Environmental and Experimental Biology (2012) 10: 41–47 *Original Paper*

Changes in breeding bird distribution in Latvia and their correspondence to modelled changes in distribution in Europe due to climate change

Viesturs Ķerus*, Ainārs Auniņš, Māris Strazds, Jānis Priednieks

Faculty of Biology, University of Latvia, Kronvalda Bulv. 4, Riga LV-1010, Latvia

*Corresponding author, E-mail: viesturs@lob.lv

Abstract

The aim of our study was to evaluate changes in breeding bird distribution in Latvia from 1980 – 1984 to 2000 – 2004 and to compare the recorded changes with predictions on range shifts on a European level due to climate change by the end of the 21st century. To evaluate changes in breeding bird distribution we used data from two nation-wide breeding bird atlas studies, controlling for differences in grid square size, grid projections and different levels of survey effort. The significance of the recorded change, as well as that of predicted change, was calculated using chi-square tests of independence. The results showed that the distribution of breeding birds in Latvia has changed significantly from 1980 – 1984 to 2000 – 2004, with 53.8% of the species either decreasing or increasing in distribution. During that time, also the climate in Latvia has undergone a general trend of "becoming warmer". In general, the recorded changes in breeding bird distribution in Latvia do not match the predictions regarding change in distribution due to climate change. Several limitations hinder making sound conclusions, but we found no evidence of a major impact of climate change on recorded changes in breeding bird distribution. However, for some species, climate change can be seen as one of the main drivers of the change.

Key words: atlas studies, breeding bird atlas, breeding bird distribution, climate change.

Introduction

Today, public awareness of conservation of biodiversity is increasing, while biodiversity is on a decline. Birds are one of the best studied groups of living organisms (Greenwood 2007). This, as well as the popularity of birds among the general public, has led to the use of birds as „flagships" to illustrate the necessity of biodiversity conservation and to assess the factors leading to the decline.

One of the most popular forms of bird studies is preparation of atlases (Gibbons et al. 2007). They involve large number of people and obtain relatively detailed information on bird occurrence in large regions. When repeated, atlases show changes in bird distribution and allow to evaluate the reasons behind the changes.

Climate is generally considered to be one of the main limiting factors of species geographic ranges (Krebs 1994; Gaston 2003), and increasing attention is paid to the impact of climate change on, amongst other population parameters, the distribution of species (reviewed in McCarty 2001; Crick 2004). One of the widely-used methods of relating climatic factors to species distribution is the so called "climate envelope" model (Pearson, Dawson 2003; Thomas et al. 2004; Pearson et al. 2006), although these at times have been heavily criticized (Beale et al. 2008). Probably, the most prominent recent publication using climate envelope models is "A Climatic Atlas of European Breeding Birds" (Huntley et al. 2007), in which models are used to predict shifts in suitable climate space for breeding birds of Europe. The "present simulated distribution" in this case is based on bird distribution data from the EBCC Atlas of European Breeding Birds (Hagemeijer, Blair 1997), which were collected mostly in 1980s.

Bird populations and their distribution in Europe have changed since the 1980s (BirdLife International 2004), which allows to evaluate the changes taking place against the predictions made by Huntley et al. (2007). This type of stydy was made by Gregory et al. (2009), who compared recent changes in population sizes of breeding birds of Europe with the predictions of range changes, to develop an indicator of the impact of climate change on European bird populations. The indicator showed noticeable impact of climate on bird populations starting in the 2nd half of 1980s. It must be noted, however, that the authors themselves acknowledge the problem of using population change estimates together with predictions on ranges.

In Latvia three nation-wide breeding bird atlas studies have been carried out: (1) the first Latvian Breeding Bird Atlas (1980 – 1984; Priednieks et al. 1989), (2) the European Breeding Bird Atlas (1985 – 1989; data used in Hagemeijer, Blair 1997), and (3) the second Latvian Breeding Bird Atlas (2000 – 2004; Latvian Ornithological Society, unpublished data). We compared the recorded changes in bird distribution in Latvia with the predictions made by Huntley et al. (2007), to attempt to relate recent changes in bird distribution in 15 to 20 years in Latvia to the predicted trends due to climate change.

