

Prospects for ecologically and socially sustainable management of total grazing pressure in the southern rangelands of Australia

R. B. Hacker^{A,D}, K. Sinclair^B and L. Pahl^C

^ARon Hacker Rangeland Consulting Services, 29 Edward Street, Tenambit, NSW 2323, Australia; formerly NSW Department of Primary Industries, Trangie Agricultural Research Centre, Trangie, NSW 2823, Australia.

^BNSW Department of Primary Industries, Wollongbar Primary Industries Institute, 1243 Bruxner Highway, Wollongbar, NSW 2477, Australia.

^CQueensland Department of Agriculture and Fisheries, PO Box 102, Toowoomba, Qld 4350, Australia.

^DCorresponding author. Email: ron.hacker@crt.net.au

Abstract. Numerous large herbivore species, both native and exotic, share the southern Australian rangelands with domestic livestock, which often account for only about half of the total grazing pressure. Although each presents its individual challenge to landholders, the management of kangaroos is a key component of ecologically sustainable management of the region because (a) they represent a significant component of the non-domestic grazing pressure, particularly in areas from which dingos and wild dogs have been (partially) removed; (b) commercial harvesting, the means of control that has the highest social acceptability, has been rendered ineffective by the actions of activist groups and market closure due to food safety concerns; (c) the task is largely beyond the capacity of individual landholders; and (d) the same constraints do not apply to other non-domestic components of total grazing pressure. Management of total grazing pressure, and particularly kangaroos, currently represents a case of market failure because the level of management that can be expected of landholders is not consistent with public expectations for resource conservation and animal welfare. Several avenues are available by which kangaroo management could be advanced to achieve both public and private benefits. These include adoption of an active, adaptive management approach to the kangaroo population, establishment of arrangements that will shift the general perception of kangaroos from pest to resource, development of an appropriate incentive framework to achieve desirable landscape outcomes, and continued evaluation of the benefits and costs of cluster fencing. These initiatives require both a greater commitment from governments to address the market failure and a proactive stance by industry to engage stakeholders, self-regulate, and objectively demonstrate environmental and animal welfare credentials.

Additional keywords: duty of care, kangaroos, social licence.

Received 9 February 2020, accepted 28 February 2020, published online 24 March 2020

Introduction

The southern rangelands of Australia, as defined by Hacker *et al.* (2019), lie almost entirely within the 500 mm average annual rainfall (AAR) isohyet, and mostly within the 250 mm AAR isohyet. Extensive tracts are not used for pastoral production but where grazed the broad vegetation types comprise arid mulga woodland (dominantly *Acacia aneura*), central arid woodlands (*A. aneura* and other species), semiarid woodlands (*Eucalyptus*, *Acacia* and other species), saltbush (*Atriplex* spp.) and bluebush (*Maireana* spp.) communities and mallee (*Eucalyptus* spp.), with some areas of Mitchell grasslands (*Astrebla* spp.) in the north-east. Properties range from around 20 000 ha on the wetter fringes to more than 200 000 ha in the more arid areas and are mostly held under some form of pastoral lease from State and Territory governments. The pastoral industry within this region

is sedentary. There are no seasonal movements of livestock, and more-or-less continuous grazing is still widely practiced.

Sustainable use of this region requires that pastoralism is conducted in a way that either maintains or improves the condition of land resources, conserves biodiversity over the entire landscape (and, therefore, in conjunction with pastoral production), and contributes to socially resilient rangeland communities. Other dimensions of sustainable use could also be identified, particularly the economic performance of pastoral businesses, but we would argue that these are the main ones in terms of the issues canvassed in this special issue of *The Rangeland Journal*.

A capacity to effectively manage total grazing pressure (TGP) – the grazing pressure attributable to all vertebrate herbivores – is fundamental to achieving these objectives.

Historical failure in this aspect of pastoral management has had major consequences for the land resources and pastoral industry of the southern rangelands. Six of seven major degradation events in these landscapes can be attributed to excessive grazing pressure both immediately before and during periods of severe drought (McKeon *et al.* 2004).

