Science for Saving Species

Research findings factsheet

Project 4.4.1/4.4.3.2

Threatened Species Recovery Hub

National Environmental Science Programme

Using soil moisture and biophysical models to identify habitat-specific species refuges in response to climate change

In brief

The persistence of many threatened species under climate change will depend on their ability to exploit habitat patches that can support resilient populations.

These refuges are shifting with the changing climate, providing food sources during hard times as well as providing protection against warming, drying climate conditions and other threats such as predators and disease.

We looked at shifting refuges of different kinds used or potentially used by the plains mouse, the night parrot and the growling grass frog, and used soil moisture modelling and biophysical modelling to advance our understanding of such refuges, and what makes the refuges viable for the species.

Our findings provide evidence that will help managers identify, create, conserve and protect shifting refuges for these and other threatened species in Australia.

Background

Refuges are important to many of Australia's threatened species, as they support survival during environmentally stressful times, such as drought, fire and outbreaks of disease. While fixed refuges like mountain tops can be readily identified, it can be more difficult to locate shifting refuges – yet it is important to do so for the effective management of species that rely on them in hard times. The effects of climate change on shifting refuges must be taken into account, but data about these effects are often limited.

This research used modelling for species' biophysical traits (e.g., physiology, morphology and behaviour), as well as for weather and habitat features they use (e.g., vegetation, burrows, soil moisture, soil type, wetland size) to predict the suitability of particular places as refuges for particular species under current and projected future climates.

Understanding these species-specific traits and habitat features can help us identify, create and/or manage refuges for threatened species that provide protection against climate change and other threats such as disease and predators.

We looked at shifting refuges of different kinds used by or potentially used by three species: the plains mouse (*Pseudomys australis*), night parrot (*Pezoporus occidentalis*) and growling grass frog (*Litoria raniformis*).

1. The plains mouse

In arid zones, rodent populations fluctuate greatly in what are known as "boom and bust" cycles that result from the pattern of infrequent rainfall events in the arid zone. One such species is the plains mouse, a moderate-sized (42 g) native Australian rodent that occupies cracking clay and gibber plains in arid central and southern Australia. It is classified as Vulnerable nationally.

Plains mouse. Image: Nicolas Rakotopare

The University of Melbourne · Bush Heritage Australia · CSIRO · The University of Western Australia

Background (continued)

The plains mouse now occupies just a small part of its former range, with continuing predation by introduced cats (*Felis catus*) and red foxes (*Vulpes vulpes*).

The plains mouse is nocturnal, sheltering during the day in deep soil cracks or burrows. Although it eats mostly plants, it is able to persist in very dry conditions.

Its present distribution is associated with areas that have experienced runs of up to 300 consecutive days without rain over the 28-year period from 1990 to 2017 (Figure 1).

2. The night parrot

The night parrot was thought to be extinct for much of the last century, but small populations have recently been located in arid areas of Queensland and Western Australia.

Very little is known about its ecology and physiology, and due to its Endangered status invasive studies are out of the question. Predation by feral cats poses a significant threat to this species.

3. The growling grass frog

The growling grass frog was once distributed across a large area of south-east Australia, including Tasmania, at altitudes of up to 1300 m, but its range has contracted greatly, especially in Victoria and New South Wales, and it is listed nationally as Vulnerable.

It is found in a variety of habitats but prefers the edges of still or slow-flowing water bodies such as lagoons, swamps, lakes, ponds and farm dams. It is dependent on permanent freshwater for breeding. The growling grass frog can be found in relatively warm waters of between 18–25°C, and has been observed to bask during the daytime.

The species is facing threats including habitat loss and fragmentation, predation by introduced fish, and chytridiomycosis, an infectious disease caused by chytrid fungus that is impacting amphibians worldwide.

Growling grass frog. Image: Natalie Briscoe

Research aims

We sought to use modelling of different kinds to advance our understanding of both fixed and shifting refuges for these three threatened species to enhance their protection and management.

