

Biodiversity on private land: Lessons from the Mid-Murray Valley in South-eastern Australia

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Summary In this article, we use an autoethnographic approach to explore relationships between landholders and government agencies and natural resource management projects. We use this exploration to argue for a holistic, collaborative approach to decision making around the implementation of biodiversity conservation on private and public land. This approach aligns with principles underpinning reconciliation ecology, which emphasises the inclusion of grass-roots communities for promoting biodiversity conservation in human-dominated landscapes where approaches to the management of natural resources may be contested. We present three projects (Environmental Champions; Fencing Incentive programmes; Plains-wanderer programme) and other research from the Mid-Murray Valley region of southern New South Wales to highlight the positive and negative aspects of relationships between landholders and others in natural resource management. We argue that for a more collaborative approach; we need to build relationships based on understanding, trust, respect, ownership and partnerships between rural communities, landholders, education and research institutions and government agencies as recognised in reconciliation ecology.

Key words: landholder, Murray Valley, natural resource management, reconciliation ecology, research collaboration.

Implications for Managers

- NRM across Australia needs to include private lands to effectively maintain and conserve biodiversity.
- Changes to Landcare illustrate how farmers and their communities have been marginalised in NRM and biodiversity conservation.
- Farmers have had mixed experiences with researchers in the Murray Valley.
- Farmers' experiences were explored to address relationships with researchers through concepts drawn from reconciliation ecology.
- Mutual trust and respect should be the basis for future approaches to promote biodiversity conservation on private land.

Introduction

The existing broad environmental legislative framework in Australia should enable an inclusive, respectful approach to natural resource management (NRM), where rural and Indigenous communities, landholders, environmental groups and government agencies can work cooperatively to manage and protect biodiversity (Wyborn 2015). However, NRM has become increasingly partisan and

conflicted, at times pitting rural communities against state and national government agencies and urban-based environmental groups (Curtis *et al.* 2014; Wyborn 2015; Pfeiffer *et al.* 2017). Developments in NRM that have influenced this increasing conflict include: shorter policy cycles, rigid structures within agencies, reductions in staffing, redirection of government resources, more centralised command and control over bureaucratic governance, and a lack

of acknowledgement of the role rural communities and landholders play in NRM and biodiversity conservation (Robins & Kanowski 2011). The examples we present highlight collaboration and conflict surrounding NRM in the New South Wales (NSW) Mid-Murray Valley. They also emphasise the value of approaches that engage communities and landholders in the research that informs NRM and impacts on rural and regional Australians.

Biodiversity conservation in Australia has largely relied on governments setting aside and managing protected areas and developing measures to protect endangered species (Finlayson 2006; Lockie 2009). Measures on private land have primarily focused on regulatory approaches, such as those for native vegetation clearing, and on landholder incentive programmes (Cooke *et al.* 2012). Successful community and landholder management of biodiversity in agricultural landscapes is critically important for meeting national biodiversity conservation objectives, as more than 60 per cent of the Australian land area is under private ownership or long-term leases, of which 58 per cent is recognised as agricultural or grazing lands (ABARES 2016).

In this paper, we investigate the role of communities and private landholders in NRM and biodiversity conservation, considering landholders' self-reflections on their experiences through the lens of reconciliation ecology. We focus on the productive irrigated landscapes of the Mid-Murray Valley and draw on autoethnography of five of the authors, farmers and community members from the area, to explore their experiences of NRM.

Community and landholder participation in NRM in Australia

The story of Landcare illustrates the changing relationships between communities, governments and NRM in regional Australia – see Curtis *et al.* (2014) for a short history. Since the 1980s, the community-based movement has been a central element of NRM and biodiversity conservation on private land locally and nationally. From its earliest days, views differed on Landcare: as a 'grass-roots', community approach to NRM on private land supported by state government resources that engendered a degree of local group autonomy (Cary & Webb 2000); or as a government-led and branded 'participatory' NRM programme for communities (Wilson 2004). In the former view, Landcare established relationships between landholders and State agency staff, and

engendered mutual trust and respect (Curtis & DeLacy 1995). In the latter, Landcare groups developed through different pathways depending on local contexts, resulting in different experiences (Wilson 2004).

