Science for Saving Species

Research findings factsheet

Project 4.1.7

Threatened Species Recovery Hub

National Environmental Science Programme

The ecosystem effects of burrowing by translocated boodies

In brief

Boodies are a commonly translocated medium-sized species once found across Australia's arid and semi-arid zones but now restricted to islands and fenced mainland reserves. The species creates large, complex warrens, but how the warrens affect soil properties and vegetation communities was unknown.

We investigated key ecosystem properties (soil, vegetation communities, and fauna) on warrens at three translocation sites across the boodies' former range.

We found increased soil moisture and soil nutrient concentrations and reduced compaction on warrens in all sites and habitat types compared to undisturbed ground, but little difference in vegetation properties. At plots where non-native plants were present, cover was greater on warrens than elsewhere.

We found evidence of 14 species of native mammals and reptiles using the boodie warrens.

Our findings suggest that translocated boodie populations may benefit both native and non-native fauna and flora, which has implications for managers planning boodie translocations.

Rabbit control may be beneficial before translocations are carried out, and when multiple burrow-using species are being translocated to a site, it may also be beneficial to translocate boodies first.

Background

Boodies, also known as burrowing bettongs (*Bettongia lesueur*), are listed as Vulnerable under the EPBC Act. The world's only burrowing macropod, boodies create large, complex warrens, which can be more than 90 m in diameter and persist for decades after abandonment.

A medium-sized marsupial (~1kg), boodies were formerly distributed widely across Australia's arid and semi-arid zones but natural populations are now restricted to three Western Australian islands, together with populations successfully translocated to two additional islands and four mainland reserves. More translocations of boodies are currently being planned to at least six fenced or island sites. Predation by introduced red foxes (*Vulpes vulpes*) and feral cats (*Felis catus*), human persecution and habitat degradation are the main causes of the decline of boodies. The last boodies were recorded on the mainland in the 1960s.

When animals become extinct, it can degrade ecosystems because their activities can contribute to or alter ecosystem functions, structure and health. Returning lost species to ecosystems through translocations therefore has the potential to enhance restoration efforts, especially if those species carry out important ecosystem functions. However, for many ecosystems, the contributions of individual species to processes that keep ecosystems stable are not fully understood.

Mammals that dig for food or to create shelter in the form of burrows or warrens are ecosystem engineers that play an important role in regulating ecosystem processes such as soil nutrient and water cycling, and they also provide shelter resources for other fauna.

Predicting the effects of translocating a species requires a thorough understanding of its historical roles in regulating key processes, such as nutrient cycling and plant recruitment, and insight

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Background (continued)

into how these may be altered by the presence of novel ecosystem elements. These novel elements can include species introduced to the ecosystem by humans, such as feral cats and weeds, or abiotic conditions like salinity.

We know from prior studies that boodies' foraging diggings alter the levels of moisture and nutrients in soil and support higher numbers of seedlings, but we know very little about the effect of their warrens on soils and vegetation.

Most planned translocations of boodies are being conducted at least partly to restore the ecological roles and functions of the species, so it is important to fully quantify those roles and functions. In Australia, animals are rarely, if ever, translocated into pristine environments. For example, most conservation reserves support numerous introduced species, may have been degraded by pastoral or logging activities, and are or will be impacted by the effects of climate change. This highlights the importance of assessing how boodies may interact with novel elements in their ecosystems.

Research aims

We aimed to quantify how boodie warrens affect ecosystems. To do this, we addressed four primary questions:

1. How does boodies digging warrens alter soil properties and ground cover?
2. How does boodies digging warrens alter native vegetation communities and plant productivity?
3. How do non-native plants and animals interact with boodie warrens?
4. How do boodie warrens vary with habitat, and how does this influence their effects on soils and vegetation communities?

BELOW: Juvenile numbat (Myrmecobius fasciatus) *sheltering in a boodie warren. Image: Bryony Palmer*

Surveying soils on a boodie warren at Matuwa-Kurrara Kurrara. Image: Bryony Palmer

What we did

We assessed boodie warrens at three translocation sites in 2018 and 2019 – Matuwa-Kurrara Kurrara Indigenous Protected Area, Faure Island Wildlife Sanctuary and Yookamurra Wildlife Sanctuary.

At each site, we searched for boodie warrens, and then measured their size and abundance (measured as warrens per hectare).

We compared soil properties – moisture, compaction and nutrients – of boodie warrens to undisturbed plots.

We looked at the number of different plant species, their composition and cover on boodie warrens, and compared it to undisturbed plots.

We assessed differences in numbers of species and cover between native and non-native plant species to investigate whether boodies are facilitating the growth or spread of non-native plants.

Using a drone equipped with near-infrared and true-colour cameras, we collected aerial imagery and used those images to compare the plant productivity of boodie warrens to undisturbed plots.

