

REPORT

International Conservation Policy Delivers Benefits for Birds in Europe

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One-sentence summary: The first quantitative appraisal of an international conservation policy instrument, the EU Birds Directive, yields results consistent with a measurable positive impact, though such an assessment would not have been possible without the fortuitous availability of monitoring data at comparable spatial and temporal scales

Conservation of the planet's biodiversity will depend on international policy intervention, yet evidence-based assessment of the success of such intervention is lacking. Poor understanding of the effectiveness of international policy instruments exposes them to criticism or abandonment and reduces opportunities to improve them. We present an assessment of one such instrument, the European Union's Birds Directive, which incorporates data from all the species and countries to which the agreement applies. Comparative analyses of population trends provide strong evidence for a positive impact of the Directive, and we identify positive associations between the rate of provision of certain conservation measures through the Directive and the response of bird populations. The results suggest that supra-national conservation policy instruments can bring measurable conservation benefits, though future assessments of their effectiveness will require the setting of measurable, quantitative objectives and an increase in the availability of data from appropriate, well-designed monitoring schemes.

As global threats to biodiversity are largely anthropogenic, already considerable in scale and accelerating rapidly (*I*), their solutions will depend largely upon international policy intervention. This was recognised in the formulation of

international agreements such as the Convention on Biological Diversity (CBD); at least twenty regional or global conservation agreements currently exist, absorbing a high proportion of global conservation resources (2). Evaluation of the impact of international conservation policy intervention lags far behind that of most other policy fields (3), due largely to a paucity of data on the response of the species to which intervention is targeted (4, 5). This leads to a poor understanding of the cost-effectiveness of the relevant policy instruments (6), reducing opportunities to improve them (7) and exposing them to criticism from both within and outside the conservation lobby (8). Although properly implemented conservation legislation can bring measurable benefits to wildlife (9-11), evaluation has hitherto been based either on an assessment of the provision of conservation resources, rather than the population responses of the target species to such provision, or on the responses of a small, possibly unrepresentative, proportion of the species or countries at which such legislation was targeted. Here we assess the impact of an international bird conservation policy that covers all Member States of the European Union (EU), for the first time using data on all the species and countries to which the agreement applies. We aimed to provide an independent assessment of the extent to which a major international policy instrument has resulted in the delivery of measurable conservation outputs.

The EU Birds Directive. Biodiversity conservation legislation in the EU is founded primarily on two Directives, the Birds Directive (1979) and the Habitats Directive (1992). The Birds Directive set out to establish a framework and objectives for the conservation of all birds throughout the EU, though the precise legal mechanisms for achieving this aim were left to the discretion of individual Member States. Central to the Directive was a list (“Annex I”) of species considered particularly vulnerable or rare, or requiring special conservation measures (12). Member States are bound by the Directive to improve the conservation status of these species by protecting or enhancing their habitats, for example through the designation of Special Protection Areas (SPAs) (12). Furthermore, a number of general measures to protect populations of all bird species was also agreed. No quantitative targets were set in the Directive, so we developed five expectations that we considered should be met if it can be deemed to have had a detectable positive impact. (1) We expected to detect an improvement in the population trajectory of species listed on Annex I after the implementation of the Directive, relative to that of non-Annex I species within the

EU15. (2) We expected any improvement in population trajectory of Annex I species relative to non-Annex I species in the EU15 to be significantly greater than that recorded in parts of Europe to which the Directive does not apply. (3) We expected trends of Annex I and non-Annex I species to be more positive within the EU15 than outside it. (4) We expected any positive impacts of Annex I listing to be most apparent in species that have been listed on it for longest. (5) We expected to detect a positive association across participating countries between the extent to which the Directive's conservation initiatives were deployed and trends in bird populations. Our analytical approach was based on the statistical testing of these five expectations.

Comparative analysis of population responses. Major inventories on the status and population trends of all Europe's breeding birds, collected at a country level and covering the periods 1970-1990 and 1990-2000 (*13, 14*), provided the opportunity to evaluate the impact of the Birds Directive. In each period, population trends of each species in each European country were allocated a single population trend score; these have already been published (*13, 14*) and formed the data we modelled to test the expectations described above. The availability of data from two time periods, and from within and outside the EU, permitted an analysis with serendipitous characteristics of a highly replicated Before-After-Control-Impact (BACI) approach (*15*). This permitted comparison of trends before and after 1990, between Annex I and non-Annex I species within the EU, and between Annex I species in the EU and the same group of species outside the EU (*16*). The use of a semi-experimental design based on both horizontal and longitudinal comparisons and the testing of multiple expectations maximised the likelihood that the observed patterns were causally related to variables identified by the models as having significant explanatory power. As the aim of the analysis was to examine the impact of Annex I listing using trends over the period 1990-2000, we limited comparisons to data from the original fifteen Member States of the EU (the EU15), all but three of which joined the EU before the start of the 1990-2000 census period (*17*). For the same reason, we restricted our list of Annex I species to those added to the Annex before 1993 (*12*). Because trends were recorded in bands of unequal width (ordered from increasingly negative to increasingly positive population trends), we treated the response variable as ordinal, and used the proportional odds model to assess differences between groups of species in the cumulative probabilities of being in higher ordered trend bands (*16*). After controlling for known variation within the

database in trends between species using different habitats (18) and between migrants and non-migrants (19), and for the non-independence of trends within countries and species, we detected a highly significant effect of Annex I listing (Fig. 1). In the EU15, Annex I species were significantly more likely to be assigned to a lower population trend class than non-Annex I species in 1970-1990. However, this pattern was reversed in 1990-2000, when Annex I species were significantly more likely to be recorded in a higher population trend band than non-Annex I species (Fig. 1A), thus meeting our first expectation. Outside the EU15, although trends of Annex I species improved significantly compared to those of non-Annex I species, they were no more likely to have more positive trends than non-Annex I species in 1990-2000 (Fig. 1B). The difference in trend between Annex I and non-Annex I species did not differ between the EU15 and non-EU15 countries in 1970-1990 (difference in $\log(\text{odds-ratios}) = 0.17$, $\text{SE} = 0.22$) but was significantly greater in the EU15 than in non-EU15 countries in 1990-2000 (difference in $\log(\text{odds-ratios}) = 0.52$, $\text{SE} = 0.18$). Thus, our second expectation was met.