The early success of Landcare was attributed to landholders, conservationists and state agencies collaborating to address land management issues such as soil salinity, initially with minimal government funding and eventually with considerable impact on the wider catchments (Tennent & Lockie 2013). Local landholders provided contextual knowledge and enabled access to private property, council reserves and local ecological assets (Robinson *et al.* 2015) to enable biodiversity conservation and improve land management (Lockie 2009).

With these initial successes, the Commonwealth government established a National Landcare Program in 1996 (Cary & Webb 2000), whereby government agencies centralised policy and programme development and imposed increasingly inflexible requirements on landholders to enable access to funding. There was an increasing focus on government-developed criteria and priorities through competitive grant funding, rather than financially facilitating community-initiated and developed priorities. These actions caused community disengagement and reduced local commitment essential to achieve sustained, on-ground outcomes in biodiversity (Head *et al.* 2016). The shift from community-based projects to government targeted, competitive project-based grants further eroded landholder input and participation (Robins & Kanowski 2011); centralised and narrowed the scope of Landcare, reducing local ownership of regional projects (Paton *et al.* 2004); reduced community or stakeholder input and consultation on narrower, 'top-down' targets (Vella *et al.* 2015); and increased competition for funding and conflict about priorities (Prager 2010). This shift in focus for Landcare groups to small, short-term, easily measured projects also contributed to a decline in collaborative NRM research between landholders,

universities and State agencies (Robins & Kanowski 2011).

In recent years, community groups have become increasingly concerned that their contextual knowledge and input is being dismissed in the design of many NRM programmes and projects: from the traditional knowledge regarding water management targets and objectives (Robinson *et al.* 2015), to farmer experience in sustainable native pasture production for extensive grazing (Cross & Ampt 2017), and in mitigating the effects of climate change on large-scale dryland cropping (Raymond & Robinson 2013). Having experienced the increasing consequences of climate change and biodiversity loss, communities feel a loss of control over their local circumstances, and are seeking atonement through 'restorative justice', wanting increased involvement and participation in NRM decision making that impacts their community (Wood & Suzuki 2020).

We contend that ongoing co-ownership and informed engagement between landholders and researchers on programmes and research that inform NRM policy is more likely to deliver sustained commitment from local stakeholders to agreed outcomes and reduce potential conflict. Limiting the value placed on the importance of long-term relationships between key stakeholders in NRM risks undermining opportunities for improved NRM outcomes and biodiversity conservation across all land tenures (Howard 2010; Robinson *et al.* 2015; Cross & Ampt 2017). In this paper, we address this risk by presenting an alternative approach – reconciliation ecology – that incorporates and improves on past experiences in NRM and engages local communities and private landholders in the research required to deliver improved outcomes in local subcatchments while maintaining a productive agricultural sector.

Reconciliation ecology in rural Australia

In response to concerns with recent NRM practices, the authors investigated alternative approaches to biodiversity conservation in agricultural landscapes, including

Reconciliation Ecology as proposed by Rosenzweig (2003b). Reconciliation ecology recognises the need to reconcile human use and highly modified landscapes with biodiversity conservation, defined as “the science of inventing, establishing, and maintaining new habitats to conserve species diversity in places where people live, work, or play” (Rosenzweig 2003b: 7), and complements rather than replaces traditional conservation and restoration ecology. (The authors acknowledge that in an Australian context, the term ‘reconciliation’ is used to describe the ongoing process of acknowledging Aboriginal and Torres Strait Islander peoples as Australia’s First Peoples.)

