Science for Saving Species

Research findings factsheet

Project 4.4

Threatened Species Recovery Hub

National Environmental Science Programme

Large-scale refuge and small-scale rocky refuges for Australian biodiversity

In brief

Australia's climate extremes and frequent bushfires mean that many species are adapted to seek out and retreat to refuges, which enable them to survive until conditions improve in the broader landscape. Refuges can provide more water or food, or protection from fire, climatic extremes or predators.

Identifying these refuges, and managing threats to the species that use them, can have great conservation benefits.

Protecting refuges will be important for the persistence of threatened species and other Australian biodiversity.

We used several types of existing datasets and methods to identify large-scale areas of refuge across the continent, particularly for those that are likely to contain areas of rocky refuge.

We overlaid these findings with areas of high species richness to show areas that are likely to offer refuge to multiple threatened species.

We recommend that the areas that serve as both long-term climate refugia, and small-scale areas of rocky refuges, be priorities for conservation. These important areas are within both the current protected area network and, for some, on other land tenures. Future work should investigate which areas are the most important refuges to the most species and their threats, so that we can prioritise their protection.

*Gulbaru gecko (*Phyllurus gulbaru*), a Critically Endangered gecko from north Queensland, reliant on rainforest habitat in gullies protected by fire. Image: Eric Vanderduys*

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Background

Many parts of Australia have highly variable rainfall, which creates "boom or bust" conditions, and are subject to bushfires. In response to these conditions, many Australian species are adapted to seek refuge when conditions in the broader landscape threatened their survival.

Refuges typically provide more water, food and cover, or maintain these attributes longer during an extreme event such as a drought. Cover can include more and denser vegetation – particularly at ground level – or rocky cover. Cover can provide protection from fire, predators, excessive heat or water shortages.

Vegetative cover is typically found in areas that are protected from fire, are moister and/or are protected from grazing. These areas can include areas alongside watercourses, drainage lines, gullies or rocky areas.

Rocky outcrops and areas of complex topography can often provide most of the important refuge features: cover from predators, water (by providing run-on areas, and areas with lower rates of evaporation), food (protection from grazing) and protection from fire.

Australia experiences substantial climatic variability but the effects of climate change are expected to exacerbate extremes such as high temperatures, droughts and floods. Bushfires may become more frequent and intense in some areas due to climate change, and this will in turn reduce vegetation cover and food for native wildlife and increase the risk of predation by feral predators, such as red foxes (*Vulpes vulpes*) and cats (*Felis catus*).

Much of Australia's biodiversity has faced major declines over the past 200 years and declines are ongoing. Effective conservation management needs careful planning and the prioritisation of management actions on a large, even continent-wide, scale while achieving results at the local scale.

To achieve this, we need to identify refuges that species use that work at both very large and very small scales. In particular, regions of habitat that are intact need to be protected, as they will give biodiversity a better chance of adapting to climate change.

However, there is still much to learn about the role of refuges in protecting Australia's threatened species, and their function in ecosystems more generally. Furthermore, locating small-scale refuges across extensive landscapes is a daunting task.

Main aim of the research

We aimed to locate areas across Australia that are likely to serve as refuges, and discuss methods for locating refuges at smaller, management scales.

Central rock rat. Image: Michael Barritt & Karen May, CC BY-SA 2.0, Wikimedia CommonsCommons

What we did

We reviewed published studies to understand how threatened species use refuges, and the threats that the refuges protect against.

We located "hotspots" of threatened species richness by using the Australian Government's 1 ha gridded spatial data of occurrence for each threatened species and subspecies. The occurrence maps have three categories: "known to occur", "likely to occur" and "may occur". For these purposes, we used all three categories. Knowledge of the distributions of many threatened species can be limited, so the "may occur" parts of species' ranges could still be important habitat.

To identify potential rocky refugia we identified rocky outcrops and topographically complex locations using topographical mapping and remotely sensed data. We used high-resolution CSIRO maps that show the depths to bedrock across Australia and Geoscience Australia's Surface Geology data. We identified all areas where the depth to bedrock was 2 cm or less, as these are highly likely to contain rocky outcrops. We then identified areas with potential rocky refuges that may be important for threatened species by intersecting this layer with the threatened species richness map.

Further indication of refuge value can be found in topographically complex areas. One method for identifying these is through topographic position index. We created a topographic position index layer for the Wet Tropics Bioregion of north Queensland, known for its richness of species that are found nowhere else. We combined aspect and topographic position to create a fine-resolution (1 arc second) map of the areas most likely to harbour cool, moist microclimates. We used the fine-resolution digital elevation model to create a layer showing the facing direction of any slope in the study area. The layer was reclassified into three classes: coolest (south-east to south-facing, 900–2250), warmest (north-facing, 3150–2250) and moderate (all remaining orientations). The topographic position index uses a neighbourhood function to classify the target cell in relation to its surroundings. The values of the aspect and topographic position index suitability layers were added together to create six classes, with the highest value being the greatest refuge value.

