

Bioturbation by bandicoots facilitates seedling growth by altering soil properties

In brief

Mammals and other animals who dig for food or shelter move and rework the soil, a process known as bioturbation. The cumulative effect of this small-scale bioturbation by digging animals can be surprisingly important for broader-scale landscape processes. Consequently, many of Australia's digging mammals are considered ecosystem engineers. In particular, their bioturbation influences soil turnover, nutrient cycling and water infiltration, which in turn facilitates seedling recruitment and growth.

Australia once hosted an abundance of digging mammals. However, the majority are now absent from much of their former range. Most are now also threatened, and their numbers have greatly declined. Without them, the vital ecosystem functions that they provide are no longer taking place.

This may be compromising landscape health by reducing key processes. To improve the status of these species, many conservation agencies are reintroducing them to predator-free exclosures and islands. Reintroducing digging mammals could help to restore or reinvigorate lost ecosystem functions even though the landscapes they are being returned to are very different to the past due to anthropogenic changes.

We set out to investigate the combined effects of bioturbation by the quenda (*Isoodon fusciventer*), a type of bandicoot, on soil properties and plant growth. To do this, we measured several properties of soil. To do this, we measured several soil properties. We also grew seedlings of a native eucalypt in soil disturbed by quenda and undug soil. We found that soil disturbed by quenda promoted faster growth of seedlings.

Quenda: Australian ecosystem engineers

Digging mammals influence their environment by changing the physical and chemical properties of soils through bioturbation, or the reworking or moving of soil. When they dig, burrow or forage in soil in search of food or to create shelter, they break through the soil crust, often mixing soil types and horizon layers, and changing the ability of the soil to repel water. These digging species thus modify how resources are located in soils, and thereby the availability of those resources for other plant and animal species. When digging animals are numerous, as was the case before European arrival, their cumulative effects can facilitate landscape-wide changes.

This research looked specifically at how the foraging pits created by quenda affect seedling growth. Like other bandicoots, this medium-sized (800–1200g) omnivorous mammal has suffered population declines and contraction of its former range in south-western Australia, principally due to introduced predators and habitat loss. Nevertheless, it persists in some forest remnants and peri-urban bushlands, especially where the understorey vegetation is dense enough to provide protection from predators.

Quenda use their well-developed fore-limbs to dig for underground food such as invertebrates, fungi and tubers, creating foraging pits and associated conical-shaped spoil heaps of discarded soil known as the spoil heap or ejecta mounds.

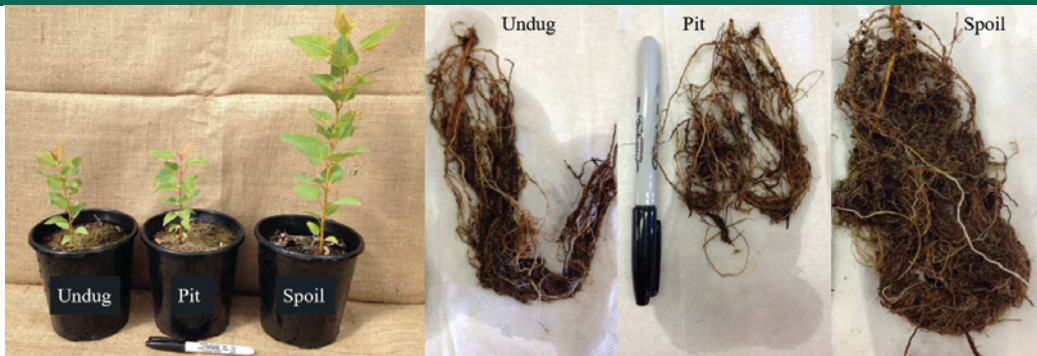


The quenda, an ecosystem engineer. Photo: Leonie Valentine

Quenda: Australian ecosystem engineers (continued)

Creating around 45 pits each night, quenda can displace nearly four tonnes of soil annually per individual. This combination of digging and discarding soil exposes subsurface soil and buries organic matter and litter under the spoil heaps, which helps with the decomposition of litter. This in turn enriches the soil with nutrients such as nitrogen, phosphorus and potassium, which are essential for plant growth. In addition, quenda can play a key role in dispersing mycorrhizal fungi, which allow plants greater access to limited soil nutrients.

Foraging pit created by quenda at Yalgorup National Park
Photo: Leonie Valentine



Tuart seedlings, and their root mass, after growing in undug soil, a quenda foraging pit and a quenda spoil heap. Photo: Leonie Valentine

What we did

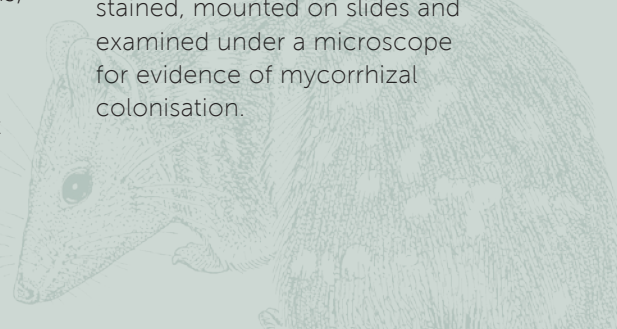
We examined the role that quenda foraging plays in altering the nutrient profile of soil and aiding the growth of seedlings. Our location was Yalgorup National Park, which sits in the Swan Coastal Plain bioregion of south-western Australia and supports a naturally occurring population of quenda. We conducted our work on the Spearwood Dune system of the park, where the habitat is open woodland dominated by tuart (*Eucalyptus gomphocephala*), with a mid-storey of banksia species. South-western Australian soils are old, leached and nutrient deficient, and consequently, mycorrhizal fungi play an important role in maintaining plant health.

