1. Introduction

Knowing where species occur is essential to guide conservation action or to predict the likely effects of future environmental change. Large-scale atlas projects, where the distribution of all species within a taxonomic group is documented are particularly suitable to achieve these aims as they provide background information against which assessments at smaller spatial scale can be measured.

Grid-based atlases have become a standard way of mapping the distribution of species, in particular for breeding birds. The first atlases only presented the distribution of bird species, often combined with a measure of breeding evidence. The so-called second-generation atlases used statistical methods to map the relative abundance of species often based on information recorded for a sample of smaller units within the standard atlas grid. In more and more countries atlas work has been repeated usually one or more decades after the publication of the first atlas. This offers the possibility to compare changes in distribution and abundance between atlas projects. Comparing successive atlases, however, poses a challenge because the objective to improve the methodology can be in conflict with the one to allow comparisons with the previous atlas. Changes in observer effort and/or geographical coverage make comparisons difficult as well.

Changes in distribution between atlas projects can be shown on maps and/or quantified. Out of 21 repeat atlases of breeding birds 14 showed the distribution from the previous atlas in map form, providing separate maps for each atlas period, combining the data in one map, or making change visible in a separate "change map". Differences in coverage are usually not indicated. Many atlases provide quantitative information on range change by indicating the number of occupied, new or lost squares or more detailed statistics on changes in number of occupied squares per category of breeding evidence. Difference in observation effort is taken into account in a few cases. Comparisons based on standardised surveys provide robust results but are still rare. The same is true for analyses of changes in abundance, since only a few very recent atlases have repeated standardised approaches suitable for appropriate statistical analyses. The combination of atlas projects with population monitoring programmes and the use of web tools to collect data also offer new possibilities to document and analyse changes in distribution and abundance at different temporal and spatial scales.

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on information recorded for a sample of smaller units within the standard atlas grid, in which a variety of methods was used, such as recording complete lists of species (e.g., Gibbons et al. 1993), a combination of timed visits and point counts (Hustings & Vergeer 2002, Vermeersch et al. 2004) or simplified territory mapping (e.g., Schmid et al. 1998, Estrada et al. 2004).

The methods used in bird atlas projects as well as the uses of atlases and the underlying data have been the topic of earlier reviews (Donald & Fuller 1998, Gibbons et al. 2007). Both reviews also showed the potential of repeated atlases to document changes in distribution. The number of repeated atlases, however, has increased since, and, contrary to the prediction by Gibbons et al. (2007) the number of new atlases has increased again. This is partly due to recent national atlas projects in large countries (Britain and Ireland: Balmer et al. 2013, Germany: Gedeon et al. 2014, France: Issa & Muller 2015), which have led to the publication of many sub-national atlases, often based on at least partly the same data as the corresponding national atlases. Within Europe, the project for a second European Breeding Bird Atlas (EBBA2) has led to a large number of national atlas projects, several of which are repeat atlases. By 2016, 30 (63.8 %) out of 47 countries in Europe (not considering a few very small countries or those that have only a small proportion of their territory within Europe) had published a national breeding bird atlas. For 12 countries this was the first atlas, for 12 the second and for six the third. If we consider the ongoing national atlas projects as well, the number of countries with a national atlas increases to 42 (89.4 %), of which 11 projects are second atlases, 11 third and two fourth atlases (EBCC unpubl.).

Documenting change between atlas projects therefore becomes relevant for more and more countries. Here, I review challenges faced by atlas projects when comparing results with earlier surveys and ways how changes were presented and analysed in different countries. I concentrate on national atlas projects for breeding birds but include some examples of sub-national atlases that have followed specific methodologies.

2. Comparing atlases: a challenge

Sound data on changes in distribution and abundance are an essential basis to understand dynamic processes of colonisation and disappearance of species but also to evaluate their conservation status. The International Union for Conservation of Nature (IUCN) criteria for Red Lists, for example, evaluate extinction risk from a combination of population and range size with the rate of change in population size/abundance and distribution (IUCN 2001). While changes in abundance are usually estimated from monitoring programmes such as standardised breeding bird monitoring schemes or, mainly for rarer species, from estimates of the size of national populations, changes in distribution are often estimated by comparing data collected in two or more atlas projects. For national Red Lists or the evaluation of priority species as part of a national conservation strategy information on range change and abundance is also needed but detailed data are usually available for only a small number of species or only part of the country. Atlas projects which cover the whole country and all species, are therefore an important data source for such analyses. For several reasons, however, comparing successive atlases poses a challenge.