We intersected rocky areas, defined as depth to bedrock as 2cm or less, with Geoscience Australia's Surface Geology data, where geological descriptions fall into one of three broad geological categorisations incorporating basalts, granites, and sandstones.

Wollemi pine. Image: Akerbeltz, CC BY-SA 3.0, Wikimedia Commons

Key findings (continued)

Rocky features form important habitats, particularly for Australia's 160 vertebrates that depend on rocks. Among these are 10 species of frogs, 78 reptiles, 61 mammals and 10 birds. Among the mammals, 16 species of rock wallabies (*Petrogale* spp) are rock specialists. Many more threatened species use rocky features intermittently, as key refuges from threats. For example, the northern quoll (*Dasyurus hallucatus*) uses rocky habitats to avoid introduced predators, such as cats (*Felis catus*).

Some species are found only or predominantly around one type of rock. This can be because of certain habitat features, such as vegetation types, that are associated with the specific geology; or as an evolutionary outcome. For example, granite outcrops are home to groups of particular reptiles in south-eastern and north-eastern Australia, such as the Granite Belt thick-tailed gecko (*Uvidicolus sphyrurus*) (see inset box). Also, granite outcrops in Western Australia are home to invertebrates and reptiles that are restricted to those areas, and also support a number of rock-specialist mammals.

The rocky areas that provide the ecological refuges for threatened species are also likely to form important long-term refugia from climate change, for example, the rugged gorges that have protected the Wollemi pine (*Wollemia nobilis*) for thousands of years. Rather than a clear distinction between short-term ecological refuges and long-term climate refugia, we found that species used refugial areas on a continuum from days and weeks, through to decades and millennia. For example, the range of the central rock rat (*Zyzomys pedunculatus*) retracts to high-elevation quartzite peaks and ridges, where it persists in bust times over the long term. It is believed that these refuge-refugial areas protect the central rock rat from predation, fire and drought.

Given the importance of the topographically complex and rocky areas for key habitat, short-term ecological refuges, and long-term climate refugia, and the vastness of the Australian continent, locating the key rocky areas for Australia's threatened species is a challenging task. Therefore, the use of topographical mapping and remotely sensed data is a good place to start. For example, fine resolution digital elevation models can be used to find features, such as cooler aspects (e.g., south-facing slopes) and topographically complex areas.

Figure 1 shows areas where rocky outcrops are likely to occur, as depth to bedrock is 2 cm or less. More research is needed to verify that rocky outcrops are present in these areas. However, many of the areas we identified are already known to be important refuges for species across time scales of evolutionary significance, such as the Devonian Reef System in Western Australia, which is a fauna hotspot and has a geology that provides small-scale rocky refuges. Likewise, areas of boulders in Queensland provide cover for many species and are important rainforest refuges.

