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Pushing back the baseline: a novel approach to detect long-term changes in terrestrial faunal abundance using historical qualitative descriptions

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ABSTRACT

Studies that examine changes in the populations of flora and fauna often do so against a baseline of relatively recent distribution data. It is much rarer to see evaluations of population change over the longer–term in order to extend the baseline back in time. Here, we use two methods (regression analysis and line of equality) to identify long-term differences in abundance derived from qualitative descriptions, and we test the efficacy of this approach by comparison with contemporary data. We take descriptions of bird population abundance in Cambridgeshire, UK, from the first half of the 19th century and compare these with more recent estimates by converting qualitative descriptions to an ordinal scale. We show, first, that the ordinal scale of abundance corresponds well to quantitative estimates of density and range size based on current data, and, second, that the two methods of comparison revealed both increases and declines in species, some of which were consistent using both approaches but others showed differing responses. We also show that the regional rates of extinction (extirpation) for birds are twice as high as equivalent rates for plants. These data extend analyses of avifaunal change back to a baseline 160-190 years before present, thus bringing a novel perspective on long-term change in populations and categories of conservation concern (e.g., Amber- or Red-lists) based on recent data. Changes in status are discussed in relation to various factors, although perhaps the most pervasive were of anthropogenic origin.

KEYWORDS

Birds – Cambridgeshire – historical records – Jenyns – land use change – long-term – population – qualitative data

INTRODUCTION

In order to assess changes in abundance of species over time, reference points or baselines need to be established from which to measure any such change. Ideally, a baseline should be established at a point before any changes have occurred or else we may fail to recognise both the true magnitude of any change or the full effects of particular causal factors. Historical records are useful for informing us of long-term change but remain an underused resource (Shaffer et al. 1998). Long-term data are essential for elucidating the dynamics of populations, species interactions, and communities. A wealth of such information exists for animals, but have often only been collated for single species (e.g., Otter *Lutra lutra* (Jefferies 1989), Corn Bunting *Miliaria calandra* (Donald et al. 1994)), for particular sites such as Wicken Fen (Friday 1997; Friday & Harley 2000), or using historical records, bone assemblages, and archaeological records (e.g., Yalden 1999; Saenz-Arroyo et al. 2006; Yalden & Albarella 2008; Miller 2011).

Bonebrake et al. (2010) reviewed 265 long-term studies of population decline and found only 15% used data more than 100 years old. Any such historical data become very powerful when a wide range of species can be assessed simultaneously over the same period. For example, historical documentation of regional floras have been used to assess change in plant abundance, in extirpation rates, and in plant trait response over decadal and centennial time-scales and have been used to inform us about the consequences of long-term change to landscapes (McCollin et al. 2000; Stehlik et al. 2007; van der Veken et al. 2004; Walker & Preston 2006; Walker et al. 2009).

The post-WWII period has seen the development of long-term citizen-collected data on bird populations in several countries including the UK (e.g., Batten & Williamson 1974; Freeman et al. 2007), North America (Robbins et al. 1989), Mexico (Ortega-Alvarez et al. 2012) and Turkey (Abolafya et al. 2013). Species distribution atlases based on such data are useful in helping to understand the long-term dynamics of populations, their distributions, and the effects of proximate causal factors (e.g., Gibbons et al. 1993; Sharrock 1976). In the absence of such regularly collected long-term data, scientists have often had to rely on 'snapshots' taken at various times to infer long-term change (e.g., Bernstein et al. 1990; Bousman 2007; Catterall et al. 2010; Jeromin 1999; Lowther 1984; Nowakowski 1996; Peterson et al. 2015) or else species distribution modelling based upon a knowledge of autecological requirements (Schulte et al. 2005) or other ingenious methods including mentions of species in news media (Martínez-Abraín et al. 2013). However, such studies are often focused on individual species and historical data on whole assemblages are rare (but see Tait et al. 2005).

Here, we explore the potential for investigating population changes over a centennial time frame (160-190 years) using only qualitative information. We illustrate this approach using records of birds in a single region, the county of Cambridgeshire, eastern England, using contemporary bird records collated by the Cambridgeshire Bird Club (2011), hereafter CBC, and comparing these to the early 19th century descriptions given by the Reverend Leonard Jenyns, a distinguished 19th century naturalist (Preece & Sparks 2012). We compare two techniques for evaluating change based on converting qualitative descriptions to an ordinal scale.

