Rewilding: an Australian perspective

Abstract

Rewilding is increasingly recognised as a conservation tool worldwide, but rewilding is often context specific which inhibits broad application of initiatives from one area to another. Rewilding in Australia seeks to enhance ecosystem function and promote self-sustaining ecosystems. But an absence of large-bodied native herbivores means that trophic rewilding in mainland Australia has largely focused on the restoration of functions provided by apex predators and small mammal populations. Because of the pervasive influence of introduced mesopredators, predator-proof fences and the establishment of populations on offshore islands (free of introduced predators) are often a necessary step to ensure rewilding success in the short term. This sets Australian rewilding apart from most jurisdictions, and provides insights that are relevant on a global scale, but presents challenges to restoring function to broader landscapes. Passive rewilding is of limited utility in the arid zone. Although it may be more applicable in mesic coastal areas to increase habitat extent and quality, it will still likely be necessary to undertake active management. Because much of Australia's population lives in urban areas, future rewilding efforts must include urban areas to maximise effectiveness, and rewilding is thus not synonymous with remote wilderness and can occur over multiple scales. Rewilding efforts must recognise the influence of humans on other species and benefit both nature and humans. Rewilding in Australia requires the development of a shared vision and proof-of-concept projects to demonstrate the benefits. This vision should avoid the re-badging of existing conservation activities as rewilding, which could potentially confuse and undermine the future success of rewilding programs. Like in other parts of the world, rewilding should be viewed as an important tool to further conservation goals in Australia.

Rewilding: popular, but contested

The undeniable success of rewilding in capturing the public imagination has been based upon its reframing of conservation from a negative (look what we're losing) to a positive (look at what we can achieve) activity (Monbiot 2013). The appeal of rewilding to the public helps explain why several non-governmental organisations (NGOs) identify as being active in rewilding. Examples include Australian Wildlife Conservancy, Greening Australia, Conservation Volunteers Australia and WWF (vis its support for Rewilding Europe). Governments too are embracing rewilding: Rewilding Europe, for instance, is supported financially by the European Commission, while in Australia the New South Wales, South Australian and Commonwealth Governments all either practice, or are intending to practice, different forms of rewilding.

Since gaining prominence as a conservation ethos, there is a growing consensus that rewilding should focus on restoring ecosystem processes and species interactions, in order to promote complexity and self-sustaining ecosystems (Fernández et al. 2017; Pettorelli et al. 2018), although a number of definitions have been described (Jørgensen 2015; Pettorelli et al. 2018). 'Trophic rewilding' (Svenning et al. 2016b) usually refers to environmental change driven by strongly interacting species (*sensu* Soulé et al. 2003). Rewilding can therefore include restoration of predatory interactions that trigger trophic cascades ultimately affecting vegetation (as per Ripple & Beschta 2007), but could also encompass restoration of the ecological functions of ecosystem engineers like beavers (*Castor spp.*) (Law et al. 2016) and bilbies (*Macrotis lagotis*) (James et al. 2009), large-bodied herbivores (Ripple et al. 2015), seed-dispersers (Griffiths et al. 2011) and granivores (Fricke et al. 2018; Mills & Letnic 2018). In contrast, 'passive rewilding' is where vegetation encroachment, such as via the abandonment of European pastoral land, drives changes in fauna and flora species composition and biodiversity (Pereira & Navarro 2015; Regos et al. 2016).

Rewilding can therefore mean different things in different places (Seddon et al. 2014) and the lack of a fixed definition (Jørgensen 2015) makes setting goals and evaluating success difficult (Nogués-Bravo et al. 2016). Questions exist as to what ecological state, if any, rewilding efforts should seek to replicate (Corlett 2016) and there is a lack of empirical evidence to support rewilding (Nogués-Bravo et al. 2016; Svenning et al. 2016b). Trophic rewilding has been criticised as distracting from more urgent conservation issues (Rubenstein & Rubenstein 2016) while others argue that rewilding can help reverse the decline of biodiversity and ecosystem function in a human-dominated world (Svenning et al. 2016a). There are doubts as to whether rewilding is relevant to the deliberate introduction of non-native species outside their range as part of conservation efforts for that species (Bradshaw et al. 2006), while some suggestions to introduce ecological surrogates have attracted controversy (Donlan 2005).

In Australia, rewilding initiatives are gaining prominence and support from NGO's and governments. This support stems from the fact that threats to biodiversity are increasing (Watson et al. 2016; Cresswell & Murphy 2017) and the need for action is urgent. Novel approaches are needed to reverse the decline and extinction of species, and rewilding may complement other conservation initiatives. However, there remain several hurdles for rewilding to be used more broadly, and successfully, in Australia. Here we discuss how rewilding experiences and approaches in other jurisdictions around the world are relevant to Australia. In doing so, we compare and contrast Australia with other parts of the world, make suggestions as to future rewilding directions in Australia and identify lessons that can be learned from Australia that are applicable elsewhere in the world.

Trophic rewilding in Australia—opportunites and limitations

Restoring long established predator populations that have experienced range contractions may play a particularly important role in Australian rewilding. Top-down control by dingoes (*Canis dingo*,

mainland Australia's largest terrestrial carnivore), for instance, is a potentially cost-effective mechanism to suppress or alter the behaviour of recently introduced invasive mesopredators such as the red fox (*Vulpes vulpes*) and/or feral cat (*Felis catus*) (Brook et al. 2012; Letnic et al. 2012). This may in turn enable improved coexistence of native and non-native species (Wallach et al. 2015). Control of overabundant small or medium-bodied native and invasive herbivores may also be achieved through top-down control (Letnic et al. 2012; Morris & Letnic 2017), which may lead to positive economic outcomes for primary producers in some circumstances (Prowse et al. 2014). Similarly, the reintroduction of Tasmanian devils (*Sarcophilus harrisii*) to mainland Australia may lower red fox and feral cat abundance, influence trophic cascades and benefit small mammals (Hollings et al. 2014, 2016) though such effects may not apply universally (Hunter et al. 2015).

