well contribute to divergent population trends and this hypothesis deserves further attention.

The forest bird indicators we present update a provisional set published in 2005 (Gregory *et al.* 2005). They differ because the latter considered a small group of common woodland, park and garden birds (24 species), whose populations were on average stable over the last 20 years, whereas we focus on a larger group of birds using forest of different types (57 species), and a smaller specific group more dependent on forest (33 species). On average, both of these groups of birds have declined to some degree from 1980 to 2003. We have also specifically identified habitat generalists and shown that their trends tend to be much more positive than other species. Thus, a formal process of species selection seems to provide greater insight into the trends of the birds in question. We intend to improve the process of species selection further by examining habitat selection and specialization of birds at a biogeographical scale in Europe. The change in methods also allows us to reappraise the potential role of this indicator as a general barometer of forest bird populations, forest biodiversity and forest health. Gregory *et al.* (2005) concluded that the original indicator was unlikely to be a reliable indicator of general forest health. The common forest bird indicators presented here appear to be more promising in this respect. It seems to be a useful indicator of the *state* of European forest birds in general, and might with further work prove to be a useful surrogate for trends in forest biodiversity and forest health. A key area for research is to establish whether trends in particular elements of biodiversity (e.g. vertebrates, plants, insects, fungi) are correlated in forests across Europe, and how these elements reflect forest management practices and perceptions of forest health. Specifically, for forest birds, we would like to know much more about the factors driving their trends and how the trends in different groups of species are correlated.

For forestry management the consensus is that the best umbrella or focal indicator species will be those that are most sensitive to habitat alteration that affects the degree of naturalness (Angelstam *et al.* 2004a, 2004b, Roberge & Angelstam 2006). This suggests a number of different species in different forest types – for example, in deciduous vs. coniferous. A number of species have been promoted as indicators by different authors. The woodpeckers often feature in these assessments as good indicators, at least of bird diversity, and by inference of bird and biodiversity trends (Angelstam & Mikusinski 1994, Mikusiński *et al.* 2001, Roberge & Angelstam 2006). The variety of trends among the European woodpeckers we considered (Fig. 2) suggests that a range of different factors might regulate and limit their populations at this scale. Angelstam and Mikusinski (1994) reviewed habitat specialization of woodpeckers and their associations with forest management. It is clear that woodpeckers differ in their ecological requirements and sensitivity to environmental change (and that the rarest, most sensitive species are not covered by the PECBMS). The authors concluded that as a group woodpeckers could be used as monitoring tools and indicators of forest practices and thus forest health, because to retain all species in the landscape requires management to create old, dead and deciduous trees, but also to maintain open wooded habitats at the same time. It seems highly plausible that differences in the specialization of species lies behind the variation we observe in species trends in other bird families (Fig. 2, Appendix 2). This reinforces the point that species choice is both difficult and yet critical to indicator concepts (Roberge & Angelstam 2004, 2006). The more inclusive approach we use to select species attempts to capture broader changes in the state of nature, producing mostly *state* indicators, although the habitat-specific trends may shed light on the possible drivers of change – as appears to be the case for farmland birds (Gregory *et al.* 2005). It should be possible to use this approach, with due care to species selection and analysis, to develop *pressure* or *driver* indicators relevant to specific questions relating to forestry and forest management in Europe, but more work is required in this respect.