Hacker *et al.* (2019) argued that TGP is a defining concept for extensive grazing systems in the southern rangelands, noting that, globally, Australia is the only country where large native herbivores have been advantaged by pastoral development. These native herbivores – various macropod species – together with sizeable populations of exotic species including (unmanaged) goats, rabbits, camels, donkeys and pigs, can at times exert grazing pressure equivalent to that of domestic livestock (Waters *et al.* 2018; Atkinson *et al.* 2019). Their management is thus as important as that of domestic livestock in meeting the criteria for sustainable use stated above, but also presents some unique challenges for both landholders, as lessees, and State and Territory governments, as lessors, of the pastoral land. These challenges arise not only from complexities associated with the status of non-domestic species as native or exotic, and as pests or economic resources, but also from clearly established public concern for animal welfare which ultimately will determine the control practices available to landholders.

The development of management systems for all components of TGP that are both ecologically and socially sustainable is a major issue for the pastoral industries of the southern rangelands and the goal towards which this synthesis is intended to contribute.

The social environment

With the exception of the minority of individuals who identify as animal liberationist or vegan, Australians generally condone the use of animals to satisfy human needs, and their control where populations are considered to be producing undesirable impacts. However, regardless of the circumstances, the Australian public will not accept cruelty (i.e. pain, suffering or distress) to animals, perceived or otherwise (Sinclair *et al.* 2019a). The resulting tension between acceptability and effectiveness of some animal control practices (Sinclair *et al.* 2019a, 2019b) represents the fundamental reality within which management of TGP and ecological sustainability of rangeland landscapes must be achieved. Although the attitudes of the Australian public will ultimately determine the acceptability of TGP control practices, these attitudes will be strongly influenced by key stakeholders who seek to sway public opinion in favour of their perspective.

The tension between effectiveness and acceptability of control practices is most evident in relation to kangaroos (Sinclair *et al.* 2019b). Commercial shooting (i.e. shooting by licenced professional harvesters in accordance with a Code of Practice, with the carcass entering commercial trade) is the most acceptable control practice for kangaroos among key stakeholders but, as discussed further below, is currently of little if any value in limiting kangaroo populations. For feral pigs and unmanaged goats, the other species addressed specifically by Sinclair *et al.* (2019b), some of the control practices used by landholders are acceptable (e.g. trapping of unmanaged goats at water points), but their effectiveness is variable depending on the scale and duration of application.

The pastoral operating environment

Across the southern rangelands there is widespread agreement among both land managers (the term used in the study reported here) and service providers (professionals in natural resource management and other organisations that support the pastoral industry) that on average non-domestic animals account for 40–50% of the total forage demand, that these levels are at least double the ‘desirable’ level, and that a reduction in this component of TGP is required (Atkinson *et al.* 2019). Both land managers and service providers assessed kangaroos to have a ‘large negative’ impact on pastures, livestock production and business profitability more frequently than for any other herbivore, although the assessed impact of other non-domestic species sometimes differed between land managers and service providers, and also between States. Two-thirds of survey respondents identified TGP management as a high priority issue, with ‘improved kangaroo management’ and ‘fencing’ (apparently aimed primarily at kangaroo control) as the main factors with potential to make a substantial difference to TGP management in the next 10 years.

Waters *et al.* (2019), citing UNCCD (2019), noted that grazing management practices that incorporate strategic periods of rest have been identified globally as best practice. However, given that landholders in the southern rangelands are often able to control less than half of the TGP, the opportunities to provide strategic rest are severely limited. Other authors (e.g. Hacker and McLeod 2003) have also noted, in a similar vein, that the most important impact of kangaroos over the long-term is the limitation they impose on the ability of land managers to restore pasture productivity through non-continuous grazing practices.

In the sparsely populated southern rangelands, landholders manage their properties in a complex operating environment with an extremely variable climate, commodity price fluctuations and limited capital available for investment in new technologies. Properties are typically operated by family members with non-family labour seriously limited by both availability and, for many businesses, the financial capacity to employ labour. This leaves time poor landholders with little capacity to meet any additional requirement to manage the ‘unmanaged’ component of TGP (Sinclair *et al.* 2019a).