Increases in large carnivore populations in Europe, including outside of protected areas (Chapron et al. 2014), has raised concern that there is insufficient space for large predators and humans to coexist (Rubenstein & Rubenstein 2016). However, mainland Australia is sparsely populated and Tasmanian devils and humans successfully coexist in Tasmania (where the species is extant). Other objections to restoring predators relate to issues of human safety and whether large carnivores can coexist with livestock (Fleming et al. 2012). Human injuries from Tasmanian devils or dingoes are extremely rare, but legitimate concerns do exist in farming communities about potential impacts of dingoes and devils on livestock (particularly sheep) (Fleming et al. 2012; Jones et al. 2003). Thus, as in parts of Europe where lethal culling of wolves (*Canis lupus*) is currently being considered, societal values will be the primary determinant to the success of trophic rewilding of predators in Australia.

Australian 'critical weight range' (CWR) mammals—ground-dwelling species between 35 grams and 5.5 kilograms most vulnerable to decline and extinction (Burbidge & McKenzie 1989)—are particularly susceptible to predation by red foxes and feral cats because they lack appropriate anti-predator responses (Moseby et al. 2016). Since European colonisation, a variety of functions and

processes have been reduced or eliminated in Australian ecosystems due to extinctions and range contractions of mammals (Bilney et al. 2010; Fleming et al. 2014) (Fig. 1). This makes mammals, including the CWR guild, a priority for Australian conservation efforts, but a lack of effective control of red foxes and feral cats, in combination with habitat loss and altered fire regimes, remains the key challenge to trophic rewilding of small mammals (Bilney et al. 2010; Woinarski et al. 2015).

In Europe, Asia and North America reintroducing large bodied (>100kg) herbivores (or surrogates) is a key part of trophic rewilding, but Australia lacks comparable native herbivores. Australia possesses horses (*Equus caballus*), donkeys (*E. asinus*), water buffalo (*Bubalus bubalis*) and camels (*Camelus dromedarius*), but they are all introduced and have impacts on ecosystems that are generally perceived to be negative. Ecological control of these species cannot currently be achieved in Australia because of the lack of native predator species of sufficient size to exert top-down control on large herbivore populations (Forsyth et al. In press). Introducing extant surrogates of long-extinct predators is, in the short term at least, unrealistic in Australia due to intolerance and persecution of existing predators. The broader effects of such reintroductions on other species are also unknown.

Passive rewilding in Australia – opportunites and limitations

Passive rewilding (defined broadly as 'letting nature take its course') in Europe has yielded biodiversity benefits (Pereira & Navarro 2015), and benefits would likely accrue from passive rewilding in parts of Australia. Australia has lost approximately 40% of its forest cover, with much of the rest highly fragmented (Bradshaw 2012) and/or previously logged (Hobday & McDonald 2014). Passive rewilding would increase the area of forest cover and, within forests, the density of large, old trees and the biodiversity values they support (Lindenmayer et al. 2014). The loss of hollow-bearing trees is a threat to many forest-dependent mammals (Woinarski et al. 2014) and birds (BirdLife

Australia & Australian Government Department of Environment 2015), because Australia possesses a disproportionate number of species that use hollows (Gibbons & Lindenmayer 2002).

However, complex interactions between forest disturbance (e.g. logging, fragmentation), ~~the~~ invasive plants ~~*Lantana camara*~~ and despotic native ~~bell~~ miners (*Manorina melanophrys* and *M. melanocephala*) has resulted in a phenomenon called '~~bell~~ miner associated dieback' affecting localised but extensive areas of eucalypt forest (Silver & Carnegie 2017) and woodlands (REF). Recovery of affected areas will require management intervention, limiting the application of passive rewilding. Additionally, many forest ecosystems in Australia are fire prone, and historic Aboriginal fire management is likely to have influenced the development of forests. Contemporary fire management following restoration of forest cover may be necessary to protect fire-sensitive ecosystems such as rainforests, or for hazard reduction purposes. This is also likely to be a management concern in passively regenerating fire-prone Mediterranean vegetation types in southern Europe. As climate change alters the profitability of arid-zone pastoral enterprises, some of these lands may become available for inclusion in the conservation estate. However, passive rewilding in Australia's arid interior, which retains extensive areas of intact native vegetation, may fail to stop declines in biodiversity if introduced mesopredators remain present or if introduced weeds such as Buffel Grass (*Cenchrus ciliaris*) continue to proliferate and alter fire regimes. Efforts to restore populations of native fauna will therefore likely need (at least initially) to be accompanied by some form of pest and weed control to help shift the ecosystem back into a preferred state.

Rewilding in oceans requires a different approach to terrestrial systems, as the ecology and management tools differ in marine ecosystems. Restoring ecosystem function is no less urgent in marine ecosystems as trophic cascades commonly occur (Estes et al. 2011) and predatory fish biomass has been extensively depleted in the world's oceans (Christensen et al. 2014). The recovery

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Thomson JR, Maron M, Grey MJ et al (2015) Avifaunal disarray: quantifying models of the occurrence and ecological effects of a despotic bird species. Diversity and Distributions 21(4):451-464

of large predatory fish can occur with minimal human intervention, through the creation of marine protected areas (MPAs), but to maximise effectiveness MPAs must be large, no-take, long-established, well enforced and isolated by deep water or sand (Edgar et al. 2014; Edgar et al. 2018). In marine systems, widespread loss of habitat forming species such as macrophytes, oysters and corals and the facilitation cascades they support simplifies ecosystems and threatens biodiversity conservation, and their restoration may thus be construed as rewilding (Thomsen et al. 2010; Marzinelli et al. 2016). The restoration of such structural elements need not be confined to MPAs, but is likely to be promoted within them via restrictions on fishing and physical damage from human infrastructure.

Fenced enclosures: rewilding or not?

Like many other of the Earth's islands Australia's fauna has been devastated by the introduction of novel predators due its long history of evolutionary isolation (Medina et al. 2011). The use of fences to exclude introduced mesopredators in Australia has been a response to catastrophic impacts of red foxes and feral cats on predator-naïve CWR mammals, as distinct from fencing in Africa that is used to separate humans and large predators, or to maintain predator density in rewilding efforts (Bull et al. 2018). Predator-proof exclosures have also been used successfully in New Zealand to provide havens for birds, reptiles and invertebrates that are threatened by introduced predators (Pech & Maitland 2016).

