Predicting species' responses to climate change – the importance of ecological detail

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Climate Change and Migratory Species'

• By 2099 global surface temperatures are predicted to increase by 1.8 to 4 °C, accompanied by increases in the frequency of extreme weather events, the rate of sea level rise and contractions of snow cover (IPCC 2007)

•Such changes in climate present particular challenges to migratory species, as the impacts in the breeding, staging and wintering areas, may operate in different manners, extents and even directions.

Migratory shorebirds are a good model for determining the importance of ecological detail in predictive models of the impacts of climate change.

Climate Envelope Modelling

•"Climate Envelope" modelling has been given much attention in recent years as a tool for making predictions of distributional changes in response to climate change (e.g. Berry *et al* 2002, Pearson *et al* 2002).

•While these simple models are easy to parameterise they make a number of assumptions, many of which limit their predictive power (for reviews see e.g. Hampe 2004; Guisan and Thuiller 2005).

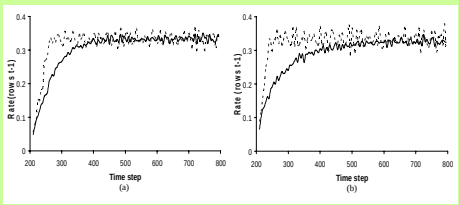

Figure 1 – Rate of movement of the leading (solid lines) and trailing (dashed lines) edges of the occupied range where latitudinal habitat quality affects:

(a) the probability of colonisation,

(b) the probability of extinction.

The rate of climate change is 0.25 rowst-1.
From Mustin et al (a)

A New Generation of Predictive Models

- In recent modelling we have explored the effect of spatial structuring of a metapopulation along a gradient, on the dynamics of range shifting during a period of climate change (Mustin et al (a)-Submitted).

The results show that:

1. the rate of range shifting during such a dynamic period is unlikely to be constant
2. in the case of this type of spatial structuring the rate increases through time (Figure 1).
3. Importantly, the occupied range fails to keep pace with the location of the suitable "climate window" (Figure 2).

References

•Berry et al (2002). *Global Ecol. Biogeogr.*, 11, 453-462;
•Guisan & Thuiller (2005). *Ecol. Lett.*, 8, 993-1009;
•Hampe (2004) *Global Ecol. & Biogeogr.* 13, 469-76;
•IPCC (2007) http://www.ipcc.ch/SPM2feb07.pdf;
•Mustin et al (a) (Submitted) A metapopulation perspective on climate-induced range shifting dynamics. *Oikos;*
•Mustin et al (b) (In review) The complexities of predicting climate-induced ecological impacts. *Climate Research* (special edition "Bird migration and climate change");
•Pearson et al (2002). *Ecol. Model.*, 154, 289-300.

Migratory Shorebirds: A Case Study

•In a recent review we examine the mechanisms by which climate change can impact upon the population size of migratory shorebirds (Fig. 3 from Mustin et al (b)-In Review).

•It is not feasible to incorporate this level of complexity in to predictive models, however this is an important first step in ranking the relative importance of ecological interactions in determining species' responses to climate change.

•For migratory shorebirds we highlight changing vegetation structures and reduced water availability as key factors due to their dependence on arctic tundra and wetlands as breeding habitats. We also stress the importance of socio-economic and policy responses in governing these changes, and so ultimately shorebird population size and distribution.

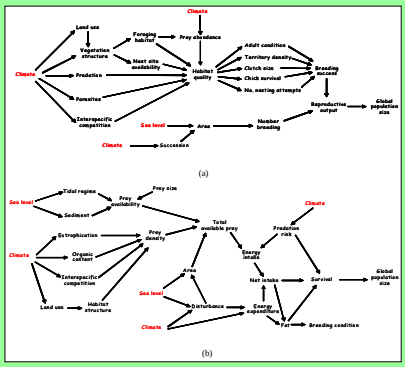

Figure 3: Mechanisms of climate change impacts on shorebird population size during the (a) breeding season and (b) non-breeding season.
From Mustin et al (b)

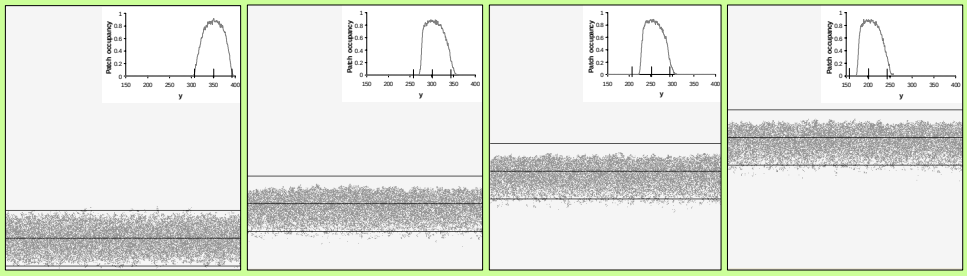

Figure 2 – Simulations showing the extent of the occupied range, the position of the optimum climate and the "climate window" at time steps 200, 400, 600 and 800.

The three black lines on this figure indicate the position of the climate optimum (the middle line) and the position of the climate envelope, the shaded areas represent occupied patches, white areas are unoccupied.

The occupied range falls further behind the "climate window" through time until the rate of movement has increased to match the rate of climate change, and the range then keeps pace, though it is still geographically mismatched with the area of suitable climate.
From Mustin et al (a)