Soil moisture modelling: The plains mouse

For the plains mouse, we used soil moisture modelling to better understand how this arid zone rodent uses refuges, its population dynamics and the predation pressure it is under from native and introduced predators. We wanted to know whether refuges are important sites for the species' persistence during the low phase of its boom–bust population cycle, and how plant growth rates predicted by the model might help identify refuges that continue to provide food for the species during drought-time low population phases.

Biophysiological modelling: The night parrot

For the night parrot, we used physiological modelling to determine the bird's needs for free water. This knowledge will inform better control of feral cats, which represent a significant threat to this species, and tend to be found around waterways in the arid interior where the night parrot occurs.

Biophysiological modelling: The growling grass frog

For the growling grass frog, we measured the thermal physiology of the frogs with the aim of identifying temperature refuges from the threat posed to their populations by the deadly chytrid fungus. Chytrid grows and reproduces between 4–25°C, and growth is highest at temperatures between 17–25°C; however, temperatures over 28°C can be lethal.

What we did

1. Plains mouse

We studied the population dynamics and occurrence of populations of the species in the Simpson Desert, Northern Territory. We developed a soil moisture model and incorporated it into a general microclimate model. The model can make hourly predictions of soil–water balance at different depths, according to soil texture and local microhabitats, including shade, slope and aspect. From the model we generated a series of microclimate layers for Australia, that included information about soil moisture, which can be obtained here. The model can predict growth for particular plant species in their microhabitats, which we examined for its ability to identify resource supply for this desert rodent at different phases of its boom–bust population cycle.


Night parrot. Image: Steve Murphy

2. Night parrot

In collaboration with Bush Heritage Australia, we developed a biophysical model for the Endangered night parrot. See box on page 5.

The model looked at the heat flow between the birds and their habitat, and how much water they would need to evaporate to keep cool. Because so little is known about the physical characteristics of night parrots and we wanted to avoid stressing the birds by capturing them, we modelled their physiology on another very well-known and physiologically similar Australian desert parrot, the budgerigar. We also used measurements of museum specimens of night parrots, thermal photographs of living birds, and measurements of habitat temperatures and plausible food plants.

3. Growling grass frog

We measured the thermal physiology of the threatened growling grass frog and used the data to develop a biophysical model of frogs and the threatening chytrid fungus that can identify disease and climate refuges.

Body temperatures of growling grass frogs in the wild are driven by the daily microclimates available in different habitats and locations. We collected microclimate data from habitats of the frog in Victoria and used these to test predictions from microclimate models of soil and water temperatures and the timing of wet periods of wetlands.

As part of this project, we worked with Dr Matt Hipsey, a hydrologist at the University of Western Australia, to modify and test a widely used open-source general lake model (GLM) to predict temperatures and wet periods of shallow, potentially ephemeral wetlands and ponds used by growling grass frogs and other threatened species.

Using the biophysical model, we generated predictions of how potential body temperatures and chytrid risk of growling grass frogs varies through time across their range, in environments with different levels of shade.

Key findings

1. Plains mouse

Our results demonstrate that the plains mouse contracted to refuges during periods of low populations that are a small proportion (approximately 17%) of the range the species occupies during population peaks.

Animals in refuge populations had comparable body mass, and were found at similar densities, to those in boom phase populations, and they continued to reproduce during dry conditions.

The retreat to refuges represented a significant concentration of prey for predators hunting in an otherwise resource-poor environment. Native predators of the plains mouse were rare in such times and places, suggesting that refuges naturally experience low levels of predation, but the two introduced predators, feral cats and red foxes, persisted, and exploited the refuge populations of the plains mouse, posing a significant threat to its survival.

Our microclimate soil moisture model enabled us to relate plant growth in different soil types to trapping success of plains mice in the Simpson Desert, which indicates locations of refuges from predation for species such as this mouse that are able to persist in very dry conditions. Clay-rich soil types appear to predict a supply of the food resources that drives periodic population explosions for the plains mouse.