1. METHODS AND MATERIALS

1.1. Study Region

The county of Cambridgeshire (centred on c. 52.5°N, 0°E) covers 3045 km^2 and has a population of 600,800 (2009 estimate). Excluding the main county town of Cambridge, agriculture makes up 80% of the land-use of the county with woodland accounting for only 3% of land cover (Cambridgeshire County Council 2010). The topography is in general low lying with over 50% of the land being less than 30 m above sea level and includes the lowest point in the entire country, at Holme Fen, which is 2.7 m below sea level. There are large flat topped plateaux in the west and south of the county and an outcrop of chalk hills running across the southern part. The east and north of the county is dominated by fenland with peat soils, almost all of which have been subject to drainage. With a mean annual rainfall of 600 mm, Cambridgeshire is one of the driest counties in the UK and, as such, has affinities to continental Europe (Farewell et al. no date; Perring et al. 1964).

Babington (1860) noted that only small areas of fenland, such as at Wicken, remained undrained and that much of the species–rich chalk grassland had disappeared. By 1860 the heathland on the Greensand in the far west of the county (e.g., Gamlingay Heath) and that in the east (Newmarket Heath) had already undergone transformation. Leonard Jenyns (born 1800) deplored the drainage and enclosure that had rapidly changed the landscape of his youth, and which had contributed to the impoverishment of the county's fauna (Preece & Sparks 2012). The county of Cambridgeshire has undergone boundary changes since 1800 (e.g., the incorporation of Huntingdonshire), but hereafter we refer to the modern county unless otherwise indicated. Although the county has grown in size, the landscape and landuse of the older and newer parts were similar. For example, in 1866 (old) Cambridgeshire was 88% farmed (crops, bare, fallow, grass) while Huntingdonshire was 84% farmed and both had similar levels of grazing (55 and 61 sheep/40 ha of farmland respectively) (HMSO 1867). Thus, we do not believe that boundary changes will have biased our results.

1.2. Bird Population Estimates

Here, we arrange qualitative descriptions of the abundance of the birds of Cambridgeshire in the early 19th century provided by Leonard Jenyns (Preece & Sparks 2012), and compare them to similar qualitative descriptions in the CBC annual report for 2010 (CBC 2011). Leonard Jenyns (Leonard Blomefield after 1871) completed an unpublished account of the wildlife of the then county of Cambridgeshire and sent it to the University Museum of Zoology, Cambridge in 1869. This account essentially describes the wildlife in the period from 1818, when he enrolled at the University of Cambridge, to 1849 when he left the county. An examination of early 19th century accounts of wildlife from areas subsequently assimilated into the current county (Preece & Sparks 2012) suggests that Jenyns's description would remain valid for the area now forming the present county. All qualitative descriptions were ranked and assigned an ordinal score from 1 (least abundant) to 5 (most abundant; Table 1). We extracted contemporary qualitative descriptions of bird abundance from the CBC report for 2010 (CBC 2011), similarly converting these to a 1 to 5 score (Table 1). We attempted to use similar conversions of qualitative descriptions, e.g., 'common' was scored 4 for both CBC and Jenyns, but we recognise that the level of abundance that constitutes "common" may differ between the two periods (e.g., Papworth et al. 2009). Thus, our work may be more accurately viewed as measuring relative, rather than absolute, change.

Nomenclature follows International English names (Gill & Donsker 2012). Since the mid 19th century three 'species' have each been split into two distinct species: Marsh Tit *Poecile palustris* and Willow Tit *P. montanus* (in 1897); European Herring Gull *Larus argentatus* and Yellow-legged Gull *L. michahellis* (1997); and Common (or Mealy) Redpoll *Carduelis flammea* and Lesser Redpoll *C. cabaret* (2001); see Collinson (2006) for summary of taxonomic changes. In practice, these changes had no effect on our analyses since Willow Tit was not recorded in CBC (2011), Yellow-legged Gull is a fairly common visitor in summer and autumn whereas European Herring Gull is a very common winter visitor. The latter species and its status were used in analyses. Both Common (Mealy) Redpoll and Lesser Redpoll are scarce winter visitors although the latter is a former breeder (CBC 2011). The latter presents a problem for the analysis since we are unable to ascertain how common it was as a breeder, and it is a species that appeared and disappeared in the interval between the two survey dates. However, there are only a few species with uncertainties over both identification and breeding status. Although unlikely, we cannot rule out the possibility that one or more of these species' pairs were formerly dominated by the species now least common.

1.3. Statistical Approach

To test the efficacy of our approach we firstly calculated rank correlations between current abundance scores with density and range size estimates from a Breeding Bird Survey (BBS) of up to 47 × 1 km squares surveyed and reported on in CBC (2011). Next, we plotted current abundance scores against Jenyns's abundance scores separately for breeding and non-breeding species/passage migrants. This classification may not be mutually exclusive since some species that breed may have populations that are augmented by winter visitors (e.g., Common Starling *Sturnus vulgaris*). In such cases, a decision of which was the dominant classification was made based on the descriptions given.

