Change index: a measure of change in range size that is independent of changes in survey effort

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Abstract

A major problem in studying the range changes of invertebrates using atlas data, is discriminating the effects of changing survey effort from the real biological changes. Using the data sets collated by the UK Biological Records Centre, a method has been developed which allows for the effects of variation in survey effort, by calculating an index of relative change in range size. The method is applicable to a wide range of atlas data sets.

Key words: change index, decline, distribution atlas, recorder effort.

Introduction and rationale

Range size is an important measurement for conservationists. The allocation of Red Data Book threat statuses for invertebrates has often been based on range size, as a measure of rarity. More recently, a greater emphasis has been placed on decline in addition to rarity (IUCN 1994, 2001). An accurate measurement of change in range size is thus important to allow conservationists to set priorities, and to target limited resources with the greatest effect in the battle against extinction. Though conservationists need to measure declines, it is equally important to be able to accurately measure increases in range size. In particular, there is a need to quantify the range expansions of invasive alien species in order to monitor the potential risks they pose. Range expansions of native invertebrates are also of considerable interest, linked as they are to climate change. A method is thus needed which measures both increases and decreases in range size on the same scale. To understand the impacts of climate change, of pollution, and of changes in land use on the distributions of invertebrates, it is valuable to be able to quantify change in range size accurately.

For most of the biota of even the best recorded countries, monitoring data do not exist with which to assess changes in range size. This is particularly true for invertebrates. However, biological atlas data sets do exist for many groups. For example, there are atlases of the Orthoptera and carabid beetles of the Netherlands (Kleukers et al. 1997, Turin 2000) and of Britain and Ireland (Haes and Harding 1997, Luff 1998). In Britain, such atlases provide the main source of data on the distributions and conservation statuses of the majority of the biota (Harding and Sheail 1992). These data sets generally include the results of at least one national survey, plus collated historical records, and so the data may be divided into two or more date periods. They are based on information gathered by recorders who visit a grid cell and record all the species (in the particular group) which they encounter.

Surveys rarely achieve complete geographical coverage. In Britain, the grid cells which tend not to be surveyed are in very remote upland areas, or are coastal or island squares with a small area of land. For a valid comparison of data from two survey periods, it is essential firstly to compare only the subset of grid cells which have been surveyed in each period.

Atlas data sets are generally based on survey work carried out largely or entirely by volunteers. It has proved impractical to impose rigid survey methodologies on volunteer recorders, without severely reducing the numbers of volunteers prepared to contribute. For this reason, most atlas data sets contain no information on the amount of survey effort expended (time spent and area covered) for each record submitted. However, information on survey effort is important for an accurate interpretation of atlas data.

The biases caused by differences in survey effort can be illustrated by considering atlas data for the silver-washed fritillary *Argynnis paphia* (Linnaeus, 1758). This local woodland butterfly of southern Britain was recorded from 381 British grid cells (10 km squares) during the 13 year (1970-1982) period of survey work for the first atlas (Heath et al. 1984), and from 495 such grid cells during the five year (1995-1999) period of survey work for the second atlas (Asher et al. 2001). This represents a 30% increase in recorded range size. However, this is a species which is believed to have declined in range over the period, albeit with a slight re-expansion of that range in some areas.

The apparently contradictory information for silver-washed fritillary, and several other British butterflies, may be better understood by considering the sizes of the two surveys being compared. The earlier survey collated 124 978 records over a 13 year period, whereas the later survey collated 1 548 963 records: an order of magnitude greater. This volume of data on a fauna of 62 species makes this the premier invertebrate data set in Britain. The numbers of records provides a good indication of the much greater survey effort expended on the later survey, although it should be noted that recorders in the earlier period had a greater tendency to summarise their records before submitting them. For the silver-washed fritillary, the greater survey effort during the 1990s lead to its being recorded from 30% more squares than during the 1970-1982 period, but not quite as many as would have been expected had its actual range size remained stable.

The rationale underpinning this new method is that the real biological change in actual range sizes is confounded with changes in survey effort. This makes the estimation of actual change in range size problematic. However, it is possible to calculate an index of relative change in range size, as outlined below.