It has been increasingly acknowledged that conservation within protected areas needs to be complemented by activities in agricultural and forestry areas (Fitzsimons & Wescott 2001; Fischer *et al.* 2006). Activities within these areas generally aim to maintain the economic viability and ecosystem services on which agriculture and forestry depend. Rosenzweig (2003b) argues that traditional approaches to biodiversity conservation based on protected areas and restoration

of human-impacted ecosystems can, at best, only slow biodiversity loss unless they are part of a wider strategy that includes human-dominated ecosystems. Further, better outcomes can be achieved through community-driven approaches and partnerships to establish, maintain and expand suitable habitats including in human-dominated ecosystems. Reconciliation ecology embraces the concept of subsidiarity, whereby, while recognising the role of government, action is taken at the lowest level of organisation and as close to citizens as possible (Head 2007).

Reconciliation ecology aims to protect, maintain and improve biodiversity conservation across the landscape, with proponents emphasising the benefits that can accrue by altering and diversifying human modified ecosystems to enable them to support a wider variety of species over a wider possible range (Holt 2004). While no examples were found in the literature on application of reconciliation ecology for NRM on Australian farms, Bartel and Graham (2019) have outlined the activities of four Australian landholders who have reconciled agricultural practices with the local environment using

principles from regenerative agriculture and reconciliation ecology. This has allowed significant expansion of areas for biodiversity conservation while maintaining agricultural viability of landholdings. Their stories support Rosenzweig’s (2003a,b) proposal that reconciliation ecology can be used to identify opportunities to modify and improve agricultural ecosystems, increasing biodiversity and available habitat for endangered and threatened species.

In this paper, we present three case studies and associated research in the Mid-Murray Valley region of southern New South Wales to highlight the positive and negative aspects of relationships between landholders and other stakeholders in natural resource management, and analyse how a community-led approach using reconciliation ecology improved NRM outcomes and biodiversity conservation in the region.

The case of the Mid-Murray Valley of New South Wales

The Mid-Murray Valley region is bordered by the Murray River and Victoria to the south, the Riverina catchment to the



Figure 1. Map of the Murray Valley Region of NSW. Source: CSU SPAN

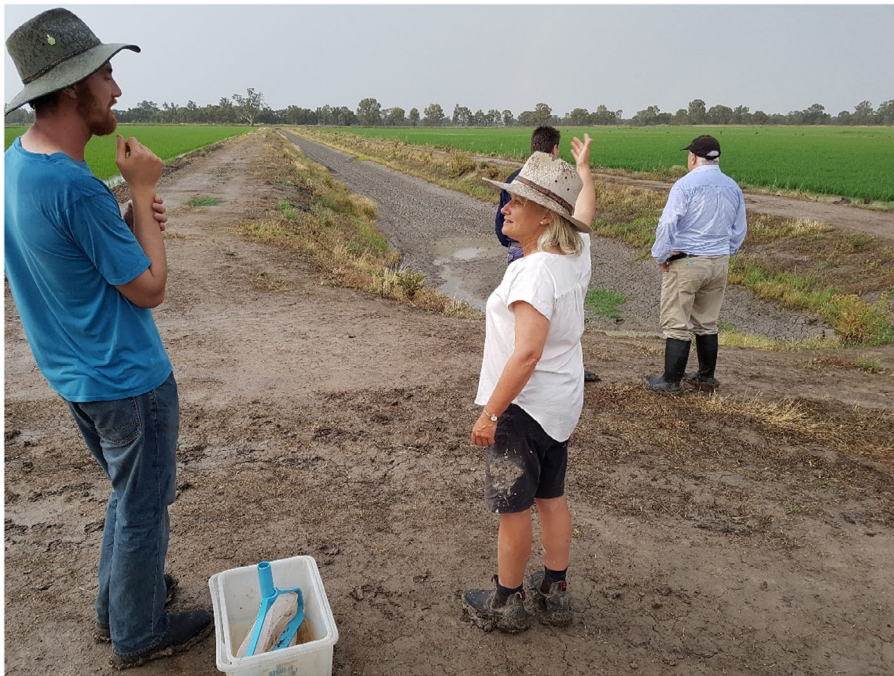


Figure 2. Farmer and co-author Louise Burge (centre) discusses biodiversity management in rice paddies in the Mid-Murray Valley with wildlife ecologist and researcher Matthew Herring (left).