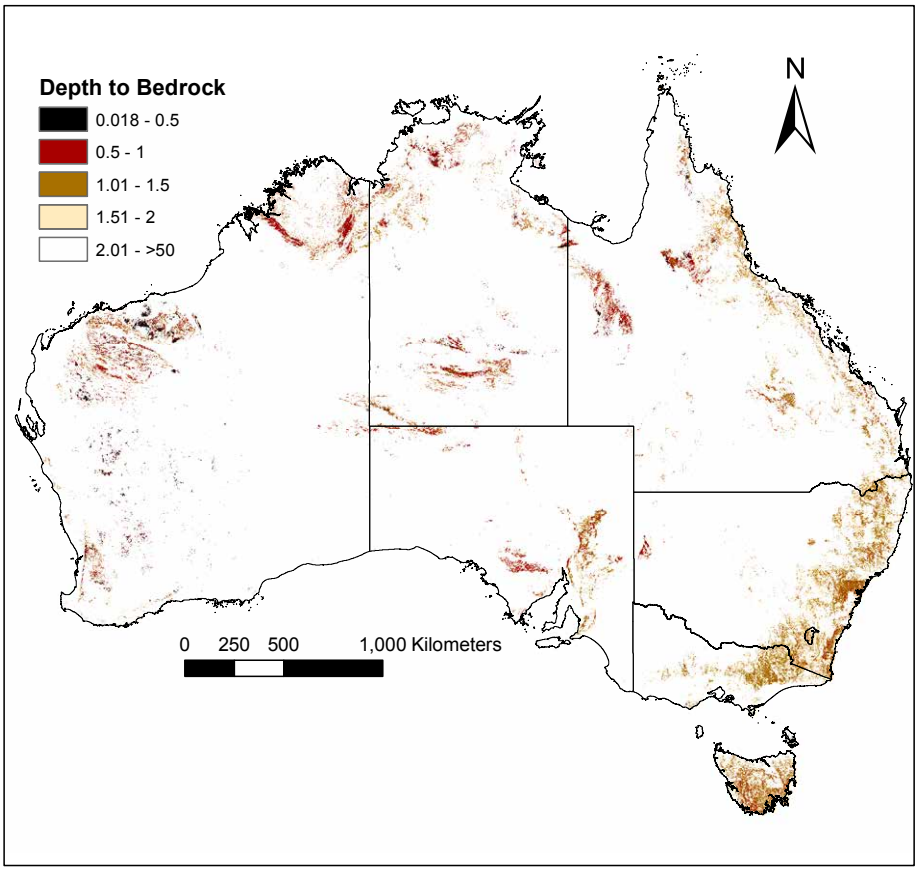

Figure 1. *Depth to bedrock. Coloured areas (2 cm or less to bedrock) are likely to contain rocky outcrops and rocky refuges.*

Key findings (continued)

Other methods of finding potential refuges include calculating Topographic Position Index to find valleys and cool aspects in topographically rugged parts of the landscape.

Australia has over 1660 predominantly terrestrial and freshwater threatened species and subspecies that occur on the mainland and continental islands. These threatened species are spread across Australia, with greater richness of threatened species around the east coast (Figure 2). The east coast has overlaps between high richness of threatened species and rocky areas of disproportionate conservation importance.

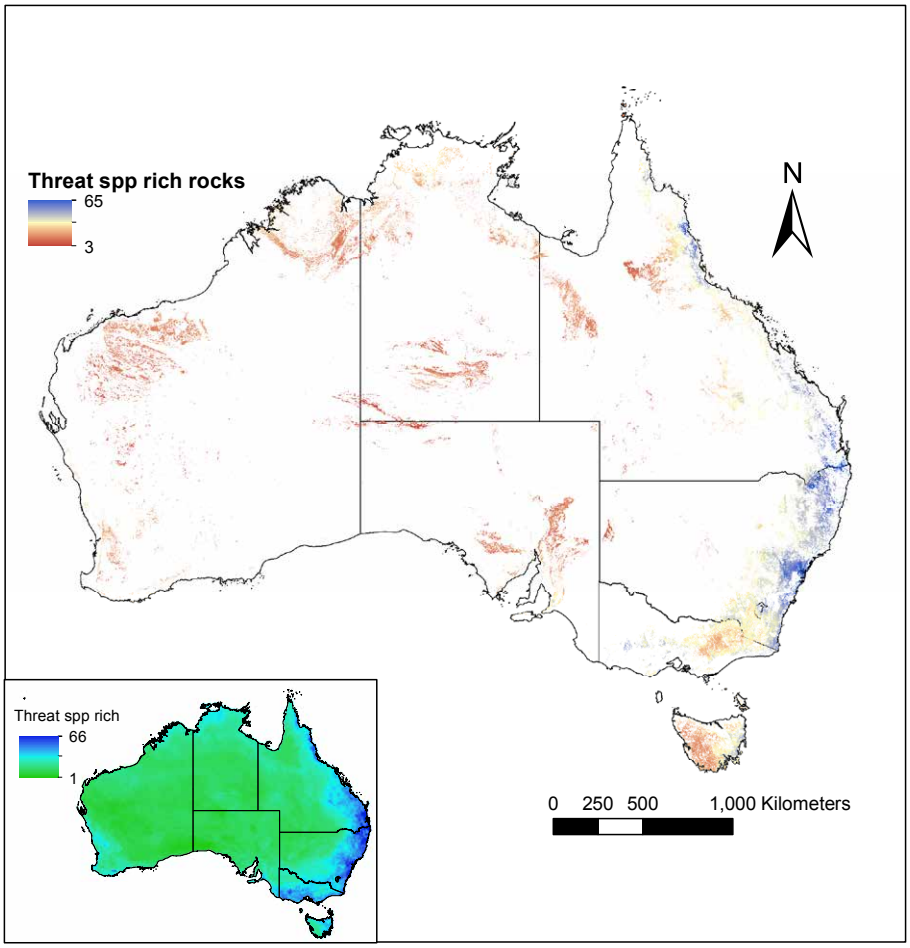

Figure 2. Topographic Position Index is one method of identifying potential refuge areas for threatened species. Topographic Position Index was calculated using a 1 arc second digital elevation model for the Wet Tropics region of north-east Australia, a region that has high numbers of threatened species.

South-east Queensland and northern New South Wales feature high species richness and important rocky refugia. For example, the Granite Belt thick-tailed gecko (*Uvidicolus sphyrurus*) is listed as Vulnerable and occurs on rocky outcrops and stony hills in this region. It may have once been more widespread in other habitat types that have since been cleared. The granite boulders are believed to be important refuge habitat for this species.

