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Waterbirds around the world

A global overview of the conservation, management and research of the world's waterbird flyways

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Cover photography: Whooper Swans *Cygnus cygnus* arriving at Martin Mere, England. Photo: Paul Marshall.
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Climate change and coastal waterbirds: the United Kingdom experience reviewed

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ABSTRACT

Climate change is occurring world-wide, and its effects are already visible in species and their habitats. The internationally important populations of waterbirds in the UK, and waders in particular, are already affected by climate change. So far, changes in distribution, timing of arrival to winter and to breed, and laying dates have been linked to it. Changes in the distributions of certain wintering waders, linked to changing winter temperatures, have affected the proportions of their flyway populations on sites designated as being of conservation importance for the species. This has major implications for conservation policy. Waders are declining in the UK and world-wide, and it is possible that climate change is in part responsible, both directly by affecting their energy balance, and indirectly by affecting the availability, quantity and quality of their habitats. Waders appear to be good indicators of climate change, and the development of reliable scenarios of waterbird distributions occurring under future, changed climate scenarios would help with nature conservation planning, raise public awareness and, perhaps, lead to constructive political action to curb greenhouse gas emissions. However, before such scenarios can be developed, much work is necessary to help define appropriate parameters for such models.

INTRODUCTION

Globally, the ten hottest years on record occurred between 1991 and 2004; during the last century temperatures have risen by 0.6ºC, and global sea level has risen by 20 cm (Houghton *et al*. 2001). Ice caps are disappearing from mountain peaks, and Arctic sea ice has thinned by 40% (Wadhams 1997). Thus, climate change is occurring and the causal link to increased greenhouse emissions is established (Houghton *et al*. 2001). The Chief Scientific Adviser to the British Government has suggested that climate change is the most severe problem being faced today (King 2004). In 2003, in France and the United Kingdom (UK), 20 000 people died as a consequence of an unprecedented heat wave that the French Ministry of the Environment expects to occur henceforth every three to four years. By 2080, extreme tidal events that are now expected in the UK once every 100 years could be occurring every three years, and 3.5 million people could be at "high" risk of flooding, with hundreds of millions at risk world-wide (King 2004). The distribution and phenology of a wide range of biota have been affected by changing weather over recent decades world-wide (Parmesan & Yohe 2003, Root *et al*. 2003).

The UK, with its extensive coastline and low-lying land, is internationally important for its wintering waterbird populations. This paper concentrates on the Sub-order Charadrii or waders (shorebirds), of which the UK holds over 20% of the flyway populations of 10 species (Rehfisch *et al*. 2003a). World-wide, 103 out of 207 wader populations with known trends are probably extinct or in decline for reasons that are unclear (International Wader Study Group 2003, Stroud *et al*. 2006). In Great Britain, the numbers of eight out of 14 common species of wintering wader are in decline (Rehfisch *et al*. 2003a), with particularly large declines being apparent on non-estuarine coasts (Rehfisch *et al*. 2003b). Waders include the world's longest-distance migrants, with some breeding in the circumpolar tundra and wintering in the Southern Hemisphere. These "integrators" of change could be particularly prone to the effects of factors, such as climate change, that occur on vast spatial scales (Piersma & Lindström 2004). In the UK, it has been suggested that declines may be due to a combination of factors that include habitat changes resulting from land-claim, dredging, loss of saltmarsh and urbanization (Goss-Custard *et al*. 1995, Dolman & Sutherland 1995), shell-fisheries (Atkinson *et al*. 2003), human disturbance (Liley 2000, Burton *et al*. 2002), and water abstraction. Furthermore, recent legislation that is limiting the amount of organic nutrients entering coastal waters could be lowering the biomass of the invertebrate prey of waders (Burton *et al*. 2003).

Principally using the example of the present and predicted future situation in the UK, this paper briefly reviews climate change itself, and considers its effects on sea level and coastal geomorphology, on the plant and invertebrate food resources and habitats of waterbirds, and on the waterbirds themselves. The possible mitigation of any adverse effects within present legal frameworks is considered, and research priorities that could help make it possible to develop scenarios of the likely effect of climate change on waterbirds are identified.