Table 1. Summary of most recent human population statistics (2016) for the NSW shires of Edward River and Murray River (ABS 2016a,b) compared to national figures

Statistic	Edward River	Murray River	Australia
Total population (number)	8,851.0	11,680.0	23.3 million
Female (%)	50.8	50.4	50.7
Median age (years)	45.0	49.0	38.0
Aboriginal population (%)	4.0	3.2	2.8
Education: Up to Year 10	15.0	13.6	10.8
University Bachelor +	10.1	11.1	22.0

north, the Australian Alps to the east, and the Western catchment area to the west, marked by the junction of the Murrumbidgee and Murray rivers. The Valley is a highly modified landscape dominated by dryland and irrigated agriculture that surround rural townships and seminatural areas including the Barmah-Millewa, Koondrook-Perricoota and Werai forests (Murray LLS 2016). Differing landscape attributes are interconnected by rivers, primarily the Murray and the Edward-Wakool, and a large gravity-fed irrigation system with 2,000 kilometres of irrigation canals (MIL 2019; Fig. 1).

The Barmah-Millewa river red gum forests encompass 66,000 ha of the Murray River floodplain. Comprising river red

gum (*Eucalyptus cameldulensis*) and black box (*E. largiflorens*) communities, these forests are nationally and internationally significant and listed on the Register of the National Estate, as Wetlands of International Importance under the Ramsar Convention, and as *Living Murray* icon sites. The northern part of the catchment is dominated by the treeless Hay Plains which support native grasses and the endangered weeping myall (*Acacia pendula*) vegetation community. In addition, remnant vegetation on private and public property across the region is important for supporting biodiversity (Figure 2).

The NSW Mid-Murray region includes the shires of Edward River (based in

Deniliquin) and Murray River (based in Moama - see Figure 1). Outside of these centres, human populations are scattered in small rural towns (including Moulamein and Jerilderie) and on private agricultural properties. A summary of the human landscape is provided in Table 1, illustrating an older rural population with lower formal education and higher proportion of Aboriginal peoples compared to more urban areas.

This human and biophysical landscape provides important context for agricultural production and NRM in the Mid-Murray Valley.

Gathering landholder stories

Autoethnography is a process and product of research where the researchers draw on their personal experience to understand cultural experience (Ellis *et al.* 2011). The researchers are part of the research focus, writing reflexively to explore their own positionality in the context under consideration (Rogers *et al.* 2013). This approach acknowledges the relationships between researchers and others and aims to “make life better” by exploring one’s struggles (Adams *et al.* 2015: 2). This approach is relevant to farming in the Murray Valley, where conflict has been felt by farmers but remains unexplored.

In the last two decades, NRM in the Mid-Murray Valley has been dominated by short-term programmes based on government incentives (‘carrot’); agency-led, top-down programmes based on regulations (‘stick’); and bottom-up, community-led programmes. The differing approaches have resulted in both collaboration and conflict, and provided a basis for local communities to look for alternative, more participatory landholder-led NRM models. This emphasis on a broad-based, bottom-up participatory, community-led context distinguishes this paper from other works that argue for collaborative or consultative approaches to NRM. We propose rural communities’ and farmers’ voices are central to this discussion and they should be considered in addition to previous studies and reviews as valid accounts of the real



Figure 3. Contrasting ecosystems: rice paddy (foreground) surrounded by a river red gum/black box community in the distance, and cumbungi (*Typha orientalis*) in the irrigation channel; near Deniliquin, NSW.

world. We contend that NRM research would be better if based on participatory processes from the outset.

