PRIZE ESSAY

CATEGORY WINNER: ECOLOGY AND EVOLUTION

**Orsi Decker**

Orsi Decker completed her undergraduate degree at Eötvös Loránd University in Budapest, Hungary. She went on to receive her master's degree in Ecology and Evolution at the University of Amsterdam. Decker completed her doctoral research at La Trobe University in Melbourne, Australia, where she investigated the extinctions of native digging mammals and their context-dependent impacts on soil processes. She is currently a postdoctoral researcher at La Trobe University, where she is examining how land restoration efforts could be improved to regain soil functions through the introduction of soil fauna to degraded areas. **www.sciencemag.org/content/370/6519/925.1**

ECOLOGY AND EVOLUTION

# Losing Australia's native gardeners

## The loss of the country's digging mammals compromises the continent's arid soil health

*By* **Orsi Decker**

When many of us think of outback Australia, we imagine desolate sands stretching out to the horizon, with either droughts or flooding rains. But what if this state of desolation is a result of the European colonization, poor land management, and native species extinctions driven by introduced plants and animals? What if the infertile soils that exist in the country today were once productive, with plant and animal communities maintaining a sensitive balance that reduced the impact of droughts and capitalized on flooding rains? What if our ideas of functioning ecosystems are the end-product of shifting baselines (*1*)?

### DIGGING MAMMALS ARE CRUCIAL FOR HEALTHY SOILS

As a graduate student in the Insect Ecology lab at La Trobe University, I studied the ecologically extinct digging mammals of Australia to better understand their long-lost functions and to model historic functions of a world now largely lost: the world of pre-European Australia. The once widespread native digging mammals include a diverse group of charismatic animals that evolved to survive the desert heat but not to escape from introduced cats and foxes (*2*). These include bettong and potoroo species (*Potoroidae* spp.), bilbies (*Macrotis lagotis*), numbats (*Myrmecobius fasciatus*), and bandicoots (*Peramelidae* spp.), all of which are now mostly restricted to predator-free areas such as islands and fenced reserves (*3*).

Digging mammals create small pits while foraging for food, which turns over the soil (*4*). The pits capture organic material, seeds, and, most importantly, water (*5*). In this way, these creatures are the keen gardeners of their own habitat, constantly turning over and fertilizing the soil while creating up to 200 pits per night for a grand total of about 4 tonnes of soil turned over per individual per year (*6*, *7*). (This metric only includes foraging and does not account for burrowing activities.)

Through my research, I discovered that the loss of these animals has profoundly altered soil functioning. Other researchers have documented the effect of foraging pits on soil processes; however, my research represents an attempt to determine the "landscape-scale" effects of digging mammals on soil functions. To do this, I compared predator-free reserves that support reintroduced native digging mammals with adjacent control areas in southern Australia where these mammals are extinct.