Finally, we recorded the use of boodie warrens by other vertebrates by identifying and counting scats on the warrens and by observing fauna using the warrens.

Key findings

Our key finding was that soils on boodie warrens were consistently moister, less compacted and had higher concentrations of nutrients that are important for plant growth, including nitrogen, sulphur and potassium, than soils on undisturbed ground (Figure 1).

Soils on boodie warrens were less compacted than undisturbed soils because the boodies turn over and rework the soil while constructing their warrens. These less compacted soils increase water infiltration, which is likely why the soils on warrens had more moisture than undisturbed plots. The increase in the concentration of nutrients was likely caused by the accumulation of nesting materials, urine and scat. For example, the abundance of boodie scat was two to 14 times higher on the warrens than on undisturbed plots.

In contrast to the effect of boodie warrens on soils, vegetation on boodie warrens was mostly similar to vegetation growing in undisturbed plots (Figure 2). This was surprising because limited water and soil nutrients typically restricts plant growth in Australian arid and semi-arid zones. It is possible that other factors, particularly herbivory by boodies and co-occurring species or climatic variables, play an important role in regulating the vegetation communities at our study sites. Very low rainfall at all three sites in the year before our research, for example, may have reduced the response of vegetation to the soil conditions on boodie warrens and/or increased the impact of herbivory on the vegetation.

At Yookamurra, we found that non-native plants were more abundant on the boodie warrens than in undisturbed plots. This may be because non-native plants are adapted to disturbance, because non-native plants need more moisture and

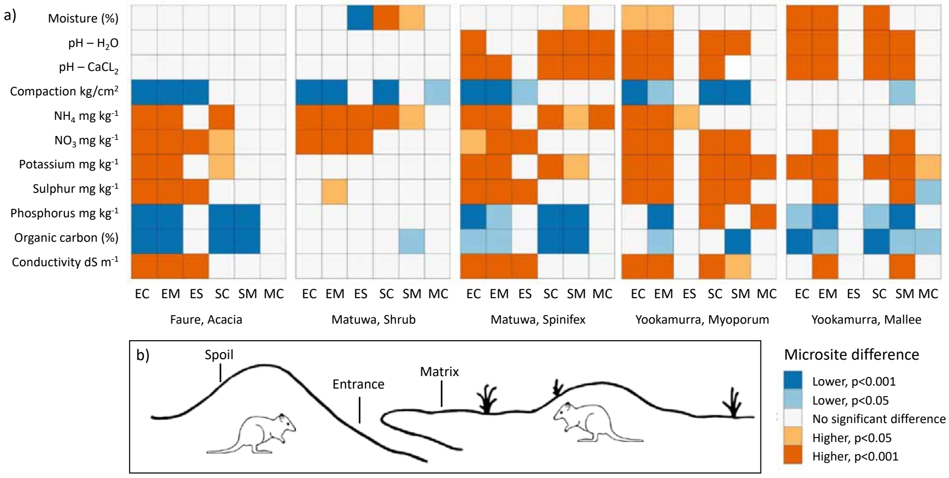

Figure 1: ***a)*** *Boodie warrens modify soil properties in largely consistent ways across three sites and five habitat types. Plot shows the results (p values) of generalised linear mixed-effects models comparing soil properties at microsites on boodie warrens (entrances, spoils, matrix) and at paired undisturbed controls. Blue cells indicate the value for first microsite in the pair was significantly lower than the second microsite. Orange cells indicate the value for the first microsite in the pair was significantly higher than the second microsite. The microsite pairs are denoted by the codes: EC – entrance and control, EM – entrance and matrix, ES – entrance and spoil, SC – spoil and control, SM – spoil and matrix, MC– matrix and control.* ***b)*** *A schematic representation of a boodie warren showing the locations of the warren microsites: entrances are the holes through which the boodies enter and exit the warren, spoils are the mounds of loose soil that accumulate through the excavation of burrows and the matrix is the relatively undisturbed area of ground interspersed between entrances and spoils within the warren boundaries. Undisturbed control sites were located 50 – 100 m from each warren.*

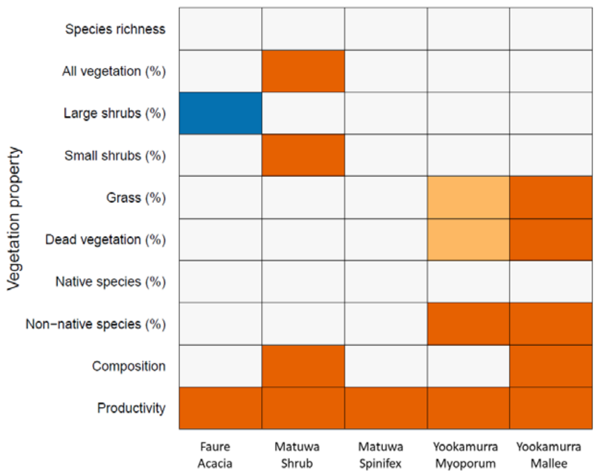

Figure 2: *There were few differences in vegetation species richness, percent cover or composition between boodie warrens and undisturbed control plots. Plot shows the results (p values) of generalised linear mixed-effects models comparing vegetation properties between warrens and controls.*

soil nutrients than native species and/or because animals feed on native species more than they do on less palatable non-native species.