The conceptualisation of this paper stemmed from a group of farmers who formed a community-based organisation and approached university researchers with the aim of improving NRM in their region. The collaboration between all authors in this paper has been born out of lived-experiences. The stories were either written by the farmers, or by the researchers in close consultation with the farmer-author during face-to-face meetings. The stories were reviewed several times by the authors, all of whom live and work in the Murray-Darling Basin. The authors' collective experiences include active participation in water management planning in the MDB in conjunction with federal and state agencies, community-based groups, media and government, university and private researchers. These experiences have led to involvement in on-ground projects and contributions to governmental and parliamentary panels; and input to and participation in inquiries and research publications (Figure 2).

Experiences of NRM in the Mid-Murray Valley

Following are three case studies using autoethnographic principles. These demonstrate the opportunities and challenges facing NRM on private lands in the Mid-Murray Valley, which could be addressed through reconciliation ecology.

Encouraging community commitment to environmental conservation: Environmental Champion Program

Initiated by the Ricegrowers Association of Australia (RGA), the Environmental Champion Program (ECP) was designed by farmers primarily for rice-based farming systems in the Murray Valley irrigation areas (RGA 2019). As local agricultural production is based around a complex farming system where rice is but one component of crop selection, the ECP was applied across various production systems. It involved a voluntary, five-step performance improvement programme, where achievement thresholds were recognised through an accredited

Environmental Management System. Participants moved towards different levels according to the individual landholder's personal commitment and business capacity.

The programme has operated in parallel with the rice industry's scientific and collaborative research programs and included understanding the role that Riverina rice fields play in conserving biodiversity, which supported greater commitment from individual landholders (see Figure 3). For example, collaborative scientific studies between universities, farmers and the rice industry since the 2000s confirmed the presence of the endangered Southern Bell Frog (*Litoria raniformis*) in rice agroecosystems in the region (Hoffmann 2018). Initiated by farmers and leading to partnerships between farmers, scientists and the rice industry, the *Bitterns in Rice* research programme monitors the migration of the endangered Australasian Bittern (*Botaurus poiciloptilus*) (Herring *et al.* 2014). The programme raised \$65,000 in 'crowdfunding' to determine the relationship between bitterns, Murray Valley rice fields and the location and distance that individual birds travelled after rice was harvested. This identified the Riverina as a 'population hotspot' for the Australasian Bittern (RGA 2016).

Increasing individual commitment: fencing incentive programmes

Fencing incentive schemes supported by various programmes have for decades provided support for farmers within the Murray Valley for fencing native vegetation to manage livestock grazing pressure. They have been well supported by NRM-based bodies, such as Catchment Management Authorities in Victoria and Local Land Services in NSW, not-for profit agencies such as Greening Australia, and by the farming communities who hold the private properties such schemes were designed to support. Evaluation of the effectiveness of these programmes has shown varied results (Spooner *et al.* 2002). In general, fencing programs demonstrated positive flora and fauna impacts where the fencing had been maintained (Higgisson 2014).

Voluntary schemes have been found to deliver cost-effective outcomes, but ownership by landholders during and after the initiative was deemed important, for example, to ensure fences were maintained (Ansell *et al.* 2016).

In one example, the 'Fencing Incentive Program' administered by Greening Australia provided incentive to family farms, supporting their long-term commitment to enhancing areas of native bushland. Areas were fenced to exclude stock, understory species were planted, and mixed tree plantations were established to support biodiversity within productive farming systems. Long-term ecological monitoring enabled research into the positive impacts of fencing for biodiversity conservation (Michael *et al.* 2014; Lindenmayer *et al.* 2018). Farmers acknowledged the importance of forming open relationships in ensuring that data collection and monitoring occurred. Close relations with researchers provided farmers with feedback that confirmed ecological successes (Lindenmayer *et al.* 2013) that they witnessed first-hand.

Reintroducing local experiences: plains-wanderer programme

Introduction of State Environmental Planning Policy (SEPP) 46 by the NSW government in August 1996 led to the development of Regional Vegetation Plans (RVPs) across rural areas in NSW. The initial concept of Regional Vegetation Committees developing RVPs did not correspond to broader community expectations; government policy requirements within the plans and restrictive overlays applied to private land use led to a protracted conflict between the government and local communities, with legacy effects evident.