Ecological drivers of change

Statistical analysis of the species trends did not always support the emergent patterns in the indicators (Table 2). The lack of statistical effects is not surprising if we consider the large scale of analysis and the many sources of potential variation and error within the trends. The analyses suggest a degree of variability in pan-European species trends that is unexplained by the chosen variables, and this suggests that species trends are driven by specific and particular sets of variables. In fact, we know this to be the case for example from a range of autecological studies on farmland birds (e.g. Aebischer *et al.* 2000, Vickery *et al.* 2004). Hence, at the scale of this study, we might only expect to detect high-level effects. In this respect, it is encouraging that we are able to show significant effects of habitat specialization, migration strategy and nest-site on species trends across Europe. This approach, however, is simplistic and a more detailed analysis of ecological factors is warranted. Of course, we must also treat simple correlations with care. It seems possible, for example, that the correlations we find with nesting and migration strategy may be surrogates of each other (because long-distance migrants tend to be ground-nesting and vice versa), and it is difficult to disentangle these effects. Minimal models only retained nest-site as a significant predictor of the trends (Table 2). This suggests migration strategy may be a surrogate for nesting effects, which could be driven by nest predation or other effects. The equivalent minimal model for specialist forest birds retained nest type with marginal significance (Table 2). One interpretation of these results is that nest predation might be an important factor influencing species trends in Europe. A number of studies have shown a link between bird life-history traits, population declines and nest predation, but these interactions can be complex (Donovan *et al.* 1995, Martin 1995, Martin & Clobert 1996, Chalfoun *et al.* 2002). Perhaps surprisingly, Martin (1993) found that predation rates of ground-nesting birds were lower than those nesting higher in North American forests, but the reverse was true in shrub or grassland habitats. Note that the influence and severity of nest predation may be different in Europe and North America, so comparisons need to be made with care (see Martin & Clobert 1996; Newton 2004). Interestingly, trends of closed-nesting species were more negative than those of open-nesters (Table 2, Fig. 5c). This may have implications for forest management, as modern intensive practices can be associated with reduced availability of dead and decaying wood for cavity-nesters to use when breeding. Equally, one could interpret patterns, such as declines among ground- or low-nesting birds, and those with invertebrate diets, to be associated with intensive forest management through modification of understorey vegetation and removal of dead wood, respectively, but again this is speculation. Another key driver in forests could be browsing pressures, which appear to be changing and are linked to management. There would be great merit in extending the present study to consider trends and a wider range of potential drivers at a national level across Europe, because this would provide much higher power to detect significant effects and to understand what are likely to be complex interactions between bird populations and their drivers across Europe.

Our results are similar to those found by Julliard *et al.* (2003), who examined drivers of change among common birds in France. They showed that specialist bird species tended to decline compared with non-specialists, although they measured habitat specialization in a different way. They also showed that more northerly breeding species in France had declined more sharply, an effect we did not test. Interestingly, they failed to find any effect of migration strategy, whereas many other studies have shown long-distance migrants to be declining more strongly than other groups of birds (Böhning-Gaese 1992, Berthold *et al.* 1993, Böhning-Gaese & Bauer 1996, Berthold 2001, Berthold & Fiedler 2005, Karlsson *et al.* 2005). Similarly, while Flade and Schwarz (2004) detected predominant declines in long-distance migrants in their study of forest species in Germany, they also showed short-distance and partially migrant species to be doing well – a pattern we detect at a pan-European level. Overall, Flade and Schwarz concluded that the main driving forces in German forest birds were migration strategy, winter weather, tree seed production, and the increasing importance of human settlements in providing habitat and resources for some forest birds. At a continental scale, Sanderson *et al.* (2006) analysed species trends for all species with good quality information from 42 European territories taken from *Birds in Europe* (Tucker & Heath 1994, BirdLife International 2004). They showed that the trends of intercontinental migrants were significantly more negative than those of short-distance migrants or residents, and that these trends seemed to be driven by birds wintering in dry, open habitats in Africa, echoing earlier findings (see Newton 2004). It should be noted that they found significant declines among intercontinental migrants for the period 1970–90, but not for 1990–2000, suggesting that the rate of decline may have eased. It is difficult to compare the current results with those of Sanderson *et al.* because we considered a smaller set of species and countries. In the main, our results are consistent with previous work, as long-distance migrants have declined more strongly than other groups (Table 2, Fig. 5a). If we take our sample of species as a whole (i.e. 77 species), then long-distance migrants have declined most (–28%), followed by partial migrants (–4%), while resident birds have increased (+13%). This is not, however, a random sample and we cannot generalize this result. In fact, the increase among resident birds is strongly influenced by generalists and by two wetland specialists (Cetti's Warbler *Cettia cetti* and Zitting Cisticola *Cisticola juncidis*), whose numbers are booming on a scale quite unlike any other species. If we examine trends among forest birds, then a pattern emerges of similar declines among residents and long-distance migrants, with partial migrants bucking the downward trend and doing relatively well (Fig. 5). It is important to recognize that the resident birds in this instance tend to be habitat specialists, and that trends among a wider group of residents are likely to be more positive (see Flade & Schwarz 2004). These observations emphasize the need to interpret composite indices with care, considering how individual species might influence the trends. In the future, the PECBMS plans to expand species, habitat and country coverage to gain greater understanding of both the generality of population trend patterns and their drivers across Europe.