The abundance scores were plotted and changes in abundance between the two periods were inferred using departure from either a regression line of best fit or the line of equality. The null hypothesis of no change would mean that all the points of the scatter plot would lie on these lines. Accordingly, points above the line may be inferred to have increased in abundance and points below the line to have declined. Species with the greatest departure from the lines are inferred to have changed in abundance to the greatest extent. We take the standardised residuals greater than or less than one standard deviation above or below the lines to infer changes using both approaches. As in McCollin et al. (2000), the use of a least-squares regression line of best fit controls for differences in the application of the scores, rather than, say, trying to force a line of equality on the assumption that the data are equitable. Further, both approaches assume that descriptions, e.g. "common", are equitable between the two surveys. For regression, since significance testing is not being attempted, lack of normality is not a barrier. All analyses were performed using Minitab version 16.

2. RESULTS

Jenyns recorded 226 bird species in total of which 121 were recorded as breeding species (including 24 species implied to be breeding for which no assessment of abundance was made and thus excluded from the analyses here, e.g., Common Blackbird *Turdus merula*, Common Chiffchaff *Phylloscopus collybita*, Common Redstart *Phoenicurus phoenicurus*). A further 43 species were classed as over-wintering or passage migrants (e.g., Common Goldeneye *Bucephala clangula*, Merlin *Falco columbarius*) and the remainder were vagrants, species recorded infrequently often far outside their native ranges (e.g., Spotted Nutcracker *Nucifraga caryocatactes*, Purple Heron *Ardea purpurea*) or possible escapes from captivity (e.g., Passenger Pigeon *Ectopistes migratorius*). The identities of the vagrants are typically confirmed by well-documented extant museum specimens (Preece & Sparks 2012). Only the breeding species and over-wintering/passage migrants are considered further in this paper. Of the breeding species, several no longer breed in the county, including Hen/Northern Harrier *Circus cyaneus*, Eurasian Wryneck *Jynx torquilla*, Black Tern *Chlidonias hybrida*, and Eurasian Bittern *Botaurus stellaris* (Table 2, although the last named species is currently making a recovery). In addition, a number of species have colonised, and of the non-breeding species, Twite *Carduelis flavirostris*, and Hooded Crow *Corvus cornix*, now no longer over-winter in Cambridgeshire

The 2010 CBC Report provides estimates of breeding density and range size for 72 bird species. The rank correlations of the abundance scores with estimates of breeding species density (Spearman's r_s=0.81, p<0.001, n=72) and range size (r_s=0.76, p<0.001, n=72) revealed highly significant relationships between the ranks of the contemporary abundance de-

Table 1. Descriptions used to generate abundance scores for Cambridgeshire birds in the early 19th century (Jenyns) and for 2010 (CBC, 2011).

Score	Jenyns	CBC
1	[<3 specific records mentioned] Extinct, extremely rare, rare, rarely met, rather scarce, seldom met with, not recorded	[not seen since ….] Extinct, none, rare , very rare
2	[less than 5 specific records mentioned] Few, few instances, not common, not often met with, occasional, occasionally met, several, sometimes seen, sparingly	Scarce, scarce/uncommon, uncommon, very small numbers
3	[irruptions] Less than common, not infrequent, not infrequently, not uncommon, not unfrequently, not very common, not very uncommon, observed most years, regular	Common but declined, fairly common, locally common, locally fairly common
4	Common, formerly abundant, formerly plentiful, frequent, large flocks, tolerably plentiful	Abundant but declining, common, common and widespread, resident breeder greatly increased
5	Very common, abundant, extremely abundant, plentiful, plenty, very abundant	Abundant, abundant and widespread, very common,

Table 2. List of birds in Cambridgeshire referred to by Jenyns which have become regionally extinct, or not referred to and which are newly established as breeding species. Lists compiled with comparison to CBC (2010). [1]introduced