REVIEW

Climate change

In the UK, summer and winter isotherms increase from north to south, and east to west, respectively. During the twentieth century, temperatures in central England rose by almost 1˚C, and the decade of the 1990s was the warmest since records began in the 1660s. Average sea level is rising by about 1 mm per year, and winters across the UK have been getting wetter, with a larger proportion of the precipitation falling on days of heavy rainfall (Hulme *et al*. 2002a). Average minimum temperatures increased by about 1.5˚C between 1984/85 and 1997/98 (Austin & Rehfisch 2005).

Some degree of further climate change is inevitable over the next 30-40 years as a consequence of past and present emissions of greenhouse gases and the inertia of the climate system. However, the greenhouse gases emitted over the next few decades will influence the climate of the second half of the twenty-first century and beyond. Based on future global emissions of greenhouse gases, Hulme *et al*. (2002a, 2002b) detail four scenarios (low emissions, medium-low emissions, medium-high emissions and high emissions) of how climate change will affect the UK climate by 2020, 2050 and 2080. By 2080, under the medium-high emissions scenario, the UK climate will become warmer by 2.3-3.2°C. Warming will be greatest in the south and east and in the summer and autumn. Temperatures in coastal waters will increase, and very cold winters will become increasingly rare. Winters will become wetter and summers drier. By 2080, summer soil moisture may be reduced by over 40% over large parts of England, while snowfall will decrease on average by 60-90% in Scotland. Heavy winter precipitation will become more frequent. The relative sea-level rise around the UK will vary according to local isostatic forces, and will range from -2 to 86 cm above the current level in Britain. Under the medium-high emissions scenario, extremely high sea levels could occur 10-20 times more frequently by the 2080s than at present.

Coastal geomorphology

The present coastal configuration of the UK reflects unregulated pre-twentieth century development. In England alone, over 860 km of soft cliffs are protected from erosion (23% of the coastline), and in excess of 1 259 km of sea-defences provide flood protection for 2 347 square km of embanked lowlands where over two million people live and half of the highest-grade agricultural land is found (Crooks 2004). The remaining coastal natural resources, including coastal birds, are suffering from a sustained net decline largely related to coastal squeeze of inter-tidal habitat (Carpenter & Pye 1996). Large-scale coastal landforms are currently adjusting to two major perturbations: rising sea level and the loss of flood plains with their hydraulic functions (Crooks 2004). Because of the land-ward migration of coastal landforms, coastal “roll-over” and the redistribution of sediments, maintaining the coast in its present state is not possible. The existence and quality of certain landforms, such as dune-fields and shingle ridges, are dependent upon allowing natural migration. Management intervention to prevent migration will result in degradation of the natural form of these systems and their associated biodiversity values. Maintaining fixed flood defences will, with rising sea level, result in the loss of many of the inter-tidal foraging grounds of the UK’s waders unless a policy of land ward coastal realignment is enacted. Such a policy, however, would conflict with the maintenance of freshwater lowland habitats (Lee 2001) and the interests of a human population with assets entrenched behind flood defences.

Plant and invertebrate resources

Salt-marshes are areas of high primary productivity subject to tidal inundation. Their greatest significance for coastal birds is probably as the base of estuarine food webs, for salt-marshes export considerable amounts of organic carbon to adjacent habitats, particularly to the invertebrates of mudflats; in addition, they provide sites for feeding, nesting and roosting (Hughes 2004). Climate change can affect salt-marshes in a number of ways, including through sea-level rise. When the sea level rises, the marsh vegetation moves upward and inland, but sea-walls that prevent this lead to coastal squeeze and loss of marsh area. However, evidence from south-east England indicates that sea-level rise does not necessarily lead to loss of marsh area, for marshes accrete vertically and maintain their elevation with respect to sea level, where the supply of sediment is sufficient. Lower down the shore, the abundance and productivity of brown algae is likely to decrease as the climate warms and the increasing size of waves and frequency of storms increase exposure (Kendall *et al*. 2004). This would represent a loss of feeding grounds for species such as Ruddy Turnstone *Arenaria interpres* that feed on invertebrates associated with the seaweed. Furthermore, algal debris exported to sediments boosts the production of bacteria at the base of the food web.