CONCLUSIONS

By combining national trend information from across Europe, we have been able to create pan-European indices for species and then pan-European indicators for groups of these widespread and common species. This synthesis raises issues for the conservation status of several forest birds that appear to be in sharp decline across Europe, for example, Lesser Spotted Woodpecker, Eurasian Wryneck, Tree Pipit *Anthus trivialis*, Willow Tit, Marsh Tit, Common Nightingale, Spotted Flycatcher *Muscicapa striata*, Icterine Warbler, Willow Warbler, Wood Warbler and Brambling *Fringilla montifringilla* (Appendix 2). Some 15 common forest specialists (46%) showed moderate declines from 1980 to 2003, which compares closely with nine common farmland specialists (47%) over the same period (Appendix 2). We recommend that this information is used in reviewing the conservation status of European birds.

Our results are consistent with earlier studies showing that while some generalist species have responded positively to human-induced change, many specialist species have responded negatively – a process known as 'biotic homogenization' (McKinney & Lockwood 1999). In this way, a few 'winners' that respond positively to human disturbance and management practices replace the many 'losers' in wholesale change in the countryside. The result, it is suggested, will be a more homogeneous environment with lower biodiversity at national, regional and global scales (McKinney & Lockwood 1999). A further notable pattern in our dataset is the contrast between the population trends of partial migrants and those of long-distance migrants and residents (Fig. 5a). The implication is that partial migrants are gaining some advantage through short-distance migration, perhaps by reacting to local weather conditions and food resources, and that their populations are increasing as a result (see Berthold 2001). This finding deserves further investigation. Overall, our pan-European dataset demonstrates unambiguous signals of environmental change, which we argue should be taken seriously by policy-makers and acted upon accordingly. It is abundantly clear that if Europe is to meet its official target 'to halt the decline of biodiversity by 2010', then we must redouble our efforts to put in place conservation actions with sufficient urgency and at a sufficient scale to make this a reality. The indicators we present provide a basis to measure progress towards this admirable aim.

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Appendix 1. Species list and characteristics.

Species	Use of forest	Habitat specialization	Migration strategy	Nest-site	Nest type	Diet
Accipiter nisus Eurasian Sparrowhawk	Use forest	Generalist	Partial migrant	Tree/Shrub	Open	Carnivore
Aegithalos caudatus Long-tailed Tit	Use forest	Generalist	Resident	Tree/Shrub	Closed	Invertebrate
Alauda arvensis Sky Lark	Do not use forest	Farmland	Partial migrant	Ground/low veg.	Open	Omnivore
Anthus trivialis Tree Pipit	Use forest	Forest	Long distance	Ground/low veg.	Open	Invertebrate
Bonasa bonasia Hazelhen	Use forest	Forest	Resident	Ground/low veg.	Open	Herbivore
Burhinus oedicnemus Stone-curlew	Do not use forest	Farmland	Partial migrant	Ground/low veg.	Open	Invertebrate
Buteo buteo Common Buzzard	Use forest	Generalist	Partial migrant	Tree/Shrub	Open	Carnivore
Carduelis cannabina Common Linnet	Use forest	Generalist	Partial migrant	Tree/Shrub	Open	Herbivore
Carduelis carduelis European Goldfinch	Use forest	Farmland	Partial migrant	Tree/Shrub	Open	Herbivore
Carduelis chloris European Greenfinch	Use forest	Generalist	Partial migrant	Tree/Shrub	Open	Herbivore
Carduelis flammea Common Redpoll	Use forest	Forest	Partial migrant	Tree/Shrub	Open	Herbivore
Carduelis spinus Eurasian Siskin	Use forest	Forest	Partial migrant	Tree/Shrub	Open	Herbivore
Certhia brachydactyla Short-toed Treecreeper	Use forest	Forest	Resident	Tree/Shrub	Closed	Invertebrate
Certhia familiaris Eurasian Treecreeper	Use forest	Forest	Resident	Tree/Shrub	Closed	Invertebrate