Materials and methods

To avoid confusion of different scales of distribution, in this paper we use the term "range" to refer to the distribution on a continental scale, and "distribution" to mrefer to finer-scale distribution within the range (i.e., the area of occupancy indicated by the number of atlas squares occupied by a species).

Bearing in mind that Huntley et al. (2007) produced models of where the suitable climate range for the species will be at the end of 21st century, if their climatic requirements (realised climatic niche *sensu* Guisan, Zimmerman 2000; Kearney 2006) will be the same as today. Nevertheless, for ease of presentation we use the term "predicted distribution", as the "simulated potential late 21st century distribution" used by Huntley et al. (2007).

To evaluate changes in breeding bird distribution in Latvia we compared two nation-wide atlas studies: the first Latvian Breeding Bird Atlas (Priednieks et al. 1989) data, which were collected during 1980 – 1984, and the second Latvian Breeding Bird Atlas (Latvian Ornithological Society, unpublished data) data, which were collected during 2000 – 2004. In both cases the data, originally recorded as level of breeding probability, were transformed to presence/absence.

There were three problems that hindered evaluating changes in distribution between 1980 – 1984 and 2000 – 2004: (1) different grid square sizes (10 × 10 km in the first and 5 × 5 km in the second study period) ; (2) different grid projections (UTM in the first and LKS-92 in the second study period); and (3) different levels of survey effort. In the case of the second Latvian Breeding Bird Atlas, data originally collected in 5 × 5 km grid were transformed into 10 × 10 km grid by merging each four neighbouring squares. To control for differences in grid projections and survey effort, only numerical data (i.e., the number of squares with the species recorded) were used, instead of spatial data (i.e., maps), and only the squares considered sufficiently surveyed were included in the analysis.

To set a threshold for considering a square sufficiently surveyed we used the total number of species recorded, this was done because for a portion of squares the time spent in a square was available (and only for the second Latvian Breeding Bird Atlas). However, to calculate this threshold we used the time data for the squares for which this was recorded. By using logarithmic regression of number of species recorded against the time spent in the square we calculated by the threshold as the total number of species recorded when a hour increment led to an increase of less than 1% (Soberón, Llorente 1993). Using the equation of regression We calculated the sufficient survey effort threshold to be 84 (Fig. 1). Thus 256 and 534 squares were suitable for analysis for the first and the second Latvian Breeding Bird Atlas, respectively.

Extent and significance of the changes in bird distribution was calculated using the chi-square test