We looked at areas with maximum runs of up to 300 consecutive days without soil moisture suitable for plant growth over a 28-year period from 1990 to 2017 and found that the present distribution of the plains mouse is indeed associated with such areas – see Figure 1. We propose managing threatened rodents in arid habitats by focusing threat management on those parts of the landscape that function as drought refuges. The relatively small size of these refuges can help make such management more cost-effective.

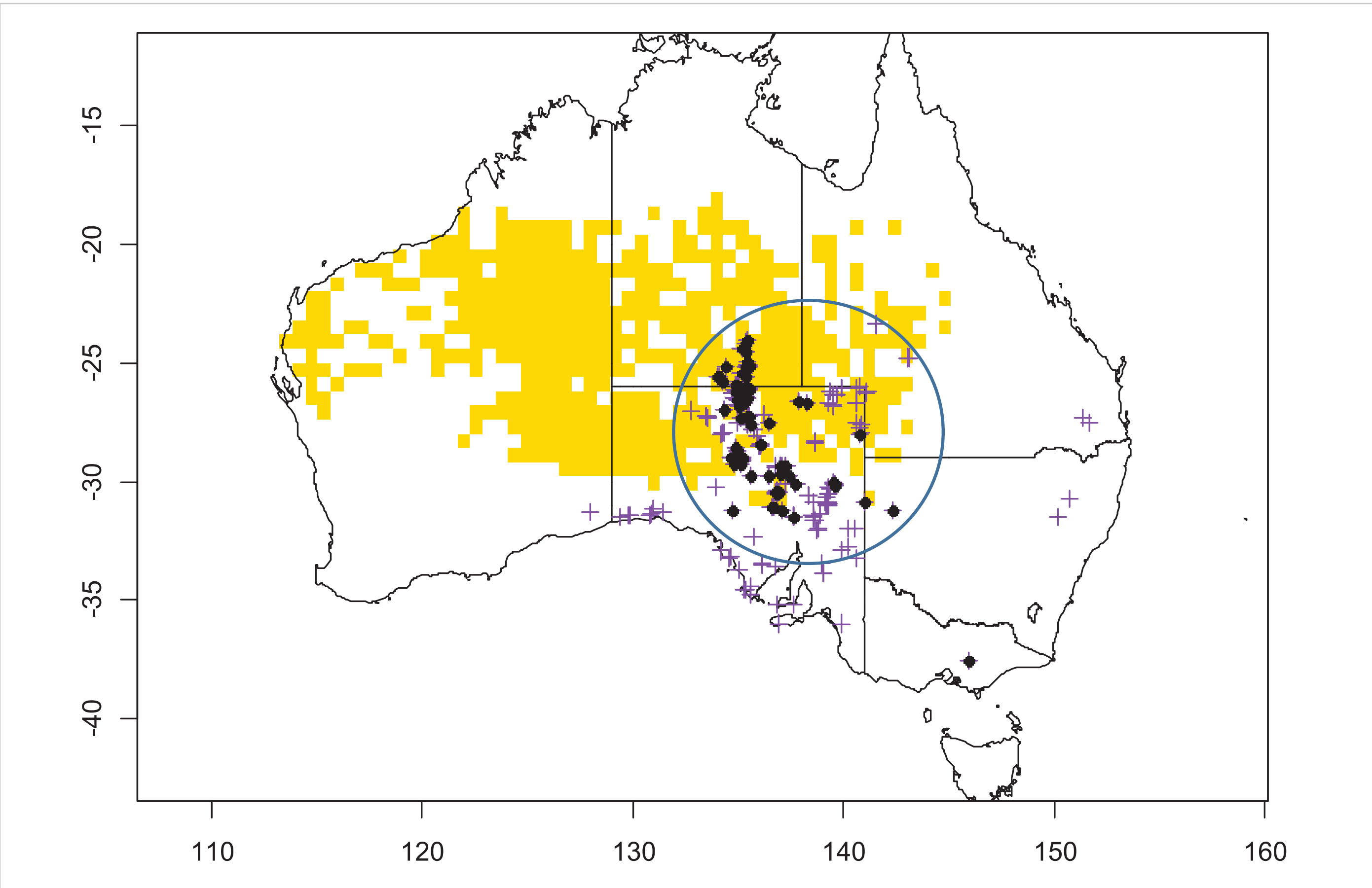

Figure 1. The regions of Australia (in yellow) predicted by our microclimate model to have a continuous run of at least 300 days without suitable conditions for plant growth over a 28-year period from 1990 to 2017. Superimposed are the Mammal Action Plan records for the plains mouse (Pseudomys australis), with the populations in black being current and the purple crosses being pre-1970.