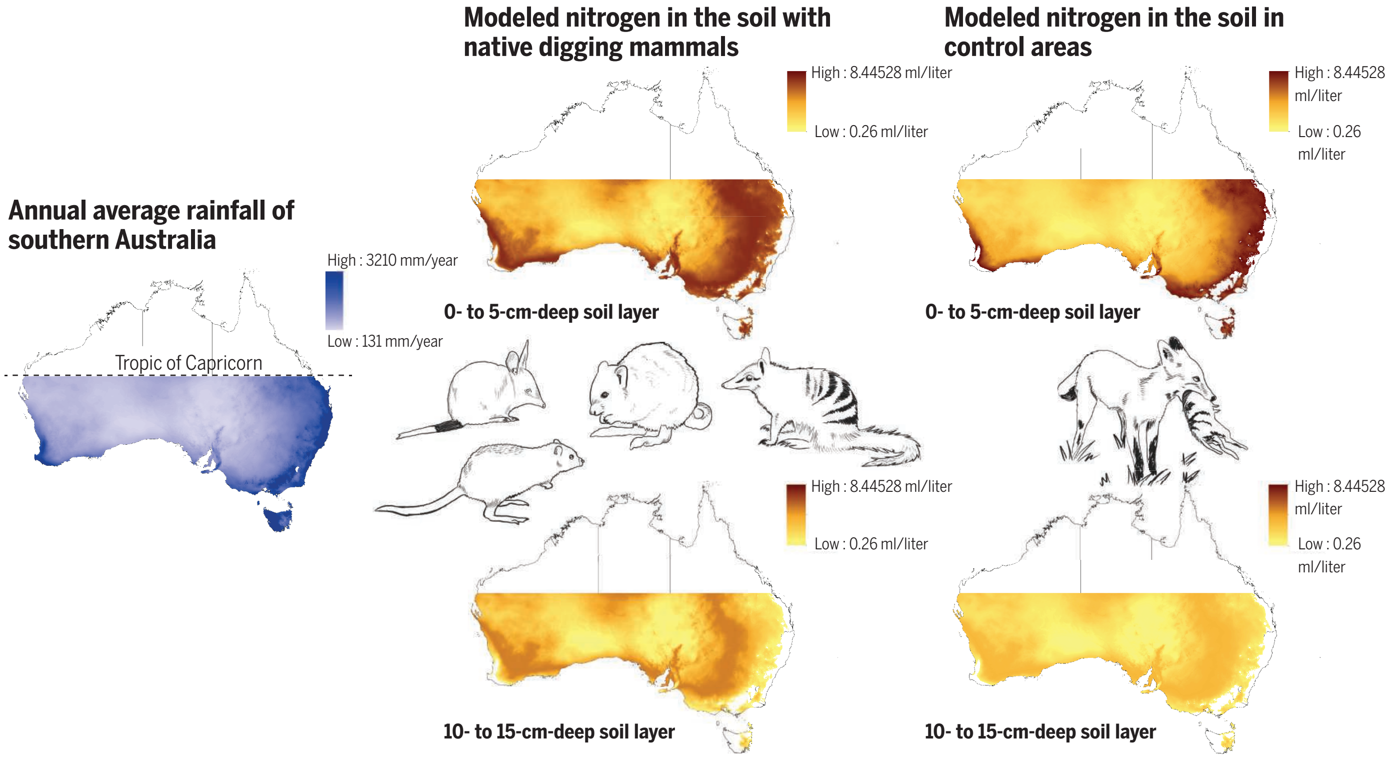
After taking 1334 soil samples from five predator-free reserves and five control areas, we determined that the loss of digging mammals has had a pronounced impact on soils. Soil organic material and available carbon, nitrogen, and phosphorus were all higher in reserves (*8*). Increased soil carbon indicates an increased water-holding capacity, which is crucial in dry, sandy soils (*9*). The plant-available forms of nitrogen and phosphorus are scarce in many soil types (*10*); therefore, mechanisms increasing these elements will likely support greater rates of plant establishment and growth (*11*). These results suggest that native digging mammals increase carbon sequestration and the water-holding capacity of soils and may therefore be able to mitigate some of the effects of drought (*12*). This is extremely important in a warming climate (*13*).

To respond to extreme environmental conditions, soils must also be resilient. The presence of healthy microbial communities is vital to this resilience (*14*). Microscopic communities, it turns out, are also affected by digging mammals, and the diversity of microbes is higher in the mammal sanctuaries (*15*, *16*). Our preliminary research indicates that beneficial bacterial species, such as nitrogen-fixing and antipathogenic species, were associated with sanctuaries.

Science & SciLifeLab PRIZE For Young Scientists

Department of Ecology, Environment, and Evolution, Latrobe University, Melbourne, VIC, Australia.
Email: o.decker@latrobe.edu.au

PHOTO: COURTESY OF O. DECKER




Modeled difference in soil available nitrogen between an Australian continent with abundant native digging mammals and an Australian continent in which native digging mammals are extinct or very rare. Average annual rainfall is shown, excluding the tropical regions (left). Modeled soil nitrogen (in milliliters per liter of soil) can be seen in the topsoil (0- to 5-cm-deep soil layer) and subsoil (10- to 15-cm-deep soil layer) in reserves (middle). Modeled values are shown in areas without native digging mammals (right). The greatest differences are in the semiarid regions (medium blue on rainfall map) between reserves and control areas. Areas where annual rainfall is >900 mm/year were excluded because we did not have sites that received rainfall above that amount.

## DRY CLIMATES BENEFIT FROM DIGGING MORE THAN WET CLIMATES

The loss of Australia's digging mammals has occurred in a range of ecosystems (*17*, *18*) and has been followed by the loss of their ecological functions across much of the continent. This made me wonder if digging activities affected the environment differently across the continent, because species roles can be context-dependent (*19*, *20*).