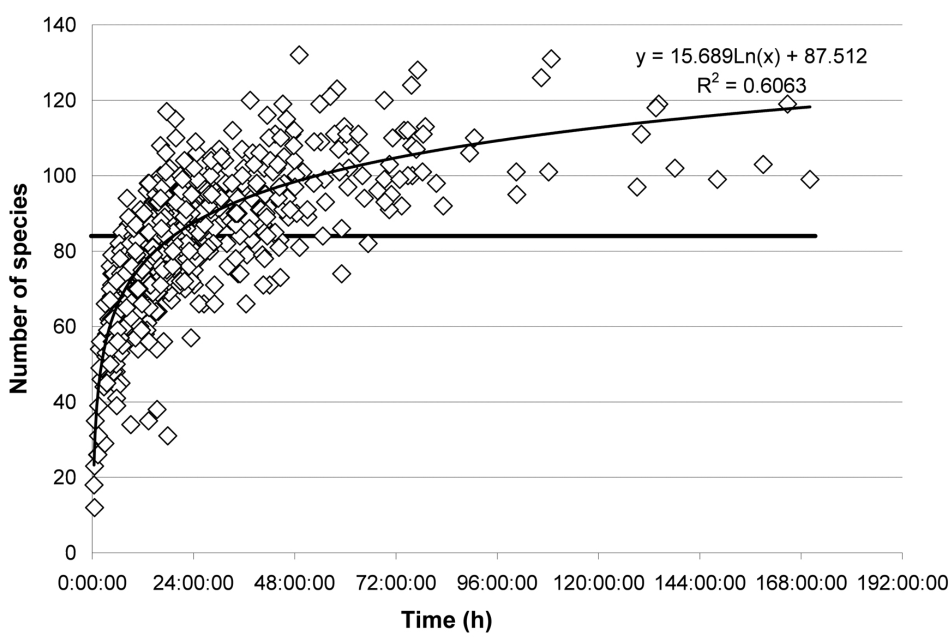

Fig. 1. The number of species recorded in a 10 × 10 km square during the second Latvian Breeding Bird Atlas (2000 – 2004) in relation to the time spent in the square. The bold horizontal line marks the threshold of sufficient survey effort of the square – 84 species recorded.

(Sokal, Rohlf 1995). This analysis was not carried out for species that were recorded in < 21 squares in both of the atlases and for the species for which the improvement in recording methods was significant and known (e.g., Pygmy Owl *Glaucidium passerinum*; V. Liepa, personal communication). Therefore, the total number of species analysed was 175.

As the methods described above allow to exclude only the impact of overall changes in survey effort on the results, but not differences in survey of specific habitats, species or groups of species, the results obtained were submitted for evaluation to seven ornithologists who had participated in fieldwork of both atlas studies. They were asked to indicate possibly imprecise results and their causes. If experts thought that the calculated trend was incorrect, but had no convincing explanation for this, the calculated result was left without correction. Corrections were made in 11 cases (6.3% of all species analysed).

Recorded trends in breeding bird distribution were compared with the trends modelled by Huntley et al. (2007) in their Climatic Atlas of European Breeding Birds. Huntley et al. (2007) provided distribution maps of 50 × 50 km square resolution, and we selected 34 of these squares as representing Latvia (Fig. 2). We selected species with the "best" models (good, very good and excellent according to Huntley et al. 2007), which made comparison possible for only 87 of the 175 species. The significance of the predicted changes in distribution was calculated using the chi-square test of independence.

The recorded and modelled trends were compared using a chi-square test of independence in three ways:

1) dependence of the recorded distribution trend categories "increasing", "stable", "decreasing" on the predicted trend in distribution ("to increase", "to decrease");

2) dependence of the pooled recorded distribution trend categories "decreasing", "not decreasing" on the pooled predicted trend categories "to disappear", "not to disappear";

3) dependence of the recorded distribution trend categories "increasing", "stable", "decreasing" on the proximity of the European range border to Latvia ("close" (i.e., crossing any of neighbouring countries, except Russia, or Latvia), "far") for the species that are predicted to disappear as breeders.

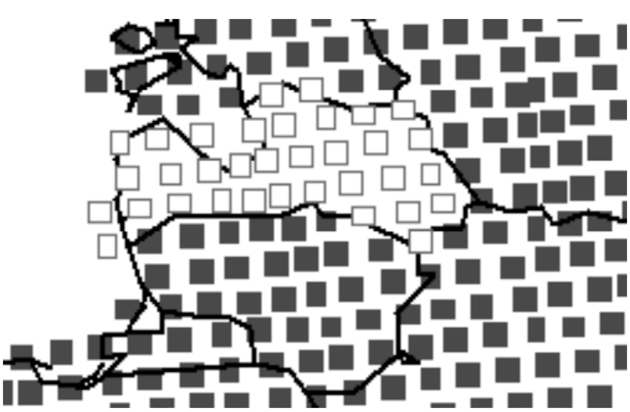

Fig. 2. Squares selected as representing Latvia (in white) in the *Climatic Atlas of European Breeding Birds* (modified from Huntley et al. 2007).

