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Are existing biodiversity conservation strategies appropriate in a changing climate?

Tom H. Oliver [a,*], Richard J. Smithers [b], Colin M. Beale [c], Kevin Watts [d]

[a] School of Biological Sciences, University of Reading, Whiteknights, Reading RG6 6AS, UK
[b] Ricardo Energy & Environment, The Gemini Building, Fermi Avenue, Harwell, Didcot OX11 0QR, UK
[c] University of York, Department of Biology, Heslington, York YO10 5DD, UK
[d] Forest Research, Alice Holt Lodge, Farnham, Surrey GU10 4LH, UK

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Many countries have conservation plans for threatened species, but such plans have generally been developed without taking into account the potential impacts of climate change. Here, we apply a decision framework, specifically developed to identify and prioritise climate change adaptation actions and demonstrate its use for 30 species threatened in the UK. Our aim is to assess whether government conservation recommendations remain appropriate under a changing climate. The species, associated with three different habitats (lowland heath, broadleaved woodland and calcareous grassland), were selected from a range of taxonomic groups (primarily moths and vascular plants, but also including bees, bryophytes, carabid beetles and spiders). We compare the actions identified for these threatened species by the decision framework with those included in existing conservation plans, as developed by the UK Government's statutory adviser on nature conservation. We find that many existing conservation recommendations are also identified by the decision framework. However, there are large differences in the spatial prioritisation of actions when explicitly considering projected climate change impacts. This includes recommendations for actions to be carried out in areas where species do not currently occur, in order to allow them to track movement of suitable conditions for their survival. Uncertainties in climate change projections are not a reason to ignore them. Our results suggest that existing conservation plans, which do not take into account potential changes in suitable climatic conditions for species, may fail to maximise species persistence. Comparisons across species also suggest a more habitat-focused approach could be adopted to enable climate change adaptation for multiple species.

1. Introduction

Climate change is already impacting upon biodiversity and represents an important future challenge for biodiversity conservation strategies (Bellard et al., 2012). Interactions between climate and land use provide opportunities for climate change adaptation that increase species' adaptive capacity (Smithers et al., 2008; Heller and Zavaleta, 2009; Oliver and Morecroft, 2014). In many cases, existing conservation policy and practice already promote actions that will reduce vulnerability to climate change (e.g. habitat management, restoration or creation that improves the functional connectivity of landscapes). However, explicitly addressing climate change impacts when developing species and habitat action plans could lead to differences in the balance of recommended conservation actions or in the priority given to actions in different locations. At present, we do not know the extent of these differences and their likely importance, yet such information will be critical in designing biodiversity conservation strategies that will remain appropriate and effective under climate changes in coming decades.

In this study, we use the UK as an example and demonstrate the use of a climate change adaptation decision framework to consider the efficacy of national government conservation recommendations for threatened species. In the UK (which comprises Great Britain and N. Ireland), threatened species are identified in the Natural Environment and Rural Communities Act 2006 (NERC Act). Conservation plans have been identified for many of these species and are documented on the website of the statutory body responsible for co-ordinating conservation in the UK (Joint Nature Conservation Committee, JNCC; http://jncc.defra.gov.uk). These plans have been developed by JNCC with input from species experts and list key actions that are thought necessary to protect and enhance the status of the threatened species. However, they do not explicitly consider the projected impacts of climate change scenarios, which may vary in magnitude and direction of effect across species ranges (Berry et al., 2002; Pearson and Dawson, 2003). Climate change has the potential to compound other drivers of population decline (Brook et al., 2008; Oliver and Morecroft, 2014). Threatened species

* Corresponding author.
E-mail addresses: t.oliver@reading.ac.uk (T.H. Oliver), richard.smithers@ricardo-aea.com (R.J. Smithers), colin.beale@york.ac.uk (C.M. Beale), kevin.watts@forestry.gsi.gov.uk (K. Watts).

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may be particularly vulnerable, as a consequence of their small populations, limited geographic ranges or both (IUCN, 2001).

A climate change adaptation decision framework was recently published (Oliver et al., 2012, 2015), aiming to promote integration of climate change adaptation principles into conservation planning by prioritising and targeting relevant actions to increase the adaptive capacity of species (Hopkins et al., 2007; Huntley, 2007; Mitchell et al., 2007; Smithers et al., 2008; Heller and Zavaleta, 2009; Mawdsley et al., 2009; Pettorelli, 2012). In doing so, the framework extends the prioritisation of landscape-scale actions by Lawton et al. (2010) from 'more, bigger, better, joined' to 'better, bigger, more, improve connectivity, translocate and ex-situ'. Thus, it reflects recent debate about the need to address existing threats to species before enhancing functional connectivity (Hodgson et al., 2011). The decision framework helps users to prioritise adaptation actions for species through qualitative consideration of results from climate envelope/species distribution models (hereafter referred to as 'bioclimate' models; Pearson and Dawson, 2003; Elith and Leathwick, 2009). The framework also uses available data on species attributes and status (e.g. frequency of occurrence, population trends, habitat associations and dispersal abilities), habitats (e.g. quality, extent and fragmentation) and land cover (with regard to potential edge effects from land use surrounding habitat patches and the permeability of the intervening matrix).

