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Use of environmental stratification to derive non-breeding population estimates of dispersed waterbirds in Great Britain

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ABSTRACT

Population estimates provide a baseline to inform conservation and management decisions. In this paper, we present a novel method to derive non-breeding population estimates of waterbirds in Great Britain. We combined Wetland Bird Survey (WeBS) data with a detailed environmental stratification to calculate population estimates for widely dispersed waterbird species, populations of which tend to be relatively poorly monitored by WeBS and other established schemes. These stratification-based estimates were then compared with published estimates, most of which were derived using extrapolations based on WeBS information and a small number of intensive surveys. We discuss the limitations and merits of the stratification method, and conclude by suggesting the species for which future use of the approach would be most appropriate for derivation of population estimates. We also outline potential ways to improve the baseline information on abundance of widely dispersed non-breeding waterbirds in Great Britain.

1. Introduction

Robust population estimates are extremely important as they provide a baseline to inform conservation and management decisions. They are generally used, in conjunction with other statistics, to evaluate the conservation status of species at global, flyway, national or sub-national levels (e.g. Nagy, Fink, & Langendoen, 2014), and to assess the ecological determinants of species abundance and distribution (e.g. Goss-Custard et al., 2006). Population estimates are also used to determine the proportion of a species' global or national population held in a given geographical area and to identify sites that are internationally or nationally important for that species according to various numeric conventions, and therefore where the species requires special conservation attention (Atkinson-Willes, 1976; Atkinson-Willes et al., 1982). As such, population estimates are central to evaluating the potential contribution that different areas or countries can make for species protection and conservation (Keller & Bollmann, 2004). Therefore, it is important to provide accurate estimates of population size to assist in the implementation of these conservation measures. Furthermore, because species can undergo major changes in abundance and/or distribution, population estimates need to be regularly updated.

The outstanding importance of Great Britain for non-breeding migratory waterbirds has long been recognised. Great Britain attracts a large number of waterbirds (Musgrove et al., 2011) due to its favourable conditions in the non-breeding season, with extensive and highly productive estuaries, large areas of still water and relatively mild winter temperatures, coupled with its situation at the juncture of major flyways for Arctic-nesting species (Prater, 1981). Consequently, the United Kingdom has assumed international obligations to protect waterbirds and their habitats as a signatory to the Convention on Wetlands (Ramsar Convention), the Convention on the Conservation of Migratory Species (CMS), the African–Eurasian Migratory Waterbird Agreement (AEWA), the Convention on Biological Diversity (CBD), and as a Member State of the European Union, and is bound by the requirements of the EU Birds Directive 2009/147/EC and Habitats Directive 92/43/EEC. The criterion commonly used for evaluation of site importance for wintering waterbirds at national and international scales is the 1% threshold, where a site is assessed as nationally or internationally important when it regularly supports, respectively, 1% of the individuals of the national or biogeographic populations of a species

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or subspecies (Stroud et al., 2001; Secretariat, 2010). Thus, knowledge of waterbird population sizes is fundamental for the effective application of this criterion.

The principal way of monitoring non-breeding waterbirds in the United Kingdom is through the Wetland Bird Survey (WeBS). WeBS data provide the basis for assessment of waterbird population size, distribution and temporal trends, and has enabled important sites for most waterbird species to be identified (Austin et al., 2014). For the purpose of important site identification, population estimates of non-breeding waterbirds are generally provided for Britain or All-Ireland; numbers in Northern Ireland are combined with those from the Republic of Ireland to derive All-Ireland estimates (Crowe & Holt, 2013). WeBS data are collected during synchronised monthly counts at over 2000 sites throughout the UK. These 'Core Counts' cover all wetland habitats, including most estuaries, some non-estuarine coastal areas, most reservoirs and gravel-pits, and a small proportion of other inland still waterbodies, rivers, canals and marshes. Complementary surveys are carried out intermittently to estimate the number of birds using habitats not well covered by WeBS Core Counts, or to target species that do not lend themselves to monitoring under the protocols of the WeBS Core Count scheme. An example is the Non-estuarine Coastal Waterbird Survey (NEWS), which covers most of the rocky and sandy shores around the UK on a roughly decadal basis (Austin, Collier, & Rehfisch, 2008). By virtue of this extensive monitoring across all coastal wetland habitats, the population estimates generated for species that tend to concentrate in coastal wetland habitats are considered accurate and robust (Rehfisch et al., 2003; Musgrove et al., 2011). However, due to incomplete coverage of inland wetlands (and other non-aquatic habitats used by some waterbird species), a substantial proportion of the national populations of some widely dispersed species are not directly counted through either WeBS Core Counts or other complementary surveys. This makes calculating the population sizes of such species a major challenge. To deal with deficiencies of both inland survey coverage and lack of readily accessible data on the extent of inland wetlands in Britain, previous waterbird population estimates have been generated by extrapolation from the results of a limited number of comprehensive surveys which, by their very nature, were not geographically extensive (reviewed in Musgrove et al., 2011). However, a major limitation associated with this approach is the assumption of environmental homogeneity across Britain, as the scaling factor employed is assumed to be representative of all habitat types present. Consequently, national population estimates of these species may be imprecise and potentially unreliable.

