Climate Change Research: Evaluation and Policy Implications
S. Zwerver, R.S.A.R. van Rompaey, M.T.J. Kok and M.M. Berk, (Eds.)

The effect of sea level rise on a migratory wader

B.J. Ens[a] and J.D. Goss-Custard[b]

[a]Institute for Forestry and Nature Research (IBN-DLO), P.O. Box 167, 1790 AD Den Burg, The Netherlands

[b]Institute for Terrestrial Ecology (ITE), Furzebrook Research Station, Wareham, Dorset BH20 5AS, United Kingdom

Abstract

To investigate the possible effects of sea level rise on the migratory waders that depend on the Wadden Sea for their survival, we chose the well-studied Oystercatcher (*Haematopus ostralegus*) as a representative of a short-distance migrant. The total population size is modelled as an equilibrium between density-dependent mortality during winter and density-dependent reproduction during summer. Loss of winter habitat will increase mortality in winter and reduce population size. Even under extreme current scenarios of sea level rise, the negative effects on population size seem small. However, the current model ignores effects of temperature, which may affect winter habitat quality through its known effects on the population dynamics of the prey, and the possible effects of changes in breeding habitat.

1. INTRODUCTION

The Wadden Sea is renowned worldwide for its importance as a breeding, wintering, and, especially, staging area for migratory waterbirds. A significant proportion of at least 52 distinct populations of 41 species of waterbirds utilize the Wadden Sea at some stage in their annual cycle and in 8 cases this involves no less than the entire world population [1]. For these birds the Wadden Sea is a vital link in their migrations along what is generally referred to as the East Atlantic Flyway. To conserve this rich nature area, the three Wadden Sea countries Denmark, Germany and the Netherlands have taken many protection measures over the last two decades. For instance, the Wadden Sea is recognized as the most important nature area of the Netherlands in the Physical Planning Decision (PKB) for the "Waddenzee" and 2000 km^2 are protected under the Nature Conservation Act. Internationally, it has been given the status of "Wetland of international importance" under the Convention of Ramsar, and it is recognized as a Biosphere Reserve by UNESCO. Very recently, a new potential threat to the system has appeared that might have disastrous consequences: global climate change. Due to the magnitude of its effects, global climate change could easily wipe out all progress that has been made so far in conserving the Wadden Sea. As formulated by Peters [2] " What is clear .. is that the climatological changes would have tremendous impact on communities and populations isolated by development and, by the middle of the next century, may dwarf any other consideration in planning for reserve management."

In an early appraisal of the problem for marine coastal ecosystems, Beukema et al. [3] took the necessary first steps of making an inventory of present knowledge, identifying uncertainties and formulating research needs. Although apparently nobody seriously suspects an effect of heightened levels of UV-B on migratory birds, the diversity of hypotheses on the effects of climate change on bird migration is nonetheless bewildering [4-6]. To fight this chaos we need a conceptual framework that allows us to answer a set of interrelated but precise questions, like:

1. Which aspects of the climate change or secondary effects will have the greatest impact: global warming, storms, rainfall patterns, sea level rise?
2. At what stage of the life cycle of the birds does the climate change or climate-induced effect operate: breeding season, autumn migration, spring migration, nonbreeding season?
3. Which processes must be considered: vagaries during the migratory flight, interspecific competition between resident and non-resident species, intraspecific competition on the breeding grounds, intraspecific competition on the wintering grounds, phenology of the food supply, evolution of the migration schedule?

We apply the conceptual framework described by e.g. Goss-Custard [7] and Ens et al. [8], which emphasises the importance of individual-based concepts for understanding population processes, to construct mathematical models with a strong empirical basis. Ideally, the models allow us to calculate the effect on the population for a given climate scenario. Space limitations do not permit us more than a brief description of one example: the potential effect of sea level rise on the population dynamics of the oystercatcher *Haematopus ostralegus*, i.e. we do not report on our work on the long-distance migrants.

2. MODEL DESCRIPTION

The basic idea of the model is that both reproduction in summer and mortality during winter are density-dependent.

The primary source of density-dependence in summer is assumed to result from territorial exclusion, i.e. relatively fewer birds breed when the density of potential breeding birds increases. We express the proportion excluded as a k-value: $k = a_T + b_T \log_{10} N$, where N is the number of potential breeding birds and the slope b_T measures the compressibility of the territories. When $b_T = 1$, the territories cannot be compressed any further so that, above the number set by the intercept a_T, a constant number of pairs breed, irrespective of the numbers attempting to do so. Thus, $b_T = 0$ implies no density dependence and $b_T = 1$ implies perfect 'contest' density dependence. We do not allow $b_T < 0$.

The primary source of density-dependence in winter is decreased survival chances due to competition for food. At low densities, there is no competition, but only a density-independent proportion (m_W) starving. When bird density increases, eventually a point, c_W, is reached at which mortality begins to increase and so becomes density-dependent. From then on, mortality increases by b_W for every unit increase in bird density.

We estimated these parameters for each sub-population and, where necessary, age class. Furthermore, we knew the size for each of the four sub-populations that we distinguished: Continental coastal, Continental inland, Atlantic coastal and Atlantic inland. Within the Continental and Atlantic regions, inland-breeding and coastal-breeding sub-populations use the same coastal areas in winter. Finally, the sometimes quite substantial annual fluctuations in the main production and mortality parameters were generally not correlated across sites within a sub-population. This allowed the standard deviations of the annual variations in these parameters to be estimated for both sub-populations in each region so that realistic annual variations could also be included in the model. For more details we refer to [9].

