Science for Saving Species

Research findings factsheet

Project 4.4.8

Threatened Species Recovery Hub

National Environmental Science Programme

Predicting species persistence in a changing climate:
Using biophysical models in spatially-explicit population simulations

In brief

For most native wildlife, it is not known how their population will respond to climate change and land use change, making it challenging to manage these species for future conditions. Modelling can be used to help predict the viability of species under different scenarios. This research set out to link biophysical models with models of landscape dynamics and population dynamics to improve our understanding of future changes in species populations. We demonstrated our framework by projecting the long-term persistence of the threatened greater glider (*Petauroides volans*) in the Central Highlands region of Victoria under a changing climate and landscape.

Our results predicted significant declines in greater glider populations over a 50-year period. By considering biophysical processes (e.g., biological characteristics and functions that influence survival and fecundity), our modelling framework suggested additional population declines that would not be captured with other modelling techniques. These results indicate that models used to support analysis of climate impacts and land use change should incorporate both population dynamics and biophysical processes. This is particularly important for species where climate change is likely to interact with other threats such as habitat fragmentation and fire.

The population estimates from this model can be used to predict the effectiveness of proposed management actions and decisions about where and how to allocate management resources.

Greater glider.
Image: Toby Hudson

Background

Managing and predicting the persistence of species in the face of climate change and land-use change is becoming increasingly complex. One solution to this is to develop habitat models, such as correlative species distribution models. These are a statistical description of the association between a species' occurrence and its environment. Such models can provide a broad characterisation of current and future changes in species distributions. But to effectively characterise population change, models need to also include information about biological processes, such as species interactions, and information about human impacts, such as habitat modification.

Spatially-explicit population modelling has an advantage over other modelling strategies in that it can incorporate information about how populations change, interact with environmental effects and disperse in a landscape. The vital rates information (e.g., survival and fecundity, or ability to reproduce) entered into these models is often sourced from historical data and generally unknown for future conditions. These parameters are often assumed to be static; however, the link between the environment and vital rates can

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Background (continued)

be partially captured by modelling the physical processes by which physiology and environment interact to affect an organism's vital rates. For example, energy and mass balance equations from the field of biophysical ecology can be used to identify the habitat requirements of species with respect to their energy and water requirements for thermoregulation (their ability to maintain their body temperature). Such an approach can be used to predict future changes in vital rates linked to changing climatic conditions more confidently. In this way, it is possible to integrate correlative species distribution models and spatially-explicit population models together with biophysical data to improve the robustness of model predictions.

Main aims

This research aimed to demonstrate how linking biophysical models with models of landscape dynamics and population dynamics can improve our understanding of future changes in species populations.

We aimed to demonstrate our modelling framework by projecting the long-term persistence of the threatened greater glider (*Petauroides volans*) under a changing climate and landscape.

What we did

We demonstrated our modelling framework by simulating the persistence of the greater glider in a changing climate and landscape. The modelling landscape was the Central Highlands region of Victoria. Greater gliders were once known to occur across this entire region, but populations have declined in some areas.

We created three separate models: "landscape dynamics" that predicted changes in forest resources; "species distribution" that predicted the quality and configuration of suitable habitat; and "biophysical" that predicted survival and birth rates. We input climate projections to each of these three models (see Figure 1). We simulated biological (e.g., thermoregulation) and behavioural (e.g., activity) responses of the glider to daily weather rather than to long-term average monthly climate. This allowed us to account for the impact of weather extremes that can be important for understanding the population dynamics of greater gliders.

The outputs from the three models were then used to parameterise a spatially-explicit population model. The population model simulation started with a plausible, but unsubstantiated, estimate of approximately 5,000 greater gliders across the study area and predicted population changes at annual time steps over a 50-year simulation horizon, from 2019 to 2069. The model simulation included the effects of key threats of wildfire, logging and habitat fragmentation on glider populations.

We ran the spatially-explicit population model under four scenarios, and compared the resulting predictions. The different scenarios included or excluded parameters which affected glider vital rates. These parameters included the length of time foraging, breathing (panting) rate, food intake and water intake.