The general method for calculating relative change in range size

In outline, the method is first to define the set of grid cells which have been surveyed in both survey periods; subsequent calculations are based solely on these cells. For each species, the number of recorded grid cells is counted for each period. These counts of grid cells are expressed as proportions of the total survey area, and then

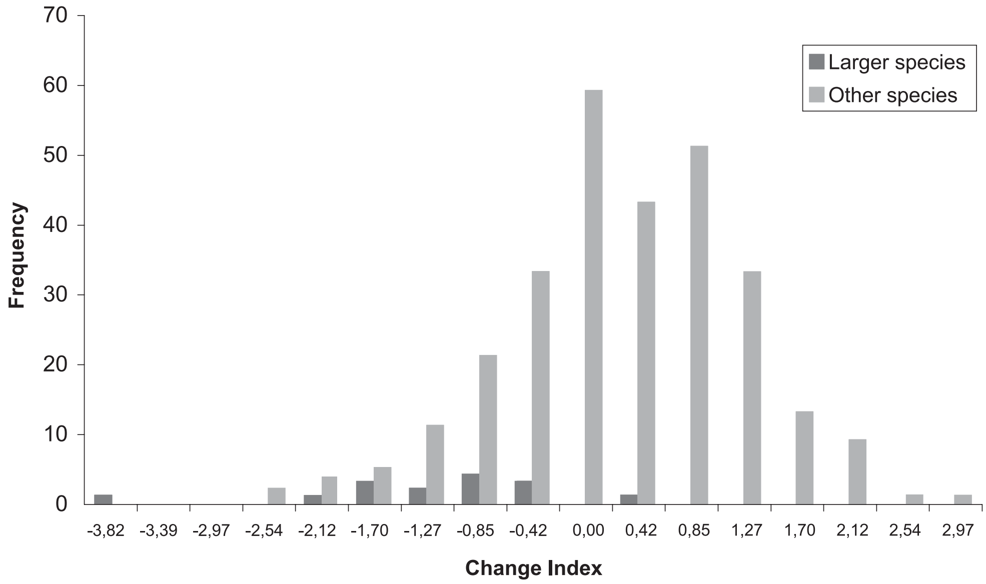

Figure 1
Frequency histogram for the British Change Indices of large carabids (in the genera *Cicindela*, *Carabus* and *Calosoma*), and of the remainder.

logit-transformed. A linear regression model is then fitted to the relationship between counts of grid cells in earlier and later survey periods. A weighted regression is used to allow for non-constant variance. The standardised residuals for each species provide its change index: an index of its change in range size relative to the trend in the whole group.

Full details of the method will be published elsewhere, including a detailed discussion of the assumptions underlying this method (Telfer et al. 2002).

Application of the method to a representative dataset

The Ground Beetle Recording Scheme (GBRS) data on British carabids is typical of an initial atlas data set, in which miscellaneous records made over a period of 70 years (1900-1969) before the formation of the recording scheme are available for comparison with a more systematic 10 km square survey (1970-the present). The data set analysed here is based on the data underlying the published atlas (Luff 1998), with subsequent updates. Change indices were calculated for each species.

A thorough analysis of the patterns of change in British carabids is in preparation. Here I present a simple comparison to illustrate the use of change indices for understanding the causes of change.

Desender & Turin (1989) analysed change in range size of the carabids of Denmark and the Low Countries, and found significant declines in most species of *Carabus*, and all of the *Cicindela* and *Calosoma* species. The British Change Indices of species in these genera are significantly lower than the remaining carabids (mean +/- standard error Change Index of *Cicindela*, *Carabus* and *Calosoma* = -1.39 +/- 0.91, mean of remainder = 0.08 +/- 0.95, $F_{1.301} = 36.63$, $p < 0.0005$; fig. 1).

An apparent decline of *Carabus* species, at least in south-eastern England, has been noted anecdotally by Allen (1983) and others (pers. comm.). It should be noted that species in these genera are all relatively large species, and Telfer et al. (2002) reports a significant negative relationship between adult body size and Change Index. It is not currently known why large body size should be correlated with declining range size.

When is this method suitable?

For a detailed comparison of this new method with previously published methods for the estimation of change in range size using atlas data, see Telfer et al. (2002), which also discusses the advantages and limitations of the new method. Here I outline the types of atlas data sets to which this method is applicable, with an emphasis on the invertebrates of Europe.

- The method has been successfully applied to national scale atlas data from Britain (Telfer et al. 2002, Preston et al. 2002), but is applicable to atlas data at a range of scales, national, regional and local.
- The method is best suited to survey data based on grid cells of equal area. However, it may also be used for data from grid systems where there is some variation in area of grid cells. It could also be applied to survey data based on political or organisational units (such as British parishes), especially where these tend to be of similar area.
- The method is ideally suited to analyse change between two similar surveys. However, where recording has taken place over a protracted period, it is usually possible to divide the records into two coherent periods to provide a valid comparison. Even where there have been closely comparable levels of survey effort, the present method will prove helpful, but it is especially valuable for comparisons between surveys of different intensities. For an analysis of more complex temporal trends in range sizes over three or more survey periods, a method such as that of Maes & van Swaay (1997) is appropriate.
- The change index works best for larger taxonomic groups. For data sets covering less than about 50 species, extreme range changes of individual species or suites of species may have a large influence on the regression model, and thus on the residuals and change indices of all other species.

This new method will provide a useful and widely applicable tool to enhance the value of biological atlas data on the invertebrates of Europe to nature conservation, and to our developing understanding of the causes of range expansions and contractions.

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