In many cases, the methodology between subsequent atlases has been changed. Atlas methodologies are always a compromise balancing the wish to use the best available approaches for as many species as possible with the capacities and resources available. When the first national atlases in Europe were produced, much of the work was done without computers. The standard recommendations provided by the EOAC for national atlases, which would then be compiled for the European Atlas, set minimum standards applicable in all participating countries (Greenwood 2017). New atlas projects, started ten, twenty or more years later, often improved the methodology, introduced new aspects and made use of new tools such as computerised databases and new statistical methods. The objective to improve the information gathered using the best available techniques can therefore be in conflict with the one to allow comparisons with the previous atlas (Balmer & Gillings 2013, Herrando et al. 2013). The most common approach to tackle this dilemma consists of keeping the less standardised surveys for mapping distribution for the larger grid comparable to the previous atlas, and introducing a new level of standardisation in a sample of smaller grid cells within the original grid, which allows inferring information on relative abundance (e.g., Gibbons et al. 1993, Schmid et al. 1998, Hustings & Vergeer 2002). The same approach has been chosen for EBBA2, where information gathered for the 50 x 50 km grid used for the first atlas follows the same methodology but standardised data are collected at a smaller scale to allow spatial modelling at the level of 10 x 10 km (Herrando et al. 2013, Herrando et al. 2017).

Changes in the grid used for consecutive atlases also pose a challenge for comparing results. Decisions to use a different grid for a second or third atlas are usually taken because of constraints imposed by other projects or objectives. Countries in the European Union, for instance, are required to use the ETRS89 grid for reporting protocols which may make them decide to change the grid from the UTM or a national grid used for their earlier atlases.

Whether or not consecutive atlases use the same or different methodologies there will always be differences in coverage, which is related to observation effort. In most atlas projects remote areas are covered less well
than regions close to where most observers live. This is particularly the case where fieldwork is carried out entirely by volunteers but even in countries with enough resources to pay professionals to survey remote areas differences in observer effort will vary between squares. In repeated atlases observer effort and coverage are usually higher due to a larger number of volunteers, the increase in the use of cars, better accessibility due to new roads (although the opposite may also be the case when land is abandoned or regions are not accessible in areas with military conflicts). Observer effort is hard to measure and volunteers are not keen to record information on the locations where they went or the amount of time spent there. An example where observers were asked to classify survey effort is the second Finnish atlas (Väisänen 1998).

Previous knowledge on geographically explicit occurrence of bird species facilitates fieldwork in new atlas projects thus providing the same results with less effort. Fieldworkers in a first atlas often had only their local knowledge whereas those working for the next one already had information from the first atlas. This is illustrated by the example of the three Swiss atlases (Schifferli et al. 1980, Schmid et al. 1998, Knaus et al. in prep.). Data for the first atlas were recorded at the level of a 10 x 10 km grid and thus available only at this level when fieldwork started for the second atlas in 1993. Individual records for the 1990s atlas were recorded in the database at the level of 1 x 1 km squares, thus providing the observers for the atlas 2013-2016 with more detailed information, allowing them to target the search for individual species. The increasing amount of casual records collected between the atlas periods and often recorded with precise locations provided additional information.

The many political changes that happened in Europe over the last decades also affected atlas work across Europe. The first European Breeding Bird Atlas contained little information from the former Soviet Union and Turkey was not included. EBBA2 therefore covers a much larger overall area. The atlases for the Czech Republic followed on an atlas for the whole of Czechoslovakia (Stastny et al. 1987, 1997, 2006), the regional atlases of Wallonia, Flanders and the city of Brussels the one for the whole of Belgium (Devillers et al. 1988, Rabosée et al. 1995, Vermeersch et al. 2004, Jacob et al. 2010). As a consequence of political changes the institutions coordinating atlas work often change as well, sometimes limiting the accessibility to old data.