Key findings (continued)

2. Night parrot

Like many arid zone species, night parrots have evolved to be nocturnal. They feed and move about in the cool and darkness of night. By day, they shelter in the protection afforded by clumps of spinifex.

Many arid zone species have also evolved to meet their water needs from their food, and the night parrot is no exception. However, we know from previous GPS-tracking research that the parrots do go to waterholes to drink sometimes, and this has implications for their management. In particular, managers are concerned to prevent them from being preyed on at waterholes by feral cats, which are known to live at water points, where they benefit from the extra cover afforded by plants and a continual supply of birds and other small animals coming to drink.

The modelling showed that if night parrots are living in dense spinifex tussocks eating only dry seeds, they would need permanent water sources most nights in summer.

The results of simulations indicate that if the night parrots shelter in burrows (a behaviour which has not been observed) and supplement their diet with succulent vegetation (there is some anecdotal evidence that they do this), they could reduce their water needs, but during really hot periods over summer they would still need access to free water to avoid dangerous levels of dehydration.

Air temperatures in the locations where they are found are projected to increase by 3°C by 2070, which would lead to lethal levels of daily dehydration of around 22% of the birds' body mass in some years and make safe access to drinking water critical for them.

Implications and recommendations

The implications of this are that water resources such as farm dams and natural soaks in night parrot habitat must be carefully managed. During hot weather, and especially when food is scarce, night parrots will rely heavily on these sites and could be very vulnerable to predation at such times.

Our findings also point to areas for future research: how much night parrots actually feed on succulent plants; and whether they change their roost sites in summer to places that are more sheltered from daytime heat, such as burrows and caves.

A better understanding the physiology of night parrots developed through this modelling will ultimately help protect them from the very challenging threat posed by feral cats.

3. Growling grass frog

We found that growling grass frogs can tolerate a wide range of temperatures (5.5–38°C), have broad temperature preferences (12.8–24.8°C), and perform well after short-term exposure to temperatures as high as 34–36°C (measured by maximum hopping distance). When basking, they can allow their body temperature to reach temperatures that can cause mortality in chytrid and can maintain such temperatures for at least two hours.

Biophysical modelling across the growling grass frog's range, predicted that chytrid risk increased with latitude, altitude and shade level, and varies between years. Chytrid risk was substantially higher at sites with high shade cover, and so our results emphasise that disease refugia should ensure microclimates with no shade are accessible.

RIGHT: Night parrots occur in arid zones where temperatures can be extreme. By day they shelter in spinifex clumps. Image: Nick Leseberg

Further applications

Soil moisture modelling has other potential applications for identifying fixed and shifting refuges for threatened species. This includes testing whether predictions about soil moisture can help us understand and predict patterns on breeding activity in the Endangered malleefowl.

We are using a version of the GLM we used for the growling grass frog to model Ellenbrook wetland, an ephemeral wetland that is home to the western swamp tortoise, a species that is highly imperilled due to the hotter and increasingly dry conditions under climate change. This modelling may help us in identifying, managing and protecting potential future refuges for the tortoise.

The integrative approach used for the growling grass frog shows great promise for evaluating pathogen risk at sites with differing habitat characteristics and microclimates. The methodology applied here can be adapted for other frog species threatened by chytridiomycosis.

The disease chytrid fungus grows and reproduces best in shady wetlands with temperatures below 26°C. Wetlands that have more sun and temperatures which exceed 25°C pose a lower chytrid risk to frogs. Image: Jaana Dielenberg

Growling grass frog. Image: Natalie Briscoe

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Further Information

Michael Kearney
m.kearney@unimelb.edu.au

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