Appendix 1. *Continued.*

Species	Use of forest	Habitat specialization	Migration strategy	Nest-site	Nest type	Diet
Cettia cetti Cetti's Warbler	Do not use forest	Inland wetland	Resident	Ground/low veg.	Open	Invertebrate
Cisticola juncidis Zitting Cisticola	Do not use forest	Inland wetland	Resident	Ground/low veg.	Closed	Invertebrate
Coccothraustes coccothraustes Hawfinch	Use forest	Forest	Partial migrant	Tree/Shrub	Open	Omnivore
Columba palumbus Common Wood Pigeon	Use forest	Farmland	Partial migrant	Tree/Shrub	Open	Herbivore
Corvus corone/Corvus cornix Carrion/Hooded Crow	Use forest	Generalist	Partial migrant	Tree/Shrub	Open	Omnivore
Corvus monedula Eurasian Jackdaw	Use forest	Generalist	Partial migrant	Tree/Shrub	Closed	Omnivore
Cuculus canorus Common Cuckoo	Use forest	Generalist	Long distance	Tree/Shrub	Open	Invertebrate
Cyanistes caeruleus Blue Tit	Use forest	Forest	Partial migrant	Tree/Shrub	Closed	Omnivore
Dendrocopos major Great Spotted Woodpecker	Use forest	Generalist	Resident	Tree/Shrub	Closed	Omnivore
Dendrocopos minor Lesser Spotted Woodpecker	Use forest	Forest	Resident	Tree/Shrub	Closed	Invertebrate
Dryocopus martius Black Woodpecker	Use forest	Forest	Resident	Tree/Shrub	Closed	Invertebrate
Emberiza calandra Corn Bunting	Do not use forest	Farmland	Partial migrant	Ground/low veg.	Open	Omnivore
Emberiza citrinella Yellowhammer	Use forest	Farmland	Partial migrant	Ground/low veg.	Open	Omnivore
Emberiza schoeniclus Reed Bunting	Do not use forest	Inland wetland	Partial migrant	Ground/low veg.	Open	Omnivore
Erithacus rubecula European Robin	Use forest	Generalist	Partial migrant	Other	Open	Invertebrate
Falco tinnunculus Common Kestrel	Do not use forest	Farmland	Partial migrant	Other	Closed	Carnivore
Ficedula albicollis Collared Flycatcher	Use forest	Forest	Long distance	Tree/Shrub	Closed	Invertebrate
Ficedula hypoleuca Pied Flycatcher	Use forest	Forest	Long distance	Tree/Shrub	Closed	Invertebrate
Fringilla coelebs Chaffinch	Use forest	Generalist	Partial migrant	Tree/Shrub	Open	Omnivore
Fringilla montifringilla Brambling	Use forest	Forest	Partial migrant	Tree/Shrub	Open	Omnivore
Galerida cristata Crested Lark	Do not use forest	Farmland	Resident	Ground/low veg.	Open	Omnivore
Garrulus glandarius Eurasian Jay	Use forest	Forest	Partial migrant	Tree/Shrub	Open	Omnivore
Hippolais icterina Icterine Warbler	Use forest	Forest	Long distance	Tree/Shrub	Open	Invertebrate