Prior to SEPP 46, scientific or general observation of bird species on private property commonly occurred around NSW. The 'open gate' policy enabled the conduct of bird surveys on properties on the Hay Plains region north of Billabong Creek (Fig. 1). Surveys included the monitoring of the critically endangered Plains-wanderer (*Pedionomus torquatus*), a small ground-dwelling bird that favours

short grasses growing on reddish soils (Baker-Gabb *et al.* 2016). This species cohabitated with sheep grazing in highly modified agricultural landscapes, which included little dryland or irrigated cropping.

Restrictive land clearing and vegetation management laws under SEPP 46 were replaced by the NSW Native Vegetation Conservation (NVC) Act (1997). The perceived risks of future agricultural development in the region were embodied in RVPs and NSW native vegetation, and threatened species policies were embodied in the NVC Act (1997). The original data collected in earlier bird surveys on private properties in the region were reported to be included in NSW Government datasets and incorporated into regulatory policies. The Western Riverina RVP, which included objectives for habitat linkages and mapping of specific areas, was added to the draft RVP. Largely focussed on a desktop mapping approach to species protection, these mapping overlays created ongoing conflict and concern over the rigour of the scientific information included in the RVP.

During the mapping exercise for the Hay Plains, core habitat areas for the Plains-wanderer were identified based primarily on soil type and native grass species. Each core habitat area mapped on private land also included a two-kilometre-wide buffer zone, with multiple sites often occurring on individual properties. Because the Plains-wanderer was listed as an endangered species under the NSW Threatened Species Conservation Act (1995), this led to considerable conflict between landholders and the NSW National Parks and Wildlife Service (NPWS). In addition, NPWS had to develop a Plains-wanderer Recovery Plan within three years, which some landholders feared could exclude them from accessing or using their land for efficient agricultural production, with implications for the management of weeds and pests.

During this time, the dominant concept was that species protection primarily required the restriction of activities including agriculture. Consequently, conservation agencies purchased several historical sheep grazing properties and converted

them to national parks (Lunt *et al.* 2007). The subsequent exclusion of livestock led to high densities and height of plants that were not preferred habitats for the Plains-wanderer. Indeed, Wong *et al.* (2006) showed that the controlled use of fire and sheep grazing on the northern lowland plains of Victoria could reduce plant cover and help maintain the Plains-wanderer's habitat. This was consistent with the ongoing advice of local landholders who had long argued against the regulatory restrictions being applied.

Local concerns regarding mapping, datasets and regulatory overlays continued until efforts by landholders, supported by five local shire councils, led to an independent scientific review. The landholders contended that the accuracy and implication of mapping and associated regulations were not considered in conjunction with local knowledge about the distribution and movement of the Plains-wanderer, as supported by Wong *et al.* (2006). The prolonged conflict also influenced other NSW agricultural regions; private landholders developed a 'lock-the-gate' policy and restricted access to their properties for scientific research, arising from their view of unfairness.

A more cooperative partnership model between landholders and NPWS was later developed, with greater involvement of landholders in the design and implementation of processes to protect the Plains-wanderer, and financial incentives for the landholders.

This conflict had widespread ramifications for species conservation and NRM programmes across Australia. Questions on how scientific data are collected and used were overshadowed by a broader legacy: many farmers felt there was a breach of trust by the research community, and the onus of species protection became a liability for landholders.

Developing Farmer-led Reconciliation Ecology

The authors contend that the complex socioecological system of the Mid-Murray Valley region, based on the family farm, is a prime site for the application of reconciliation ecology, to both ensure coming

generations see a future in agriculture and the survival of key species. Lawrence *et al.* (2004) observed that farmers in their studies had a sense of land stewardship and a desire to leave their land in a better place for the future. Furthermore, when profitable farmers are willing to participate in NRM programmes, they are happy to undertake their own projects to improve biodiversity on-farm, particularly where programmes are demonstrated to have economic benefits (Pannell *et al.* 2006).