In the British Isles, some coastal invertebrates live close to the geographical limits of their distribution. With climate change, some of these southerly species might be expected to extend their range as climatic restraints are relaxed (Kendall *et al*. 2004). In most cases, the effects on the distribution of waterbirds are likely to be small; for example, the replacement of the northern limpet *Patella vulgata* by the southern *Patella depressa* is unlikely to have an adverse effect on predators such as Eurasian Oystercatchers *Haematopus ostralegus*. An increase in sea level will only have a major impact on the extent of invertebrate communities on rocky shores, where shore topography prevents the upward migration of the biota. Where a seawall limits shores, for example, biological production will be curtailed as the area available for colonization decreases. However, environmental cues control or synchronize the reproductive cycle of many marine invertebrates, and climate change will modify the relationship between temperature and photoperiod (Lawrence & Soame 2004). It is uncertain whether such invertebrates, the major prey of overwintering coastal birds, will be able to adapt sufficiently rapidly to changing conditions to avoid major population change and local extirpations.

Waterbird phenology

Meta-analyses confirm the changing phenology of bird populations (Parmesan & Yohe 2003, Root *et al*. 2003). The timing of arrival and breeding of migrant waders in the UK can be responsive to ambient temperatures and, where long-term trends exist, they can often be explained by trends in climate. Records of the first arrival of Common Sandpipers *Actitis hypoleucos* at four bird observatories around the British Isles show no trend over time or relationship with spring temperatures (Loxton & Sparks 1999). Similar results are obtained for the Common Sandpiper, Eurasian Oystercatcher, Northern Lapwing *Vanellus vanellus* and Common Redshank *Tringa totanus* in north-east Scotland over the period 1974-1999, although the arrival date of the Eurasian Curlew *Numenius arquata* became 25 days earlier (Jenkins & Watson 2000). Between 1950 and 1998, the first arrival dates of Little Ringed Plovers *Charadrius dubius* and Whimbrels *Numenius phaeopus* in south-east England became earlier by six and 22 days per decade, and three and six days per °C in relation to mean January to March temperatures, respectively (Sparks & Mason 2001). In a study that included seven species of waterbirds wintering in Britain, the duration of stay did not change, but the first arrival date of Tundra Swan *Cygnus columbianus* advanced by seven days per decade, while that of Jack Snipe *Lymnocryptes minimus* regressed by six days per decade, between 1966-67 and 2000-01 (Sparks & Mason 2004).

In the UK, the Common Ringed Plover *Charadrius hiaticula* exhibits no overall trend in laying date between 1944 and 1995. However, its laying date has become earlier in relation to mean monthly temperatures at a rate of 1.1 days per °C, the temperatures in the relevant months showing little trend over time (Crick & Sparks 1999). Although the Eurasian Oystercatcher demonstrates a curvilinear trend in average laying date between 1962 and 1995 (peaking in the mid-1970s), this is not related to temperature, but partially to precipitation in May, becoming earlier at the rate of 0.06 day per mm.

Waterbird distributional shifts

The breeding distributions of some British birds have extended northwards with climate change (Thomas & Lennon 1999). Eurasian Golden Plover *Pluvialis apricaria* and Common Sandpiper populations in the Pennine Mountains of England fluctuate in relation to changes in the North Atlantic Oscillation (NAO), a meteorological feature that determines the weather affecting north-west Europe (Forchhammer *et al*. 1998). Eurasian Golden Plover numbers increase two years after warm and moist winters, presumably as a result of improved juvenile survival. Common Sandpiper numbers increase after cool, dry winters, perhaps due to changes in food supplies or habitat on their African wintering grounds.

The distribution of wintering waders in Britain has changed since the 1970s (Austin *et al*. 2000). Since the mid-1980s, with an increase of 1.5°C in the mean winter temperature in the UK, the estuarine distributions of seven out of nine common wader species have moved in an eastwards direction across the winter isotherms (Fig. 1), with the smaller species showing the greatest shifts, as is expected if mediated by temperature (Austin & Rehfisch 2005). Between the 1984-85 and 1997-98 winter surveys of Britain's non-estuarine coasts, the distributions of eight wader species moved in an eastwards and/or northwards direction with increasingly mild winter temperatures and changes in mean rainfall, wind speed and wind-chill (Rehfisch *et al*. 2004). In both instances, the waders appear to be wintering closer to their breeding grounds, which are predominantly to the north and east of Britain, as milder winter weather has diminished the risk of cold-induced mortality in the colder east. The recent decline in eight of the 14 species of common coastal waders in Britain (Rehfisch *et al*. 2003a, 2003b) could be due to the waders now wintering even further to the north and east, on the European mainland (Rehfisch & Crick 2003).