Fenced exclosures (Fig. 2) have been used successfully in Australia to protect threatened species and increase their populations (Moseby et al. 2009). Current exclosures range from small to reasonably large (123km^2 - Arid Recovery) and a 2,000km^2 exclosure is proposed for Yorke Peninsula in South Australia. Recovery of small mammal populations influences fungi (Clarke et al. 2015) and termite assemblages (Coggan et al. 2016), soil properties (James et al. 2009), seed dispersal and shrub

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recruitment (Mills et al. 2017). In this regard, fenced exclosures do achieve rewilding objectives, at least for a subset of functions driven by smaller species. Only the largest exclosures are sufficient to achieve rewilding of devils and dingoes (Moseby et al. 2018), ~~but~~ and these exclosures would need to be much larger to host self-sustaining populations or allow multiple groups or packs of these predators. .

However, fences are ultimately inconsistent with the goal of reinstating self-sustaining ecosystems due to the maintenance requirements of fences, the need for managed migration between metapopulations, and the disruptions to ecosystem processes and habitat degradation that may arise with growing animal populations contained within fences (Hayward & Kerley 2009). Without the reintroduction of native predators, fenced exclosures also exacerbate the problem of prey naïveté (Moseby et al. 2016). Fences may therefore be best viewed as a starting point on a rewilding continuum and a stepping stone towards landscape-scale rewilding—achieved in theory through a combination of restoration of native predator populations, the use of livestock guardian animals, shifts in pastoral practices, financial incentives to farmers (Van Eeden et al. 2017), and novel means such as promoting conditions for native prey species to co-evolve with introduced predators and learn to avoid them (Moseby et al. 2016; West et al. 2017). Concurrent efforts to improve outcomes on a landscape-scale are necessary in order to restore self-sustaining ecosystems, and to avoid a future where native species are confined to small fenced exclosures and their functions lost to the broader landscape.

Assisted colonisation

Enthusiasm in the Australian NGO and academic sectors for Tasmanian devil reintroductions to the Australian mainland (Ritchie et al. 2012) (Supporting Information) highlights support for

translocations of native species to improve ecosystem function. In the case of the devil, translocation to mainland Australia would reintroduce a species that became extinct ~3,000 years ago (White et al. 2018). But in the absence of a demonstrated broader functional role, assisted colonisation of non-native animals as a global conservation tool (Bradshaw et al. 2006) does not fit rewilding goals. For example, proposals by the Australian Rhino Project (http://theaustralianrhinoproject.org/) to bring black (*Diceros bicornis*) and white rhinos to Australia have not focused on the restoration of ecosystem processes, but rather to assist conservation efforts for those species. De-extinction also typically focuses on resurrecting lost species rather than aiming to restore ecosystem function and is therefore not consistent with the aims of rewilding.

People and rewilding—lessons from around the world

One criticism of rewilding has been a perceived aim of excluding human involvement with, and influence upon, nature and ecosystems (Jørgensen 2015), and some rewilding efforts in Europe do seek to reduce human influence on modified agricultural landscapes (Ceauşu et al. 2015; Pereira & Navarro 2015). But benefits can accrue to humans from rewilding. These may accrue directly, such as income derived from wildlife tourism and dingoes increasing profitability of farming in some circumstances (Prowse et al. 2014; Johnson & Wallach 2016), or indirectly via influencing ecosystem services. For example, restoring forest ecosystems in catchments could reduce flood risk and provide clean water, while reintroducing digging animals to urban areas could assist in pest control and water infiltration in gardens. In this context, rewilding shares similarities with the concept of 'nature-based solutions' that aim to address a societal problem in ways that deliver both biodiversity and human benefits (Nesshöver et al. 2017) (Fig. 3).

The importance of community involvement, particularly in trophic rewilding, cannot be overstated. Predator conservation efforts are likely to be initially opposed by some sections of the community,

and social impacts of rewilding should be assessed and made clear (Pettorelli et al. 2018). Predator-friendly farming, designed to integrate socio-economic and environmental outcomes (Johnson & Wallach 2016) (Fig. 3) is used in North America and Africa and has potential to overcome social barriers to predators in Australia too.

Globally, rewilding is synonymous with large, near-continental scale projects. Yet in Australia, approximately 70% of the human population live in cities and 85% in urban areas. Urban rewilding is therefore a high priority in Australia to demonstrate tangible outcomes and increase engagement with nature (Jepson 2016). Programs suitable for urban areas, such as reintroductions of pollinators or small mammals readily accepted by humans, should occur alongside initiatives in rural landscapes with the dual aim of increasing ecosystem function and engaging the public in conservation (Watson & Watson 2015). Rewilding must therefore occur at multiple spatial scales (Fig. 4) and rewilding should seek to increase non-human autonomy, rather than spatially separate humans and non-humans (Prior & Ward 2016). But, because of human dominance of urban areas, rewilding efforts will necessarily become a compromise between restoring ecosystem function and raising public awareness through species tolerated by humans. There will also be a need to target the key threats that led to the loss of species in the first place, and this may not be surmountable in some cases.

Location is an important consideration in rewilding because some areas and landscapes will be more suitable than others—both ecologically and socially (Supporting Information). Identifying priority rewilding areas has been proposed for Europe in the form of a network of experimental rewilding sites (Jepson 2016), which could offer a model for Australia. Locating rewilding initiatives where they have a good chance of success, (e.g. through an accepting community or an appropriately designed project), and where economic benefits can accrue (e.g. through tourism and enhanced agricultural productivity) may help provide proof of concept and raise the profile of rewilding. In addition,

success may be more readily achieved in areas where there are ongoing conservation programs run by local communities. Indigenous owned and managed land in Australia potentially offer great potential in this regard, especially where there are established conservation programs or voluntary conservation agreements such as Indigenous Protected Areas. As an added benefit, Indigenous land is extensive and covers 52% of the country, and around three quarters of Australia's terrestrial or freshwater vertebrate species listed as threatened under national legislation occur on these lands (Renwick et al. 2017).