To evaluate actual changes in climate in Latvia between 1984 and 2005, data from 21 meteorological stations were used (Latvian Environment, Geology and Meteorology Centre, unpublished data). Two parameters (both of them used by Huntley et al. (2007) in their models) were considered: (1) annual temperature sum above threshold of 5 °C (degree days); (2) mean temperature of the coldest month. Data on the third parameter used by Huntley et al. (2007) – ratio of actual to potential evapotranspiration – was not available. Spearman's rank correlation (SPSS Inc. 2004) was determined between year and mean annual climate parameters (of all 21 meteorological stations) .

Results

Of the 175 breeding bird species analysed, 54 (30.9%) showed significant increases in distribution during 1980 – 1984 to 2000 – 2004, 40 (22.9%) had declined and the distribution of the remaining 81 (46.3%) species was stable.

Analyses of the climate data revealed significant changes in the climate of Latvia. Annual temperature sum above the threshold of 5 °C was positively correlated to year (Spearman's rank correlation, $r = 0.233$, $P < 0.01$), as was mean temperature of the coldest month ($r = 0.120$, $P < 0.05$). The range temperature sum above the threshold of 5 °C for the entire period varied between 854 degree days in 1987 and 1214 degree days in 1999 (Fig. 3). The range of mean temperature of the coldest month was from –15.17 °C in 1987 to –0.93 °C in 1992 (Fig. 4).

For four species of the 87 species, for which the recorded trends in distribution were compared to the models by Huntley et al. (2007), the European range models were found to be unsuitable for Latvia: they either showed no "present" occurrence of species recorded breeding in Latvia (Whooper Swan *Cygnus cygnus*, Eurasian Wigeon *Anas penelope*, Jack Snipe *Lymnocryptes minimus*) or showed presence of species that were not recorded in Latvia in 1980-1984 (Grey Wagtail *Motacilla cinerea*). Of the remaining 83 species, 20 species were predicted to disappear as breeding species from Latvia, 47 species to decrease in distribution, 2 species remaining stable and 14 species were predicted to increase their distribution.

Of these 83 species, the recorded trend matched with the predicted trend in 27 cases (33.3%) of which 20 species had decreasing and 7 species increasing trends (Table 1, Table 2). However, in general, the recorded trends were independent of the predicted trends (Chi-square test of independence, $\chi^2 = 1.23$, $P > 0.05$).

After pooling the trend categories, for five of the species predicted to disappear from Latvia, a decrease in distribution was recorded, while for the other 15 no decline

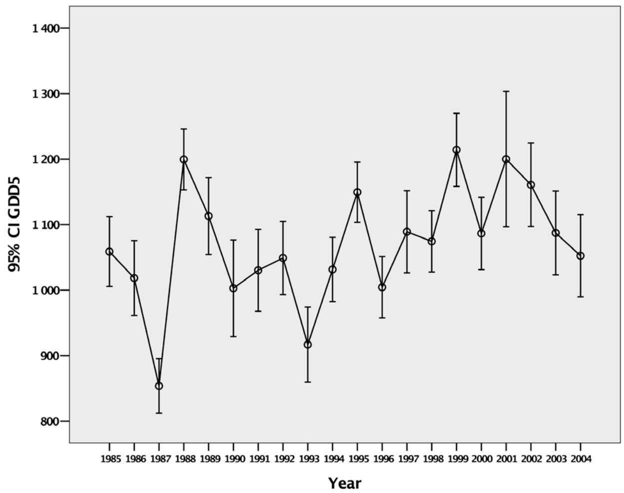

Fig. 3. Changes in the annual temperature sum above the threshold of 5 °C (degree days) in Latvia during 1985 – 2004 with 95 % confidence intervals (vertical bars).

