National Environmental Research Program

LANDSCAPES & POLICY hub

King Billy Pine. Photo: Natalie Tapson

Modelling species distribution under climate change: it's important to represent uncertainty

- Species distribution models can be used to project whether a species' range or 'climatic envelope' is likely to shrink or otherwise change under different climate conditions.
- However, modelling practitioners often fail to acknowledge the limitations of their choice of climate variables, climate models and emissions scenarios. This failure can substantially affect the conclusions about the impacts of climate change on a species, and can increase the uncertainty in the projections.
- We offer conservation planners a five-step protocol for ensuring they represent the full range of futures.

Research summary

Many species have successfully evolved with changing climatic conditions, but the process can take hundreds of years. As we now face a rapid change in our climate, knowing the locations of areas likely to be climatically suitable for species in the future is crucial for conservation managers and policymakers.

Our review of the literature found that with common approaches to modelling future species distribution under climate change, practitioners often fail to acknowledge the limitations of their choice of climate variables, climate models and emissions scenarios. This can substantially affect the conclusions about the impacts of climate change on a species.

We offer conservation planners a five-step process for ensuring they represent the full range of plausible futures.

Modelling species distribution with climate change

Species distribution models are one of the most important tools available to conservation planners for assessing the potential impacts of climate change on species. They are commonly used to:

- project potential changes in the geographic ranges of species
- estimate extinction rates
- examine how well reserve systems are working
- prioritise efforts to conserve biodiversity.

Species distribution models correlate historical records of where species have been observed with environmental and climatic variables such as seasonal maximum temperature and annual rainfall. They can also be used to project whether a species' range or 'climatic envelope' is likely to shrink or otherwise change under different climate conditions; in this instance, the practitioner's choice of climate variables, climate model projections and emissions scenario can substantially influence the results.

What are climate variables?

Climate variables are used to express a region's weather conditions over the long term — usually over a period of about 30 years.

The climate variables used in species distribution models usually represent climate data that is meaningful to biological processes; for example, the long-term mean annual temperature, seasonal trends, and extremes such as the temperature of the coldest month.

Common approaches to modelling are inadequate

Our review of the literature shows that 119 different variables are in use in species distribution models, the most common being climate variables such as mean annual precipitation and temperature. The three most common approaches used to select climate variables are to:

- select all available climate variables, without justification
- select a subset of variables that are not correlated
- select a set of variables based on ecological knowledge of the species.

With each of these approaches, we found that practitioners often ignored the limitations of their choice of climate variables.

Similarly, practitioners rarely justified their choice of climate model and in most cases presented results for only one climate model or emissions scenario.

Ignoring the limitations of these choices can substantially affect the conclusions about the impacts of climate change on a species.

How to represent the full range of plausible futures

Tailor the variables to the species

Using all available climate variables may lead to an under-estimate in the range of the species and a misleading conclusion that the species is likely to become extinct. For best results, conservation planners should tailor the climate variables to the species being modelled.

Ptunarra Brown Butterfly (*Oreixenica Ptunarra*):
We modelled the butterfly's distribution at the end of this century, using three different sets of variables. The three projections diverged widely, ranging from almost no locations with a suitable climate to maintenance of the current range.
Credit: Simon deSalis

The impact of variable selection on the model results depends on the characteristics of the species modelled. For example, variable selection is less important for long-lived sedentary plant species, such as the King Billy Pine, than it is for mobile species with specific biological characteristics or requirements, such as the Ptunarra Brown Butterfly. To illustrate this, we modelled the butterfly's distribution at the end of this century, using three different sets of variables. The three projections diverged widely, ranging from almost no locations with a suitable climate to maintenance of the current range.

Biological knowledge of the species can help in choosing variables. Ideally, modellers, species experts and conservation practitioners should work as a team to build the model, interpret the results and consider conservation management responses. Unfortunately, often, little is known of the species' biology and ecology as they relate to climatic factors.

Choose multiple climate models and emissions scenarios

Climate projections from global climate models are not species dependent and always need to be documented when modelling future distributions of species.

Conservation planners should consider multiple climate models and emissions scenarios to make sure they capture the full range of plausible futures. With this approach, the modelling exercise produces a range of species distribution maps which planners can then assess and combine in a useful way to inform decision-making. Over-confidence in a single map risks the possibility that conservation funds are invested in areas that will not support the species under the future climate.

Ongoing monitoring is essential to track changes as the species responds to changing climatic conditions.

We do not recommend that conservation planners use climate projections that are the mean values of multiple global climate models (an 'ensemble') as input to a species distribution model because:

- they are a statistically-derived climate that no single model has projected
- they are not the best approach for assessing risk in conservation planning (considering the 'best' and 'worst' cases may be more useful for decision-makers)
- they are not always accurate at or below the continental scale.

The five-step protocol

We recommend that conservation planners and managers using species distribution models with future climate change follow our five-step protocol to make sure that they represent the full range of plausible futures.

Step 1. Based on the availability of presence/absence records for the species, select the statistical method to model species distribution.

Step 2. Identify climate variables for current and future climates.

Step 3. Select the species distribution models that best model current distribution of the species.

Step 4. Select global climate models to obtain the future climate projections.

Step 5. Run the species distribution models and summarise the results to identify:

- the current areas that most models project will remain suitable for the species
- the largest area that is projected to remain suitable for the species
- the best- and worst-case range scenarios; that is, the largest and smallest areas that are projected to remain suitable for the species.

Where to from here?

The models and all the data used in our analysis are publicly available. Please contact the researchers for details.

Who are the researchers?

Dr Luciana Porfirio

Luciana is a geographer and remote-sensing specialist based at the CSIRO in Canberra. She was part of the hub's Bioregional Futures team while at the Australian National University, applying tools and techniques to study characteristics of landscape ecosystems and the patterns of diversity under scenarios of natural and human-induced change.

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Dr Rebecca Harris

Bec has an extensive background in field ecology and thermal biology. As part of our Climate Futures Project, she works closely with researchers across the hub to extract, analyse and interpret climate projections for species under threat from climate change.

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Further reading

Porfirio LL, Harris RMB, Lefroy EC, Hugh S, Gould SF, Lee G, Bindoff NL, & Mackey B (2014) Improving the use of species distribution models in conservation planning and management under climate change. *PLOS ONE*, doi 10.1371/journal.pone.0113749.

About the NERP Landscapes and Policy Hub

The Landscapes and Policy Hub is one of five research hubs funded by the National Environmental Research Program (NERP) for four years (2011–2014) to study biodiversity conservation.

We integrate ecology and social science to provide guidance for policymakers on planning and managing biodiversity at a regional scale. We develop tools, techniques and policy options to integrate biodiversity into regional-scale planning.

The University of Tasmania hosts the hub.

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