Embracing change: restoring processes rather than historic states

Rewilding's focus on ecological processes means that success should be measured not by a comparison to an ideal state, but rather by the degree to which management actions result in the restoration of desired processes. The positive relationship between biodiversity and ecosystem function (Cardinale et al. 2012) suggest that this may be a viable approach to maintaining biodiversity, while recognising that ecosystems are dynamic and therefore are unlikely to possess a single historic state (Rohwer & Marris 2016). Recent evidence (Law et al. 2016; Law et al. 2017) from beaver (*Castor fiber*) reintroductions to Scotland supports predictions (Stringer & Gaywood 2016) that ecosystem processes manipulated by beavers would increase biodiversity. In Australia, the restoration of pre-European landscapes and species assemblages is most cases unachievable due to extinctions and the difficulties associated with removing invasive species. Rewilding should therefore consider contemporary patterns and processes, including widespread human settlement, and the 'new nature' whereby human activities influence abundances and distributions of species.

Policy implications

Broadly, current conservation policy settings in Australia tend to focus on species-specific or ecological-community specific threat reduction, targeting species and ecosystems listed as threatened via a nomination process. Two projects, Gondwana Link and the Great Eastern Ranges initiative, seek to enhance connectivity on the landscape-scale, and connectivity is often an aim of conservation strategies. Strategies also regularly recognise the need to build human appreciation of nature. The National Reserve System seeks to achieve comprehensive, adequate and representative protection of ecosystems at a bioregional level.

Rewilding should not replace these approaches, but could be complementary and assist in meeting goals. For example, explicitly considering maintenance of identified ecosystem processes could inform reserve selection and better identify priorities for private land conservation. Some agricultural policy settings—such as lethal control of dingoes and land clearing—are contradictory to both conservation and rewilding goals and will require policy shifts to overcome.

Where to for rewilding in Australia?

Rewilding in Australia presents some differences from rewilding in many countries on continental landmasses because it's biota has been profoundly impacted by introduced predators due to their long history of evolutionary isolation. However, there are lessons from Australia that can be useful elsewhere. For example, the focus on reconstructing all components of food webs, starting with small consumers such as small mammals and birds is under-developed globally. Predator exclosures are used to good effect in Australia and also in New Zealand and may have wider potential to facilitate rewilding by promoting persistence of smaller species impacted by introduced predators.

296 The development of a shared vision and goals for rewilding in Australia would provide more clarity
297 of purpose, a guiding policy strategy, and would better allow future evaluation of success. This
298 would also give clear signals to policy makers and funding bodies as to what constitutes rewilding
299 and help avoid rewilding becoming merely a rehash of existing conservation activities which risks
300 eroding public interest. For example, the term rewilding is used in the context of fairy bell-flower
301 (*Homoranthus spp.*) conservation to mean reintroductions following seed collections, with no
302 reference to broader ecosystem benefits (Department of the Environment and Energy 2017). A
303 distinction exists between translocations of species for the conservation of that species (not
304 rewilding) and translocations of species to perform an identified ecological role (rewilding) (Seddon
305 et al. 2014) (Supporting Information).

306

307 Developing projects that seek to demonstrate proof of concept and which integrate communities
308 and research into rewilding actions (Supporting Information) would help answer international calls
309 for more evidence (Nogués-Bravo et al. 2016; Svenning et al. 2016a). Initiating projects in urban
310 areas designed to deliver outcomes for humans and nature, as well as high-profile, achievable
311 landscape-scale rewilding zones incorporating focal rewilding targets are clear priorities. Due to the
312 differences between arid, Mediterranean and mesic Australia, rewilding approaches will need to be
313 tailored to location. Passive rewilding may play a greater role in coastal areas, but a complete
314 absence of management is unlikely to be possible. However, the important ecological role of CWR
315 mammals in Australian ecosystems, and their widespread declines (Fig. 1), means restoration of
316 their populations remains a high priority in both mesic and arid Australia. Similarly, restoring the
317 ecological functions of bird pollinators that have declined due to predation by mammalian predators
318 has been identified as a priority in New Zealand (Anderson et al. 2011).To our knowledge, few
319 rewilding efforts in other jurisdictions around the world have focussed on the restoring the
320 ecological functions of small consumers.

Engaging communities should be a fundamental component of rewilding efforts. This could be aided by focussing initially on species and functions most likely to be accepted by humans to help develop societal support before tackling more controversial activities such as large predators. However, trophic rewilding is a clear goal in Australia, and a concerted effort is needed to shift current attitudes—and government policy—from one of predator persecution to one of tolerance. Bold actions, such as trial reintroductions of Tasmanian devils to mainland Australia (Supporting Information), is broadly supported by the scientific community but has yet to gain political support. In areas of high ecological value, such as national parks, caution is warranted. But in highly modified areas, such as cities, a case can be made that more ambitious policy settings should be pursued to accelerate rewilding efforts. For example, there are large parks in many Australian cities where small mammals could be readily reintroduced and passive rewilding promoted.

The popular appeal of rewilding means it should not be lightly dismissed as to its role in conservation. In order for rewilding to be an effective addition to the conservation toolkit, it is important that rewilding is not used to rebrand existing activities due to it being *à la mode*. In contrast, provided the term rewilding is restricted to those conservation actions that fit the definition, it could play an important role in increasing the profile of conservation and wild nature more generally.

Figure legends

Figure 1: Rewilding may help reverse the loss of ecosystem function in Australia that has stemmed from population declines and species extinctions of digging animals and predators. Since European settlement of Australia, 23 species of ground-dwelling critical weight range mammals have gone extinct and many others have experienced severe range contractions. Predation by red foxes and feral cats, altered fire regimes and habitat loss are key drivers of declines (Bilney et al. 2010; Woinarski et al. 2015). Box A: impacts of reduced digging on ecosystem function; Box B: consequences of the loss of ecosystem function (Martin 2003; James et al. 2009; Bilney et al. 2010; Fleming et al. 2014; Clarke et al. 2015; Hayward et al. 2016; Mills et al. 2017).