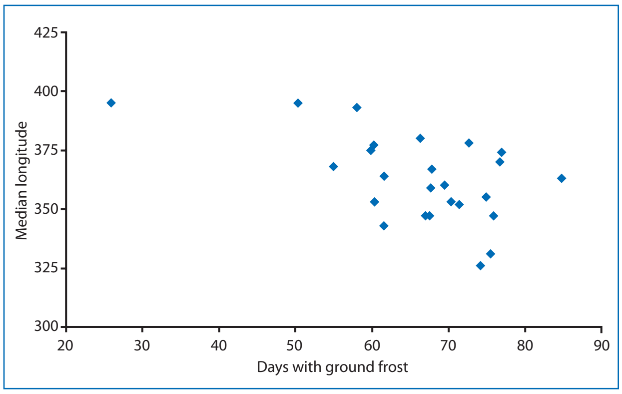

Fig. 1. Relationship between the median longitude of Common Ringed Plover *Charadrius hiaticula* distribution in Britain and the average number of days with ground frost recorded across 39 British weather stations (Rehfisch & Austin 1999).

Conservation implications for waterbirds

Waders are designated features of Special Protection Areas (SPAs) that regularly hold one percent or more of their flyway population or British wintering population, the international and national thresholds, respectively (Baker & Stroud 2006). As wader distributions in Britain change with climate change, the numbers of some species at some British SPAs are dropping below the thresholds upon which the designations are based. For example, the number of Dunlin *Calidris alpina* wintering on the Severn Estuary has dropped from an average count of over 40 000 in the mid-1970s to below the international threshold of 14 000 in recent winters up to and including the winter of 2000-01 (Austin & Rehfisch 2005). This is not an isolated example. Many species of wader are declining more rapidly in the west of Britain than in the east, as illustrated by the Common Ringed Plover (Fig. 2: Austin *et al*. 2004).

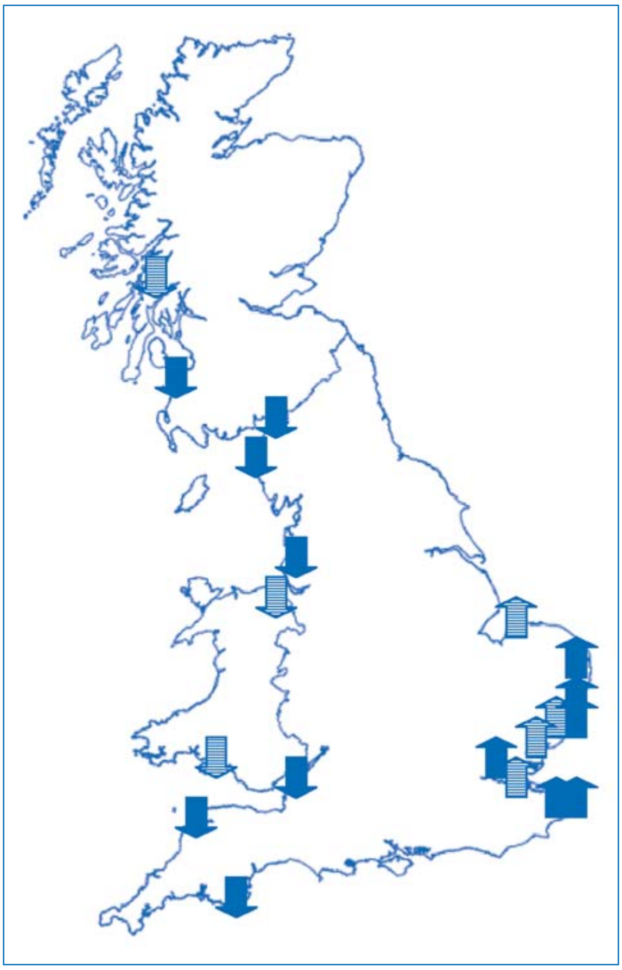

Fig. 2. Change in Common Ringed Plover *Charadrius hiaticula* numbers on Britain's SPAs designated for the species (Austin *et al*. 2004). Upward- and downward-pointing arrows indicate SPAs where numbers increased and decreased between 1994-95 and 1999-2000, respectively; filled and hatched arrows indicate changes of 50% and 25% in smoothed numbers during that period, respectively.