There was no significant difference in trends of Annex I species within and outside the EU15 in 1970-1990. However, by 1990-2000, Annex I species in the EU15 were significantly more likely to be recorded in a higher trend band than the same group of species outside the EU15 (Fig. 1C), a pattern that was not apparent in non-Annex I species (Fig. 1D) or across all species combined (Fig. 1E). Our third expectation was therefore partly met.

Between 1990 and 2000, species listed on Annex I of the Birds Directive therefore fared significantly better on average than non-Annex I species within the EU15, a pattern not apparent in the same groups of species outside the EU15. This difference withstood controls for phylogenetic non-independence (16), and was due almost entirely to trends of species that had been listed on Annex I for longest (Fig. S1), supporting both our fourth expectation and a previous estimate (9) that the lag between policy intervention and a detectable population-level response exceeds ten years. Because the effects of both habitat and migration strategy were controlled in the analyses, this difference could not be ascribed to Annex I species being disproportionately represented in habitat or migration classes that fared better than average. Nor could the difference be accounted for by the deliberate or fortuitous allocation to Annex I of species that were already increasing, since most of these species were listed well before 1990, when their trends were significantly more

negative than those of non-Annex I species (Fig. 1A). Finally, the difference in trends between Annex I and non-Annex I species in the EU could not be explained by a general global increase in Annex I species, for example in response to climate change, since outside the EU15 their trends were no different from those of non-Annex I species.

Evidence of a causal link to the Birds Directive. Evidence for a causal link between policy intervention and species response (our fifth expectation) was found in the positive association across EU15 countries between mean species trend and the proportion of land designated as Special Protection Areas (Fig. 2). This pattern was apparent for all species combined, for Annex I and non-Annex I species separately, and was significantly stronger for Annex I than for non-Annex I species. Parameters of proportional odds models suggested that for every additional 1% of a country's land area designated as SPAs, the odds of a species of being in more positive population trend classes increased by around 4% across all species and for non-Annex I species, and by around 7% for Annex I species (16). The significantly stronger response of Annex I species to the provision of SPAs is consistent with a causal link between the delivery of conservation measures through the Directive and the response of the target species, since SPA designation and management are targeted largely towards Annex I species.

Therefore, four of our five expectations of a positive impact of the Birds Directive were fully met, and the remaining one was partly met (populations of Annex I species, though not of non-Annex I species, had more positive trends in the EU15 than outside it). Furthermore, although trends of non-Annex I species did not differ between the EU15 and other countries, there was evidence that trends of these species were more positive within the EU15 in countries with higher deployment of SPAs. The data are therefore consistent with the hypothesis that that the Birds Directive has brought demonstrable benefits to bird populations in the European Union, and that international policy intervention can be effective in addressing conservation issues over large geographical areas.

The importance of monitoring. Our results support previous assertions (4, 5, 20) that relatively simple yet robust population monitoring can play a significant role in assessing the success of supra-governmental conservation policies, as it already has in demonstrating the environmentally damaging effects of international policy in other sectors (21). Much biodiversity monitoring is undertaken by volunteers (22), making

it inexpensive relative to the costs of developing and implementing international policy. If such policies were to provide support for monitoring, for example by contributing to a global monitoring network (23), their success could be evaluated. Furthermore, setting targets that are both quantitative and measurable would increase the resolution of subsequent assessments. Precise goals and specific measures for monitoring policy effectiveness should be designed and tested at the time that the policy is implemented. Otherwise, quantitative assessments of policy intervention will continue to depend on *post hoc*, serendipitous analyses of the type presented here. Until policy and monitoring become more integrated, the success of international conservation policies in protecting the planet's biodiversity, or in achieving goals such as the CBD's 2010 target to reduce the rate of biodiversity loss (24), will be difficult or impossible to quantify. The prognosis for biodiversity is grim, because this lack of feedback can only serve to weaken international policy intervention at a time of unprecedented loss.

References and Notes

1. A. Balmford, W. Bond, *Ecol. Letters* **8**, 1218 (2005).
2. G. C. Boere, C. D. A. Rubec, in *Conserving Bird Biodiversity: General Principles and their Application* K. Norris, D. J. Pain, Eds. (Cambridge University Press, Cambridge, 2002) pp. 246-270.
3. P. J. Ferraro, S.K. Pattanayak, *PLoS Biology* **4**, e105 (2006).
4. R. E. Green *et al.*, *Conserv. Biol.* **19**, 56 (2005).
5. A. Balmford, R. E. Green, M. Jenkins, *TREE* **18**, 326 (2003).
6. F. Watzold, K. Schwerdtner, *Biol. Conserv.* **123**, 327 (2005).
7. D. J. Rohlf, *Conserv. Biol.* **5**, 273 (1991).
8. E. Stokstad, *Science* **309**, 2150 (2005).
9. T. D. Male, M. J. Bean, *Ecol. Letters* **8**, 986 (2005).
10. D. J. Pain *et al.*, *Anim. Conserv.* **9**, 322 (2006).
11. A. J. Cahill, J. S. Walker, S. J. Marsden, *Oryx* **40**, 161 (2006).
12. Further information on the Birds Directive, the suite of conservation measures it introduced and a list of species classified in the analyses as Annex I species are given in the Supporting Online Material (SOM).
13. G. M. Tucker, M. F. Heath, *Birds in Europe: their conservation status*. BirdLife Conservation Series No. 3 (BirdLife International, Cambridge, UK, 1994).
14. BirdLife International, *Birds in Europe: population estimates, trends and conservation status*. BirdLife Conservation Series No. 12 (BirdLife International, Cambridge, UK, 2004).
15. A. Stewart-Oaten, *The Before-After/Control-Impact-Pairs design for environmental impact assessment* (Marine Review Committee, California, 1986).
16. Full details of data collection and analysis, and further results, are provided in the SOM.
17. Austria, Finland and Sweden joined on 1 January 1995 and so were Member States for six of the 11 years of the 1990-2000 census period.
18. P. F. Donald, F. J. Sanderson, I. J. Burfield, F. P. J. van Bommel, *Agric. Ecosyst. Environ.* **116**, 189 (2006).
19. F. J. Sanderson, P. F. Donald, D. J. Pain, I. J. Burfield, F. P. J. van Bommel, *Biol. Conserv.* **131**, 93 (2006).