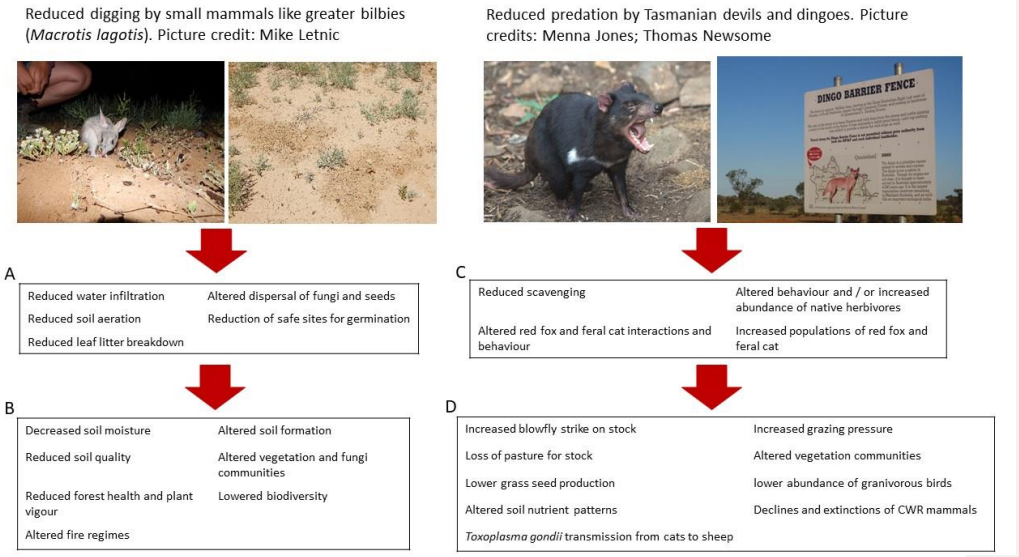
Tasmanian devils became extinct on the Australian mainland around 3,000 years ago (Brown 2006). They have undergone recent sharp disease-driven declines that have reduced the population by up to 95% in some areas. Dingoes (and their 'wild dog' hybrids) are persecuted to reduce the predation risk to farm animals, particularly sheep, and excluded from south-eastern Australia via the 'dog fence'. Box C: impacts of reduced predation on ecosystem function; Box D: consequences of the loss of ecosystem function (Letnic et al. 2012; Hollings et al. 2013; Prowse et al. 2014; Hollings et al. 2015; Hollings et al. 2016; Morris & Letnic 2017; Rees et al. 2017).

Figure 2: Fenced areas, such as this 123km^2 exclosure at Arid Recovery, from which feral predators like red foxes and feral cats are eradicated achieve some rewilding objectives but are ultimately inconsistent with the broader aims of rewilding (Picture credit: Charlotte Mills).

Figure 3: Rewilding can benefit people and biodiversity: A. Wildlife watching can bring economic gain for communities, helping establish direct links between nature and human wellbeing. Rewilding

Europe actively promotes this through its *Rewilding Europe Capital* program. B. Dingoes may confer an economic benefit to farmers in the Australian rangelands by reducing grazing pressure from native herbivores, leaving more vegetation for stock. C. Urban owls, including the powerful owl (*Ninox strenua*) pictured here, may benefit humans and biodiversity via predation on rodents and aggressive birds (Kavanagh 2004). D. Eastern barred bandicoots (*Perameles gunnii*) are widespread in Tasmanian gardens. Diggings have positive influences on soil and bandicoots are predators of pest invertebrates such as curl grubs (beetle larvae that may feed on live plant roots). E. Blue-banded bees (*Amegilla spp.*) perform a specific type of pollination known as buzz pollination. They have been shown to increase tomato yields (Hogendoorn et al. 2006). F. Using storm water runoff to create wetlands in cities, such as this example from Portland, Oregon can provide recreation opportunities and wildlife habitat.

Figure 4: Rewilding is relevant on multiple scales: A. Large-bodied herbivores such as wisent (*Bison bonasus*) exert strong trophic influences over landscape-scales. B. Dam building by beavers (*Castor fiber*), shown here in Sweden, affects tree density, alters flow patterns and influences water tables which influences aquatic biodiversity at regional and local scales. C. Pygmy possums (*Cercartetus spp.*) are small nocturnal marsupials that eat nectar, pollen and insects and have home ranges of under 1 hectare.



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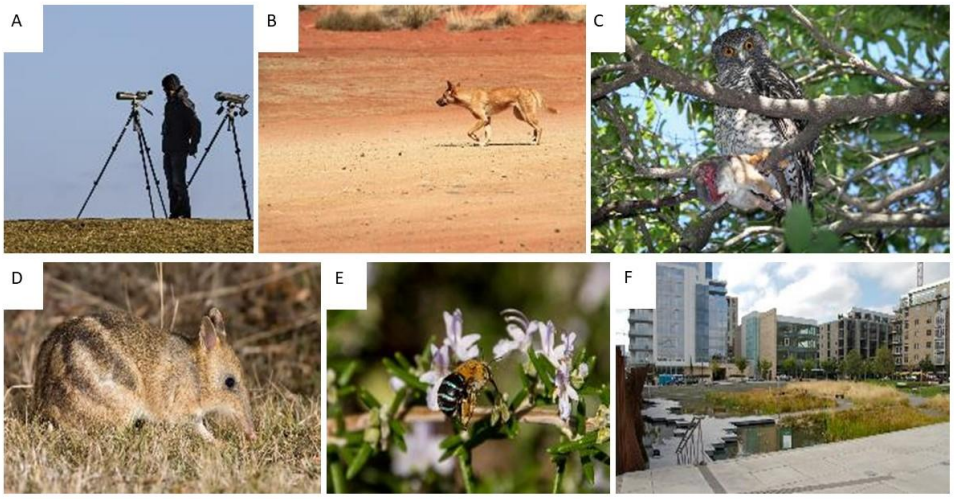

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Supporting Information

Participants (Appendix S1), Methods (Appendix S2), Results (Appendix S3) and a XXX translation of the article (Appendix S3) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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Supporting information

Appendix S1

45 people representing 27 organisations attended the forum (Table 1). Participants involved in rewilding at an academic, government or non-government level were identified by the four organising organisations: National Parks Association of NSW Inc; Taronga Conservation Society; Conservation Volunteers and FAUNA Research Alliance.

