

COMMENTARY

Small patches make critical contributions to biodiversity conservation

David Lindenmayer^{a,1}

Vast areas of the earth's land surface have been altered by human activities such as clearing native vegetation for agriculture and livestock grazing, logging of natural forests, and land conversion for urban settlements (1). These activities have had profound impacts on biodiversity and on key ecosystem processes (e.g., pollination and nutrient cycling) (2). Many ecosystems have been markedly reduced in extent (often termed "habitat loss") (3, 4), with remaining areas subdivided into small, isolated remnants (typically termed "habitat fragmentation") (5). In PNAS, Wintle et al. (6) explore some perspectives associated with the conservation value of small, isolated remnants and demonstrate that they are more important for biodiversity conservation than often recognized.

A large and rapidly expanding scientific literature has accumulated on the effects of habitat loss and habitat fragmentation (e.g., refs. 5, 7, and 8). Based on concepts such as island biogeography theory (9) and species–area relationships (10), a general conclusion from the myriad of studies to date has been that larger and more-intact patches are better—they support more species and larger populations of individual species that are more likely to persist for longer. Part of the explanation for this is that there are more niches and resources and thus more species (and more individuals of those species) in larger patches (10–12). An outcome of these general conclusions has been a focus of conservation efforts on protecting larger and more-intact areas with high levels of landscape connectivity (e.g., wilderness with relatively limited human impact) (e.g., ref. 13). There is no doubt that large, intact patches are vitally important for the maintenance of some key ecological processes (13) and biodiversity conservation (14). However, Wintle et al. (6) counsel against the uncritical application of this approach. The authors demonstrate the high conservation value of small patches, particularly in heavily modified, human-dominated landscapes. In their global analysis encompassing 28 countries, Wintle et al. (6) show that many species would be lost if small, isolated patches of remnant habitat were ignored and

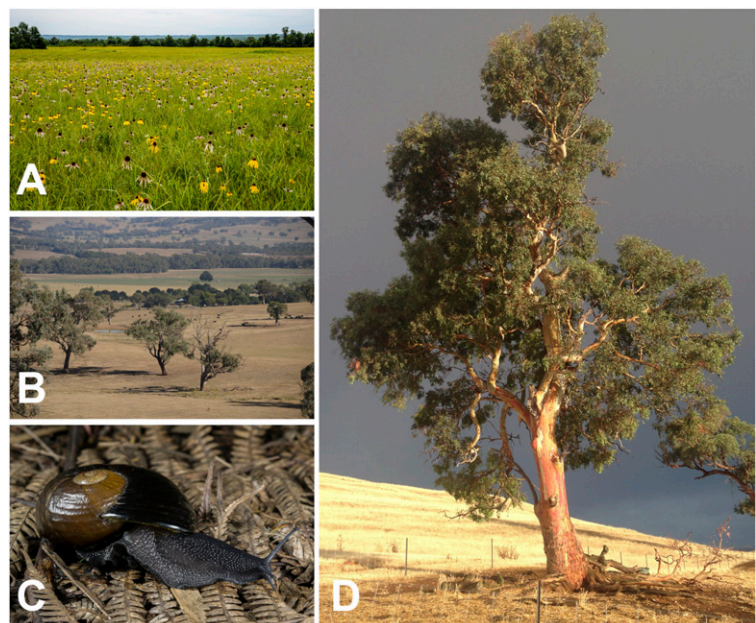


Fig. 1. Ecosystems in which only small patches remain after extensive human disturbance. (A) Temperate grassland ecosystem in the United States. Image courtesy of Reed Noss (photographer). (B) Temperate woodland in southeastern Australia. Image courtesy of David Blair (The Australian National University, Canberra, Australia). (C) *Paryphanta* sp., a native snail species in New Zealand, typically restricted to pig-free small patches of native vegetation. Image courtesy of Euan Brook (photographer). (D) Single, isolated, large old tree that has acted as a nodal point for natural regeneration of woodland vegetation in eastern Australia. Image courtesy of Mason Crane (The Australian National University, Canberra, Australia).

conservation efforts were focused solely on large, intact, and highly connected areas. The work of Wintle et al. (6) adds to the array of more spatially limited case studies that likewise highlight the importance of small (and often relatively isolated) patches for conservation (e.g., refs. 15–19).

There are several reasons why small, isolated patches can make an important contribution to biodiversity conservation. First, in some heavily modified ecosystems, small patches are all that remains; no

^aSustainable Farms, Fenner School of Environment and Society, The Australian National University, Canberra, ACT 2601, Australia

Author contributions: D.L. wrote the paper.