3. Documenting changes in distribution

Changes in distribution between atlas projects can be shown on maps and/or quantified. Out of 21 repeat atlases 14 showed the distribution from the previous atlas in map form. The simplest solution is printing the old map alongside the new one (e.g. Yeatman-Berthelot & Jarry 1994, Väisänen et al. 1998, Stastny et al. 2006, Robertson et al. 2007, Gedeon et al. 2014, Issa & Muller 2015). Marked changes in distribution such as the disappearance of a species from large areas or the colonisation of new ones are easily recognisable, also in cases where the grid changed between atlases, but it is more difficult to detect changes at smaller scales. Such smaller-scale changes in the pattern of distribution become more apparent if the new distribution is plotted on top of the map of the old atlas, a solution usually only feasible when the grid used has remained the same (e.g. Schmid et al. 1998, Herrando et al. 2014, Fig. 1). An alternative solution consists of plotting

**Fig. 1:** Documenting change by plotting data on distribution on top of data from the previous atlas. Provisional map for Black-headed Gull Larus ridibundus based on a pilot data collection for the second European Breeding Bird Atlas EBBA2. Squares without data from the first atlas are not marked (Herrando et al. 2014).
Breeding evidence – Bruttostatus

Aantal blokken – Anzahl der Gitterfelder

- mogelijki 134 (55%)
  - possible – möglich

- waarschijnlijk 573 (65%)
  - probable – wahrscheinlich

- zeker 208 (32%)
  - confirmed – bestätigt

Veränderung

Change – Veränderung

Aantal blokken - 915 (55%)

- verdwenen 360
  - disappeared – verschwunden

- verschenen 207
  - new – neu

Fig. 2: Change map (right) alongside the current distribution (left). Example of the Eurasian Golden Oriole Oriolus oriolus, The Netherlands (Hustings & Vergeer 2002). – Veränderungskarte (rechts), der aktuellen Verbreitungskarte gegenübergestellt (Beispiel Pirol, Niederlande). Die Veränderungskarte zeigt die Atlasquadrate, in denen die Art im zweiten Atlas nicht mehr (rot) oder neu (blau) gefunden wurde (Hustings & Vergeer 2002).


Gain – neu aufgetreten

Present both – in beiden Atlanten vorhanden

Loss – verschwunden

Fig. 3: Maps showing changes in distribution (left) and abundance (right) for the Common Cuckoo Cuculus canorus in Great Britain and Ireland (Balmer et al. 2013). – Karten, welche die Veränderungen in Verbreitung (links) und Abundanz (rechts) des Kuckucks in Großbritannien und Irland aufzeigen (Balmer et al. 2013).
squares where a species was no longer or newly found in a separate map (Gibbons et al. 1993, Hustings & Vergeer 2002, Fig. 2). These maps, which only indicated squares where changes occurred, were rather difficult to interpret and in more recent atlases they were refined by indicating changes with more easily interpretable symbols and the inclusion of the squares without change (Fig. 2, Balmer et al. 2013). Information on breeding evidence for both atlases is rarely presented in change maps (e.g. Grell 1998), sometimes as a layer on top of presence/absence information from the previous atlas (e.g. Fig. 4, Estrada et al. 2004). The combination of breeding evidence classes of the current with the two combined previous atlases indicates changes in occurrence (Valkama et al. 2011). – Veränderungskarte des Singschwans in Finnland. Die Kombination der Brutwahrscheinlichkeitsklassen des aktuellen und der beiden früheren Atlanten zeigt die Veränderungen im Auftreten (Valkama et al. 2011).

and in notebooks of observers active at the time could not cover all mountainous regions adequately. An index of coverage was therefore calculated by dividing the number of species recorded per square by the mean number of species recorded in the two “real” atlases from the 1970s and the 1990s (multiplied by 100). Squares with a coverage index of less than 50% were classified as not adequately covered. No information was given for these squares and the squares were specially marked in the map to make the gaps visible (Fig. 6, Knaus et al. 2011).