Status	Species
Extirpations: established breeding species recorded by Jenyns but now regionally extirpated.	Black Tern *Chlidonias niger* Common Quail *Coturnix coturnix* Common Redstart *Phoenicurus phoenicurus* Corn Crake *Crex crex* Eurasian Stonechat *Saxicola torquatus* Eurasian Wryneck *Jynx torquilla* European Nightjar *Caprimulgus europaeus* Hen/Northern Harrier *Circus cyaneus* Northern Wheatear *Oenanthe oenanthe* Ruff *Philomachus pugnax* Spotted Crake *Porzana porzana* Tree Pipit *Anthus trivialis* Whinchat *Saxicola rubetra* Wood Warbler *Phylloscopus sibilatrix*
Species which were rare and irregular breeders according to Jenyns now regionally extirpated.	Great Bustard *Otis tarda* Montagu's Harrier *Circus pygargus* Northern Raven *Corvus corax* Savi's Warbler *Locustella luscinioides* Short-eared Owl *Asio flammeus*
Species which were extirpated for several years but now recovering or have been reintroduced.	Common Buzzard *Buteo buteo* Common Crane *Grus grus* Eurasian Bittern *Botaurus stellaris* Red Kite *Milvus milvus* Western Marsh Harrier *Circus aeruginosus*
Species which have become established as breeding species since Jenyns (excluding newly separated species, see Methods).	Black-tailed Godwit *Limosa limosa* Canada Goose[1] *Branta canadensis* Egyptian Goose[1] *Alopochen aegyptiaca* Eurasian Collared Dove *Streptopelia decaocto* Eurasian Oystercatcher *Haematopus ostralegus* Great Cormorant *Phalacrocorax carbo* Great Crested Grebe *Podiceps cristatus* Lesser Black-backed Gull *Larus fuscus* Little Egret *Egretta garzetta* Little Owl[1] *Athene noctua* Little Ringed Plover *Charadrius dubius*

scriptions with independent estimates of density and range size derived from BBS survey data (Fig. 1). These close agreements between ordinal abundance scores (derived from descriptions) and density and range values justify plotting the current abundance scores against the early 19th century abundance scores. This has been done separately for breeding (Fig. 2a,b) and non-breeding species (Fig. 2c,d). For over-wintering species/passage migrants the equivalent data on species density and range size were not recorded in the Breeding Bird Survey.

For breeding birds, there was agreement between the two comparison approaches for 10 and three species for decreasing and increasing species, respectively (Appendix 1 sections i, iii; Fig. 2a,b). For over-wintering species and passage migrants there was agreement for one and two species, respectively (Appendix 1 sections v, vii; Fig. 2c,d). The differences between species identified by the two approaches lie in the way the regression line and line of equality capture points in the mid-range and marginalise outlying points, which are thus classified as having changed abundance to the greatest extent. Thus, the location and slope of the lines differed to an extent that the line of equality generated higher numbers of decreasing species whilst conversely, the line of best fit resulted in higher numbers of increasing species for both breeding species (Appendix 1 sections ii, iv, and for over-wintering species and passage migrants (Appendix 1 sections vi, viii).

3. DISCUSSION

3.1. Extirpation (local extinction) rates

Using data from the 2010 CBC Report we have shown that descriptions of abundance converted to a simple 1-5 scale correlate well with density and range size estimates from BBS monitoring programmes. Using this fact we have then compared modern scores with those from 160-190 years previously using regression. This reveals a number of both breeding and non-breeding bird species that have undergone marked increases or declines in abundance over this period. In addition to Hen

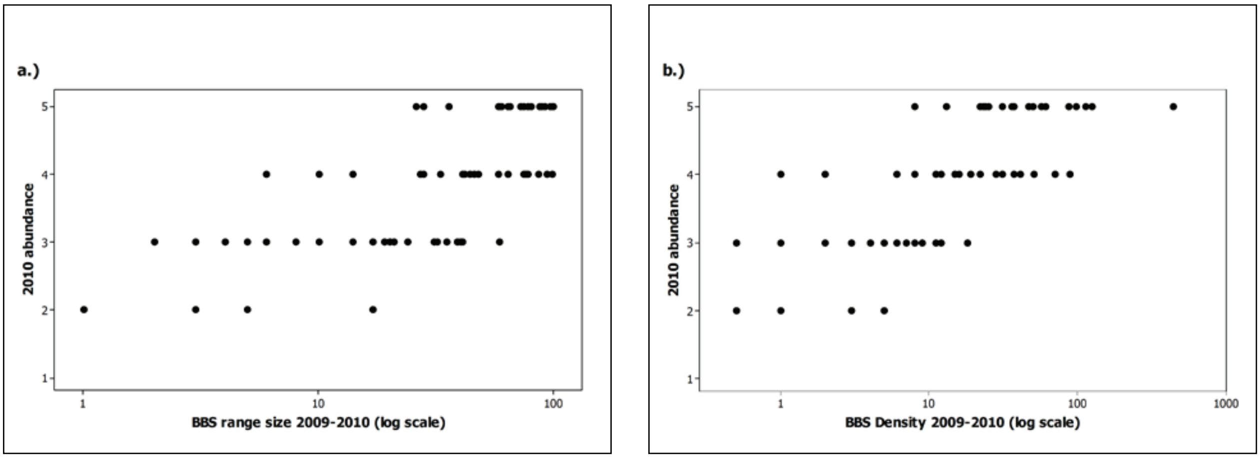

Figure 1. Relationship between abundance score and a.) range size, and b.) density derived from Breeding Bird Survey data in the Cambridgeshire Bird Club Report for 2010.