Industries represented included environmental NGOs; academia; the zoo industry; wildlife disease specialists; government natural resource management agencies; animal welfare groups and land managers. Animal welfare groups, land managers, policy makers, the corporate sector, the tourism sector, the education sector and the Indigenous community were under-represented.

Table 1: Participants in the National Rewilding Forum and their affiliated organisations

Name	Organisation
Andrea Reiss	Zoo and Aquarium Association / Wildlife Health Australia
Andy Sharp	South Australian Department of Environment Water and Natural Resources
Andrew Elphinstone	Taronga Conservation Society
Anne Reeves	National Parks Association of NSW
Ben Holmes	Conservation Volunteers Australia
Bob Debus	FAUNA Research Alliance
Cameron Kerr	Taronga Conservation Society
Cathy Merchant	NPA NSW
Cecilia Myers	FAUNA Research Alliance / Land manager
Dave Watson	FAUNA Research Alliance
Diane Latta	National Parks Association of NSW

Frans Schepers	Rewilding Europe
Gary Fry	Taronga Conservation Society
Geeta Ortac	National Parks Association of NSW
Gilly Llewellyn	Worldwide Fund for Nature
Hayley Bates	University of New South Wales
Ian Walker	Conservation Volunteers Australia
Jeff Bell	Natural Resources Commission
John Rodger	FAUNA Research Alliance
John Turnbull	National Parks Association of NSW (Facilitator)
Kellie Leigh	Science for Wildlife
Kevin Evans	National Parks Association of NSW
Kiran Charles	National Parks Association of NSW
Lachlan Howell	University of Newcastle
Leah Kemp	Australian Wildlife Conservancy
Linda Bell	Office of Environment and Heritage NSW
Madeline Lalor	University of Newcastle
Maggie Watson	Charles Sturt University
Mandy Paterson	Royal Society for the Prevention of Cruelty to Animals Queensland
Margot Law	National Parks Association of NSW
Mark Anscombe	Worldwide Fund for Nature
Mark Bachmann	Nature Glenelg Trust
Matthew Taylor	Bush Heritage
Menna Jones	University of Tasmania
Mike Archer	University of New South Wales
Mike Letnic	University of New South Wales

Monique Van Sluys	Taronga Conservation Society
Nardi Simpson	Taronga Conservation Society
Oisín Sweeney	National Parks Association of NSW
Pete Ridgeway	Greater Sydney Local Land Services
Peter Mawson	FAUNA Research Alliance / Perth Zoo
Phil Palmer	Bush Heritage
Renae Hockey	Conservation Volunteers Australia
Rob Brewster	Rewilding Australia
Rob Quirke	National Parks and Wildlife Service NSW
Rod Kavanagh	Australian Wildlife Conservancy
Ryan Witt	University of Newcastle
Scott Ryan	Australian Reptile Park
Simon Clulow	FAUNA Research Alliance
Suzanne Hand	University of New South Wales
Tim Faulkner	Devil Ark / Australian Reptile Park
Thomas Newsome	Deakin University / University of Sydney
Vince Scoleri	University of Tasmania

660

661 **Appendix S2**

662 The forum lasted for a single day (7th September 2016) and adopted a facilitated group format where
663 the 45 participants split into six groups. In session one the groups were asked to define what
664 activities were and were not rewilding. In session two, each group was asked to identify the goals of
665 rewilding and to put forward five main goals to the broader group. In order to achieve this
666 participants were asked to rank the identified goals and to vote on which were priorities if needed.
667 Those goals that addressed a common theme were clustered together as participants presented
668 their goals to produce overarching goal themes. The third session focused on identifying and

669 overcoming obstacles to progressing the identified goal themes, and the forth session invited
670 participants to identify those initiatives or projects would be most effective to progress rewilding in
671 Australia.
672
673 **Appendix S3**
674 The results of session one (defining rewilding) are summarised in Table 2. Session two identified six
675 overarching rewilding goal themes. These themes, their contributing goals and the top three success
676 factors and obstacles as identified in session three are summarised in Table 3. Identified projects
677 from the session four are presented in Table 4. Note that results are presented in 'raw' format and
678 thus there may be duplication in tables. This is done in order to reflect as accurately as possible the
679 outputs from attendees. Results were summarised and discussed and made available, along with the
680 raw data, to all participants in October 2016 Sweeney 2016.
681

682 *Table 2: Outputs of session one: responses of participants to the scoping session designed to elucidate what does and does not constitute rewilding in Australia*

Rewilding is	**Rewilding is not**
• Optimising the biodiversity of an ecosystem • Giving control back to nature and changing the emphasis from holding what we have now—including in protected area management • Existing activities (e.g. reintroductions) conducted in a holistic context • Using the paleo record to see how things have changed and to inform rewilding under future climate • A means to restore ecosystem function, leading to better environmental health for flora and fauna and 'future proofing' landscapes • Restoring interactions between species, including predation, parasitism and other ecological processes	• De-extinction • Recreating a given point in history or an idealised time period • Using non-native species as ecological surrogates • Standard threatened species recovery actions • A mammal-centric concept (it's an ecosystem approach) • A complete lack of management intervention • Restoring a perfect picture or ideal state of the past (human settlement and the new nature are inescapable) • Ruling out the use of ecologically important species because they are considered socially unacceptable • The use of animals as tools or quick fixes • Single species reintroductions solely to conserve that species (a focus on ecological function must accompany reintroductions to be considered rewilding)

- Reducing the need for human control of pests species as natural processes (such as predation) take over
- The reintroduction of species to areas of their former range
- A complementary approach to other conservation initiatives (not a replacement)
- Using indigenous Aboriginal knowledge
- Engaging the community in environmental decision making
- Restoring ecosystem resilience and adaptability using climate modelling and the paleo record
- Helping ecosystems to become self-sustaining
- A 'total ecosystem' approach—i.e. considers ecosystems in their entirety and not components in isolation
- Appreciating the role that predation plays and the necessity of predation in ecological systems
- Adaptive and should accommodate the 'new nature'[1]