At Matuwa, where the introduced rabbit (*Oryctolagus cuniculus*) co-occurs with boodies, rabbit scat was significantly more abundant on boodie warrens than in undisturbed plots.

We recorded the scat of seven native species on the boodie warrens, and also recorded another seven species using the warrens. This included an observation of a numbat (*Myrmecobius fasciatus*) at Yookamurra using an active boodie warren to raise its young, showing that boodie warrens can provide key breeding resources for other threatened species where these co-occur.

Finally, we found that the size and density of boodie warrens was influenced by the soil substrate. In areas where there was a calcrete layer, such as at Matuwa, boodie warrens were much larger but

Cited material

Palmer, B. J., Valentine, L. E., Lohr, C. A., Daskalova, G., Hobbs, R. J. (2021) Burrowing by translocated boodie (*Bettongia lesueur*) populations alters soils but has limited effects on vegetation. *Ecology and Evolution*. DOI: 10.1002/ece3.7218

Palmer, B. J., Valentine, L. E., Page, M., Hobbs R. J. (2020) Translocations of digging mammals and their potential for ecosystem restoration: a review of goals and monitoring programmes. *Mammal Review* 50(4): 382-398. DOI: 10.1111/mam.12208

Further Information

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Key findings (continued)

there were fewer of them; boodies cannot dig into the calcrete layer, but it provides structural integrity to warrens where boodies are able to dig underneath it (Table 1). In areas where the soil was very sandy, such as at Faure Island, boodies constructed many more warrens, but they were much smaller (Table 1).

Table 1: The density, size and activity levels of boodie warrens at three sites

	Faure	Matuwa	Yookamurra	p value
Warrens ha^{-1}	5.65	0.1	0.3	
Proportion of warrens active	95%	57%	79%	
Mean size (m^2)	133.88 (17.12)	452.98 (68.36)	186.68 (21.1)	M > Y, F ($p < 0.01$)
Area covered by warrens	7.5%	0.45%	0.5%	
Mean number entrances	3.11 (0.51)	13.58 (2.02)	7.05 (0.66)	M > Y, F ($p < 0.01$); Y > F ($p < 0.01$)
Mean number active entrances	2.64 (0.47)	9.37 (1.63)	2.46 (0.35)	M > Y, F ($p <0 .01$)

Implications and recommendations

Our study shows that by constructing substantially sized, numerous and sometimes long-lived warrens, translocated boodie populations play an important role in structuring ecosystems. When managers translocate boodies to a new site, they can expect that the boodies will increase levels of moisture and nutrients and decrease compaction in the soils on their warrens.

Boodie warrens provide shelter, a critical breeding resource, for other threatened species like the numbat, but they also provide shelter to rabbits, which have the potential to compete with native species for food resources and to degrade habitats through overgrazing.

The soil type at a site may influence the size and density of warrens that boodies construct, which may have flow-on effects for the boodie population size and density, and their overall effects on their ecosystem. Boodies typically forage within a few hundred metres of their warrens, so if, for instance, the soil type promotes the construction of a small number of very large warrens, the impacts of boodie foraging diggings and herbivory may be more concentrated around areas where there are warrens.

The results from this study could be used by managers planning translocations of boodies to:

- help predict the effect boodies will have on the release site
- assess the benefits and risks of a boodie translocation to local flora and fauna
- plan pre-translocation risk mitigation strategies, such as weed or rabbit control.

At sites where translocations of multiple threatened species are being planned, it may be beneficial to release boodies before other species that use burrows as breeding or shelter resources.

Managers of existing boodie populations could use the results of this study to:

- understand what effect boodies are having on their environment, specifically, how they are altering soils, and potentially facilitating the growth or spread of weeds
- assess the use of boodie warrens as focal points for the control of weeds and/or rabbits.

Further research will help to disentangle the effects on vegetation of herbivory by boodies from the effects of their warren construction. Abandoned warrens, for example, may retain the improved soil conditions while the vegetation there may experience reduced herbivory, thus providing sites of higher plant productivity.

Finally, conducting repeat surveys after high rainfall events may provide additional information about the effect of boodie warrens on vegetation communities at a time when vegetation responses are expected to be enhanced.

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Cite this publication as NESP Threatened Species Recovery Hub. 2021. The ecosystem effects of burrowing by translocated boodies, Project 4.1.7 research findings factsheet.

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