20. A. Balmford, P. Crane, A. Dobson, R. E. Green, G. M. Mace, *Philos. Trans. R. Soc. London Ser. B* **360**, 221 (2005).
21. P. F. Donald, R. E. Green, M. F. Heath, *Proc. R. Soc. London Ser. B* **268**, 25 (2001).
22. R. D. Gregory *et al.*, *Philos. Trans. R. Soc. London Ser. B* **360**, 269 (2005).
23. H. M. Pereira, H. D. Cooper, *TREE* **21**, 123 (2006).
24. A. Balmford *et al.*, *Science* **307**, 212 (2005).
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Supporting Online Material

SOM text

Materials, methods and additional results

References

Figure S1

Appendix S1

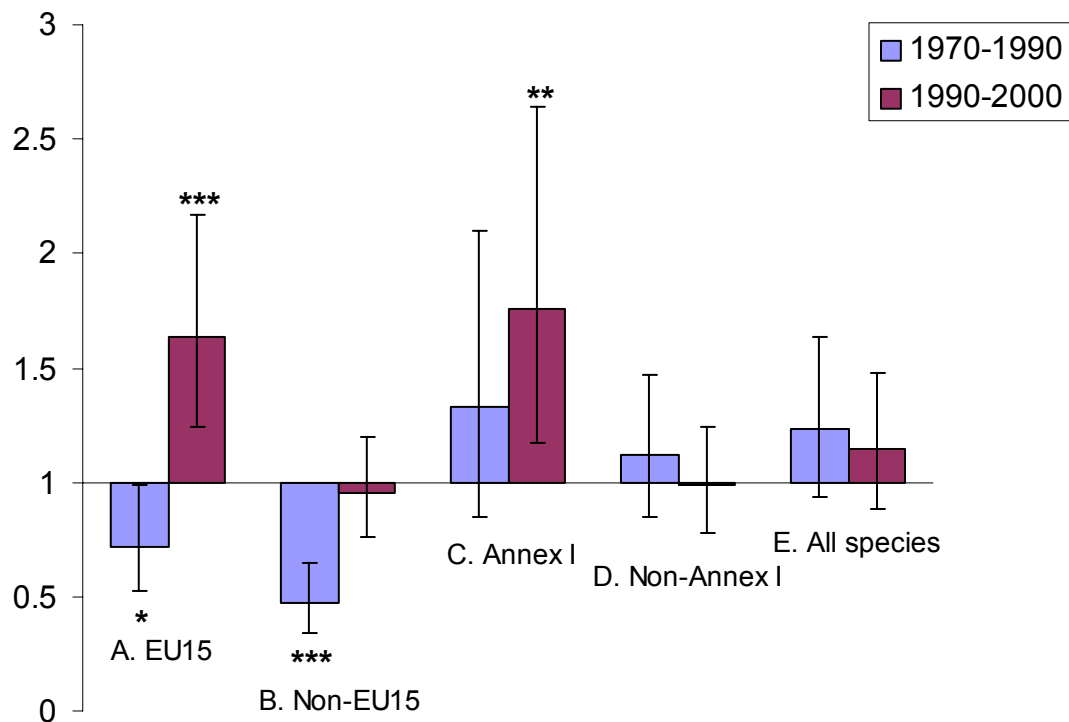


Fig. 1. Odds-ratios (with 95% CL) from proportional odds models (16). Each bar indicates the ratio of two groups of species in their cumulative odds of being in a more positive trend band in one of two time periods, with significant deviations from 1 indicated (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$). In A and B, the odds-ratios indicate how many times higher the odds were of populations of Annex I species having more positive trends than populations of non-Annex I species in the EU15 (A) and outside the EU15 (B) in each time period. Significant positive

deviation from an odds-ratio of 1 indicates a significantly higher probability that Annex I species had more positive trends than non-Annex I species; odds-ratios that are significantly smaller than 1 indicate the reverse. In C-E, the cumulative odds of species in the EU15 having a more positive population trend than those in non-EU15 countries are shown for Annex I species (C), non-Annex I species (D), and all species combined (E). All models controlled for the known effects on trend of each species' habitat and migration strategy, and controlled for the non-independence of trends within species across countries.

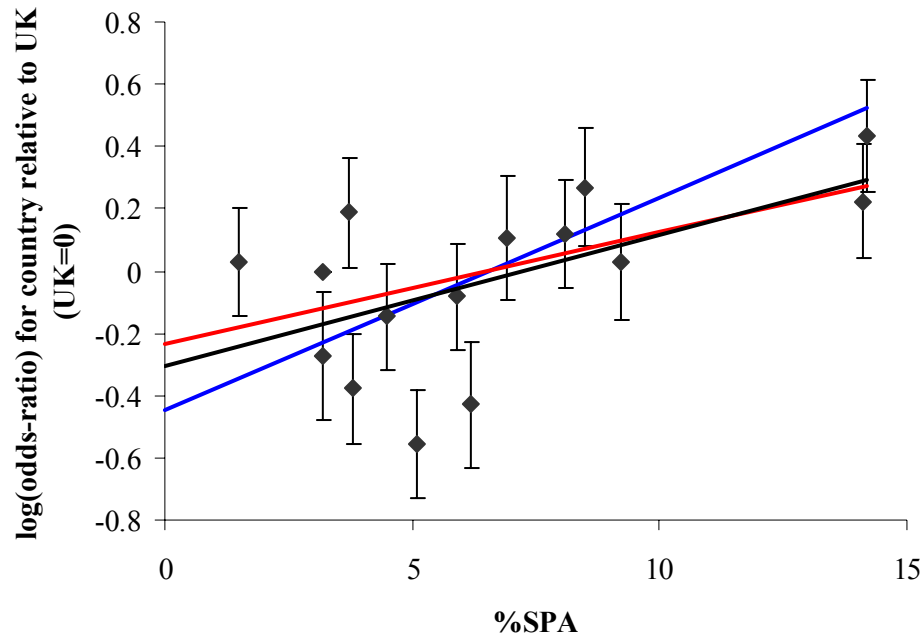


Fig. 2. Plot of country estimates of log(odds-ratios) against the percentage of land area designated as Special Protection Areas (SPAs) in the EU15 Member States, for Annex I and non-Annex I species combined (points with SEs and black regression line; slope = 0.042). The odds-ratios indicate the extent to which species are more or less likely to appear in more positive trend classes than species in the reference country (UK), which has a value of zero and no SE. In order to graphically represent this relationship, country effects of odds-ratios were extracted from a proportional odds model of trend class with migration strategy and breeding habitat also fitted as fixed effects and species fitted as a random effect. The regression coefficient differed significantly from zero ($P < 0.02$) and was estimated by fitting percentage SPA cover directly as a covariate in a proportional odds model and including a random country effect (16). A similarly significant positive association was apparent for Annex I (regression line only shown: blue line, slope = 0.068) and non-Annex I (regression line only shown: red line, slope = 0.036) species separately. A significant ($P < 0.01$) interaction term indicated that the slopes for Annex I and non-Annex I species differed.