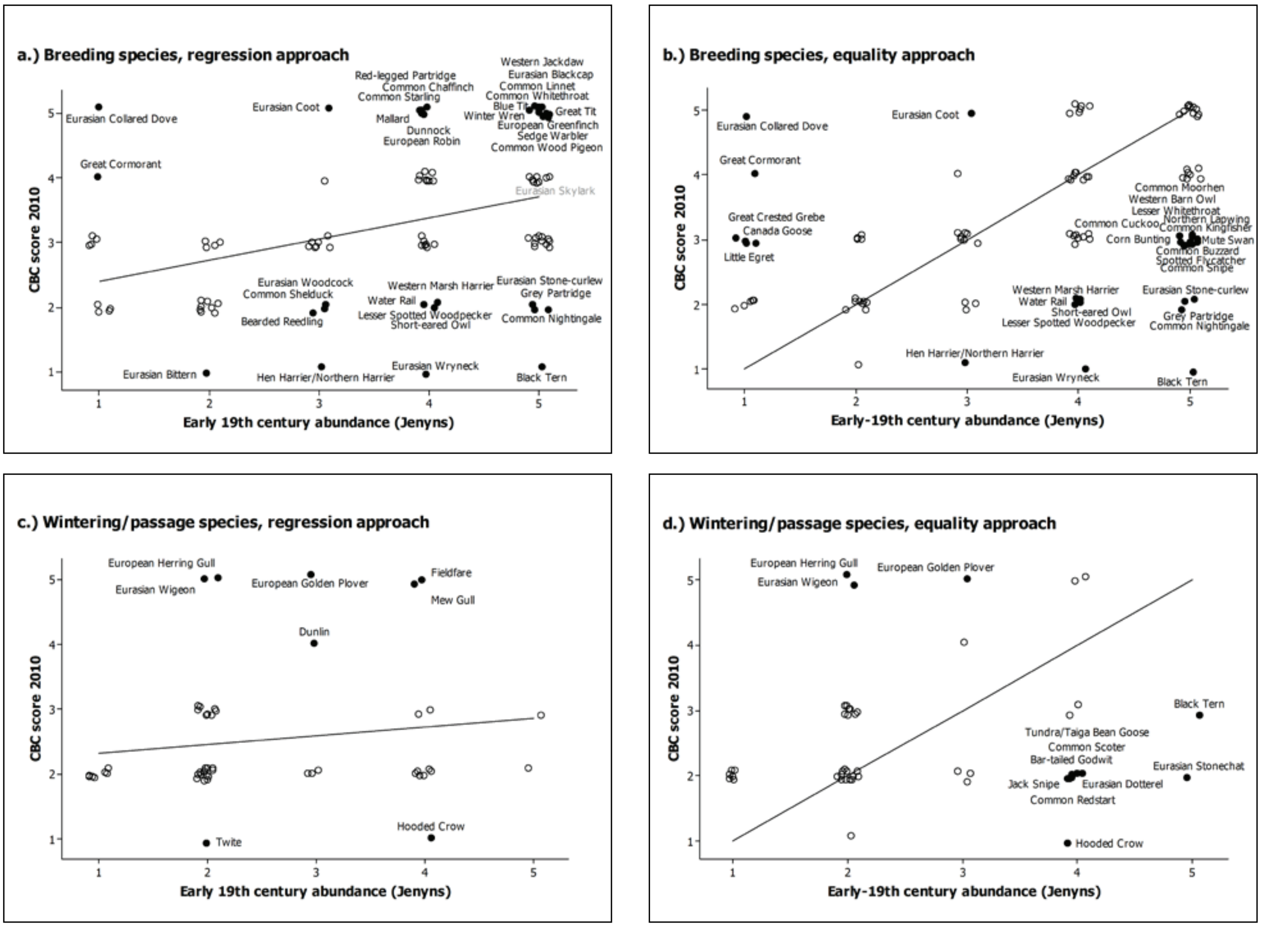

Figure 2. The relationship between current (CBC) abundance scores and those from the early 19th century (Jenyns) for: breeding bird species using a.) regression, b.) a line of equality; and for over-wintering species and passage migrants, similarly using c.) regression, and d.) a line of equality. Solid symbols indicate standardised residuals >|1|, and are thus inferred to be those species which have changed the most in abundance. One additional species labelled in grey is referred to in the text. Symbols have been jittered to reveal coinciding points.