Landholders thus find themselves in the unenviable position of being required to satisfy both legal and community expectations in relation to management of natural resources while having limited capacity to manage a large proportion of the grazing pressure exerted upon their land. In those States, notably Queensland and New South Wales, in which legal arrangements have allowed unmanaged goat populations to form the basis of a profitable industry, goats are generally not considered a burden on landholder resources, in fact the reverse. Other species (e.g. feral pigs) are of more restricted distribution and can be subject to control measures even if not providing a useful source of income. However, kangaroos are universally considered a major impediment to sustainable land management over which individual landholders have little control.

The kangaroo conundrum

Hacker (2010) noted the long-term contraction of the rangelands sheep industry to the south and east of the continent, with

New South Wales and South Australia progressively accounting for an increasing proportion of the pastoral flock, and its replacement by cattle in northern regions and those areas where wild dog predation precluded extensive sheep production. He also noted that much of the south-eastern part of the continent is able to maintain extensive sheep production because of the presence of the 5400 km 'dog fence' enclosing most of the rangeland sheep producing areas in Queensland, New South Wales and South Australia. Furthermore, he suggested that 'in the long run the extensive sheep industry may come to be exclusively confined to this area' (Hacker 2010; p. 508).

In the intervening decade, the shift of rangeland sheep production has apparently continued, with New South Wales and South Australia now accounting for 85% of the sheep flock in the southern rangelands (Waters *et al.* 2018). However, although retention of the dog fence is strongly supported by the pastoral industry, and by State and Commonwealth governments – as illustrated by a recent State, Commonwealth and industry commitment of \$25 million to rebuilding old sections of the fence in South Australia (PIRSA 2019) – wild dogs are now present over extensive areas of the southern rangelands (e.g. NSW Department of Industry 2017) despite local control efforts within the fence. In Queensland, most notably, and to a lesser extent in New South Wales, this has resulted in recent years in a move to 'cluster fencing' in which substantial dog-proof barrier fences have been erected around groups of collaborating properties with financial assistance from Commonwealth and State governments (Waters *et al.* 2019).

A consequence of these long-standing attempts to remove wild dogs from the sheep-grazed rangelands, together with other aspects of pastoral development, particularly the vast expansion in the availability of permanent or semi-permanent water supplies (Hacker and McLeod 2003), has been an increase in the macropod population within the fenced area. Cluster fences have not been in place long enough to allow their impact on macropod populations at smaller scales to be evaluated, but essentially they produce the same ecological conditions pertaining within the 'dog fence'.

Kangaroo surveys undertaken between 2011 and 2018 across the southern rangelands have reported kangaroo densities (all macropods) ranging from 0.005 to 0.2 dry sheep equivalents¹ (DSE) ha⁻¹ compared with livestock densities ranging from <0.2 DSE ha⁻¹ in South Australia to 0.6–0.8 DSE ha⁻¹ in western Queensland (Waters *et al.* 2019). These surveys reveal large spatial and temporal variation. Kangaroo densities are highest in southern and eastern areas protected by the dog fence and lowest in parts of South Australia and Western Australia where dingos are more prevalent. Kangaroo populations fluctuate widely with seasonal conditions (Waters *et al.* 2019). The Millennium drought of 2001–2009 (van Dijk *et al.* 2013), for example, caused the kangaroo population in New South Wales to decline from an estimated 15.9 million in 2002 to an estimated 5.7 million in 2005. With conditions favourable for breeding and survival following drought breaking rains, the population increased to an estimated 9.8 million by 2011 (Australian Government 2018).

Based on recent data (2016–2018), it is estimated that unmanaged species represent just over half of the TGP across the southern rangelands (i.e. 53% of 28.9 million DSE) with kangaroos estimated to comprise 83% of the unmanaged component, or around 44% of TGP (Waters *et al.* 2018). This contribution of kangaroos to TGP is comparable to the historic range of 28–40% estimated by Hacker and McLeod (2003) for the Western Division of NSW (excluding feral goats and rabbits, and assuming a DSE rating of 0.75 for kangaroos).