3. MODEL SIMULATIONS

In the model the effect of loss of winter habitat is simulated by removing an increasing proportion of the winter habitat and thus, initially, increasing the density of birds on the wintering grounds. Simulations over a range of probable parameter values show that the density at which winter mortality becomes density dependent, c_W, simply determines the point at which population size is affected as habitat is gradually removed. The population is affected sooner in the more widely fluctuating Continental sub-populations than in the less variable Atlantic sub-populations. Once winter density reaches c_W, the consequences depend on the slope, b_W, of the density-dependent winter mortality function. In all sub-populations, the reduction in population size increases sharply as b_W increases, but only at low values; above a certain level, further increases in b_W make less difference. Because of their higher reproductive rate, inland sub-populations are initially less affected by winter habitat loss than coastal sub-populations. These conclusions are robust over a range of assumptions about competition for territories in summer and age differences in mortality in winter [10]. However, the conclusion that inland sub-populations are initially less affected by winter habitat loss depends very much on the assumption that coastal and inland birds compete on equal terms on the wintering grounds. Work is in progress to test the hypothesis that coastal birds may actually be at an advantage, because, as residents, they are likely to dominate their migratory conspecifics. It is unlikely though that our conclusions on the effects of winter habitat loss on the total population size would be greatly altered if this hypothesis was found to be true.

4. THE EFFECT OF SEA LEVEL RISE

Given these and other uncertainties in parameter values it is not possible to arrive at a precise prediction of the change in population size under different climate scenarios. However, within the large range of parameter values assessed, there were no cases where population size increased following loss of winter habitat, a theoretical possibility according to Fretwell [11]. Furthermore, it was generally true that the equilibrium population size decreased by a smaller percentage than the reduction in surface of winter habitat. This was especially true for small reductions of winter habitat. Thus, if habitat loss is small, reduction in population size will be even smaller.

Under the most extreme scenario of a sea level rise of 85 cm during the next century, the calculations of Louters and Gerritsen [12] indicate that the overall surface area of the Dutch Wadden Sea flats will not change significantly in the next fifty to a hundred years; in the order of 1% of the intertidal area will be lost. Even if this estimate is out by a factor of 10 it seems unlikely on the basis of the above that the equilibrium population size would be reduced by more than 5%.

5. CONCLUSION

Although we think it unlikely that oystercatchers will suffer much from sea level rise, it would be premature to conclude that they are not affected by climate change. The model is able to handle changes in breeding habitat, but we did not include such changes in the scenario calculations. More importantly, we did not allow for possible changes in the quality of the remaining habitat. Simulations with an individual-based physiologically-structured game theoretic model show that deteriorating habitat quality can greatly reduce population size [13]. Thus, our current model cannot handle changes in the population dynamics of the bivalve prey. Recruitment in these prey species depends strongly on temperature [14]. We are currently extending the oystercatcher population model to include the dynamics of the prey. The extended oystercatcher population model will also allow evaluation of the effects of other man-induced habitat changes, like shellfisheries.

6. REFERENCES

1 H. Meltofte, J. Blew, J. Frikke, H.-U. Rösner, and C.J. Smit, Wader Study Group Bulletin, 74 (1994) 1.

2 R.L. Peters, pp. 99-118 in R.L. Wyman (ed.), Global Climate Change and Life on Earth, Chapman and Hall, New York, 1991.

3 J.J. Beukema, J.J. 1990. pp. 83-92 in J.J. Beukema et al. (eds.), Expected Effects of Climatic Change on Marine Coastal Ecosystems, Kluwer Academic Publishers, Dordrecht, 1990.

4 J.D. Goss-Custard, S. McGrorty and R. Kirby, pp. 189-193 in J.J. Beukema et al. (eds.), Expected Effects of Climate Change on Marine Coastal Ecosystems, Kluwer Academic Publishers, Dordrecht, 1990.

5 R.T. Lester, and J.P. Myers, J.P., pp. 119-133 in R.L. Wyman (ed.), Chapman and Hall, New York, 1991.

6 P. Berthold, Bird Migration: a general survey, Oxford University Press, Oxford, 1993.

7 J.D. Goss-Custard, Bird Study 40 (1993) 81.

8 B.J. Ens, T. Piersma and R.H. Drent, Ophelia Suppl. 6, (1994) 127.

9 J.D. Goss-Custard, R.T. Clarke, K.B. Briggs, B.J. Ens, K.-M. Exo, C.J. Smit, A.J. Beintema, R.W.G. Caldow, D.C. Catt, N Clark, S.E.A. le V. dit Durell, M.P. Harris, J.B. Hulscher, P.L. Meininger, N. Picozzi, R. Prys-Jones, U.N. Safriel and A.D. West, J. appl. Ecol. 32 (1995) in press.

10 J. D. Goss-Custard, R. T. Clarke, S.E.A. le V. dit Durell, R.W.G. Caldow and B.J. Ens, J. appl. Ecol. 32 (1995) in press.

11 S.D. Fretwell, Populations in a seasonal environment, Princeton University Press, Princeton, 1972.

12 T. Louters and F. Gerritsen, report RIKZ-94.040.

13 J.D. Goss-Custard, R.W.G. Caldow, R.T. Clarke, S.E A. le V. dit Durell and W.J. Sutherland, J. Anim. Ecol., 64 (1995) in press c.

14 J.J. Beukema, K. Essink, H. Michaelis and L. Zwarts, Neth. J. Sea Res. 31 (1993) 319.