Harrier/Northern Harrier, Eurasian Wryneck, Black Tern, and Eurasian Bittern, species which no longer breed in the county also include some that Jenyns implied were breeding but for which he did not provide any abundance estimates: Corn Crake *Crex crex*, Tree Pipit *Anthus trivialis*, Common Quail *Coturnix coturnix*, and Spotted Crake *Porzana porzana*. Including these, the loss of breeding species totals 14 (Table 2), equivalent to a loss of seven to nine species per century (the range depends on whether extirpation rates are estimated for 160 or 190 years). If the species that became extinct but which have since recovered are included, this rate increases to 10 – 13 species per century. These estimates are only about one tenth to one fifth of the mean extirpation rate for vascular plants at the county level (Walker 2003). However, in order to compare taxa these rates should be compared using the numbers of species extirpated relative to the overall number of breeding species in the region. For breeding birds, this equates to a rate of 12 – 16% of species per century. In comparison, 73 plant species per century have become extinct in Cambridgeshire (Plantlife 2012), which for 1159 species (including common, uncommon, and rare species but not aliens, varieties and sub-species (Crompton no date) equates to an extirpation rate of 6.3% of species per century. Hence, although crude rates per unit time indicate that extirpations for birds are much less than for plants, when differences in the total numbers of species in the species pool are taken into account the extirpation rate for birds is actually twice as high as that for plants.

3.1.1 Changes in abundance and their causes

The analysis of extirpation rates masks the considerable changes that may be inferred from the data. Given such a long time span between surveys, it should be no surprise that some changes are historical whereas others are more recent. The factors underlying changes in abundance encompass both natural range extensions from the continent and changes due to human activities including of land-use and persecution.

We can be reasonably confident that the species which were identified in both approaches represent actual changes in abundance (Appendix 1 sections i, iii, v, vii). For breeding species, Eurasian Collared Dove *Streptopelia decaocto* is a species that expanded its range across Europe naturally during the 20th century (Fisher 1953; Hengeveld & Van Den Bosch 1979), too late to be noted by Jenyns. In contrast to these species, an increase in Great Cormorant *Phalacrocorax carbo* probably arose due to a relaxation in persecution combined with an increasing amount of habitat available in terms of flooded gravel pits (Kirkland 1976; Newson et al. 2007). The apparent increase in Eurasian Coot *Fulica atra* is surprising but again may be attributable to an increase in suitable habitat.

Breeding species that have declined include those which may have been lost due to fenland drainage (perhaps combined with persecution) such as Western Marsh Harrier *Circus aeruginosus*, Hen/Northern Harrier, Water Rail *Rallus aquaticus* and Short-eared Owl *Asio flammeus* (Holloway 2002), species lost due to agricultural intensification, such as Grey Partridge *Perdix perdix* (Potts 1970), Corn Crake (Green et al. 1997) and Eurasian Stone-curlew *Burhinus oedicnemus* (O'Connor and Shrubb, 1986), and species associated with woodland, such as Lesser Spotted Woodpecker *Dendrocopos minor*, Eurasian Wryneck, and Common Nightingale *Luscinia megarhynchos* (Gibbons et al. 1993; Gregory et al. 2002; Marchant et al. 1990; Holt et al. 2012). Reasons for these declines in woodland birds are complex and possibly multi-factorial (Vanhinsbergh et al. 2003).

For passage migrants and over-wintering species, despite declines over the past 25 years (Eaton et al. 2012), European Herring Gull has undergone a marked increase over its entire European range and expanded inland in the 20th century to now become common in towns and on farmland (Chabrzyk & Coulson 1976; Merne 1997). The apparent increases in Eurasian Wigeon *Anas penelope* and European Golden Plover *Pluvialis apricaria* are surprising since these do not correspond with recent trends (Defra 2011), highlighting the value of using an historical baseline to measure change. Any such increases in these species since the early 19th century could result from a greater number of flooded gravel pits in the county, many of which began to be excavated after WWII but well before 1970 (the year used as a national baseline for national monitoring of waterbirds). In England as a whole, sand and gravel extraction increased by well over 300% between 1944 and 1973 (Kirtland 1976). For Eurasian Wigeon and for some of the aforementioned breeding species such increases possibly resulted directly from the amount of available habitat or indirectly via increasing the area of open water, facilitating movements along migration corridors (e.g., for Dunlin *Calidris alpina*). Whilst increased habitat availability would seem the likeliest explanation for these apparent increases we cannot rule out a possible decline in hunting pressure (Shrubb 2003). For declining species, the loss of Hooded Crow as an over-wintering species had already been noted by Lord Lilford in nearby Northamptonshire in the late 19th century (Lilford 1895).