The author declares no conflict of interest.

Published under the PNAS license.

See companion article on page 909.

¹Email: david.lindenmayer@anu.edu.au.

Published online December 27, 2018.

large patches exist. Species endemic to these systems must either persist within the remaining small patches or not at all. The critically endangered temperate woodlands of southeastern Australia are one of many examples of such ecosystems. In these environments, which have been 95 to 99% cleared for agriculture and livestock grazing, there are few patches larger than a few hectares in size (20) (Fig. 1). However, ensembles of temperate woodland patches, including those in poor ecological condition, can nevertheless be species-rich (supporting >150 species of birds) (21). Kirkpatrick and Gilfedder (22) showed that small reserves (often in poor ecological condition) supported many rare plant species that had been eliminated from the heavily modified remainder of the landscape. There are many other ecosystems worldwide that have been extensively modified in which small remaining patches of remnant vegetation make a major contribution to the persistence of biodiversity (that likely would otherwise have been lost) in those regions [e.g., natural grasslands in the United States (4)] (Fig. 1).

A second reason why small patches can be critical for biodiversity is the absence of key processes that drive species decline elsewhere. For instance, small patches of remnant native vegetation are vital for the conservation of native land snails in New Zealand. The size of these areas precludes populations of feral pigs that can be a major predator of snails in large patches (16).

Small patches can play other crucial ecological roles beyond conserving sets of species that are extinct elsewhere in a landscape or region. For example, they can act as stepping stones that promote connectivity in otherwise highly modified environments (23). They also can be nodal points for stimulating natural regeneration of modified ecosystems, thereby contributing to vegetation restoration and broader community and biodiversity recovery (24, 25). In these and other cases, such patches may be as small as an individual tree (26).

Island biogeography theory, which has been so widely employed to promote the conservation of large patches, also may be invoked to highlight the importance of small patches. That is, under island biogeography theory, in heavily altered and highly fragmented landscapes there may be “concentration effects,” with animal populations retreating from a poor-quality surrounding matrix (with limited or no resources) (27) and then being reluctant to travel into the surrounding matrix, thereby becoming confined to remaining small patches (28).

The work by Wintle et al. (6) has significant implications for conservation policy and resource management. In particular, it suggests that while large intact areas can be critical for conservation, the potential value of small patches should not be ignored.

The work by Wintle et al. has significant implications for conservation policy and resource management. In particular, it suggests that while large intact areas can be critical for conservation, the potential value of small patches should not be ignored.

Such patches will often have substantial conservation value, precisely because they typically are located in highly modified environments where only limited areas of original habitat remain and the species confined to them are absent from elsewhere in the landscape. However, the management of small and isolated patches can be particularly challenging, such as protecting them from invasive species, edge effects, and clearing. Their protection also can be costly, although there are good examples of where it has been successful, especially when the public advocates for (and participates in) enhanced management (29). Investments in small and isolated patches should be underpinned by cost–benefit analyses to assess trade-offs involved with interventions relative to the conservation outcomes. Such analyses also may be important to assess the opportunity costs for biodiversity conservation arising from not managing other (sometimes larger) patches. A further implication of the work by Wintle et al. (6) is that some policies, like those for biodiversity offsetting, may require reform, as they currently have an inherent bias against appropriate protection of small patches (e.g., ref. 30).

Given that major global initiatives like the Aichi Biodiversity Targets aim to prevent extinctions, Wintle et al. (6) show that a focus of policy reform by governments must include not only the protection of large, intact areas but also small, isolated patches within highly modified environments. In addition, despite the massive and rapidly increasing literature on landscape change and habitat fragmentation, it is remarkable how rarely the contribution to landscape and regional species pools from taxa inhabiting small patches has been quantified (but see ref. 15). More empirical work is urgently needed to underpin the case for their conservation.