Hirundo rustica Barn Swallow	Do not use forest	Farmland	Long distance	Other	Closed	Invertebrate
Jynx torquilla Eurasian Wryneck	Use forest	Forest	Long distance	Tree/Shrub	Closed	Invertebrate
Lanius collurio Red-backed Shrike	Do not use forest	Farmland	Long distance	Tree/Shrub	Open	Invertebrate
Lanius senator Woodchat Shrike	Do not use forest	Farmland	Long distance	Tree/Shrub	Open	Invertebrate
Limosa limosa Black-tailed Godwit	Do not use forest	Farmland	Long distance	Ground/low veg.	Open	Invertebrate
Lullula arborea Wood Lark	Use forest	Forest	Partial migrant	Ground/low veg.	Open	Omnivore
Luscinia megarhynchos Common Nightingale	Use forest	Forest	Long distance	Ground/low veg.	Open	Invertebrate
Motacilla alba White/Pied Wagtail	Do not use forest	Generalist	Partial migrant	Other	Closed	Invertebrate
Motacilla flava Yellow Wagtail	Do not use forest	Farmland	Long distance	Ground/low veg.	Open	Invertebrate
Muscicapa striata Spotted Flycatcher	Use forest	Forest	Long distance	Tree/Shrub	Closed	Invertebrate
Oriolus oriolus Eurasian Golden Oriole	Use forest	Forest	Long distance	Tree/Shrub	Closed	Invertebrate
Parus major Great Tit	Use forest	Generalist	Partial migrant	Tree/Shrub	Closed	Omnivore
Passer montanus Eurasian Tree Sparrow	Use forest	Farmland	Resident	Tree/Shrub	Closed	Omnivore
Periparus ater Coal Tit	Use forest	Forest	Partial migrant	Tree/Shrub	Closed	Omnivore
Phoenicurus phoenicurus Common Redstart	Use forest	Forest	Long distance	Tree/Shrub	Closed	Invertebrate
Phylloscopus collybita Common Chiffchaff	Use forest	Forest	Long distance	Ground/low veg.	Closed	Invertebrate
Phylloscopus sibilatrix Wood Warbler	Use forest	Forest	Long distance	Ground/low veg.	Closed	Invertebrate
Phylloscopus trochilus Willow Warbler	Use forest	Generalist	Long distance	Ground/low veg.	Closed	Invertebrate
Pica pica Black-billed Magpie	Do not use forest	Generalist	Resident	Tree/Shrub	Closed	Omnivore
Picus canus Grey-headed Woodpecker	Use forest	Forest	Resident	Tree/Shrub	Closed	Invertebrate
Picus viridis Green Woodpecker	Use forest	Forest	Resident	Tree/Shrub	Closed	Invertebrate
Poecile montanus Willow Tit	Use forest	Forest	Resident	Tree/Shrub	Closed	Omnivore
Poecile palustris Marsh Tit	Use forest	Forest	Resident	Tree/Shrub	Closed	Omnivore
Prunella modularis Hedge Accentor	Use forest	Forest	Partial migrant	Tree/Shrub	Open	Invertebrate
Pyrrhula pyrrhula Common Bullfinch	Use forest	Forest	Partial migrant	Tree/Shrub	Open	Omnivore