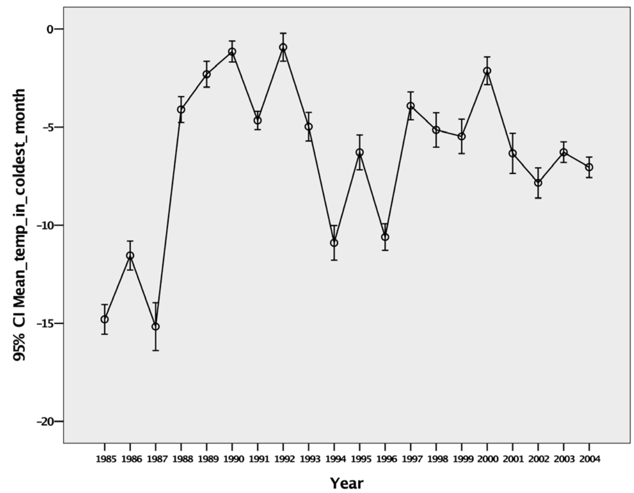

Fig. 4. Changes in the mean temperature of the coldest month in Latvia during 1985 – 2004 with 95 % confidence intervals (vertical bars).

in distribution was observed (Table 1). In this case also the recorded trends were independent of the predicted trends (Chi-square test of independence, $\chi^2 = 0.15$, $P > 0.05$).

Among the 20 species predicted to disappear, four of 14 species with a range border close to Latvia decreased in range and one of the six species with a range border far from Latvia decreased. The Chi-square test showed no dependence of the recorded trends on the proximity of range border ($\chi^2 = 0.32$, $P > 0.05$).

Discussion

The results showed that the distribution of breeding birds in Latvia changed significantly from 1980 – 1984 until 2000 – 2004 with 53.8% of the species either decreasing or increasing in distribution. During this time, the climate of Latvia become warmer, which is a consistent with the HadCM3 climate change scenario used by Huntley et al. (2007) to develop models of potential late 21st century distribution of birds. However, the actual climatic conditions in Latvia are slightly "colder" (–15 to –1 °C) than the "present" (–10 to 0 °C) data used by Huntley et al. (2007) for the coldest month. Also the existing annual temperature sum above 5 °C is in the range of 850 to 1200, rather than 1000 to 2000.

In general, the recorded changes in breeding bird distribution in Latvia do not match the European scale predictions made by Huntley et al. (2007). This might seem to contradict the suggested impact of climate change on changes in breeding bird distribution in Latvia. However, there are many limitations that need to be considered, the most apparent being: (1) different spatial scales; (2) different resolution; (3) different time scales.

Huntley et al. (2007) examined shifts in ranges on continental scale, while we used national level data on distribution. It is clear that different levels of distribution are limited by different factors. Nevertheless, keeping in mind the hierarchical model illustrated by Pearson and Dawson (2003) we argue that the factors responsible for distribution on a national level (habitat availability etc.) can only have an effect if higher scale factors, i.e., climate, are suitable. This means that species, for which climate in

Table 1. Number of species predicted to change distribution in Latvia according to Huntley et al. (2007), compared with the recorded changes between 1980-1984 and 2000-2004. Significance of the change tested using chi-square test of independence. *Numbers of species with recorded trends matching the trend directions predicted by Huntley et al. (2007) are boxed. **European bee-eater Merops apiaster has been recorded but is not considered in the analysis as it has been recorded in only two squares (see Material and methods)

Predictions by Huntley et al. (2007) Predicted trend	Total number of species	Recorded changes in distribution*				
		Disappearing	Decreasing	No significant change	Increasing	Appearing
No significant change	2	not analysed				
Disappearing	20	0	5	9	6	–
Decreasing	47	0	15	15	17	–
Increasing	14	0	3	4	7	–
Appearing	1	–	–	–	–	(1)**

Table 2. Lists of species for which recorded changes in distribution in Latvia between 1985 – 1989 and 2000 – 2004 match the direction of change predicted by Huntley et al. (2007)