With increasing numbers of repeated atlases the presentation of change becomes more difficult yet the objective of showing change in distribution becomes more important than the simple presentation of the current range. Space for maps in books is limited and there is usually more information available than what can be included in a printed publication. The presentation of additional maps and the possibility to show
different combinations of maps on the internet highly increases the information, as shown in the examples of the British and Irish atlas (http://app.bto.org/map-store/StoreServlet) or the pilot maps of EBBA2 (http://mapviewer.ebba2.info). Atlases collecting data via online portals sometimes do not only show progress with data collection but offer at the same time the possibility to compare occurrence with the distribution in previous atlases.

Many atlases provide quantitative information on range change by indicating the number of occupied, new or lost squares or more detailed statistics on changes in number of occupied squares per breeding-evidence category. The difficulties in interpretation due to unequal coverage are usually discussed in the introduction or in individual species texts, and occasionally made more clearly visible to the reader by labelling the statistics in a way that misinterpretations are less likely. The British/Irish atlas, for instance, consistently uses the expressions “apparent” gains and losses (Balmer et al. 2013). There are, however, few examples that took observer effort into account when calculating the magnitude of change. Kerus et al. (2010) proposed to calculate change based on well-covered squares only, which were defined as squares where at least 75% of the 10% most widespread species in Latvia were recorded. Change was then measured as the difference in the percentages of occupied squares per atlas period. The Catalan breeding bird atlas 1999-2002 (Estrada et al. 2004) compared the distribution with the atlas of 1975-1983 (Muntaner et al. 1983), for which no information on the duration of surveys was available. In the second atlas, the standardised surveys in a sample of 1 x 1 km squares provided the basis to explore the relationship between survey time and the number of species detected (time-species accumulation curves). Based on this relationship a regression model was built to estimate the total number of survey hours (as a proxy for observer effort) per 10 x 10 km square for each atlas, controlling for the effect of environmental heterogeneity for birds in each square. The estimated effort per square was then used as a correction factor when calculating the difference in the number of occupied squares between the two atlases.

The second and third breeding bird atlases for Great Britain and Ireland (Gibbons et al. 1993, Balmer et

**Fig. 6:** The historical atlas of breeding birds in Switzerland shows the distribution of Common Cuckoo in the three atlas periods. No data are presented for squares which were considered as insufficiently covered in the time period of the historical atlas (blank squares with black frame; Knaus et al. 2011). – Die Verbreitungskarte des Kuckucks im rückwirkend erstellten historischen Brutvogelatlas der Schweiz zeigt, wo die Art in den drei Atlasperioden nachgewiesen wurde. Für die Quadrate, die im Zeitraum des historischen Atlas sehr schlecht bearbeitet wurden, (weiss mit einem schwarzen Rahmen) sind die Daten aus den späteren Atlanten weggelassen (KNAUS et al. 2011).

**Fig. 7:** The map of the European Turtle Dove Streptopelia turtur from the Wallonian atlas combines information on changes in abundance (from increase in green to decline in red) with information on newly occupied (dots) or abandoned (crosses) squares (Jacob et al. 2010). – Verbreitungskarte der Turteltaube in Wallonien mit Angaben zu Veränderungen in der Abundanz (von Zunahme in grün zu Abnahme in rot) und zum Neuauftreten (Punkte) und Verschwinden (Kreuze) (JACOB et al. 2010).
al. 2013) used the same standardised surveys within a sample of 2 x 2 km squares (so-called tetrads) but the data sets were not completely comparable. These “timed tetrad visits” were used to calculate an index of change in distribution for each 10 x 10 km square. To account for the differences in effort between the atlases a bootstrapping method was applied that used randomly selected tetrads to maintain geographically representative coverage (Balmer et al. 2013).

4. Documenting changes in abundance

The so-called “second-generation” atlases providing maps of relative abundance were only produced from the late 1980s onwards. It is therefore not surprising that so far very few atlases exist that repeated the same procedure and presented abundance-change maps. The earlier attempt to present information on abundance by estimating the number of breeding pairs per atlas square, which was used for the first European atlas, was usually not repeated in new atlases. An exception is the breeding bird atlas for Wallonia (Jacob et al. 2010) which compared abundance estimates with those from the Belgian atlas (Devillers et al. 1988). For each grid cell the difference in abundance classes was calculated and plotted. The resulting map thus combines information on change in distribution and abundance (Fig. 7).