Supporting Online Material

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Figure S1

Appendix S1

SOM Text

1. THE EU BIRDS DIRECTIVE

Biodiversity conservation legislation in the European Union is founded largely on two Directives. In 1979, the European Community adopted Council Directive 79/409/EC on the conservation of wild birds (the Birds Directive) as a response to the 1979 Bern Convention on the conservation of European habitats and species. This was followed in 1992 by Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive). The Birds Directive, which came into effect in 1981, set out to establish a framework for the conservation of birds throughout all parts of the European territory of the European Union, though the

precise legal mechanisms for achieving this aim were left to the discretion of individual Member States. Central to the Directive was a list (Annex I) of species considered particularly vulnerable or rare, or requiring special conservation measures. Article 4.1 of the Directive states that “The species mentioned in Annex I shall be the subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution”. Member States are bound by the Directive to improve the conservation status of these species by protecting or enhancing their habitats, for example through the designation of Special Protection Areas (SPAs). The first version of Annex I listed 74 species or subspecies, to which were added a further 68 in 1986, a further 29 in 1992 and a further 7 in 1995 (Appendix S1). In 1997, one species was removed from Annex I, and in 2004 an expanding EU led to the inclusion of a further 13 species or subspecies. Although no strict ecological or conservation criteria were applied in the selection of these species, and no justification for their inclusion has been published, there is a high degree of overlap between Annex I species and species considered by two independent and objective assessments (1, 2) to be of high conservation concern in Europe. A further requirement of the Birds Directive was that regularly occurring migratory species not listed in Annex I would also be treated as being of special concern (Article 4.2) and that Member States should introduce a general system of measures to protect all bird species (Article 5). The full text of the Directive and a list of Annex I species are available at:

http://ec.europa.eu/environment/nature/nature_conservation/eu_nature_legislation/birds_directive/index_en.htm.

The Birds Directive introduced a number of measures that could have brought about the positive trends described in the paper:

1. Designation of SPAs has been an important factor in improving the conservation status of at least some Annex I species through enhanced site conservation measures on key sites across the EU (3). By 2004, over 3,600 SPAs had been designated within the original 15 Member States of the EU, covering around 243,000 km² (3). Colonial waterbirds, which generally increased in numbers and expanded in distribution during 1990-2000, are likely to have done so at least partly as a result of the network of SPAs established for them across Europe (4), although there is evidence that the locations of SPAs could be improved (4, 5). SPAs form part of Natura 2000, a

network of legally protected sites across the EU. The extent to which a particular country has designated SPAs is likely to be a good indicator of the extent to which it has implemented other provisions of the Directive, so the relationship shown in Fig. 2 may not be related causally to SPA designation. It remains possible that the relationship depicted in Fig. 2 is the result of a general correlation between SPA designation and the delivery of other conservation measures unconnected with the Directive. In reality, however, the delivery of bird conservation in EU Member States is mediated largely through the Birds Directive and there appears to be no reason why conservation effort that is politically unconnected with the Directive should be positively correlated with conservation effort resulting from adoption of the Directive, nor why Annex I species should benefit more than non-Annex I species from conservation efforts unconnected with the Directive.

2. Another conservation action targeted specifically at Annex I species has been the preparation, agreement and adoption of international Species Action Plans (SAPs) for a range of threatened species, especially those threatened with global extinction. By 2000, international SAPs had been prepared and adopted for 46 Annex I species (http://ec.europa.eu/environment/nature/nature_conservation/focus_wild_birds/species_birds_directive/birdspriority.htm). These in turn triggered the adoption of national or regional species recovery plans for Annex I species in several countries and increased levels of direct conservation action, habitat management and awareness-raising by NGOs and other actors, such as regional or local governments.
3. Funding for the implementation of recommendations from these Species Action Plans has been available through EU LIFE-Nature funds, also triggering co-financing by national and regional authorities, NGOs and other donors. Between 1992 and 2000, over 40 Annex I species benefited from LIFE-Nature funding through the co-financing of projects, at a total cost of approximately €50 million (3). At least some of these projects have contributed directly to increasing the populations of their target species (3).
4. Additional to the measures introduced specifically for Annex I species, Member States are obliged by the Birds Directive to introduce protective measures designed to benefit all naturally occurring bird species. Articles 4, 5

and 6 of the Directive require Member States to take action to create, maintain and protect habitats, to protect birds from persecution and capture, to prevent disturbance or destruction of nests or breeding birds and to prevent the trade in wild birds. Again, the effectiveness of these measures is difficult to assess, since implementation of specific legislation has been at national level and monitoring has been poor.

5. A final way in which the Birds Directive could have led to improved conservation is through the empowerment of conservation NGOs, by allowing them to achieve conservation policy outcomes that they would be unlikely to secure through national channels (6).

Despite the large sums of money that have been invested in conserving Annex I species, and in implementing other Articles of the Birds Directive, there has until now been no quantitative assessment of the Directive's success as measured by the population response of the species towards which most conservation effort has been directed. Two previous appraisals of the Directive, one internal (3) and one external (7), concentrated more on the actions implemented than on the response of bird populations, as such data were not then available. This is despite the stated objective in Article 4 of the Directive that "Trends and variations in population levels shall be taken into account as a background for evaluations".

2. MATERIALS, METHODS AND ADDITIONAL RESULTS

2.1 Data collection

The *Birds in Europe* database contains a single estimate of the population size and trend for each breeding bird species in each country in Europe for the periods 1970-1990 and 1990-2000. Data were collected via a continent-wide network of national coordinators, who sought information on each species from relevant experts, monitoring organisations and regional contributors. Data collection was entirely independent of the Birds Directive, and assessing the success of the Directive was not one of the aims of the project. Estimates were derived from a combination of published and unpublished survey data, recording all reference sources used. Of the 9987 possible species/country combinations, population trend data were available for 8838 (88.5%) in 1990-2000. In the majority of cases, each species/country trend was

expressed as a trend class, which allowed the many different national monitoring schemes (8) to be compared directly across countries. Trend classes ranged from -2 to +2 in 1970-1990 (2 = >50% change; 1 = 20-49% change; 0 = <20% change) and from -5 to +5 in 1990-2000 (1 = <20% change; 2 = 20-29% change; 3 = 30-49% change; 4 = 50-79% change; 5 = >80% change; ranges for 1990-2000 were chosen to follow the IUCN Red List category thresholds (9). The sign of the trend indicated the direction of the change. Population stability or fluctuations around an unchanging mean were represented by a value of zero. There were thus five possible trend categories in 1970-1990 and 11 in 1990-2000. For some country/species combinations, precise estimates of population change were included in the database, but these were standardised to the appropriate trend class for analysis.