Scenarios of future change

Hughes (2000) suggests that the challenge for ecologists, physiologists and land managers is to predict the effects of human-induced climate and atmospheric change on species and on communities. Such predictions should include effects on physiology, distribution, phenology and individual adaptation. Whereas it is impossible to predict accurately future responses of biota to climate change, it has become acceptable to suggest a range of scenarios of possible change (Lawton 1996, Danell *et*

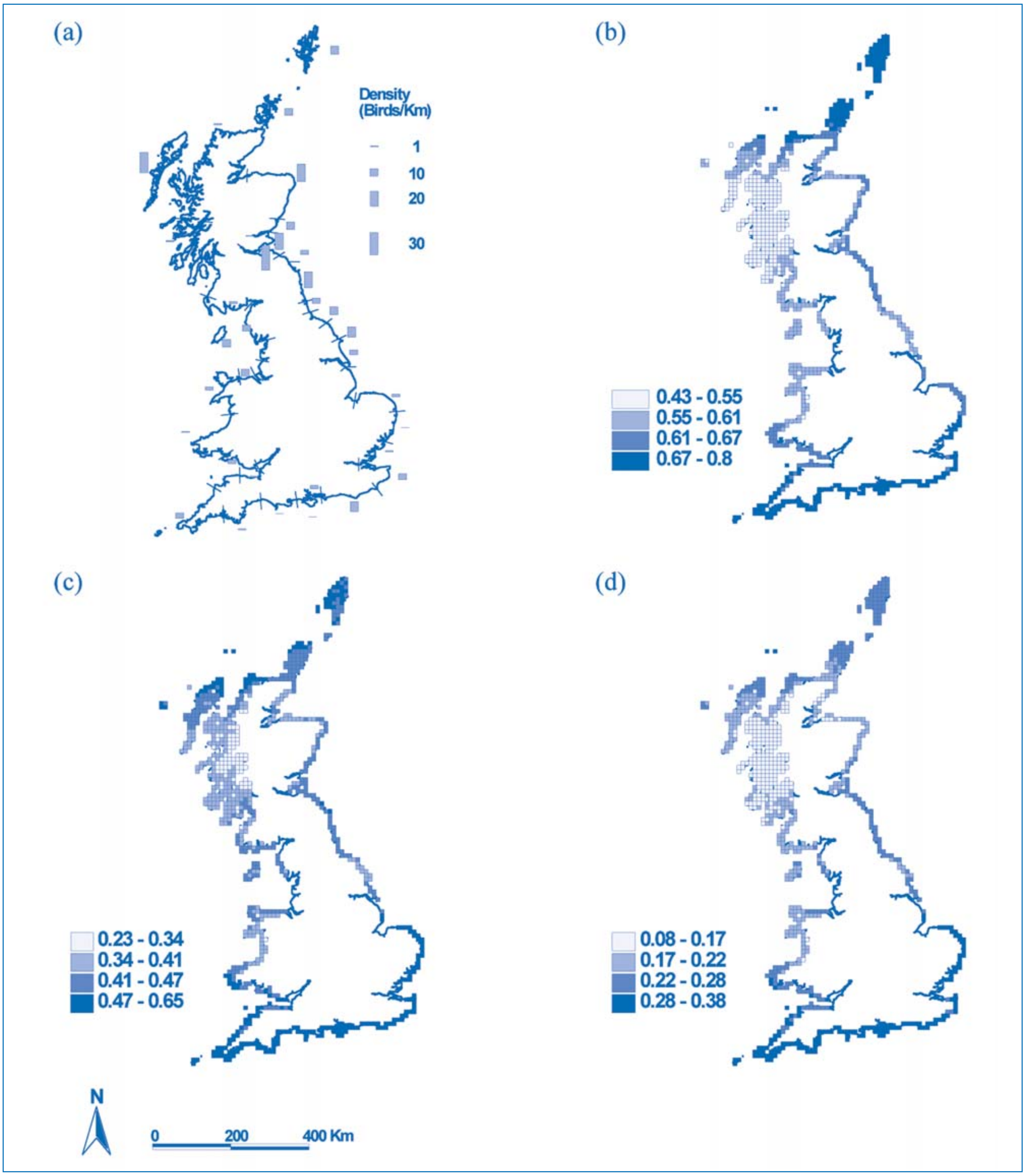

Fig. 3. (a) Ruddy Turnstone *Arenaria interpres* densities on the non-estuarine coast of each of Great Britain's counties during the winter of 1984-85; and (b) to (d) predicted relative change in their numbers at a scale of 10-km square under various UKCIP climate change scenarios: (b) 2020 medium-low versus 1961-1990 baseline; (c) 2080 medium-low versus 1961-1990 baseline; (d) 2080 high versus 1961-1990 baseline. 1 = no change, <1 = decrease, > 1 = increase (Rehfisch *et al*. 2004). All changes in (b) to (d) are <1, thus indicating declines.

al. 1999). However, modelling the future status of waterbirds or any other biota under climatic conditions that are out of the range of human knowledge is a major challenge. To develop realistic models of the likely effect of climate change on waterbirds that can migrate annually over huge distances, the factors and interactions that influence their demographics must be much better understood than at present (Rehfisch & Crick 2003, Piersma & Lindström 2004). For example, the single issue of time-lag leading to phenological disjunction is of considerable conservation importance (Sutherland 2004), since climate change is expected to occur very rapidly (Houghton *et al*. 2001), and yet there is much uncertainty as to whether biota have the capacity to respond sufficiently quickly and whether habitat responses will take years or centuries. Examples of biota finding it difficult to remain in step with their environment already exist. Although Great Tits *Parus major* can lay earlier in response to early, warm spring weather, often in parallel to the emergence of the caterpillars of winter moths on which they feed their young (Perrins 1991), they cannot significantly decrease their incubation period. However, the caterpillars can halve their development time in sufficiently warm weather, leading to an early shortage of food for young Great Tits (Buse *et al*. 1999). There is also some evidence that long-distance migrants have not responded as rapidly to climate change as short-distance migrants (Jenkins & Watson 2000, Penuelas *et al*. 2002).