A key objective of waterbird monitoring schemes should be to improve the ability to detect population change in more widespread species. Such species may be signals of change in the wider environment away from the major wetlands, most of which are well monitored but may also be part of a protected site network that can help to buffer sites from broad-scale anthropomorphically driven changes in the environment. Inadequate monitoring of widely dispersed waterbird populations in the wider countryside could conceivably result in marked population changes going undetected. Where population estimates are used to inform statutory obligations, advanced methods of indexing population trends are needed. For example, due to concerns over the economic impacts of Cormorants *Phalacrocorax carbo* on commercial inland fisheries, control measures are now in place in several European countries that permit, under derogation from the EU Birds Directive, numbers of this otherwise protected species to be shot at specific sites, mainly in winter (Marzano, 2015). In response to this legislation, improved methods for indexing population trends of Cormorant have been developed (Chamberlain, Austin, Green, Hulme, & Burton, 2013).

In order to improve the population estimates of 19 widely dispersed waterbird species wintering in Britain, we suggest incorporating environmental characteristics into the use of WeBS Core Counts, by synthesizing environmental data into different strata. The associated environmental stratification is suitable for stratified random sampling of environmental conditions, and thus can be used to extrapolate bird count data based on the different environmental strata. The stratification was undertaken by classifying different environmental gradients (freshwater and urban coverage, landscape type and climate) for each 5-km grid square aligned to the British National Grid, into distinct strata. This provides a valuable spatial framework for estimating population sizes with an objective of improving the accuracy and robustness of national population estimates of ubiquitous species, thereby enabling monitoring schemes to overcome major constraints identified for the extrapolation approach. We explore differences in the population estimates generated by the methods used in this paper and those derived previously in studies that have estimated national population sizes (i.e. stratification vs. extrapolation), discuss the merits of the stratification approach for each species, and provide associated recommendations for future calculation of population sizes. Finally, in considering the coverage by WeBS of the different environmental strata used in this paper, we suggest ways of improving the future sampling by the survey. The overall aims of this paper are therefore (i) to improve the accuracy of population estimates for waterbird species with poor abundance data, and (ii) to inform the design of future data collection protocols that provide the data used for estimating population sizes.

2. Methods

2.1. Bird data

The 19 species included in the analysis (Table 2) were selected either because they are widely dispersed across Great Britain (Balmer et al., 2013) or their total populations are relatively poorly monitored by WeBS (Musgrove et al., 2011). All 19 species tend to occur on a variety of inland wetlands, often away from major waterbodies and estuaries where WeBS coverage is almost complete. In order to derive population estimates, we used WeBS data from five winters (September–March), 2004/2005–2008/2009 inclusive, to ensure comparability with the most recent published estimates for the same period (Musgrove et al., 2011).

Population estimates for each species were generated using counts from the peak month in each of the five winters (Kershaw & Cranswick, 2003). For comparative purposes, we also calculated the equivalent population estimate based only on January data, since waterbird populations at the flyway scale are normally estimated using January counts collected as part of the International Waterbird Census (Nagy et al., 2014). January is considered the month when winter waterbird populations are relatively sedentary (Underhill & Prŷs-Jones, 1994; Wetlands International, 2002). Then, we calculated the five-year mean January counts and the five-year mean peak-month counts for each species at each site covered. By calculating five-year means, we reduce the effects of annual fluctuations in numbers and ameliorate for any missing counts (Kershaw & Cranswick, 2003; Rehfisch et al., 2003).

WeBS counts are carried out at wetland sites, which vary in size from <1 ha to >400 km^2, rather than using stratified random grid squares as used in some UK bird monitoring schemes (e.g. Harris et al., 2014). Thus, we chose to undertake the analysis at a 5-km grid square resolution, not only because it captures differences in environmental conditions, as detailed below, but also because 65% of WeBS sites can be allocated to a single grid square. Sites occupying more than one 5-km square complicate the process of allocat-