Because previous analyses of the *Birds in Europe* database (10, 11) demonstrated systematic differences in population trend between species using different migration strategies and birds associated with different habitats, the effects of these were controlled in all analyses by entering into the models a 5-level migrant term and a 9-level habitat term. Species were classified to habitat using predefined criteria (12), which divided the percentage of each European species' population occurring in each habitat into three classes: >75% (for all species), 10-75% and <10% (for Species of European Conservation Concern (SPECs) only). All species with more than 75% of their population occurring in the following eight habitats were classified as specialists of that habitat: marine; coastal; inland wetland; tundra, mires and moorland; boreal and temperate forests; Mediterranean forest, shrubland and rocky habitats; agricultural and grassland; and montane grassland. In addition, species with 10-75% of their population using only one of the above habitat types was classed as a specialist of that habitat, either according to (12) for SPECs or according to the description of (13) for non-SPECs. Farmland and woodland habitats were further sub-categorised (12); species with 10-75% of their population in three or more woodland or farmland sub-categories and 10-75% of their population in only one other habitat category were classified as woodland or farmland species respectively. Any species not falling into one of the above categories was classified to a ninth category as a habitat generalist. Each species was also assigned to one of five categories representing migration strategy, using published information on movements and distribution and following previously used aggregations (10, 14). These were: 1 = resident; 2 = partial migrant within Europe; 3 = migrant within Europe; 4 = short-

distance migrant to North Africa or the Middle East; 5 = long-distance migrant to sub-Saharan Africa or southern Asia (10).

The availability of data from two time periods, and from within and outside the EU15, permitted an analysis with characteristics of a highly replicated Before-After-Control-Impact (BACI) approach, allowing comparison of trends before and after 1990, between Annex I and non-Annex I species within the EU15, and between Annex I species in the EU15 and the same group of species outside the EU15. The testing of multiple expectations and the use of a BACI design were both necessary to reduce regression-to-the-mean effects (15). The non-random allocation of species to Annex I, and the fact that the first time period included the period both before and shortly after the Birds Directive was implemented, meant that some of the criteria of a full BACI approach were not met. However, given the time lag between policy implementation and the detection of species response, suggested by one analysis to be around 10 years (16), we consider the two periods to present a reasonable before and after comparison. As the aim of the analysis was to examine the impact of Annex I listing using trends over the period 1990-2000, we limited comparisons to data from the EU15, all but three of which joined the EU before the start of the census period. Austria, Finland and Sweden joined on 1 January 1995 and so were Member States for six of the 11 years of the second census period. Including in this group Member States that acceded to the EU more recently (the next Member States did not accede until 2004) would not assist evaluation of the Directive, since the trend data available do not overlap with their period of membership. All other European countries for which monitoring data were available ($N = 31$), including those that acceded to the EU after 1995, were classed as non-EU15, allowing a comparison of trends between two groups of countries in which Birds Directive legislation either was or was not in place during the census period. Similarly, we classified species as being listed on Annex I only if they were added to the Annex no later than 1992. From this list, we removed species that were listed in Annex I on the basis of a subspecies making up only a small proportion of the species' European population, and species for which no trend data were available, resulting in 149 species being classed as Annex I. Trend data were available for 256 non-Annex I European species. Species added to Annex I after 1992 and all other species were classed in the analyses as non-Annex I species. Data on total land area covered by Special Protection Areas (SPAs; excluding marine SPAs) in each EU15 Member State in 2000 were obtained from the April 2000

Natura 2000 newsletter of the EC Environment Directorate General (http://ec.europa.eu/environment/news/natura/index_en.htm). The correlation between percentage SPA cover and the overall mean trend across all species, and Annex I species and non-Annex I species separately, was then assessed. Other direct measures of delivery of conservation through the Directive, such as money spent on each species or the number of prosecutions for violations of wildlife law, are either inappropriate or unavailable. For example, financial spend on a particular species is difficult to estimate and will vary according to the measures undertaken and the country, making interpretation of any relationship between direct spend and population response problematic.

2.2. Data analysis and additional results

The response variable, the population trend of species i in country j in one of two time periods, was expressed in the database in the form of one of a number of trend bands whose widths were not always equal (see description of methods of data collection above) and which differed between the two survey periods. We therefore used the proportional odds model for ordinal data (17) to assess whether trends of one set of species were more (or less) likely to show more positive trends than those of another group of species. Let Y_{ij} be the categorical response variable, consisting of records of species (indexed by i) in countries (indexed by j) in $T+1$ ordered trend bands ($T = 4$ for the period 1970-1990, and $T = 10$ for the period 1990-2000; see section on data collection above). In the proportional odds model, the cumulative probabilities that the Y_{ij} are in increasingly positive trend bands are modelled as a function of groupings of species and countries using the multinomial distribution and the cumulative logit-link. We can think of Y as a discretized variable of an underlying continuous set of trends using the threshold points T . Differences between groups of species (or countries) in the cumulative odds of being in increasingly positive trend bands are estimated using odds-ratios. More specifically, odds-ratios provide estimates of how many times higher the cumulative odds (of being in a more positive trend band) of one group of species were compared to another group of species. A significant positive deviation from an odds-ratio of 1 for a group of species indicates that populations of this group of species were significantly more likely to have more positive trends than populations of another group of species. Conversely, estimates of

odds-ratios significantly smaller than 1 indicate that populations of that group of species were significantly less likely to have more positive trends than populations of the other group of species. Inherent in the models is the assumption of proportional odds, which states that the cumulative odds-ratio for any two groups of species is constant across the trend bands. We used this model framework to test each of our five expectations (see main paper).