Various approaches for involving landholders in conservation research and management are demonstrated in our case studies, including landholder involvement in:

- Collaborative ecological studies and crowdfunding research with university and industry partners on the Australasian Bittern;
- long-term on-farm monitoring of revegetated land and impacts on on-farm biodiversity; and,
- design of management plans, including financial incentives, for the Plains-wanderer.

From these experiences, the National Agricultural Productivity and Reconciliation Ecology Centre (NAPREC) was formed in 2016 as a community organisation based in Deniliquin, NSW to combine local knowledge and understanding with academic ecological and social research. The Centre aims to explore a collaborative model of NRM that could deliver sound long-term social, economic and ecological outcomes for regional Australia. Many landowners in the Mid-Murray Valley feel under increasing pressure from current NRM policies that alienate and do not recognise the considerable community work already undertaken by landowners. Head *et al.* (2016) recognised that successful engagement with local communities and landholders can value-add to government-funded programmes and create long-term benefits beyond the lifespan of individual projects. Farmers in the Mid-Murray Valley recognise that there are opportunities for both maintaining agricultural productivity and achieving positive

ecological and social outcomes (Campbell *et al.* 2017), transcending political cycles to deliver long-term benefits to people and the environment (Bouwen & Tailieu 2004).

Conclusion: Principles for People-centred NRM in the Mid-Murray Valley

By drawing on autoethnography and describing the lived experiences in relation to NRM in the Mid-Murray Valley, we have presented a case for why a different approach to NRM is needed in the region. We suggest reconciliation ecology provides conceptual foundations from which this new approach can stem.

Based on the experiences described, we support proposals that encourage effective participatory planning and management to co-design, develop and implement NRM and biodiversity conservation projects, including research, that engage local communities in decision making. We also support the development of adaptation pathways that result in effective on-ground management in NRM, as is outlined in Finlayson *et al.* (2021), and use principles of co-design and adaptive management (Mitchell *et al.* 2014; Allan & Watts 2018). In addition, NRM actions, such as those proposed by Baumgartner *et al.* (2019) for water management, should complement existing, publicly funded programmes to provide greater confidence in the likely success of such programmes, including the delivery of benefits to local communities. And finally, and possibly controversially, we consider that public figures should be accountable for the successful implementation of expensive, publicly funded programmes, after analysis by independent researchers (e.g. Colloff *et al.* 2021) that show shortfalls in expectations and outcomes from similar programmes, such as environmental watering initiatives in the MDB.

Key ingredients for such initiatives outlined above would include:

- increased focus on funding community initiated and developed research, priorities and programmes;

- increased community role and participation in NRM decision making that impacts their local and regional community; and,
- involvement and engagement of local communities and private landholders in research required to deliver improved biodiversity conservation outcomes in local subcatchments, while maintaining a productive agricultural sector.

These efforts would recognise the role of government and use the principle of subsidiarity to improve NRM and biodiversity conservation outcomes on public and private land by empowering on-the-ground action at community and sub-catchment levels.

This commentary does face some limitations. The perspectives of landholder groups in the Mid-Murray Valley were limited by the number of landholders involved. However, the rich and detailed information provided offers a detailed understanding of the positive and negative effects of recent research projects into the biodiversity of the Mid-Murray Valley, and the role that reconciliation ecology could play in addressing complex socioecological issues besetting regional communities.

Given the cases described in this paper, we believe further research into this topic could investigate:

- new methods to support NRM policy based on co-design of programmes and projects that value landholder participation and production outcomes;
- incentives for landholders to share their knowledge to support the planning and further development of more effective NRM processes; and,
- training opportunities to assist NRM researchers to engage more effectively with rural communities.

Such steps could take the best examples and insights, including lessons from the cases described in this paper, in pursuit of achieving a consistently high level of community interaction and support, and improved NRM and biodiversity conservation outcomes in Australia and

elsewhere, and potentially demonstrate more successful investment in developing adaptive management and, in the future, of adapting to global change.

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