Granite Belt thick-tailed gecko (Uvidicolus sphyrurus). *Image: April Reside*

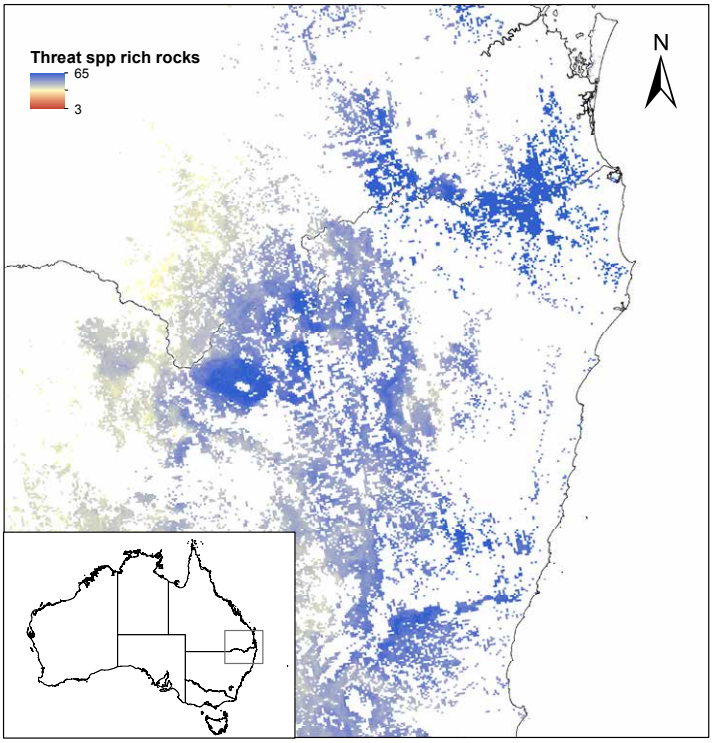

Figure 3. The number of predominantly terrestrial and freshwater threatened species and subspecies that occur across the Australian mainland and continental islands (left bottom insert), and the overlap between the richness of threatened species and subspecies and rocky areas (main map).

Further Information

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Implications and recommendations

Our work has found that cover is an important feature of refuges for many species, whether it is in the form of thick vegetation, steep gullies, rocks or rocky areas or mountains. Cover is often found in unburnt regions. Areas with good vegetative cover provide more food, protection from climatic extremes and protection from predators. Frequent intense fire, feral herbivores and higher levels of grazing are each likely to reduce cover, so should be addressed in conservation strategies. Rocky areas are important for the cover they provide, which can mitigate the threat of fire and herbivores. These rocky areas are important on short time scales as ecological refuges, as well as evolutionary timescales as climate change refugia.

This work has identified areas that are likely to be important refuges for biodiversity at a broad scale. Further work is needed to rank these areas and their threats, to prioritise areas for more detailed examination and then to map regions in greater detail and to undertake fieldwork to verify species' use of an area before declaring it an important refuge.

Our methods can help find areas of rock cover, surface rockiness and high topographic complexity, and so can be useful for identifying potential refuge areas in remote and under-studied regions. Such regions have been the sites of recently discovered reptile species, so it is likely that there are still species in remote rocky regions that are yet to be discovered.

Many areas that are likely to be important refuges are within current protected areas. However, there are many examples where existing protected areas do not contain important refuges, and many important refuge areas have little to no protection. For example, the MacDonnell Ranges contain protected areas, but the neighbouring Hartz Ranges, which are predicted to be increasingly important for refuge areas over time, have little formal protection.

Importantly, many coastal areas with very high importance as climate refugia are covered only by small and fragmented reserves which are unlikely to support many species to disperse as needed. For example, the Proserpine–Sarina Lowlands in the Central Mackay Coast in Queensland contain important refugia with high levels of endemism yet only a small proportion of this region is protected, and most of the protected areas are small. The coastal areas, particularly of the east and west, are also facing the highest development pressure. Bolstering existing protected areas in these regions is likely to be an effective conservation strategy.

Expanding around current protected areas could be a useful way to incorporate more important refuge areas, resulting in substantially larger protected areas. Larger areas would be useful, especially as many Australian species have historically had large ranges to track resources, and our previous work on refuges shows that many species use shifting refuges because they are adapted to periodic droughts and fire. Continuous habitat would allow species to reach shifting refuges as they arise, while fragmented habitat inhibits their movement through the landscape.

On the other hand, important areas are under less development pressure provide opportunities to manage biodiversity and refuge values on private land. For example, management strategies may include incentives for land-holders to manage their land for low-intensity production which maintains biodiversity values.

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