3.1.2 Differences between approaches

As noted in the Results, differences in species identified as increasing or declining arise from the classification of outliers due to the differences in the location and slope of the lines. The differences in species identified by the two approaches tend to be the most or least abundant species, not the species in the mid-range. Regression generated a set of species which have apparently increased but which had scored the same abundance scores (e.g., values 5, 5 Fig. 2a). This group includes widespread and ubiquitous species of towns and countryside including Blue Tit *Cyanistes caeruleus*, Great Tit *Parus major*, European Robin *Erithacus rubecula*, Winter Wren *Troglodytes troglodytes*, Common Chaffinch *Fringilla coelebs*, European Greenfinch *Carduelis chloris* and Common Linnet *Carduelis cannabina*. In these cases it is conceivable that these species have increased due to urbanization although we are in danger of telling 'Just So' stories in order to support our explanations (Kornberg & Williamson 1983).

Paradoxically, if we do not accept that these urban species have increased, and if we are to be consistent, we cannot accept that Eurasian Bittern and Bearded Reedling *Panurus biarmicus* have declined either. However, given their habitat requirements, the long-term declines in these two bird species would appear to be consistent with the aforementioned drainage of the fens and with persecution.

Again, if we accept the regression approach, we also exclude species identified by the line of equality approach known to have increased such as Little Egret *Egretta garzetta* and Canada Goose *Branta canadensis*. The latter is an introduction dating back to 1665 and the former is another species currently expanding its range such that within the past couple of decades its status has changed from a rarity to a well established member of the UK avifauna (Ogilvie 1996; Kirby et al. 1999).

If we accept the line of equality approach then we must also accept that there have been declines from the most common to the mid-range categories for a cluster of species including Common Buzzard *Buteo buteo*, Common Moorhen *Gallinula chloropus*, Common Snipe *Gallinago gallinago*, Common Cuckoo *Cuculus canorus*, Common Kingfisher *Alcedo atthis*, Corn Bunting, Lesser Whitethroat *Sylvia curruca*, Mute Swan *Cygnus olor*, Northern Lapwing *Vanellus vanellus*, Spotted Flycatcher *Muscicapa striata* and Western Barn Owl *Tyto alba* (Fig. 2b). The one common denominator between these species is that most are birds of farmland and again such declines are feasible given the changes in agriculture already highlighted. Similarly, for over-wintering species and passage migrants the line of equality approach identifies a group of declining species including Common Redstart, Jack Snipe *Philomachus pugnax*, and four other species including Eurasian Dotterel *Charadrius morinellus* (Fig. 2d). Jenyns did not provide an abundance description for Eurasian Dotterel but it is a bird that was once a delicacy collected on passage in Cambridgeshire and elsewhere (Bircham 1989; Preece & Sparks 2012; Shrubb 2013).

Thus far, we have discussed the species that are inferred to have undergone changes but what of the species clustered around the centroids of the plots? Species which have undergone declines since the 1980s but not identified in this analysis include Yellowhammer *Emberiza citrinella*, Reed Bunting *E. schoeniclus*, Tree Sparrow *Passer montanus*, European Turtle Dove *Streptopelia turtur* (Defra 2011) and Skylark *Alauda arvensis* (Chamberlain & Crick 1999) (labelled in grey in Fig. 2a). Therefore, by extending the baseline back it appears that the recent declines in some farmland specialists are not evident in longer term analyses. It is possible that such farmland species had increased in the intervening period, say in the late 19th or early 20th centuries, so that recent declines are simply changing the status of birds back to their historical baseline. As potential pests of the harvest, many such farmland species would have been subject to crop protection measures and persecution prior to the 20th century and the lessening of such measures may have contributed to an increase (Shrubb 2003; Lovegrove 2007). Hence, concern over the recent loss of such species may be a problem of the shifting baseline.

Our approach of utilizing old records to extend the survey period back into the early 19th century seems to have paid dividends in the detection of longer-term change. In this study we only used two time points, but the approach could easily include more if regions have other reliable population descriptions from several, preferably independently assessed and non-overlapping, periods.

3.2. Conclusions and Recommendations

Whilst perceptions of what may constitute commonness or rarity inevitably differ between widely spaced periods in time, at worst we believe our approach can assess change in relative abundance in a large group of species. We show here that over a longer timescale the baseline is shifted and we can compare abundances over periods coinciding with a period of upheaval including the final phases of the Industrial Revolution, two World Wars, and increases in production subsidies for agriculture from both the UK Government and the EU. Bird species are categorised as being of conservation concern (e.g., Amber- or Red-listed) if they show substantial declines over a period dating back to 1970 (Avery et al. 1995; Eaton et al. 2012). Whilst such listings also make allowances for long-term declines, more information is needed. For birds, the main factor affecting their abundance is probably change in land use (see also Fuller & Ausden 2008). The period covered by this analysis has seen a shift from a largely agrarian society to one in which the majority of the human population now live in towns and cities. Habitats associated with pre-industrial farmland have been replaced by intensive agriculture and there has been increased urbanization with associated transport infrastructure, housing, gardens and the formation of (flooded) gravel pits, all consequent on the demands of a growing human population.