Appendix 1. *Continued.*

Species	Use of forest	Habitat specialization	Migration strategy	Nest-site	Nest type	Diet
Regulus regulus Goldcrest	Use forest	Forest	Partial migrant	Tree/Shrub	Closed	Invertebrate
Saxicola rubetra Whinchat	Do not use forest	Farmland	Long distance	Ground/low veg.	Open	Invertebrate
Sitta europaea Wood Nuthatch	Use forest	Forest	Resident	Tree/Shrub	Closed	Omnivore
Streptopelia turtur European Turtle Dove	Use forest	Farmland	Long distance	Tree/Shrub	Open	Herbivore
Sturnus vulgaris Common Starling	Use forest	Farmland	Partial migrant	Tree/Shrub	Closed	Omnivore
Sylvia atricapilla Blackcap	Use forest	Generalist	Partial migrant	Tree/Shrub	Open	Omnivore
Sylvia borin Garden Warbler	Use forest	Forest	Long distance	Tree/Shrub	Open	Omnivore
Sylvia communis Common Whitethroat	Do not use forest	Farmland	Long distance	Tree/Shrub	Open	Omnivore
Sylvia melanocephala Sardinian Warbler	Do not use forest	Mediterranean	Partial migrant	Tree/Shrub	Open	Omnivore
Troglodytes troglodytes Winter Wren	Use forest	Generalist	Partial migrant	Other	Closed	Invertebrate
Turdus merula Common Blackbird	Use forest	Generalist	Partial migrant	Tree/Shrub	Open	Omnivore
Turdus philomelos Song Thrush	Use forest	Generalist	Partial migrant	Tree/Shrub	Open	Omnivore
Turdus viscivorus Mistle Thrush	Use forest	Generalist	Partial migrant	Tree/Shrub	Open	Omnivore
Upupa epops Hoopoe	Do not use forest	Generalist	Long distance	Tree/Shrub	Closed	Invertebrate
Vanellus vanellus Northern Lapwing	Do not use forest	Farmland	Partial migrant	Ground/low veg.	Open	Invertebrate

Appendix 2. Species list and trends

Species	Trend from 1980	se of slope	Trend classification*	Trend from 1990	se of slope	Trend classification
Accipiter nisus Eurasian Sparrowhawk	1.004	0.01	Stable	0.965	0.026	Uncertain
Aegithalos caudatus Long-tailed Tit	1.009	0.004	Moderate increase	1.002	0.011	Stable
Alauda arvensis Sky Lark	0.98	0.001	Moderate decline	0.987	0.002	Moderate decline
Anthus trivialis Tree Pipit	0.968	0.001	Moderate decline	0.974	0.002	Moderate decline
Bonasa bonasia Hazelhen	0.988	0.008	Stable	0.994	0.013	Stable
Burhinus oedicnemus Stone-curlew	1.104	0.082	Uncertain	1.148	0.089	Uncertain
Buteo buteo Common Buzzard	1.03	0.004	Moderate increase	1	0.006	Stable
Carduelis cannabina Common Linnet	0.979	0.003	Moderate decline	0.958	0.006	Moderate decline