Expectation 1: In order to compare trends of Annex I and non-Annex I species, we used a proportional odds model of the form:

$$\log \left\{ \frac{\Pr(Y_{ij} \geq T)}{\Pr(Y_{ij} < T)} \right\} = \alpha_T + \textit{habitat}_m + \textit{migration}_k + \textit{country}_j + \textit{annex}_b + u_i \quad [\text{Model 1}]$$

where Y_{ij} is the ordinal trend estimate of species i in country j , T are the thresholds (of which there are the number of ordinal trend ranks minus 1, so 4 thresholds for the 1970-1990 data, and 10 thresholds for the 1990-2000 data), α_T are the intercepts for each threshold, $\textit{habitat}_m$ is the 9-level habitat factor ($m = 1, 2, \dots, 9$; m is invariant within species i), $\textit{migration}_k$ is the 5-level migration status factor ($k = 1, 2, \dots, 5$; k is invariant within species i), \textit{annex}_b is a binary variable to indicate whether or not a species is on Annex I ($b = 1$, Annex I or $b = 2$, non-Annex I; b is invariant within species i) and u_i is a random effect for species. This last term was included in all models because it is unlikely that trends of individual species across countries can be considered independent. In this model, the odds-ratio $e^{(\textit{annex}_{b=1} - \textit{annex}_{b=2})}$ provides an estimate of the number of times that the cumulative odds (of having more positive trends) of populations of Annex I species increased, compared to populations of non-Annex I species.

Expectation 2: In order to compare the relative improvement in population trajectory of Annex I species compared to non-Annex I species between EU15 and non-EU15 countries, we used *post hoc* comparison to test for differences between the two left hand bars and between the two right hand bars in Figure 1A and 1B. In each of the two periods (1970-1990 and 1990-2000), we estimated the standard error of the difference of differences as:

$$SE = \sqrt{(SE_{EU15})^2 + (SE_{non-EU15})^2}$$

where SE_{EU15} is the standard error of the odds-ratio of difference between Annex I and non-Annex I species in the EU15, and $SE_{non-EU15}$ is the standard error of the odds-ratio of difference between Annex I and non-Annex I species outside the EU15.

Expectation 3: In order to compare trends of Annex I species, of non-Annex I species or of all species combined between the EU15 and non-EU15 countries, we used a proportional odds model of the form:

$$\log \left\{ \frac{\Pr(Y_{ij} \geq T)}{\Pr(Y_{ij} < T)} \right\} = \alpha_T + habitat_m + migration_k + eu15_d + u_i + u_j \quad [\text{Model 2}]$$

where $eu15_d$ is a binary variable ($d = 1$, EU15 countries, or $d = 2$, non-EU15 countries) indicating whether or not the country is in the EU15, and u_j is a random effect for country. In this model, the odds-ratio $e^{(eu15_{d=1} - eu15_{d=2})}$ provides an estimate of the number of times that the cumulative odds (of having more positive trends) of populations of Annex I species in EU15 countries increased, compared to populations of Annex I species in non-EU15 countries.

Expectation 4: The fourth expectation was assessed with a model fitted to 1990-2000 data from the EU15 alone to assess whether trends in Annex I species differed according to how long they had been listed on that Annex:

$$\log \left\{ \frac{\Pr(Y_{ij} \geq T)}{\Pr(Y_{ij} < T)} \right\} = \alpha_T + habitat_m + migration_k + country_j + annexyr_h + u_i \quad [\text{Model 3}]$$

where $annexyr_h$ is a 3-level variable separating the 71 species added to the Annex at its first publication in 1981 ($h = 1$), the 91 species added to the Annex later (60 in 1986, 24 in 1992 and seven in 1995; $h = 2$) and the 256 species with trend data not listed on the Annex ($h = 3$). The actual number of species for which trend data were available was slightly lower than the total number of species falling into each value of h . In this model, the odds-ratio $e^{(annexyr_{h=1} - annexyr_{h=2})}$ provides an estimate of the

number of times that the cumulative odds (of having more positive trends) of populations of the 71 species that were on the Annex in 1987 increased, compared to the populations of the 91 species which were added later to Annex I. The odds-ratio $e^{(\text{annexyr}_{h=1} - \text{annexyr}_{h=3})}$ provides an estimate of the number of times the cumulative odds (of having more positive trends) of populations of the 71 species that were on Annex I in 1987 increased, compared to the populations of the 256 species with trend data that were not on Annex I.

Expectation 5: To assess the relationship between bird population trends and the extent to which conservation measures introduced by the Birds Directive have been implemented, the following model was fitted to data to population trends of birds in the EU15 and from 1990-2000 only:

$$\log \left\{ \frac{\Pr(Y_{ij} \geq T)}{\Pr(Y_{ij} < T)} \right\} = \alpha_T + \text{habitat}_m + \text{migration}_k + \text{spaarea}_j + u_i + u_j \quad [\text{Model 4}]$$

where the covariate spaarea_j is the percentage of land cover that had been designated as Special Protection Areas in each country by 2000. In this model, $e^{(\text{spaarea}_j)}$ provides an estimate of the number of times the cumulative odds (of having more positive trends) of populations of species increased with each unit increase in spaarea_j . The model was fitted for all species combined, and for Annex I and non-Annex I species separately. In each case, spaarea_j explained significant variation in trend, in each group of species the probability of a species being in a higher trend class increasing with SPA area (all species: estimate = 0.042, SE = 0.017, $P < 0.02$; Annex I species only: estimate = 0.068, SE = 0.027, $P < 0.02$; non-Annex I species: estimate = 0.036, SE = 0.018, $P < 0.05$).

Models were specified in such a way that an odds-ratio significantly larger than 1 indicated that Annex I species were significantly more likely to have a more positive trend than non-Annex I species [Model 1], or that trends in EU15 countries were significantly more likely to have a more positive trend than those in non-EU15 countries [Model 2]. Odds-ratios of significantly less than 1 indicated the reverse. In Model 3, pairwise tests were used to compare the three factor levels. Parameters were estimated from full models and no model simplification was attempted since a single

test variable was included in each, the other explanatory variables being entered to account for their known influence on the dependent variable; in the event, all factors in the models explained significant variation. Potential dependencies in the trends of the same species across countries, and of trends of species in the same country were accounted for by fitting species and country, blocked by EU status, as factors in all models. More complex models to account for spatial autocorrelation in trends of individual species across countries were not attempted, since such effects are likely to vary between species and for many species, there were too few trends available to estimate autocorrelation effects. Furthermore, modelling such effects in a proportional odds modelling framework is problematic.