The Atlas for Britain and Ireland used the timed tetrad visits not only as a basis for estimating the rate of change in distribution but also for changes in relative abundance. For each 20 x 20 km square the reporting rate, i.e. the proportion of occupied tetrads used by a species was calculated, repeated for a large number of random samples to account for differences in the number of tetrads covered per square, which was higher in the last atlas. The means of these reporting rates provided a frequency index for each of the two atlas periods, and the arithmetic difference between the frequency indices provided the index of change. The abundance change map shows abundance change indices which were rescaled to facilitate the comparison of maps for scarce and common species (Fig. 3, Balmer et al. 2013).

The third Swiss breeding bird atlas used the results of a simplified territory mapping method in samples of 1 x 1 km squares. For each of the two atlas periods the “density” (number of estimated territories) per 1 x 1 km square was computed using a boosted regression tree model, taking into account residual spatial autocorrelation. The resulting change map shows the difference between the densities at the same resolution (Fig. 8, Guélat unpubl.).

Reporting rates are used as a measure of abundance in several large-scale atlases outside Europe which are based on lists of bird species per location. This offers possibilities for analysing changes but so far these have not yet been published in comprehensive atlases (Harrison et al. 1997, Barrett et al. 2003).
5. Discussion

The examples shown usually consider only widespread species. Most atlases that present information on abundance treat rare, colonial or nocturnal species differently. If information on change in abundance is presented for these species groups, it often relates to estimates of total population size.

For common species, authors sometimes prefer to present the population trend analyses on the basis of breeding bird monitoring programmes together with the distribution maps (e.g. Hustings & Vergeer 2002, Gedeon et al. 2014). So far, atlas and monitoring programmes have often been treated as separate projects. There are many advantages, however, if synergies between the two are sought to increase the possibilities for data analysis but also to save resources in terms of number of observers involved. Data collected at smaller scale within standard atlas grids to model relative abundance can be taken from monitoring programmes although the number of sampled squares or transects may have to be increased during the fieldwork period for the atlas to increase the reliability of models. This approach is used for EBBA2 (Herrando et al. 2013) but also for recent national projects.

Data from monitoring programmes are increasingly used to model probability of occurrence outside of atlas projects, and applications such as TrimMaps (Kampichler et al. 2016) were specifically designed for such analyses. Dynamic occupancy models can be used to produce annual maps of distribution and detection probability as well as maps of colonisation and extinction probabilities between years, allowing insights into the dynamics of changes in distribution at a shorter temporal scale (Kéry et al. 2013). Standardised monitoring programmes that achieve good spatial coverage can be more suitable to assess changes in distribution over a certain time than atlas projects with very unequal coverage and unknown observation effort (e.g. Lehikoinen & Mirkkala 2016, Tayleur et al. 2016).

Biases in spatial coverage and observer effort limit meaningful analyses of change from atlas projects. This may be a reason why atlas authors hesitate to provide estimates of range or abundance change. The examples shown indicate, however, that the robustness of analyses is not only increased by designing data collection to account for potential biases but also by accounting for them retrospectively. Tackling biases becomes more and more important where well-designed atlas projects are replaced by the continuous collection of data from online portals. The mobilisation of a large number of observers collecting data for fun combined with robust statistical analyses can form the basis to track changes as is shown by the “continuous atlas” in southern Africa (http://sabap2.adu.org.za/). In Europe, the aggregation of data from national online portals in the EuroBirdPortal project will also offer possibilities to analyse temporal and spatial changes of bird occurrence but it will take many years to achieve adequate spatial coverage across Europe (http://eurobirdportal.org/).

Monitoring programmes, non-standardised observations and atlas projects complement each other. Atlas projects, which by definition cover all species within a – usually large – area, will, however, be also important in the future in order to set a new baseline against which to measure change.

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6. Zusammenfassung


wandel, beispielsweise durch eine höhere Anzahl Freiwilliger, die sich an den Feldaufnahmen beteiligen, erschweren die Vergleiche ebenfalls.


7. References


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