Carduelis carduelis European Goldfinch	1.019	0.003	Moderate increase	1.013	0.006	Moderate increase
Carduelis chloris European Greenfinch	1.003	0.002	Stable	0.995	0.004	Stable
Carduelis flammea Common Redpoll	1.036	0.038	Uncertain	1.024	0.01	Moderate increase
Carduelis spinus Eurasian Siskin	0.998	0.003	Stable	0.999	0.005	Stable
Certhia brachydactyla Short-toed Treecreeper	0.986	0.008	Stable	1.028	0.009	Moderate increase
Certhia familiaris Eurasian Treecreeper	1.001	0.003	Stable	0.997	0.004	Stable
Cettia cetti Cetti's Warbler	1.121	0.016	Strong increase	1.096	0.014	Strong increase
Cisticola juncidis Zitting Cisticola	1.269	0.085	Strong increase	1.27	0.081	Strong increase
Coccothraustes coccothraustes Hawfinch	1.025	0.008	Moderate increase	0.979	0.006	Moderate decline
Columba palumbus Common Wood Pigeon	1.02	0.002	Moderate increase	1.007	0.002	Moderate increase
Corvus corone/Corvus cornix Carrion/Hooded Crow	1.005	0.002	Moderate increase	1.003	0.003	Stable
Corvus monedula Eurasian Jackdaw	0.99	0.005	Moderate decline	0.983	0.008	Moderate decline
Cuculus canorus Common Cuckoo	0.986	0.002	Moderate decline	0.989	0.003	Moderate decline
Cyanistes caeruleus Blue Tit	1.007	0.001	Moderate increase	1.008	0.003	Moderate increase
Dendrocopos major Great Spotted Woodpecker	1.009	0.002	Moderate increase	1.017	0.005	Moderate increase
Dendrocopos minor Lesser Spotted Woodpecker	0.921	0.029	Moderate decline	0.926	0.061	Uncertain
Dryocopus martius Black Woodpecker	1.017	0.006	Moderate increase	1.027	0.014	Uncertain
Emberiza calandra Corn Bunting	0.961	0.005	Moderate decline	0.997	0.005	Stable
Emberiza citrinella Yellowhammer	0.979	0.001	Moderate decline	0.988	0.002	Moderate decline
Emberiza schoeniclus Reed Bunting	0.992	0.002	Moderate decline	0.989	0.004	Moderate decline
Erithacus rubecula European Robin	1.013	0.001	Moderate increase	1.015	0.002	Moderate increase
Falco tinnunculus Common Kestrel	0.993	0.004	Stable	0.968	0.007	Moderate decline
Ficedula albicollis Collared Flycatcher	1.043	0.008	Moderate increase	0.999	0.008	Stable
Ficedula hypoleuca Pied Flycatcher	0.988	0.002	Moderate decline	0.984	0.003	Moderate decline
Fringilla coelebs Chaffinch	0.999	0.001	Moderate decline	0.997	0.001	Moderate decline
Fringilla montifringilla Brambling	0.967	0.01	Moderate decline	0.984	0.005	Moderate decline