In reality, the situation is probably considerably different to what these figures suggest. Pahl (2019a), following a comprehensive review of the literature, concluded that the DSE rating of kangaroos based on dry matter intake is considerably higher than the DSE rating of 0.45, widely accepted in recent years, based on energy expended during grazing. The difference probably arises from the faster rate of passage of digesta, particularly when consuming low quality forage, differences in gut architecture and the capacity of kangaroos to select a higher quality diet. In terms of dry matter intake and, therefore, its contribution to TGP, a 50 kg kangaroo is likely to be 1 DSE, consuming twice as much forage as previously assumed based on measurements of the energy used while grazing. Although the average liveweight of kangaroos may be less than 50 kg, particularly in harvested populations, their contribution to grazing pressure in any situation will be greater than what would be expected based on energy requirements. Furthermore, under deteriorating seasonal conditions, this contribution to TGP at any point in the landscape will not be offset by differences in grazing distribution and diet selection that may be manifest under better seasonal conditions. Over the sequence of boom and bust conditions that characterise the southern rangelands, there will be a high degree of overlap between kangaroos and livestock in terms of what and where they eat (Pahl 2019b).

Since the 1970s the commercial kangaroo industry has been the primary means of kangaroo population control (McLeod and Hacker 2019). This is regulated in each State by the relevant wildlife management authorities but with kangaroo management plans approved by the Commonwealth under its export control powers. These management plans are based principally on a quota set annually by applying a harvest percentage to the current population estimate. From the perspective of TGP management this process has always involved the paradox that the harvest rate has been set basically to achieve maximum sustained yield (around 15% of the population) rather than any desirable population density focussed on total grazing pressure objectives. Nevertheless, the commercial harvest, operating with a sex ratio of ~60% males, did have potential to achieve some reduction in population density while ensuring that the viability of harvested populations was not threatened, and that population dynamics were still basically determined by seasonal variation.

This control mechanism is no longer effective. The kangaroo meat industry suffered a significant setback with the loss of the Russian market initially in August 2009, largely over food safety concerns (Boronyak *et al.* 2013; pp. 21–22). Animal rights groups opposed to the shooting of kangaroos have been successful in limiting access to international markets for kangaroo

¹The energy requirement of a non-lactating 50 kg ewe or 50 kg wether at maintenance, being 8.3 MJ of metabolisable energy head⁻¹ day⁻¹.

products, severely reducing the proportion of the quota taken each year (Sinclair *et al.* 2018; Wilson and Edwards 2019). More recently, criticism of the industry in relation to the death of pouch young and young-at-foot has resulted in the commercial decision by major processors to accept only male carcasses. In 2018, the proportion of males in the harvest was around 90% compared with ~77% in 2010 (Sinclair *et al.* 2019c; citing Australian Government 2019). Since the impact of harvest is closely related to the proportion of females taken (Hacker *et al.* 2004), the current harvest regime is able to exercise almost no control over the size of the population.

As commercial harvesting is the most socially acceptable form of population control, this situation places landholders in an invidious position in trying either to protect their legitimate business interests or discharge a duty of care for the land in a manner that has public acceptance. Exclusion fencing of various types may also be socially acceptable, but it involves a major capital cost that landholders may feel neither obliged to accept nor able to afford.

The inadequacy of the current arrangements for controlling kangaroo populations within ecosystems that are unbalanced due to the removal of the top predator, the dingo, and the ready availability of permanent water supplies, has consequences not only for resource management and the financial viability of pastoralism but also for the welfare of the kangaroos themselves. In western New South Wales, kangaroo densities declined from ~30 to <10 kangaroos km⁻² between 2003 and 2004 at the onset of the Millennium drought, and increased significantly following drought breaking rains late 2009 (Waters *et al.* 2019). The same cycle has been repeated in the current drought, since ~2017, with a massive reduction of the population that had increased in the generally favourable years since 2010. These events involve the deaths of millions of animals from starvation, thirst and disease, with landholders left to manage this welfare disaster on their own.