Predictions by Huntley et al. (2007)	Species
Disappearing/decreasing	Common Teal *Anas crecca*, Northern Shoveler *Anas clypeata*, Common Pochard *Aythya ferina*, Tufted Duck *Aythya fuligula*, Hazel Grouse *Bonasa bonasia*, Western Capercaillie *Tetrao urogallus*, Spotted Crake *Porzana porzana*, Little Ringed Plover *Charadrius dubius*, Eurasian Golden-plover *Pluvialis apricaria*, Ruff *Philomachus pugnax*, Common Snipe *Gallinago gallinago*, Black-tailed Godwit *Limosa limosa*, Common Redshank *Tringa totanus*, Little Gull *Larus minutus*, Boreal Owl *Aegolius funereus*, Eurasian Nightjar *Caprimulgus europaeus*, European Roller *Coracias garrulus*, Sand Martin *Riparia riparia*, Redwing *Turdus iliacus*, Ortolan Bunting *Emberiza hortulana*
Increasing	Greylag Goose *Anser anser*, White-tailed Eagle *Haliaeetus albicilla*, Common Quail *Coturnix coturnix*, Middle Spotted Woodpecker *Dendrocopos medius*, Black Redstart *Phoenicurus ochruros*, Savi's Warbler *Locustella luscinioides*, Eurasian Penduline-tit *Remiz pendulinus*
Appearing	European bee-eater *Merops apiaster*

Latvia is supposed to become unsuitable, should, in the long run, decrease in distribution no matter how favourable the lower level factors are (also time scale should be kept in mind, see below). This would not, of course, be true in the opposite direction (if the lower level factors are unsuitable the species will not increase in distribution if climate becomes more suitable). Our results show that 29.8% of the species predicted to decrease have actually decreased while 50% of the species predicted to increase have actually increased.

Different map resolutions is probably the main factor limiting conclusions drawn from our study, as the changes in distribution might be seen differently in 10 × 10 km squares in comparison with 50 × 50 km squares. For example, 25 10 × 10 km squares with a species recorded correspond to one to 25 50 × 50 squares, thus making a huge difference on the coarse scale, while showing no change in the finer resolution. This plays no role if we consider only the species ranges with predicted to shift away from Latvia, but in this group the correspondence of recorded and predicted trends is the same as overall – 33.3% and no statistically significant dependence of the recorded change on the predicted change is seen.

As for the differences in the time scale (20 versus 100 years), it should be noted that due to the fact that the "present" range modelled by Huntley et al. (2007) is based on the distribution data collected mainly in 1980s, which means that the period of recorded change is 20% of the period for predicted change. Latvia has very narrow latitudinal range which does not exceed 260 km. This means that even species modelled to become extinct in 100 year period might still be in their climatic optimum zone during the early stages of the prediction period. However, we have no knowledge of potential speed of range shifts, which will probably differ for individual species (one might argue that sedentary species will be slower in shifting their ranges than migratory ones). We assumed that for species that are predicted to disappear as breeders from Latvia decrease might become apparent sooner if the range border is close to Latvia. However, as the results show, we found no evidence for the dependence of recorded trend on the proximity of range border.

It must also be noted that there are cases when birds have expanded their ranges outside the "climatic envelope" modelled by Huntley et al. (2007), apparently demonstrating the changes in realised niche (used in the models) while staying within their fundamental niche (Kearney 2006, Austin 2007). This is most clearly demonstrated by Great Egret *Casmerodius albus* in Latvia, where the species is not simulated to be breeding either in present or in future. Although not entirely covered by the atlas studies, there is recorded significant increase in breeding population of Great Egret in Latvia (Celmiņš et al.: www.putni.lv), while the annual temperature limited by 2000 degree days above 5 °C, as this climatic isoline does not cross Latvia (Huntley et al. 2007).

In addition to the problems mentioned above, there are apparently limits to which data in the Climatic Atlas (Huntley et al. 2007) can be used to generate predictions in changes in bird distribution on a national scale (at least in a country as small as Latvia), which is demonstrated by the number of "not applicable" models although they were considered good or excellent on a European scale.