We took samples of soil for nutrient analyses from 20 foraging pits created by quenda within the previous 1–2 months. These were collected from three locations: from the base of the foraging pit; from the associated spoil heap; and from a control of undisturbed ground located within 0.5m of the foraging pit. We measured a range of nutrients that may be important for plant growth: nitrate nitrogen; ammonium nitrogen; phosphorus; potassium; sulphur; and organic carbon – as well as electrical conductivity (which provides an indication of the level of nutrient salts present) and pH level.

We also took soil samples from the top 5cm of soil in the three locations of pit, mound and control to estimate microbial activity.

To examine the growth of seedlings, we collected 60 soil cores from the three locations (pit, mound and control) of the 20 foraging pits and transferred the soil to pots of similar dimensions to the corer while taking care to minimally disturb the soil. We placed the pots in a greenhouse and planted each one with 10 tuart seeds, watering them automatically once per day. All pots germinated seedlings (with a median 8 seedlings per pot), and we thinned them at seven weeks to the largest single seedling per pot. The growth of these seedlings was measured over a four-month period for height, maximum growth, basal stem width, and shoot and root biomass.

Finally, we assessed the seedling roots for mycorrhizal colonisation. We collected root material for testing by gently removing seedling roots from pots and washing off excess soil before drying them with paper towels. Fine root samples from each plant were processed, stained, mounted on slides and examined under a microscope for evidence of mycorrhizal colonisation.





Dr Katinka Ruthrof (Murdoch University & DBCA) with tuart seedlings in the glass house trial. Photo: Leonie Valentine

So how does quenda digging work?

The disturbed soil from the spoil heaps was found to foster the strongest seedling growth, which demonstrates the ecosystem engineering of quenda bioturbation. Potential reasons for this may be the reduced density of disturbed soil, and greater rates of litter decomposition in the mounds, which returns more nutrients to the soil and makes them available for plant uptake, thereby facilitating seedling growth. Buried litter decomposes more quickly than surface litter, potentially due to increased exposure to microbial and fungal communities, with microbial communities also varying with bioturbation. By contrast, the pit captured very little litter and had low levels of microbial activity, which may explain the slow seedling development in soil collected from this location.

The mounds created by quenda digging provide a combination of increased nutrients, reduced soil bulk density and greater water infiltration, all of which are important for seedling germination, establishment and growth.

Our findings

Our key findings were that quenda digging creates significant nutrient patchiness at a micro scale and facilitates stronger plant growth of young seedlings.

In detail, we discovered, first, that the highest levels of conductivity and potassium were found in the soil from the spoil heap. There was also more microbial activity in the mounds and control soil, which indicates that the pit soil is comparatively sterile. Further, the mounds and control soil had greater amounts of organic carbon than the pits.

When we looked at seedling growth, we found that the best predictors of strong growth were greater amounts of potassium, electrical conductivity and microbial activity. Potassium plays a key role in plant growth and is considered to be an essential nutrient for plants. It is highly mobile and readily leached from

soils, and even small increases in it, such as we measured from quenda digging, have the potential to make a difference to early seedling development. Further, these ancient, low-nutrient soils of south-western Australia typically have low levels of electrical conductivity, and small changes in conductivity such as we measured may also serve to help seedling growth during the early establishment phase.

Mycorrhizal mutualisms (the mutually beneficial relationship between a plant and mycorrhizal fungi) are also particularly important for plant growth. These fungi increase the ability of plants to take up phosphorous, nitrogen and micronutrients, and serve as a defence against plant pathogens. Colonisation by mycorrhizal fungi was greater in seedlings grown in the pit soil, where the least phosphorous was found.

Soil cores at foraging pit. Photo: Leonie Valentine



Cited material

Leonie E. Valentine, Katinka X. Ruthrof, Rebecca Fisher, Giles E. St J. Hardy, Richard J. Hobbs, Patricia A. Fleming, 2018, Bioturbation by bandicoots facilitates seedling growth by altering soil properties, *Functional Ecology* 32: 2138 - 2148
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Tuart seedlings. Photo: Katinka Ruthrof

“Soil turnover by native digging mammals can have surprising consequences”

Conclusions and recommendations

This is the first study to compare soil nutrients at different locations around a quenda foraging pit. In this study, we demonstrated that the small-scale soil disturbances created by digging mammals influence ecosystem functioning, change the composition and amount of nutrients, encourage microbial activity and facilitate plant growth. We propose that this may be caused by an enhancement of litter decomposition beneath the discarded spoil heaps.

The majority of digging mammals in Australian ecosystems are threatened. Their substantially reduced numbers or total loss in many of these landscapes means a loss of their functional role in maintaining ecosystems.

Further research is necessary to more fully understand the role of quenda and other digging

mammals as ecosystem engineers. In addition, we need to understand whether returning digging mammals to parts of their former range, such as predator-free exclosures and islands, can help with restoring landscape processes in these anthropogenically altered ecosystems. Unfortunately, across much of Australia, many native species are now missing or reduced in abundance, new species of plant and animals are present, ecological communities have been restructured by altered fire regimes and grazing by sheep and cattle, and the ecological functions of digging animals themselves have been reduced. It remains to be seen whether bioturbation by digging mammals can help to restore some of these landscapes, but our finding indicate that a small amount of soil turnover by native digging mammals can have surprising consequences.

Further Information

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Martin's Tank, Yalgorup National Park. Photo: Leonie Valentine