Imagine, for example, one garden in a dry area and one in a relatively wet climate. In the dry garden, a small amount of fertilizer and moisture will boost the growth of many plants, but the same effort in the wet garden will not have as much of an effect. This, I hypothesized, could be similar with digging mammals: Their activity might change soil properties in dry areas, where natural disturbances compensate for the lack of rainfall (*21*), but not in more productive systems (*9*). To determine if this was the case, we set up a landscape-scale study of four ecosystem types along a precipitation gradient of 150 to 900 mm/year.

My Ph.D. project showed that native digging mammals have a context-dependent effect (see the figure). The benefits of digging mammals were the greatest in arid and semiarid ecosystems but much reduced in temperate systems. Arid and semiarid environments are commonly thought to be infertile. However, my research suggests that the presence of native fauna could cause such areas to thrive, creating refuges from climate change and providing new incentives for species conservation.

Predicting the aftermath of species loss is not always easy. However, in this case, it is clear that we are losing important ecological functions that might otherwise mitigate the effects of climate change. As the world becomes hotter, many temperate regions will become semiarid (*22*, *23*) and begin to look more like Australia. Across all such regions, it is important to recognize beneficial natural processes that offer climate solutions and make it a priority to conserve these processes and the organisms in their natural habitat. ■

GRAPHIC: N. DESAI/*SCIENCE* FROM O. DECKER

### REFERENCES AND NOTES

1. M. Soga, K. J. Gaston, *Front. Ecol. Environ.* **16**, 222 (2018).
2. C. N. Johnson, J. L. Isaac, *Austral Ecol.* **34**, 35 (2009).
3. C. R. Dickman, in *Fencing for Conservation*, M. Somers, M. Hayward, Eds. (Springer, 2012), pp. 43–63.
4. P. A. Fleming *et al.*, *Mammal Rev.* **44**, 94 (2014).
5. A. I. James, D. J. Eldridge, *Biol. Conserv.* **138**, 351 (2007).
6. M. J. Garkaklis, J. S. Bradley, R. D. Wooller, *J. Arid Environ.* **56**, 569 (2004).
7. N. T. Munro *et al.*, *PeerJ* **7**, e6622 (2019).
8. O. Decker, D. J. Eldridge, H. Gibb, *Ecography* **42**, 1370 (2019).
9. A. T. Austin *et al.*, *Oecologia* **141**, 221 (2004).
10. J. J. Elser *et al.*, *Ecol. Lett.* **10**, 1135 (2007).
11. L. T. Bennett, M. A. Adams, *J. Arid Environ.* **48**, 289 (2001).
12. O.-Y. Yu, B. Raichle, S. Sink, *Int. J. Energy Environ. Eng.* **4**, 44 (2013).
13. Intergovernmental Panel on Climate Change (IPCC), "Climate change 2014: Synthesis report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change," Core Writing Team, R. K. Pachauri, L. A. Meyer, Eds. (IPCC, Geneva, 2014).
14. M. Delgado-Baquerizo *et al.*, *Nat. Commun.* **7**, 10541 (2016).
15. L. J. Clarke, L. S. Weyrich, A. Cooper, *Mol. Ecol.* **24**, 3194 (2015).
16. S. J. Dundas *et al.*, *Biodivers. Conserv.* **27**, 3071 (2018).
17. J. C. Z. Woinarski, A. A. Burbidge, P. L. Harrison, *Proc. Natl. Acad. Sci. U.S.A.* **112**, 4531 (2015).
18. A. D. Chapman, "Numbers of living species in Australia and the world" (Report, Australian Government, 2009).
19. K. H. Johnson, K. A. Vogt, H. J. Clark, O. J. Schmitz, D. J. Vogt, *Trends Ecol. Evol.* **11**, 372 (1996).
20. C. Mullan Crain, M. D. Bertness, *Bioscience* **56**, 211 (2006).
21. W. G. Whitford, F. R. Kay, *J. Arid Environ.* **41**, 203 (1999).
22. J. Huang, H. Yu, X. Guan, G. Wang, R. Guo, *Nat. Clim. Chang.* **6**, 166 (2016).
23. A. Rajaud, N. Noblet-Ducoudré, *Clim. Change* **144**, 703 (2017).

10.1126/science.abf1706

Science

# Losing Australia's native gardeners

Orsi Decker

*Science* **370** (6519), 925.
DOI: 10.1126/science.abf1706



*Science* (print ISSN 0036-8075; online ISSN 1095-9203) is published by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. The title *Science* is a registered trademark of AAAS.