A way forward for kangaroo management

The capacity of landholders to cost-effectively manage TGP in socially acceptable ways is currently incompatible with the Australian public's expectation that they will maintain the condition of their land and provide simultaneously for the conservation and welfare of several iconic species (i.e. kangaroos) (Sinclair *et al.* 2019a). This gap exists because of the limited effectiveness of existing control practices that are socially acceptable (e.g. commercial culling of kangaroos), the impracticality of others (e.g. translocation or reproduction control), and the very limited capacity of landholders to implement alternatives from their own resources (e.g. professional non-commercial culling). The current management of kangaroos represents a case of market failure in which landholders acting in their private interest cannot be confidently expected to deliver outcomes consistent with the public interest.

A case for further public investment in kangaroo management seems justified. Sinclair *et al.* (2019a; citing Industry Commission 1998) have suggested that the concept of a duty of care for the environment would provide a basis for determining the point where the responsibility for private investment in management that delivers public benefits ceases and public

responsibility begins. Determining that point would necessarily recognise that landholders have benefited from public investment in attempts to protect the sheep-grazed rangelands from dingo and wild dog predation, and should therefore contribute to the cost of the kangaroo control required as a result. However, Sinclair *et al.* (2019a) considered that the duty of care currently expected of landholders goes well beyond reasonable expectations, and that the important public values at stake warrant further public investment to better manage the rangelands, which for the most part remain public land, and iconic Australian species contributing to TGP.

Assuming that a reasonable limit to the duty of care can be defined, there are several avenues for further public investment that could lead to better public outcomes.

- McLeod and Hacker (2019) argued that current kangaroo management programs take into account only the state of the kangaroo population, satisfying the objectives of wildlife management agencies and the kangaroo industry, but ignore other critical issues such as the condition of natural resources and animal welfare. Wilson and Edwards (2019) have expressed similar concerns in arguing that population targets should be set based on total grazing pressure. McLeod and Hacker (2019) argue that kangaroo management should move to an active adaptive management framework in order to ensure that the objectives of all stakeholders are satisfied as much as possible. Specific kangaroo management objectives would thus be framed on the basis of a range of inputs and could vary in time and space. A legitimate role for government in such a process would be to fund the monitoring required to evaluate the success of interventions, and to finance interventions (e.g. professional non-commercial culling) where this is beyond the resources of either landholders or the kangaroo industry.
- Wilson and Edwards (2019) have argued that landholders should have a form of proprietorship over kangaroos so that they are regarded as a resource rather than a pest. This might lead to fewer livestock in the rangelands and a reduction in overall greenhouse emissions from rangeland meat production. Arguments for such a paradigm shift are not new, but could nevertheless be part of the future policy mix if governments are prepared to co-invest in 'product management, marketing and public attitudes', including through part-publicly funded agencies like Meat & Livestock Australia.
- Payment of direct financial incentives to landholders who are prepared to enter into agreements to maintain ground cover above agreed levels, as described by Hacker *et al.* (2010). Although maintenance of ground cover above the minimum level required to protect against accelerated erosion could be considered part of landholders' duty of care, maintenance of higher levels through effective management of TGP will almost certainly impose costs on pastoral businesses but should deliver public benefits in terms of improved functionality of rangeland landscapes, and habitat for the biodiversity which they support. Ground cover is arguably the most important single indicator of the health of a landscape and can be monitored in many rangeland ecosystems using current satellite technology (Waters *et al.* 2019). Such incentives may need to include specific provision for the deployment of socially acceptable kangaroo control measures.

- Continued evaluation of the ecological, economic and social benefits and costs of cluster fencing; and appropriate support provided for further implementation in response to these evaluations.

Implications for the pastoral industries of the southern rangelands

Kangaroo management has emerged as the most important issue facing the rangelands pastoral industry in terms of its capacity to discharge its duty of care to the rangelands environment. It is also the point at which it is most vulnerable to the actions of activist groups promoting animal welfare or animal rights agendas.