In the current study, we assessed 30 NERC Act species using the decision framework. The aim of our study was to compare how existing conservation actions identified nationally for these species differ from those keyed out using the decision framework.

2. Methods

2.1. Species selection

From the NERC Act 2006 priority species list, an initial long-list of 114 species was identified for which the UK Biological Records Centre (BRC) held sufficient data to calculate a trend over time in frequency of species' occurrence (see Section 2.4). Our subsequent intent was to select 30 of these species associated with three different habitat types: lowland heath, broadleaved woodland or calcareous grassland. These habitats were chosen, as they are widespread in the UK, can be mapped using remote-sensing data, and host a large number of other species of conservation concern. Species-habitat associations were determined from Webb et al. (2010). We randomly selected ten species associated with each habitat type and across a range of taxonomic groups. As a result of some taxonomic bias in the priority species list, the species chosen were primarily moths and vascular plants, but also include bees, bryophytes, carabid beetles and spiders. It should be noted that, in addition to lowland heath, broadleaved woodland or calcareous grassland, a number of the species are also listed as being associated with other habitats (e.g. lowland farmland). One broadleaved woodland species was removed from analysis because there were two sub-species present in the north of the UK, with different habitat associations. None of the other species in the initial long-list were associated with broadleaved woodland, therefore, an additional lowland heath species was randomly selected, giving a total of 30 species (Table 1).

2.2. Bioclimate models

For each of the 30 species, we obtained species occurrence records across Great Britain (N. Ireland was excluded due to a paucity of data) between 1970 and 89, or 1970–86 for vascular plants, to be consistent with the start and end dates of major Atlases. Using records from more recent periods would potentially have included many more data from species already showing climate-driven range changes (Thomas et al., 2011; Mason et al., 2015). Therefore, we restricted our analysis to this 'historic baseline' period (Thomas et al., 2011). The data are collected by species recording schemes and societies and collated by the BRC. For many taxa, spatial and temporal recording effort varies, although efforts are made by all schemes to ensure that coverage is as complete as possible at the hectad level before producing national atlases. Therefore, standardisation of survey data is necessary in the analysis of these data. We used the program FRESCALO (Hill, 2011) to produce estimates of recorder effort for each 10 km square for each

Table 1
Species considered in the analysis, including their habitat association from Webb et al. (2010) and their taxonomic grouping.

Species Latin name	Common name	Habitat association	Taxonomic group
Adscita statices	Forester moth	Chalk grassland	Moths
Carex ericetorum	Rare Spring-sedge	Chalk grassland	Vascular plants
Euphrasia pseudokerneri	Chalk Eyebright	Chalk grassland	Vascular plants
Hadena albimacula	White spot moth	Chalk grassland	Moths
Heliophobus reticulata	Bordered Gothic	Chalk grassland	Moths
Herminium monorchis	Musk Orchid	Chalk grassland	Vascular plants
Polia bombycina	Pale Shining Brown Moth	Chalk grassland	Moths
Pulsatilla vulgaris	Pasque flower	Chalk grassland	Vascular plants
Scotopteryx bipunctaria	Chalk Carpet Moth	Chalk grassland	Moths
Shargacuculia lychnitis	Striped Lychnis moth	Chalk grassland	Moths
Cephalanthera damasonium	White Helleborine	Broadleaved woodland	Vascular plants
Cossus cossus	Goat Moth	Broadleaved woodland	Moths
Cyclophora porata	False Mocha Moth	Broadleaved woodland	Moths
Melittis melissophyllum	Bastard Balm	Broadleaved woodland	Vascular plants
Monocephalus castaneipes	Broad Groove-head Spider	Broadleaved woodland	Spiders
Paracolax tristalis	Clay Fan-foot Moth	Broadleaved woodland	Moths
Saaristoa firma	Triangle Hammock-spider	Broadleaved woodland	Spiders
Trichopteryx polycommata	Barred Tooth-striped Moth	Broadleaved woodland	Moths
Trisateles emortualis	Olive Crescent Moth	Broadleaved woodland	Moths
Aleucis distinctata	Sloe Carpet	Lowland Heath	Moths
Andrena tarsata	Tormentil Mining Bee	Lowland Heath	Bees
Bombus muscorum	Moss Carder-bee	Lowland Heath	Bees
Carabus monilis	Necklace Ground Beetle	Lowland Heath	Carabid beetles
Chamaemelum nobile	Chamomile	Lowland Heath	Vascular plants
Dicranum spurium	Rusty Fork-moss	Lowland Heath	Bryophtyes
Haplodrassus dalmatensis	Heath Grasper	Lowland Heath	Spiders
Illecebrum verticillatum	Coral necklace	Lowland Heath	Vascular plants
Mentha pulegium	Pennyroyal	Lowland Heath	Vascular plants
Odynerus melanocephalus	Black-headed Mason Wasp	Lowland Heath	Wasps
Xestia agathina	Heath Rustic	Lowland Heath	Moths