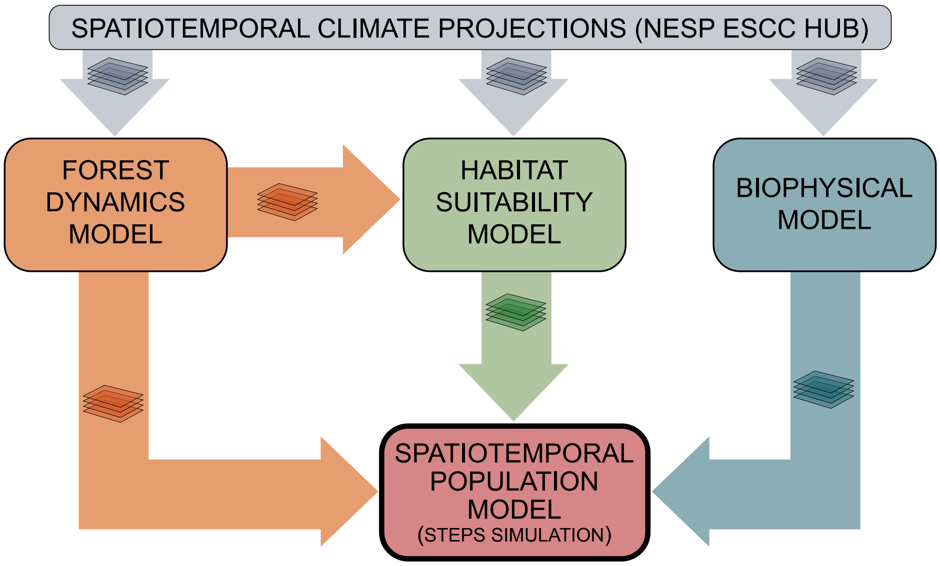

Figure 1. The modelling framework is made up of a forest dynamics model, habitat suitability model and biophysical model. Climate projections are inputted to all the models. The parameters output from these three models is then used in the spatiotemporal population model to predict a species' persistence under a certain scenario.

Key findings

Our study successfully demonstrated how different modelling methods can be combined to give more realistic population estimates under changes in climate and landscape disturbances. Incorporating the biophysical constraints on vital rates had a dramatic impact on the population outcomes for the greater glider. When we included biophysical constraints, it resulted in a reduction of approximately 25–50% in the expected minimum abundance of the great gliders across the different scenarios. In other words, the effects of climate on survival and fecundity accounted for a large proportion of the impact on future persistence of glider populations.

The estimated expected population size in 2069 across all simulations was approximately 950 gliders, or just 20% of the total initial population size in 2019 for our baseline simulation. We also ran simulations with high levels of variation in prescribed vital rates that enabled us to capture realistic fluctuations under a changing environment. The simulations that had a high level of variation in vital rates between years predicted that only 170 gliders would remain in year 50. This is considerably lower than the prediction of 540 gliders when there was a low level of between-year variation in vital rates in the model. Population levels as low as 170 could lead to local extinction.

There was little difference in the population estimates for the energy- and water-limiting scenarios we modelled.

This stag tree can provide hollows for the greater glider and other species. Image: David Blair

Survival and fecundity were consistently lower in scenarios that simulated glider activity for the full duration of night. This suggests that food intake may not be adequate to support extended glider activities, and that longer periods of denning in hollow-bearing trees is more advantageous, especially for predator avoidance.

Bringing population dynamics and biophysical constraints together into the models had a dramatic influence on the predicted outcomes for the greater glider.

Carrying capacity gradually declined over the 50-year simulation period based on land use, forest cover and age, and climate change. However, the population size dropped much more dramatically through the latter half of the simulation period due to limitations on glider movements, metabolic constraints and responses to changed habitat quality and availability. Overall, these results suggest additional population declines that may not be captured in other modelling frameworks that do not consider climate-driven constraints on vital rates.

Implications and recommendations

Biophysical effects are often implied, assumed, or completely ignored in simulations but variations in magnitudes of such impacts can be important for threatened species. Our study showed significant potential implications of climate and land use change mediated through population and biophysical processes, not necessarily captured in correlative analyses. This indicates that where possible, models used to support analysis of climate impacts and land use change should incorporate, or at least explicitly consider, population dynamics and biophysical processes.

Our modelling framework combined the effects of wildfire, logging and habitat fragmentation on populations, as well as integrating physiological responses to climate change. Overall, this enabled more accurate forecasts of whether species are declining under different scenarios. This is particularly important for managing species where climate change is likely to interact with other threats such as habitat availability. The more realistic population estimates from this model could be used to predict the effectiveness of proposed management actions and decisions about where and how to allocate management resources.

This innovative approach also responds to the widely recognised shortcomings of current approaches to predicting the impacts of changing environments on biodiversity. However, we found the parameterising of these models to be quite data-intensive, a factor to consider before commencing such a process.

Our modelling framework can be applied to any well-studied species for which the physiological data is available and would be a useful extension to existing spatially–explicit population simulations. Alternatively, the method can help guide data collection efforts for cryptic species of conservation concern.

Cited material

Casey Visintin, Natalie Briscoe, Michael Kearney, Gerry Ryan, Craig Nitschke and Brendan Wintle (2021). Mapping distributions, threats and opportunities to conserve the greater glider by integrating biophysical and spatially-explicit population models. NESP Threatened Species Recovery Hub Project 4.4.8 report, Brisbane.

Casey Visintin, Natalie Briscoe, Michael Kearney, Craig Nitschke, Gerry Ryan, Lindy Lumsden, and Brendan Wintle. (In prep). Integrating information from biophysical models into spatially-explicit population simulations to predict species persistence in a changing climate. *Journal of Applied Ecology*.

Greater glider. Image: Benjamint, CC BY SA 3.0, Wikimedia Commons

Further Information

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National Environmental Science Programme

Cite this publication as NESP Threatened Species Recovery Hub. 2021. Predicting species persistence in a changing climate: Using biophysical models in spatially-explicit population simulations, Project 4.4.8 Research findings factsheet.

This project is supported through funding from the Australian Government's National Environmental Science Program.