Opportunities for increased government involvement to address the market failure represented by the current kangaroo management arrangements have been canvassed above. However, the pastoral industries themselves need to be proactive in developing strategies that would allow them to foresee and address any threat to their capacity to implement effective control strategies, e.g. their ability to erect fences, limit access to stock water supplies or increase the number of kangaroos harvested or culled. Such strategies would include establishing platforms and processes for effectively engaging animal welfare and animal rights stakeholders, establishing a unified and resourced industry 'voice' to effectively engage with government, and ensuring that the industry self-regulates in order to avoid the potential for rogue elements to undermine its credibility and trustworthiness (Sinclair *et al.* 2019c). In addition, as noted by Waters *et al.* (2019) the industry will require a capacity to demonstrate its achievements in support of its social licence by evidence-based indicators.

Conclusions

Kangaroo management is a key component of ecologically sustainable management of total grazing pressure in the southern rangelands because (a) kangaroos represent a significant component of the non-domestic grazing pressure, particularly in areas from which wild dogs have been (partially) removed; (b) commercial harvesting, the means of control which has the highest social acceptability, has been rendered ineffective by the actions of activist groups and closure of markets due to food safety concerns; (c) the task is largely beyond the capacity of individual landholders; and (d) the same constraints do not apply to other non-domestic components of TGP.

Several avenues are available by which kangaroo management could be advanced to achieve both public and private benefits but they require both a greater commitment from governments to address the market failure inherent in the present situation and a proactive stance by industry to engage stakeholders, self-regulate and objectively demonstrate its environmental and animal welfare credentials.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgements

Comments by the Editor-in-Chief improved the original manuscript. This research did not receive any specific funding.

References

- Atkinson, T., Hacker, R. B., Melville, G. J., and Reseigh, J. (2019). Land managers' and service providers' perspectives on the magnitude, impact and management of non-domestic grazing pressure in the southern rangelands of Australia. *The Rangeland Journal* **41**, 461–476.
- Australian Government (2018). Department of Environment and Energy. Kangaroo statistics. Available at: <https://www.environment.gov.au/biodiversity/wildlife-trade/natives/kangaroo-wallaby-statistics> (accessed 8 October 2019).
- Australian Government (2019). Department of Environment and Energy. Population, quota and harvest statistics for NSW, QLD, SA and WA commercial harvest areas. Available at: <http://www.environment.gov.au/system/files/pages/ee20f301-6c6c-44e4-aa24-62a32d412de5/files/kangaroo-statistics-states-2018.pdf> (accessed 11 July 2019).
- Boronyak, L., Ben-Ami, D., Croft, D., and Ramp, D. (2013). Kanganomics: a socio-economic assessment of the commercial kangaroo industry. Report by the Centre for Compassionate Conservation at the University of Technology, Sydney, NSW, Australia.
- Hacker, R. B. (2010). Extensive grazing systems. In: 'International Sheep and Wool Handbook'. (Ed. D. J. Cottle.) pp. 507–532. (Nottingham University Press: Nottingham, UK.)
- Hacker, R. B., and McLeod, S. R. (2003). 'Living with Kangaroos. A Guide to Kangaroos and Their Management in the Murray-Darling Basin.' (NSW Agriculture: Orange, NSW, Australia.)
- Hacker, R., McLeod, S., Druhan, J., Tenhumberg, B., and Pradhan, U. (2004). 'Kangaroo Management Options in the Murray-Darling Basin.' (Murray-Darling Basin Commission: Canberra, ACT, Australia.)
- Hacker, R. B., Jessop, P. L., Smith, W. J., and Melville, G. J. (2010). A ground cover based incentive approach to enhancing resilience in rangelands viewed as complex adaptive systems. *The Rangeland Journal* **32**, 283–291. doi:10.1071/RJ10011
- Hacker, R. B., Sinclair, K., and Waters, C. M. (2019). Total grazing pressure – a defining concept for extensive pastoral systems in the southern rangelands of Australia. *The Rangeland Journal* **41**, 457–460.
- Industry Commission (1998). A Full Repairing Lease: Inquiry into Ecologically Sustainable Land Management. Industry Commission: Melbourne, Vic., Australia.
- McKeon, G. M., Hall, W. B., Henry, B. K., Stone, G. S., and Watson, I. W. (2004). 'Pasture Degradation and Recovery in Australia's Rangelands: Learning from History.' (Queensland Department of Natural Resources, Mines and Energy: Brisbane, Qld, Australia.)
- McLeod, S. R., and Hacker, R. B. (2019). Balancing stakeholder interests in kangaroo management – historical perspectives and future prospects. *The Rangeland Journal* **41**, 567–579.
- NSW Department of Industry (2017). 'NSW Wild Dog Management Strategy 2017–2021. State of New South Wales, Sydney, NSW, Australia.
- Pahl, L. (2019a). Macropods, feral goats, sheep and cattle. 1. Equivalency in how much they eat. *The Rangeland Journal* **41**, 497–518.
- Pahl, L. (2019b). Macropods, feral goats, sheep and cattle. 2. Equivalency in what and where they eat. *The Rangeland Journal* **41**, 519–533.
- PIRSA (Primary Industries and Regions South Australia) (2019). Rebuilding the dog fence in South Australia. Available at: https://www.pir.sa.gov.au/biosecurity/weeds_and_pest_animals/animal_pests_in_south_australia/established_pest_animals/wild_dogs/dog_fence/rebuilding_the_dog_fence_in_south_australia (accessed 26 November 2019).
- Sinclair, K., Atkinson, T., Curtis, A. L., and Hacker, R. B. (2018). Social Acceptability of Pest Animal Management in Meeting TGP Targets. Final Report B.TGP.1701. Meat and Livestock Australia, North Sydney, NSW, Australia.
- Sinclair, K., Curtis, A. L., Atkinson, T., and Hacker, R. B. (2019a). Public attitudes to animal welfare and landholder resource limitations: implications for total grazing pressure management in the southern rangelands of Australia. *The Rangeland Journal* **41**, 477–484.