Appendix 2. *Continued.*

Species	Trend from 1980	se of slope	Trend classification*	Trend from 1990	se of slope	Trend classification
Galerida cristata Crested Lark	1.03	0.043	Uncertain	1.01	0.038	Uncertain
Garrulus glandarius Eurasian Jay	0.999	0.002	Stable	1.01	0.007	Stable
Hippolais icterina Icterine Warbler	0.978	0.003	Moderate decline	0.99	0.005	Moderate decline
Hirundo rustica Barn Swallow	0.995	0.003	Moderate decline	0.976	0.004	Moderate decline
Jynx torquilla Eurasian Wryneck	0.956	0.009	Moderate decline	0.964	0.015	Moderate decline
Lanius collurio Red-backed Shrike	1.004	0.007	Stable	1.009	0.01	Stable
Lanius senator Woodchat Shrike	0.999	0.03	Uncertain	0.969	0.023	Uncertain
Limosa limosa Black-tailed Godwit	0.971	0.003	Moderate decline	0.971	0.003	Moderate decline
Lullula arborea Wood Lark	1.038	0.017	Moderate increase	1.007	0.01	Stable
Luscinia megarhynchos Common Nightingale	0.96	0.006	Moderate decline	0.998	0.004	Stable
Motacilla alba White/Pied Wagtail	0.997	0.002	Moderate decline	0.988	0.003	Moderate decline
Motacilla flava Yellow Wagtail	0.984	0.012	Stable	1.016	0.011	Stable
Muscicapa striata Spotted Flycatcher	0.968	0.005	Moderate decline	0.984	0.012	Stable
Oriolus oriolus Eurasian Golden Oriole	1.014	0.006	Moderate increase	1.001	0.007	Stable
Parus major Great Tit	0.997	0.001	Moderate decline	1.005	0.002	Moderate increase
Passer montanus Eurasian Tree Sparrow	0.979	0.004	Moderate decline	0.991	0.01	Stable
Periparus ater Coal Tit	1.002	0.003	Stable	0.986	0.01	Stable
Phoenicurus phoenicurus Common Redstart	0.996	0.003	Stable	1.013	0.007	Stable
Phylloscopus collybita Common Chiffchaff	1.033	0.001	Moderate increase	1.002	0.002	Stable
Phylloscopus sibilatrix Wood Warbler	0.973	0.003	Moderate decline	0.941	0.005	Moderate decline
Phylloscopus trochilus Willow Warbler	0.981	0.001	Moderate decline	0.978	0.002	Moderate decline
Pica pica Black-billed Magpie	0.997	0.002	Stable	0.963	0.005	Moderate decline
Picus canus Grey-headed Woodpecker	1.015	0.025	Uncertain	0.959	0.017	Moderate decline
Picus viridis Green Woodpecker	1.019	0.004	Moderate increase	1.025	0.011	Moderate increase
Poecile montanus Willow Tit	0.96	0.004	Moderate decline	0.977	0.011	Moderate decline
Poecile palustris Marsh Tit	0.97	0.004	Moderate decline	0.979	0.011	Stable
Prunella modularis Hedge Accentor	0.984	0.001	Moderate decline	0.991	0.003	Moderate decline
Pyrrhula pyrrhula Common Bullfinch	0.986	0.003	Moderate decline	0.986	0.005	Moderate decline
Regulus regulus Goldcrest	0.995	0.002	Moderate decline	0.982	0.003	Moderate decline
Saxicola rubetra Whinchat	0.984	0.008	Moderate decline	1	0.006	Stable
Sitta europaea Wood Nuthatch	1.01	0.003	Moderate increase	0.98	0.009	Moderate decline
Streptopelia turtur European Turtle Dove	0.962	0.003	Moderate decline	0.991	0.005	Stable
Sturnus vulgaris Common Starling	0.973	0.004	Moderate decline	0.996	0.004	Stable
Sylvia atricapilla Blackcap	1.027	0.001	Moderate increase	1.019	0.002	Moderate increase
Sylvia borin Garden Warbler	0.993	0.001	Moderate decline	0.998	0.003	Stable
Sylvia communis Common Whitethroat	1.011	0.002	Moderate increase	1.016	0.003	Moderate increase
Sylvia melanocephala Sardinian Warbler	1.035	0.011	Moderate increase	1.025	0.011	Moderate increase
Troglodytes troglodytes Winter Wren	1.02	0.001	Moderate increase	1.018	0.001	Moderate increase
Turdus merula Common Blackbird	1.006	0.001	Moderate increase	1.012	0.001	Moderate increase
Turdus philomelos Song Thrush	0.994	0.001	Moderate decline	1.011	0.002	Moderate increase
Turdus viscivorus Mistle Thrush	0.987	0.003	Moderate decline	0.994	0.005	Stable
Upupa epops Hoopoe	0.969	0.017	Uncertain	0.972	0.017	Uncertain
Vanellus vanellus Northern Lapwing	0.95	0.005	Moderate decline	0.963	0.009	Moderate decline

*Trends of species were classified into the following categories according to statistical significance and magnitude (Pannekoek & Van Strien 2001, Van Strien *et al.* 2001). The multiplicative overall slope estimate in TRIM was converted into one of the following categories depending on the overall slope as well as its 95% confidence interval (= slope ± 1.96 times the standard error of the slope). Strong increase – increase significantly more than 5% per year. Criterion: lower limit of confidence interval > 1.05. Moderate increase – significant increase, but not significantly more than 5% per year. Criterion: 1.00 < lower limit of confidence interval < 1.05. Stable – no significant increase or decline, and it is certain that trends are less than 5% per year. Criterion: confidence interval encloses 1.00 but lower limit > 0.95 and upper limit < 1.05. Uncertain – no significant increase or decline, but not certain if trends are less than 5% per year. Criterion: confidence interval encloses 1.00 but lower limit < 0.95 or upper limit > 1.05. Moderate decline – significant decline, but not significantly more than 5% per year. Criterion: 0.95 < upper limit of confidence interval < 1.00. Steep decline – decline significantly more than 5% per year. Criterion: upper limit of confidence interval < 0.95.