We have demonstrated that it is possible to assess change using qualitative descriptions as measures of faunal abundance. This enables a much longer-term perspective of population changes than is possible from an analysis of data collected for atlases or population monitoring schemes. As yet, we are unable to provide a recommendation on which approach is best but by combining approaches together with analyses of extirpations we are able to provide a conservative list of those species which have changed the most in abundance. Given that many previously limited-access and obscure texts are now becoming available online and electronically searchable, opportunities to assess population changes over the longer term using such historical accounts become ever more viable. We have had to rely on independent published accounts to support our method with regard to changes in abundance of particular faunal species. In order to test the validity of our approach and whether some of our unexpected findings are more widespread it is recommended that further regional-scale studies are undertaken.

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Appendix 1. Comparison of bird species identified as having undergone large changes in abundance using the line of equality and regression approaches. Species in each category are ordered alphabetically by common name.

Status	Line of equality	Regression
Breeding species found to have declined using both the line of equality and regression approaches	Black Tern *Chlidonias niger* Common Nightingale *Luscinia megarhynchos* Eurasian Stone-curlew *Burhinus oedicnemus* Eurasian Wryneck *Jynx torquilla* Grey Partridge *Perdix perdix* Hen/Northern Harrier *Circus cyaneus* Lesser Spotted Woodpecker *Dendrocopos minor* Short-eared Owl *Asio flammeus* Water Rail *Rallus aquaticus* Western Marsh Harrier *Circus aeruginosus*	
Additional breeding species found to have declined using each approach	Common Buzzard *Buteo buteo* Common Moorhen *Gallinula chloropus* Common Snipe *Gallinago gallinago* Common Cuckoo *Cuculus canorus* Common Kingfisher *Alcedo atthis* Corn Bunting *Miliaria calandra* Lesser Whitethroat *Sylvia curruca* Mute Swan *Cygnus olor* Northern Lapwing *Vanellus vanellus* Spotted Flycatcher *Muscicapa striata* Western Barn Owl *Tyto alba*	Bearded Reedling *Panurus biarmicus* Common Shelduck *Tadorna tadorna* Eurasian Bittern *Botaurus stellaris* Eurasian Woodcock *Scolopax rusticola*
Breeding species found to have increased using both approaches	Eurasian Collared Dove *Streptopelia decaocto* Eurasian Coot *Fulica atra* Great Cormorant *Phalacrocorax carbo*	
Additional breeding species found to have increased using each approach	Canada Goose *Branta canadensis* Great Crested Grebe *Podiceps cristatus* Little Egret *Egretta garzetta*	Blue Tit *Cyanistes caeruleus* Common Chaffinch *Fringilla coelebs* Common Linnet *Carduelis cannabina* Common Starling *Sturnus vulgaris* Common Whitethroat *Sylvia communis* Common Wood Pigeon *Columba palum-bus* Dunnock *Prunella modularis* Eurasian Blackcap *Sylvia atricapilla* European Greenfinch *Carduelis chloris* European Robin *Erathacus rubecula* Great Tit *Parus major* Mallard *Anas platyrhynchos* Red-legged Partridge *Alectoris rufa* Sedge Warbler *Acrocephalus schoeno-baenus* Western Jackdaw *Corvus monedula* Winter Wren *Troglodytes troglodytes*
Over-wintering species and passage migrants found to have declined using both the line of equality and regression approaches	Hooded Crow *Corvus cornix*	

Additional over-wintering species and passage migrants found to have declined using each approach	Bar-tailed Godwit *Limosa lapponica* Bean Goose *Anser fabalis* Black Tern *Chlidonias niger* Common Redstart *Phoenicurus phoenicurus* Common Scoter *Melanitta nigra* Eurasian Dotterel *Charadrius morinellus* Eurasian Stonechat *Saxicola torquatus* Jack Snipe *Lymnocryptes minimus* Twite *Carduelis flavirostris*	
Over-wintering species and passage migrants found to have increased using both approaches	Eurasian Wigeon *Anas penelope* European Golden Plover *Pluvialis apricaria* European Herring Gull *Larus argentatus*	
Additional over-wintering species and passage migrants found to have increased using each approach	None	Dunlin *Calidris alpina* Fieldfare *Turdus pilaris* Mew Gull *Larus canus*