- 1 Venter O, et al. (2016) Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. *Nature Comms* 7:12558.
- 2 Steffen W, et al. (2015) Sustainability. Planetary boundaries: Guiding human development on a changing planet. *Science* 347:1259855.
- 3 Fahrig L (2003) Effects of habitat fragmentation on biodiversity. *Annu Rev Ecol Syst* 34:487–515.
- 4 Noss RF (2013) *Forgotten Grasslands of the South: Natural History and Conservation* (Island, Washington, DC).
- 5 Lindenmayer DB, Fischer J (2006) *Habitat Fragmentation and Landscape Change* (Island, Washington, DC).
- 6 Wintle BA, et al. (2019) Global synthesis of conservation studies reveals the importance of small habitat patches for biodiversity. *Proc Natl Acad Sci USA* 116:909–914.
- 7 Collinge SK (2009) *Ecology of Fragmented Landscapes* (The Johns Hopkins Univ Press, Baltimore).
- 8 Haddad NM, et al. (2015) Habitat fragmentation and its lasting impact on Earth’s ecosystems. *Sci Adv* 1:e1500052.
- 9 MacArthur RH, Wilson EO (1967) *The Theory of Island Biogeography* (Princeton Univ Press, Princeton).
- 10 Rosenzweig ML (1995) *Species Diversity in Space and Time* (Cambridge Univ Press, Cambridge, UK).
- 11 Connor EF, Courtney AC, Yoder JM (2007) Individuals–area relationships: The relationship between animal population density and area. *Ecology* 81:734–748.
- 12 Root RB (1973) Organization of a plant–arthropod association in simple and diverse habitats: The fauna of collards (*Brassica oleracea*). *Ecol Monogr* 43:95–124.
- 13 Watson JEM, et al. (2018) The exceptional value of intact forest ecosystems. *Nat Ecol Evol* 2:599–610.
- 14 Gibson L, et al. (2011) Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature* 478:378–381.
- 15 Fischer J, Lindenmayer DB (2002) Small patches can be valuable for biodiversity conservation: Two case studies on birds in southeastern Australia. *Biol Conserv* 106:129–136.
- 16 Ogle CC (1987) The incidence and conservation of animal and plant species in remnants of native vegetation in New Zealand. *Nature Conservation: The Role of Remnants of Native Vegetation*, eds Saunders DA, Arnold GW, Burbidge AA, Hopkins AJ (Surrey Beatty, Chipping Norton, UK), pp 79–87.

- 17 Erwin RM, Hatfield JS, Wilmers TJ (1995) The value and vulnerability of small estuarine islands for conserving metapopulations of breeding waterbirds. *Biol Conserv* 71:187–191.
- 18 Flaspohler DJ, et al. (2010) Long-term effects of fragmentation and fragment properties on bird species richness in Hawaiian forests. *Biol Conserv* 143:280–288.
- 19 Le Roux DS, Ikin K, Lindenmayer DB, Manning AD, Gibbons P (2015) Single large or several small? Applying biogeographic principles to tree-level conservation and biodiversity offsets. *Biol Conserv* 191:558–566.
- 20 Gibbons P, Boak M (2002) The value of paddock trees for regional conservation in an agricultural landscape. *Ecol Manage Restor* 3:205–210.
- 21 Lindenmayer DB, et al. (November 15, 2018) Weather effects on birds of different size are mediated by long-term climate and vegetation type in endangered temperate woodlands. *Glob Change Biol*, 10.1111/gcb.14524.
- 22 Kirkpatrick JB, Gilfedder L (1995) Maintaining integrity compared with maintaining rare and threatened taxa in remnant bushland in subhumid Tasmania. *Biol Conserv* 74:1–8.
- 23 Manning AD, Fischer J, Lindenmayer DB (2006) Scattered trees are keystone structures – Implications for conservation. *Biol Conserv* 132:311–321.
- 24 Fischer J, et al. (2009) Reversing a tree regeneration crisis in an endangered ecoregion. *Proc Natl Acad Sci USA* 106:10386–10391.
- 25 Chazdon RL, et al. (2009) The potential for species conservation in tropical secondary forests. *Conserv Biol* 23:1406–1417.
- 26 Lindenmayer DB, Laurance WF (2017) The ecology, distribution, conservation and management of large old trees. *Biol Rev Camb Philos Soc* 92:1434–1458.
- 27 Darveau M, Beauchesne P, Belanger L, Hout J, Larue P (1995) Riparian forest strips as habitat for breeding birds in boreal forest. *J Wildl Manage* 59:67–78.
- 28 Driscoll DA, Banks SC, Barton PS, Lindenmayer DB, Smith AL (2013) Conceptual domain of the matrix in fragmented landscapes. *Trends Ecol Evol* 28:605–613.
- 29 Garnett S, Woinarski J, Lindenmayer DB, Latch P, eds (2017) *Success in Conservation* (CSIRO Publishing, Melbourne).
- 30 Office of Environment and Heritage for the New South Wales Government (2014) Framework for biodiversity assessment: NSW biodiversity offsets policy for major projects (Office of Environment and Heritage, Sydney).