- Sinclair, K., Curtis, A. L., Hacker, R. B., and Atkinson, T. (2019b). Stakeholder judgements of the social acceptability of control practices for kangaroos, unmanaged goats and feral pigs in the south-eastern rangelands of Australia. *The Rangeland Journal* **41**, 485–496.
- Sinclair, K., Curtis, A. L., and Atkinson, T. (2019c). Do concerns about kangaroo management represent an existential threat for the red meat industry in the southern Australian rangelands? *The Rangeland Journal* **41**, 557–565.
- UNCCD (2019). Reaping the rewards: financing land degradation neutrality. United Nations Convention to Combat Desertification: Bonn, Germany. Available at: http://catalogue.unccd.int/763_2015_Reaping_the_rewards.pdf (accessed 5 March 2020).
- van Dijk, A. J. M., Beck, H., Crosbie, R., de Jeu, R. M., Liu, Y., Podger, G., Timbal, B., and Viney, N. (2013). The Millennium Drought in southeast Australia (2001–2009): natural and human causes and implications for water resources, ecosystems, economy, and society. *Water Resources Research* **49**, 1040–1057. doi:10.1002/wrcr.20123
- Waters, C., Reseigh-O'Brien, J., Pahl, L., Atkinson, T., Burnside, D., and Revell, D. (2018). Addressing feed supply and demand through total grazing pressure management. NSW Department of Primary Industries, Orange, NSW, Australia.
- Waters, C. M., McDonald, S. E., Reseigh, J., Grant, R., and Burnside, D. G. (2019). Insights on the relationship between total grazing pressure management and sustainable land management: key indicators to verify impacts. *The Rangeland Journal* **41**, 535–556.
- Wilson, G. R., and Edwards, M. (2019). Professional kangaroo population control leads to better animal welfare, conservation outcomes and avoids waste. *Australian Zoologist* **40**, 181–202. doi:10.7882/AZ.2018.043