[1] 'New nature' as used here describes patterns of species abundance, distribution and interactions resulting from human activities

- Restoring ecological processes and ecosystem function
- A long-term vision
- Applicable at multiple scales
- Encompassing different types of landscapes
- Connecting nature to people and communities
- A focus on native wildlife
- Increasing ecological resilience (including through genetic diversity)
- Increasing biodiversity
- Increasing connectivity on a landscape-scale
- Moving beyond fences (fences are stepping stones to wider landscape outcomes in a staged process)
- Maximising genetic diversity
- Achieving a social license for activities

683

684 *Table 3: Outputs from sessions two and three: rewilding goal themes, the contributing goals and success factors and obstacles to achieving rewilding goals in Australia*

Goal theme	Contributing goals	Success factors to achieving goals	Obstacles to achieving goals
Ecosystem function	To secure critical weight range mammals via the restoration of apex predator populations; to restore ecosystem function and resilience in key landscapes and to ensure that ecosystems are self-sustaining with functioning ecological processes at all trophic levels.	1. Management intervention (of feral animals, weeds, aquatic and terrestrial habitats) should be minimal after an 'initial push' 2. Choose locations carefully as success is important – there is an urgent need to demonstrate 'proof of concept' 3. Solve keystone predator issues	Public relations problems (e.g. with dingoes) Aligning community animal welfare concerns with realities of ecological processes Introduced megafauna and a lack of ecological tools to cope with these
Scale and scope	To ensure that rewilding works across boundaries including state, sector (government and non-government)	1. Consensus between stakeholders and the public and a long term vision	Inadequate funding relevant to the scale and timeframe of the problem

	and tenure (public and private); rewilding promotes coexistence between native and non-native species via ecological processes and interactions; to work on a continental scale and consider climate change and connectivity and the application of rewilding to all ecosystems (marine, freshwater and terrestrial).	2. Feral species managed permanently and on a large scale 3. Definition of and a means to measure success	Fragmentation of effort when attempting to deliver national projects on a local level Public opposition to 'no boundaries' Large spatial scales Large time scales Staff turnover
People	To inspire and engage the community; to achieve a 'social license' for rewilding; to ensure the community values nature (intrinsically and economically); to incorporate Aboriginal knowledge and work with indigenous communities to increase	1. Use social research to identify the key stakeholders, values and perceptions 2. Use best-practice community engagement	Compassion fatigue leading to reduced community engagement Urbanisation and lost connections between the public and nature Differing perceptions and values between groups Heterogeneity within the community Cultural values that don't accommodate nature

	awareness of Australia's nature; to overcome the rural-urban divide to progress rewilding and to ensure communities derive economic benefit from rewilding efforts.	3. Access existing knowledge—both indigenous and non-indigenous	Lack of political support Perceived conflict between conservation and production
Vision and strategy	To articulate a vision and strategy for rewilding in Australia; rewilding as a potential means to tackle inherited and novel problems (such as introduced species); to be bold, take risks and take action.	1. An inspirational vision 2. An independent, trusted lead author 3. Overcome competing interests between organisations: Projects need to be 'tenure blind' between organisations; i.e. chose best location, chose best delivery partnership, and other partners fall into line to support	Differing agendas and competing interests between organisations Achieving cross-government agency involvement Adequate funding Commitment to ongoing involvement

Policy	To ensure that resourcing of rewilding programmes is sustainable and long-term; institutional structures support rewilding; barriers to rewilding are removed and regional management efforts for wildlife conservation and feral species control are strengthened.	1. Hold a national conference 2. Host another forum to facilitate a policy paper and communication strategy for rewilding 3. Clarify the obstacles and key issues as to why we should pursue rewilding	Political risks of introducing predators Clarifying the problem and vision to policy makers Developing a clear policy objective Developing a holistic focus (wildlife, ecosystems and economy) Identifying the next steps beyond fencing Flora and habitat have become a surrogate and fauna less important A lack of partnerships and community engagement Losing the fundamental meaning of rewilding (diluting the message) Amount of funding and the necessary timeframes
Research	To establish proof of concept and an evidence-base for Australian rewilding; to identify research	1. Proof of concept that demonstrates change visible to non-scientists	Funding

	opportunities to support rewilding objectives.	2. ‘Sell’ rewilding to the public by choosing projects that will maximise the chance of success and with high visibility (e.g. in urban areas; areas of high tourist visitation) 3. Develop rewilding monitoring protocols to maximise learning opportunities and avoid repetition

685

686 *Table 4: Outputs from session four: ideas to progress rewilding in Australia*

Project name	Description	Outcomes	Key steps	Resources required
Fences down	Removal of boundary fences to share issues with the community and lead to community feral animal control, improved networks enhanced connectivity and cooperation	1. Enhanced connectivity 2. Natural fauna movement 3. Removal of social boundaries 4. Enhanced community ownership	1. Identify trial location (farm, dingo fence, emu fence) 2. Engage local community 3. Identify species to monitor 4. Establish reverse fencing or invisible fencing 5. Monitor 6. Communicate findings	1. Community 2. Landholders 3. Researchers (academics, NGOs) 4. Community support network 5. Media 6. Education program and resources 7. Identified zones
Community behaviour change	Everyone is Australia has a role in rewilding and the urban majority become aware of the diversity of urban wildlife and	1. New behaviour becomes the norm 2. Easy to follow actions	1. Local government involvement 2. Local community group involvement	1. A national toolkit that is flexible enough to be applied locally across Australia

	alter pet ownership behaviour as a result	3. Clearly communicated and easily explained	3. 'Sustainable schools' model 4. Vegetation mapping (identify habitats and gaps)	2. Citizen science apps 3. Volunteer wildlife groups (e.g. WIRES)
De-fencing Australia	Experimental removal of fences and investigation of alternatives to fencing on farms to restore habitat connectivity on a large scale	1. Enhanced connectivity 2. Information on alternatives to fencing (bio-fencing, guardian animals) 3. Enhanced ecosystem function	1. Identify the threats driving fencing (dingoes, macropods or grazers, weeds) 2. Achieve stakeholder support (incentives may be required) 3. Communicate proof of concept 4. Remove the 'scare factor'	1. Funding (to provide incentives) 2. Community support 3. Political will 4. Stakeholder buy-in 5. Human resources (research