Phylogenetic contrasts

Although the significantly more positive trends of Annex I species within the EU15 were not replicated outside the EU15 (Figure 1), it remains possible that the significant difference in trend between Annex I and non-Annex I species within the EU15 during 1990-2000 (Figure 1A) might be influenced by the phylogenetically non-random allocation of species to Annex I. To assess this, we undertook an analysis of phylogenetically independent contrasts, using comparative methods (18-20). All species were allocated to phylogenetically independent contrasts using the phylogeny of Sibley & Ahlquist (21) and the allocation protocol of Burt (18), with the condition that each contrast contained a mix of Annex I and non-Annex I species, and the mean trend of each group of species estimated within each country/contrast combination. The paired difference in mean trends (Annex I minus non-Annex I) was then estimated across all country/contrast combinations and its 95% CIs used to assess significance of difference from zero. The mean difference was positive (0.28) and had 95% CLs that did not span zero, suggesting that the results in Figure 1A were robust to phylogenetic non-independence.

3. REFERENCES

1. G. M. Tucker, M. F. Heath, *Birds in Europe: their conservation status*. BirdLife Conservation Series No. 3 (BirdLife International, Cambridge, UK, 1994).
2. BirdLife International, *Birds in Europe: population estimates, trends and conservation status*. BirdLife Conservation Series No. 12 (BirdLife International, Cambridge, UK, 2004).

3. European Commission, *LIFE for Birds. 25 years of the Birds Directive: the contribution of LIFE Nature projects* (Office for Official Publications of the European Communities, 2004).
4. S. F. Jackson, M. Kershaw, K. J. Gaston, *Biol. Conserv.* **118**, 261 (2004).
5. J. Seoane *et al.*, *Biol. Conserv.* **128**, 241 (2006).
6. J. Fairbrass, A. Jordan, *J. European Publ. Pol.* **8**, 499 (2001).
7. W. J. M. Hagemeijer, C. J. Bibby, in *Proceedings of the Councils Directive on Conservation of Wild Birds. Elsinore, Denmark, 18-19 November 1999* F. P. Jensen, Ed. (The Danish National Forest and Nature Agency, Copenhagen, 2000) pp. 18-43.
8. P. Vorišek, J. H. Marchant, *Bird Census News* **16**, 16 (2003).
9. IUCN, *IUCN Red List Categories and Criteria: Version 3.1* (IUCN Species Survival Commission, Gland, Switzerland and Cambridge, UK, 2001).
10. F. J. Sanderson, P. F. Donald, D. J. Pain, I. J. Burfield, F. P. J. van Bommel, *Biol. Conserv.* **131**, 93 (2006).
11. P. F. Donald, F. J. Sanderson, I. J. Burfield, F. P. J. van Bommel, *Agric. Ecosyst. Environ.* **116**, 189 (2006).
12. G. M. Tucker, M. I. Evans, *Habitats for birds in Europe: a conservation strategy for the wider environment*. (BirdLife International, Cambridge, UK, 1997).
13. D. W. Snow, C. M. Perrins, Eds., *The Birds of the Western Palearctic: Concise Edition*. (Oxford University Press, Oxford, 1998).
14. S. Cramp, Ed., *Birds of the Western Palearctic: Handbook of the Birds of Europe, the Middle East and North Africa* (Oxford University Press, Oxford, 1977-1994).
15. J. M. Bland, D. G. Altman, *Brit. Med. J.* **308**, 1499 (1994).
16. T. D. Male, M. J. Bean, *Ecol. Letters* **8**, 986 (2005).
17. P. McCullagh, *J. Roy. Stat. Soc. B.* **42**, 109 (1980).
18. A. Burt, *Oxf. Surv. Evol. Biol.* **6**, 33 (1989).
19. P. H. Harvey, A. Purvis, *Nature* **351**, 619 (1991).
20. R. P. Freckleton, P. H. Harvey, M. Pagel, *Am. Nat.* **160**, 712 (2002).
21. C. G. Sibley, J. Ahlquist, *Phylogeny and classification of birds* (Yale University Press, New Haven, Conn., 1990).

Figure S1

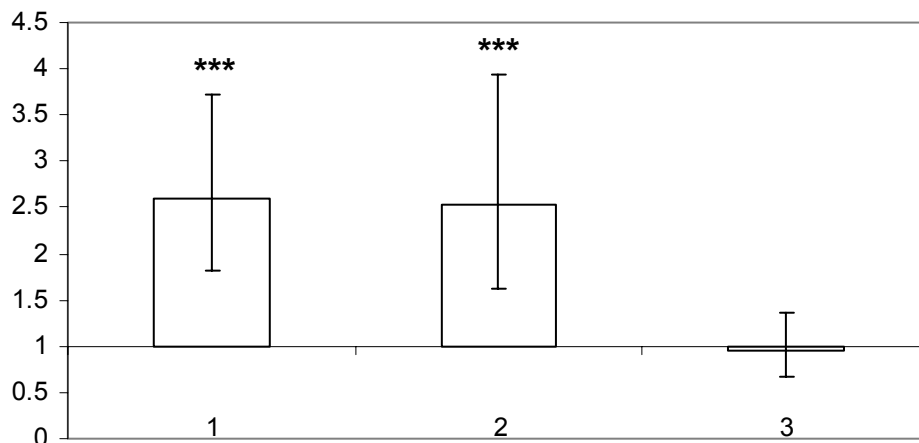


Figure S1. Odds-ratios (+/-95%CL) estimated from Model 3 (above). Odds-ratios provide estimates of the number of times that the cumulative odds (of being in more positive population trend classes) of species listed on Annex I in 1981 increased compared to those of non-Annex I species (1) and species listed on Annex I after 1981 (2). In both cases, species listed in 1981 had around 2.5 times higher cumulative odds

than species added later or not added at all. These last two groups did not differ significantly in trend (3). *** $P < 0.0001$.

Appendix S1 List of species classified in the analyses as Annex I species. This included species added to the Annex before or during 1992 for which trend data were available (see SOM Text 2: Materials, Methods and Additional Results). Species are listed in taxonomic order with the year in which they were added to Annex I.