The lack of dependence of the recorded change to the predictions should not be interpreted as lack of climate change effect, but rather, as the effect of other factors. Although we lack detailed analysis for most of the species, for some forest birds (Strazds et al. 2010) and farmland birds (Aunins, Priednieks 2003; Aunins, Priednieks 2008) the most probable impacts have been changes in land use and farming practices (Aunins, Priednieks 2010) during the period analysed, as well as introduced predator species causing declines in waterbird populations (Viksne et al. 2010).

It should again be emphasized that Huntley et al. (2007) base their models solely on climatic parameters, while there are many other factors limiting bird distribution. Therefore, given the large number of actual changes not matching the predictions, even in the case of changes that do match the predictions, it must not be assumed that climate change is the main driver. For example, the increase in White-tailed Eagle *Haliaeetus albicilla* distribution can be explained by a ban on the use of DDT and effective conservation measures (Ķuze et al. 2010). Also forest drainage and current management practices negatively affect Western Capercaillie *Tetrao urogallus* (Strazds et al. 2010) and predation by American Mink *Mustela vison* might be one of the most important drivers of declines of Northern Shoveler *Anas clypeata*, Common Pochard *Aythya ferina* and Tufted Duck *Aythya fuligula* populations (Viksne et al. 2010).

In some cases, however, there seems to be no credible alternative for climate-change driven changes in bird distribution. One example for this is the dramatically increasing distribution of Middle Spotted Woodpecker *Dendrocopos medius* (this view is supported by G. Pasinelli, personal communication) and the appearance of European bee-eater *Merops apiaster* as a new breeding species. Climate change has been mentioned as one of the key factors behind the long-term decline of Willow Ptarmigan *Lagopus lagopus* which started in the beginning of the 21st century (Taurins 1983). However, as the Latvian population of this species was on the brink of the extinction already in 1980s (Priednieks et al. 1989), we lack the data for analysis in this study.

Due to the limitations of our data and the models of Huntley et al. (2007) mentioned above we conclude that we lack evidence of a major role of climate change on the breeding bird distribution in Latvia during 1980-1984 to 2000-2004. For some species, however, climatic change is probably one of the main drivers of the change.

Given the importance of climate change issue and its probable impact on bird ranges, we strongly advocate for further attempts to validate the predictions by Huntley et al. (2007), by comparison with recorded changes in bird distribution. We consider that a continent-wide breeding bird atlas is needed to conduct this credibly, as comparisons on a national level are hindered by differences in scale, and overall range changes may be obscured by various factors operating on a finer scale.

We also argue that, although the modelling of range shifts due to climate change on a continental scale is of scientific interest and value, the models have little use for bird conservation, which usually has to be carried out on a national scale.

Acknowledgements

The study was funded by University of Latvia and ESF through the project "Support for Doctoral Studies in University of Latvia". The Latvian Ornithological Society is acknowledged for supplying the atlas data for the analysis. Calculated trends of change in breeding bird distribution were evaluated by Ainars Auniņš, Andris Avotiņš, Aivars Petriņš, Jānis Priednieks, Māris Strazds, Jānis Vīksne and Normunds Zeidaks.

References

Aunins A., Priednieks J. 2003. Bird population changes in Latvian farmland 1995 – 2000: responses to different scenarios of rural development. *Ornis Hungarica* 12-13: 41–50.

Aunins A., Priednieks J. 2008. Ten years of farmland bird monitoring in Latvia: population changes 1995 – 2004. *Rev. Catalana d'Ornitologia* 24: 53–64.

Aunins A., Priednieks J. 2009. Recent changes in agricultural landscape and bird populations in Latvia: current impacts of EU agricultural policy and future prospects. *Avocetta* 33: 93-98.

Austin M. 2007. Species distribution models and ecological theory: A critical assessment and some possible new approaches. *Ecol. Modell.* 200: 1-19.

Beale C.M., Lennon J.J., Gimona A. 2008. Opening the climate envelope reveals no macroscale associations with climate in European birds. *Proc. Nat. Acad. Sci. USA* 105: 14908–14912.

BirdLife International 2004. *Birds in Europe. Population Estimates, Trends and Conservation Status*. BirdLife International, Cambridge. 374 p.