			5. Staged approach with early adopters in areas with and without threats 6. Monitor small mammal communities and ecosystem function	
Tasmanian devils on the mainland	Tasmanian devils evolved on mainland Australia. They play a significant role in ecosystem function in Tasmania suggesting a function has been lost on the mainland	By 2020 a population of Tasmanian devils is secure on the mainland where their impacts on feral animals in regards competition, predation and altered behaviour can be tested	1. Identify literature that supports the concept 2. Define the experimental design and monitoring 3. Resource the reintroduction 4. Community consultation (preliminary and ongoing) 5. Understand baseline ecology of release site	1. Political will 2. Cross government and agency cooperation 3. Funding 4. NGOs to assist in coordination and community engagement

Dingo reintroduction	Relocating the dingo fence so that Sturt National Park is moved north of the fence	The trophic influence of dingoes is tested via a before and after experiment	1. Develop a clear narrative (costs and benefits) 2. Address community concerns and opposition 3. Communicate 4. Ensure means to address potential dingo predation / hyperpredation	1. Social science support 2. Government support
Rewilding Southern Yorke Peninsula	A. Reintroducing (i) endemic and non-endemic native predators, (ii) soil engineers, (iii) pollinators. B. Habitat restoration on Wauraltee IPA (Wardang Island), to create an in-situ captive breeding program.	1. A landscape-scale sanctuary for threatened species 2. Prevent further loss of ecological functionality 3. Increase ecosystem services to agriculture 4. Enhance natural capital available to local ecotourism	1. Pre-planning (done) 2. Community engagement (done) 3. Community group involvement (done) 4. Obtain local government support (done)	1. Funding

		5. Build resilience to climate change	5. Implement delivery partnership (MoU) (done) 6. Implement threat mitigation (done) 7. Undertake baseline monitoring (ongoing) 8. Finalise and approve translocation plans	
Rewilding supports regional economies	Prove through targeted trials that rewilding can help diversify regional and local economies	Rewilding initiatives are a win for communities and a win for biodiversity so communities achieve ownership and appreciate the benefits	1. Incorporate social and cultural values of community in project design 2. Identify and support community champions 3. Build local partnerships	1. Secure government funding 2. Secure non-government funding 3. Human resources (related to above)

			4. Community and practitioners work together to plan, implement and manage rewilding efforts 5. Communicate (social media, youth programs) 6. Monitor and market success	
Devils v foxes	Tasmanian devils are reintroduced into at least two sites (Barrington Tops and Orange) to test their impact on foxes	Information gathered on the nature of devil / fox interactions and whether devils can play a keystone role	1. Fenced exclosure as first release	1. Political will

Embedding disease risk assessment in translocations and reintroductions	Identify potential disease risks and establish processes to manage risk	1. Human intervention does not increase the risk for wildlife disease 2. Translocated and wild populations are healthy	1. Gather existing information on disease 2. Identify knowledge gaps and how to fill them 3. Prioritise diseases for investigation 4. Test, quarantine and treat animals prior to translocation 5. Monitor populations 6. Develop a national database and sample archive	1. Technical expertise 2. Guidelines 3. National policy
Devils in south-west Victoria	A single-sex trial reintroduction of Tasmanian devils into a	1. Test the efficacy of devils as a top-down tool to manage	1. Community consultation 2. Develop experimental design	1. Lead NGO 2. Partner organisation 3. Research partner

	60,000ha reserve subject to >10 years of intensive fox baiting	mainland temperate ecosystems 2. Determine whether observed perverse outcomes from baiting can be reversed 3. Subject to 1, test a self-sustaining wild population 4. Pave the way for reintroductions of other lost species using Tasmania as a reference site	3. Obtain approvals and source devils 4. Implement and monitor 5. Review, refine and progress goals 6. Conduct trials elsewhere	4. Funding (staff) 5. Permits (scientific and ethics) 6. Devils 7. Equipment
Process driven vision and strategy for Australia	Identify ecological processes that have been altered by invasive species, lost predators and ecosystem engineers and put in place bold solutions	Improved ecosystem health	1. Manipulate processes (e.g. via Tasmanian devil reintroduction to Barrington tops, cats in midland Tasmania)	1. Locations 2. Funding 3. NGO partner (AWC?) to help overcome public and political hurdles

			2. Address public and political misunderstandings and fear 3. Provide a space for researchers and NGOs to collaborate to ensure risk is spread	4. Meetings 5. Online fora 6. Websites (Rewilding Australia?)
Establishing priority areas for rewilding in Australia	Priority areas should be in locations where actions are feasible, with high connectivity, high value for eco-tourism, high conservation value, a receptive community, and be of a sufficient size	1. A tool to help guide stakeholder decision making for rewilding initiatives for use by NGOs, landholders and government	1. Develop a steering group of land managers, experts (research, NGOs), traditional owners and politicians 2. Identify willing landholders and regional organisations 3. Raise money	1. GIS mapping expertise 2. Community and landholder surveys 3. Communication strategy 4. Collaborate with Atlas of Living Australia

			4. Develop a criteria (tool) to decide on priority areas	
Rewilding data capture	To analyse the results of past reintroductions, and ensure future reintroductions provide release data (who, what, where, when, sex ratio etc) to regulator, ALA, museum	1. Compare extant animals with reintroduced to see whether reintroductions have influenced Area of Occupancy / Extent of Occurrence 2. Improved reintroduction protocols 3. Reintroduction handbook and/or template	1. Share data 2. Monitor reintroductions closely	1. Student + supervisor
Identifying metrics for baseline monitoring	Identifying ecologically meaningful, practical indices to measure before, during and after rewilding	1. Indices identified (e.g. ecological engineers) 2. Response variables identified (e.g. soil health, water quality, vegetation quality)	1. Establish protocols 2. Identify key sites 3. Share data	1. Academic researchers 2. Volunteers to undertake monitoring 3. Conservation Volunteers Australia

	3. Means of monitoring identified (e.g. teabag index)

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