Species	Year added
<i>Gavia stellata</i>	1986
<i>Gavia arctica</i>	1986
<i>Podiceps auritus</i>	1986
<i>Pterodroma feae</i>	1992
<i>Pterodroma madeira</i>	1992
<i>Bulweria bulwerii</i>	1992
<i>Calonectris diomedea</i>	1981
<i>Puffinus assimilis</i>	1992
<i>Pelagodroma marina</i>	1992
<i>Hydrobates pelagicus</i>	1981
<i>Oceanodroma leucorhoa</i>	1981
<i>Oceanodroma castro</i>	1992
<i>Phalacrocorax carbo</i>	1981
<i>Phalacrocorax pygmeus</i>	1986
<i>Pelecanus onocrotalus</i>	1986
<i>Pelecanus crispus</i>	1986
<i>Botaurus stellaris</i>	1981
<i>Ixobrychus minutus</i>	1986
<i>Nycticorax nycticorax</i>	1981
<i>Ardeola ralloides</i>	1981
<i>Egretta garzetta</i>	1981
<i>Casmerodius albus</i>	1981
<i>Ardea purpurea</i>	1981
<i>Ciconia nigra</i>	1981
<i>Ciconia ciconia</i>	1981
<i>Plegadis falcinellus</i>	1981
<i>Platalea leucorodia</i>	1981
<i>Phoenicopterus ruber</i>	1981
<i>Cygnus cygnus</i>	1981
<i>Anser erythropus</i>	1986
<i>Branta leucopsis</i>	1981
<i>Tadorna ferruginea</i>	1986
<i>Marmaronetta angustirostris</i>	1992
<i>Aythya nyroca</i>	1981
<i>Oxyura leucocephala</i>	1981
<i>Pernis apivorus</i>	1981
<i>Elanus caeruleus</i>	1992
<i>Milvus migrans</i>	1981
<i>Milvus milvus</i>	1981
<i>Haliaeetus albicilla</i>	1981

<i>Gypaetus barbatus</i>	1981
<i>Neophron percnopterus</i>	1981
<i>Gyps fulvus</i>	1981
<i>Aegypius monachus</i>	1981
<i>Circaetus gallicus</i>	1981
<i>Circus aeruginosus</i>	1981
<i>Circus cyaneus</i>	1981
<i>Circus pygargus</i>	1981
<i>Accipiter brevipes</i>	1986
<i>Buteo rufinus</i>	1986
<i>Aquila pomarina</i>	1986
<i>Aquila clanga</i>	1986
<i>Aquila heliaca</i>	1986
<i>Aquila adalberti</i>	1992
<i>Aquila chrysaetos</i>	1981
<i>Hieraaetus pennatus</i>	1981
<i>Hieraaetus fasciatus</i>	1981
<i>Pandion haliaetus</i>	1981
<i>Falco naumanni</i>	1986
<i>Falco columbarius</i>	1986
<i>Falco eleonora</i>	1981
<i>Falco biarmicus</i>	1981
<i>Falco peregrinus</i>	1981
<i>Bonasa bonasia</i>	1986
<i>Tetrao tetrix</i>	1986
<i>Tetrao urogallus</i>	1986
<i>Alectoris graeca</i>	1986
<i>Alectoris barbara</i>	1986
<i>Porzana porzana</i>	1986
<i>Porzana parva</i>	1986
<i>Porzana pusilla</i>	1986
<i>Crex crex</i>	1986
<i>Porphyrio porphyrio</i>	1981
<i>Fulica cristata</i>	1992
<i>Grus grus</i>	1981
<i>Tetrax tetrax</i>	1981
<i>Otis tarda</i>	1981
<i>Himantopus himantopus</i>	1981
<i>Recurvirostra avosetta</i>	1981
<i>Burhinus oedicephalus</i>	1981
<i>Cursorius cursor</i>	1992
<i>Glareola pratincola</i>	1981
<i>Eudromias morinellus</i>	1981
<i>Pluvialis apricaria</i>	1981
<i>Vanellus spinosus</i>	1986
<i>Philomachus pugnax</i>	1986

<i>Gallinago media</i>	1981
<i>Tringa glareola</i>	1981
<i>Phalaropus lobatus</i>	1981
<i>Larus melanocephalus</i>	1986
<i>Larus genei</i>	1981
<i>Larus audouinii</i>	1981
<i>Sterna nilotica</i>	1981
<i>Sterna caspia</i>	1986
<i>Sterna sandvicensis</i>	1981
<i>Sterna dougallii</i>	1981
<i>Sterna hirundo</i>	1981
<i>Sterna paradisaea</i>	1981
<i>Sterna albifrons</i>	1981
<i>Chlidonias hybridus</i>	1986
<i>Chlidonias niger</i>	1981
<i>Pterocles orientalis</i>	1992
<i>Pterocles alchata</i>	1981
<i>Columba trocaz</i>	1992
<i>Columba bollii</i>	1992
<i>Bubo bubo</i>	1981
<i>Nyctea scandiaca</i>	1981
<i>Glaucidium passerinum</i>	1986
<i>Asio flammeus</i>	1981
<i>Aegolius funereus</i>	1986
<i>Caprimulgus europaeus</i>	1986
<i>Apus caffer</i>	1992
<i>Alcedo atthis</i>	1981
<i>Coracias garrulus</i>	1986
<i>Picus canus</i>	1986
<i>Dryocopus martius</i>	1981
<i>Dendrocopos syriacus</i>	1986
<i>Dendrocopos medius</i>	1986
<i>Dendrocopos leucotos</i>	1981
<i>Picoides tridactylus</i>	1986
<i>Chersophilus duponti</i>	1992
<i>Melanocorypha calandra</i>	1986
<i>Calandrella brachydactyla</i>	1986
<i>Galerida theklae</i>	1986
<i>Lullula arborea</i>	1986
<i>Anthus campestris</i>	1986
<i>Luscinia svecica</i>	1981
<i>Saxicola dacotiae</i>	1992
<i>Oenanthe leucura</i>	1986
<i>Acrocephalus melanopogon</i>	1986
<i>Acrocephalus paludicola</i>	1986
<i>Hippolais olivetorum</i>	1986

<i>Sylvia sarda</i>	1986
<i>Sylvia undata</i>	1981
<i>Sylvia rueppelli</i>	1986
<i>Sylvia nisoria</i>	1981
<i>Ficedula parva</i>	1986
<i>Ficedula semitorquata</i>	1986
<i>Ficedula albicollis</i>	1986
<i>Sitta krueperi</i>	1986
<i>Sitta whiteheadi</i>	1981
<i>Lanius collurio</i>	1986
<i>Lanius minor</i>	1986
<i>Pyrrhonorax pyrrhonorax</i>	1986
<i>Fringilla teydea</i>	1992
<i>Rhodopechys githaginea</i>	1992
<i>Emberiza cineracea</i>	1986
<i>Emberiza hortulana</i>	1986
<i>Emberiza caesia</i>	1986