Scenarios of how biota may change with climate change already exist, but their value is dependent on critical assumptions being met. Three examples are discussed. First, Austin and Rehfisch (2003) use habitat association models to suggest that in 2020 and 2050, sufficient estuarine habitat will be available to sustain the present numbers of waterbirds wintering in the UK under four UK Climate Impacts Programme (UKCIP) scenarios of sea-level rise. For these predictions to be correct, the present associations between estuarine morphology and habitat must remain true in the warmer future, and habitats must continue to hold at least the present quantity of the resources of waterbirds. Rehfisch *et al*. (2004) tentatively suggest that the numbers of some wader species wintering on the UK's non-estuarine coasts may decline considerably under the 2080 UKCIP scenarios (Fig. 3). However, for these scenarios of decline to be correct, at the very least the observed relationships between weather and wader distributions must continue to hold true outside of the present range of weather, and flyway wader populations must be large enough to provide sufficient numbers of potentially overwintering individuals. Finally, to help guide UK conservation policy, the MONARCH project (Monitoring Natural Resource Responses to Climate Change) was established to attempt to predict how biodiversity will change with climate change. The first set of MONARCH predictions, based on a bioclimatic approach, took no account of plant and animal dispersal capabilities, geographical impediments to movement, and changing socio-economic conditions with a warming climate (Harrison *et al*. 2001). Subsequent regional predictions have addressed some of these factors, but the dispersal capacity of the organisms and phenological disjunction that may occur between interdependent species remain to be considered. Thomas *et al*. (2004) may also be underestimating the scale of future extinction of species, as their work also suffers these limitations. At best, without major information gathering to increase the reliability of model parameters, such scenarios of change can only be broadly indicative of what could happen, and must be treated with caution.

