WOODS HOLE OCEANOGRAPHIC INSTITUTION

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Research statement

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As a field and mathematical ecologist, I have been studying the population responses to climate change since my doctorate. During my PhD with Dr. Weimerskirch at the Centre d'Etudes Biologiques de Chizé (CEBC, France), internationally recognized for its research on marine mammals and seabird ecology, I focused on understanding the processes by which populations respond to climate change among a community of Antarctic seabirds. Then, during my post-doctorate at WHOI with Dr. Caswell, I predicted the population responses to future climate change by linking demographic models to climate projections used in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). Thanks to a CIRES visiting fellowship, I am currently working with climatologists at the National Snow and Ice data Center and National Center of Atmospheric Research in Boulder, to develop skills to adequately select the spatial scale and the climate models and eventually predict population responses to future climate change.

A) Context and previous work

In the face of climate change, there is a growing demand for accurate forecasts of its environmental, ecological and societal impacts. The objective of my researches is to understand and predict the population responses of wildlife to present and future climate changes.

Understanding the population responses to current climate change

I showed during my PhD that sea ice extent (SIE) affects the demographic traits of Antarctic seabirds and thus their population dynamics (Jenouvrier et al. 2003, 2005a,b, 2006). Population responses are different among species according to their life history, some species being more sensitive than others. For example, penguins are more sensitive to decrease in SIE than petrels. Emperor penguins breed almost annually and their adult survival decreases during year with low SIE (Jenouvrier et al 2006). On the contrary, petrels skip reproduction during years with low SIE rather than compromising their survival and future opportunities to reproduce.

Predicting the population responses to current climate change

To project the population responses to climate changes, it is crucial to couple demographic models based on long-term studies and IPCC climate projections. During my PhD and my post-doctorate, I developed matrix models to describe the demographic processes and eventually the effect of environmental variations on population dynamics. I analyzed statistical models based on capture-recapture data to estimate demographic parameters and their relationships with environmental variables necessary to parameterize the matrix models. To link demographic models with IPCC climate projections, I carefully selected appropriate climate models to reduce climate-related uncertainty and eventually project the emperor penguin population responses to future sea ice changes (Jenouvrier et al. 2009). I showed that the probability of quasi-extinction (a decline of 95% or more) is at least 36% by 2100, and the median population size is projected to decline from approximately 6000 to 400 breeding pairs by 2100.

B) Research proposal

My future work is thus to apply this original and successful approach to others species, to eventually compare the population responses to future climate change. I will select several species that differ according to their life history. For instance, we expect that penguin populations will be more sensitive to future sea ice change than petrel species because petrels can avoid the important costs of reproduction by skipping it during unfavorable years.

Moreover, it is crucial to compare population responses over the entire species range, especially since contrasted warming trends are expected among Antarctic regions. This requires further modeling and development of different approaches because there are few demographic data available for other locations. This requires also developing an international collaborative effort for sharing the data available at different locations, as well as pursuing ongoing field programs. My research project is based on one of the longest datasets on the ecology of seabirds on Earth (supervised by H. Weimerskirch). Moreover, to project Adelie and emperor penguins population responses to future climate change over the entire species range, I developed strong collaborations with Dr. Ainley (Harvey Associate) and Dr. Trathan (British Antarctic Survey) who also supervise long term data set on seabirds. My aim is to develop in collaboration with Dr. Caswell (biology department, WHOI) several modeling approaches.

1) I will develop population models for specific locations and then project populations in response to change in climate for different regions in Antarctica, using climate as a forcing. This relies on the assumption that the demographic estimates and their relationships with climate observed in the specific location are the same in the other locations.

2) I will develop 'climate envelope' models most commonly applied to plants, but also to animals, including many kinds of tropical rainforest vertebrates. Climate envelope models describe the climate encompassing the current distribution of a species (the climatic envelope), and then predict the location of this specific envelope as a response to climate change. I propose to project seabirds species responses based on correlations between selected climate variables (e.g. sea ice coverage and thickness, wind and air temperature) and seabird's habitat features. The advantages of climate envelope models are: *i*) only a few variables are necessary to predict ranges for many species and, *ii*) even small-scale, patchy data can be used. However, these models have a number of limitations and global estimates of extinctions due to climate change may be greatly biased. Therefore my aim is to compare the 'climate envelope model' with the results of population models. Furthermore, I will link these two approaches to improve the accuracy of forecasts of species responses to climate change.

Heretofore the models linking climate scenarios to populations largely ignore evolutionary and ecological mechanisms, which may radically change their predictions. Such ecological processes may alter the prediction based on single species and need to be incorporated in a modelling framework. In addition, organisms may adapt to climate change via different forms of plasticity (e.g. phenotypic plasticity, maternal effects) or by micro-evolution. Evolutionary processes, if fast enough, could potentially lead to adaptation to the 'new climate'. To link the genetic processes, individual behavior and physiology, and species interactions to population dynamics, I therefore developed collaboration with Dr. Visser to link the mechanisms occurring at different levels of biological organization using a periodic matrix population model, which includes the phenotype and genotype of individuals.

The approaches I propose to develop at WHOI for Antarctic seabirds are universal and can be applied to other organisms and systems. The main outcomes of this work will be to provide guidelines and develop original approaches to forecast the effects of climate change on species. Thus, this project will constitute a major breakthrough in our ability to adequately forecast the ecological consequences of future climate changes on populations, communities and ecosystems.

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