Crick H.Q.P. 2004. The impact of climate change on birds. *Ibis* 146: S48–S56.

Gaston K.J. 2003. *The Structure and Dynamics of Geographic Ranges*. Oxford University Press, New York. 266 p.

Greenwood J.J.D. 2007. Citizens, science and bird conservation. *J. Ornithol.* 148: S77–S124.

Gregory, R. D., Willis, S. G., Jiguet, F., Voříšek, P., Klvaňová, A., van Strien, A., Huntley, B., Collingham, Y. C., Couvet, D. and Green, R. E. 2009. An indicator of the impact of climatic change on European bird populations. *PLoS ONE* 4: e4678.

Guisan A., Zimmerman N.E. 2000. Predictive habitat distribution models in ecology. *Ecol. Modell.* 135: 147-186.

Hagemeijer W.J.M., Blair M.J. (eds) 1997. *The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance*. T & A D Poyser, London. 903 p.

Huntley B., Green R.E., Collingham Y.C., Willis S.G. 2007. *A Climatic Atlas of European Breeding Birds.* Durham University, The RSPB and Lynx Edicions, Barcelona. 521 p.

Kearney M. 2006 Habitat, environment and niche: what are we modelling? *Oikos* 115: 186–191.

Krebs C.J. 1994. Ecology. *The Experimental Analysis of Distribution and Abundance.* HarperCollins College Publishers, New York. 801 p.

Ķuze J., Lipsbergs J., Bergmanis U. 2010. News on the research and nest-site conservation of White-tailed Eagles. Putni dabā 2010/1-2: 10–19. (in Latvian)

McCarty J.P. 2001. Ecological consequences of recent climate change. *Conserv. Biol.* 15: 320–331.

Pearson R.G., Dawson T.P. 2003. Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful? *Global Ecol. Biogeography* 12: 361–371.

Pearson R.G., Thuiller W., Araújo M.B., Martinez-Meyer E., Brotons L., McClean C., Miles L., Seguardo P., Dawson T.P., Lees D.C. 2006. Model-based uncertainty in species range prediction. *J. Biogeography* 33: 1704–1711.

Priednieks J., Strazds M., Strazds A., Petriņš A. 1989. *Latvian Breeding Bird Atlas 1980–1984*. Zinātne, Rīga. 351 p.

Strazds M., Hofmanis H., Reihmanis J. 2010. Recommendations for Capercaillie lek management in Latvia. Project Report. Latvijas Ornitoloģijas biedrība, Rīga. 68 p. (in Latvian)

Soberón J., Llorente J. 1993. The use of species accumulation functions for the prediciton of species richness. *Conserv. Biol.* 7: 480–500.

Sokal R.R., Rohlf F.J. 1995. *Biometry. The principles and Practice of Statistics in Biological Research*. 3rd ed. W. H. Freeman and Company, New York. 887 p.

SPSS Inc. 2004. SPSS 13.0 for Windows. Release 13.0 (1 Sep 2004).

Taurins E. 1983. Willow Ptarmigan. In: Viksne J. (ed) *Birds of Latvia. Territorial Distribution and Number*. Riga, Zinatne: 68-69 pp. (in Russian)

Thomas C.D., Cameron A., Green R.E., Bakkenes M., Beaumont L.J., Collingham Y.C., Erasmus B.F.N., de Siquera M.F., Grainger A., Hannah L., Hughes L., Huntley B., van Jaarsveld A.S., Midgely G.F., Miles L., Ortega-Huerta M.A., Peterson A.T., Phillips O.L., Williams S.E. 2004. Extinction risk from climate change. *Nature* 427: 145-148.

Viksne J., Svazas S., Czajkowski A., Janaus M., Mischenko A., Kozulin A., Kuresoo A., Serebryakov V. 2010. *Atlas of Duck Populations in Eastern Europe*. Vilnius, Akstis. 199 p.

Received 22 March 2012; received in revised form 15 May 2012; accepted 15 May 2012