DISCUSSION AND CONCLUSIONS

Climate is changing now (Houghton *et al*. 2001, Hulme *et al*. 2002a, 2002b), and its effect on biota is apparent world-wide (Parmesan & Yohe 2003, Root *et al*. 2003). Waterbirds are, and will continue to be, increasingly affected by rising temperatures and rising sea levels that change their habitat (Crooks 2004) and the communities of plants and animals on which they depend (Hughes 2004, Kendall *et al*. 2004, Lawrence & Soame 2004). These changes are reflected in existing changes in waterbird phenology (Cricks & Sparks 1999, Rehfisch & Crick 2003, Crick 2004, Sparks & Mason 2004) and distributional shifts (Austin *et al*. 2000, Rehfisch *et al*. 2004, Austin & Rehfisch 2005). However, much of the basic information necessary to describe the existing effects of climate change on waterbirds, quite apart from allowing the development of realistic predictions to be made, is missing. Existing analyses have been patchy. For example, distributional changes with changing weather have been described for wintering waders, but not for other wintering waterbirds such as swans, geese and ducks. Only recently have wider scale analyses started to determine whether there is evidence that similar winter distributional shifts are occurring outside the boundaries of the UK and into Continental Europe. There has been no attempt to detect large-scale distributional changes in breeding waterbirds with changing weather. A few changes in the arrival and departure dates of migrant waterbirds have been described, but no systematic attempt has been made to analyse the main data sets of counts of breeding or wintering birds to determine whether there is evidence that changes in phenology are detectable at a national level or in the sequential usage of sites. Critically, no attempt has been made to determine whether the observed changes in wader distributions are causally related to the changes in the weather itself (temperature, Austin & Rehfisch 2005; temperature, precipitation and wind, Rehfisch *et al*. 2004), or whether the weather is having an indirect effect on the waders by affecting their habitat and resources. Increasing temperature has a direct effect on waders by lessening their energy losses and thus their energy requirements (Wiersma & Piersma 1994) and, as such, could allow birds living near the limit of their metabolic requirements (Piersma 1994) to winter in areas previously too energetically expensive. Changing weather can also have indirect effects on waterbirds. For example, increasing temperatures lead to rising sea levels and thus habitat change, as well as changing distributions (Kendall *et al*. 2004) and availability (Pienkowski 1983) of wader invertebrate prey. Determining the causal drivers of change would make it possible to generate more realistic scenarios of changing waterbird numbers with climate change.

Planning for the future

Realistic scenarios of change allow statutory agencies to plan for the future. Understanding how wildlife will react to climate change makes it easier for them to attempt to fulfil their legal obligations towards wildlife on designated sites and to help species at risk of major decline. Already some of the legal tools necessary to protect waterbirds in a changing environment exist (Boere & Taylor 2004), and there is an increasing understanding of how suitable waterbird habitat can be created (Atkinson *et al*. 2004, Zedler 2004). The latter is useful, for example, if bird distributions are changing rapidly at a time when rapid sea-level rise is leading to major habitat loss.

Scenarios of change can (i) allow generally scarce conservation resources to be effectively targeted at priority species, (ii) concentrate the public's attention on the effects of human-induced climate change on wildlife (e.g. Thomas *et al*. 2004) and by extension themselves, and (iii) following raised public awareness, make it easier for politicians to take action that may be unpopular with voters.

However, much work is necessary before scenario models inspiring confidence can be generated. If the future weather scenarios of the Intergovernmental Panel on Climate Change (IPCC) are correct, the predictions will have to be made for climatic conditions not yet encountered, making it particularly difficult to predict accurately the likely scale of changes to waterbirds and other biota. The development of scenarios will be particularly complex for waterbirds, as the scenarios will have to allow for events occurring on often spatially extensive flyways.

Opportunities

Assuming that the IPCC future weather scenarios are broadly correct, the Earth is about to change radically with possibly largely disastrous consequences for humans and the first human-induced massive extinction of biota (Thomas *et al*. 2004). Even with a complete and immediate switch to renewable energy, the Earth would continue to warm and sea level to rise for decades due to the time lags within atmospheric systems. Solutions to the effects of climate change on waterbirds and other fauna require changes in human behaviour. A useful first step would be to radically change the discounting philosophy that gives a very low value to long-term benefits and makes politicians reluctant to affect present economic growth for even major long-term benefits (Henderson & Sutherland 1996).

A change in the direction of the economy presents great opportunities for technological development in almost all fields of human endeavour, including renewable energy, energy conservation and thus car, house and industrial design, and agriculture. This would provide a major stimulus for growth, and the fact that countries are largely rejecting this opportunity is disappointing. The excuse that reducing carbon emissions makes humans poorer is apparently false: between 1990 and 2000, Great Britain's economy grew by 30%, employment increased by 4.8% and yet the intensity of greenhouse gas emissions fell by 30% and overall emissions fell by 12% (King 2004).

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