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Summary New evidence of impacts by feral horses in Australia's alpine parks systems confirms they endanger threatened species and extensively damage critically endangered bog communities that could take millennia to recover. These impacts are not confounded by effects of deer and accumulate over time, even when only a small number of feral horses (~100) are present. With protected areas representing only a small proportion of the area of the Australian states of New South Wales (9.3%) and Victoria (17%), allowing feral horses to degrade reserves is not a reasonable management compromise, is contrary to the purpose of the protected area system and conflicts with international obligations. Modelling and decades of management experience indicate that trapping alone does not control feral horse numbers. Trapping and fertility control can work in small populations, but not when there are several thousand horses in remote areas. Aerial culling is needed to cost-effectively and humanely control feral horse populations. The relatively small amount of suffering feral horses experience during a cull is outweighed by (i) avoiding suffering and death of horses from starvation and thirst, (ii) avoiding the suffering of native animals displaced by horses and (iii) avoiding the ethical concerns of driving threatened species towards extinction. Objections to aerial culling on welfare and cultural grounds are contradicted by evidence. Improving knowledge in the general community about what is at stake is long overdue because without this knowledge, small groups with vested interests and unfounded claims have been able to dominate debate and dictate management actions. As a result of ineffective management, horse populations are now expanding and causing well-documented damage to Australia's alpine parks, placing at risk almost $10M spent on restoration after livestock grazing ended. The costs of horse control and restoration escalate the longer large horse populations remain in the alpine parks. It is crucial that feral horse numbers are rapidly reduced to levels where ecosystems begin to recover. Aerial culling is needed as part of the toolbox to achieve that reduction.

Key words: *aerial cull, brumby, feral horse, Kaimanawa horse, mustang.*

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Introduction

Horses (*Equus caballus*) have established feral populations in many countries (Rogers 1991; Nimmo & Miller 2007; Scorolli & Cazorla 2010). They cause widespread environmental degradation, destroy ecosystems, eliminate populations of native species and spread weeds (Nimmo & Miller 2007; Loydi & Zalba 2009). Most feral animals that cause this kind of damage are managed by culling. However, in some cases, feral horse management is contentious because lobby groups put pressure on decision-makers to keep horses in natural areas, regardless of environmental impacts or animal welfare concerns (Becker 2018; Williams 2019). The US government, for example, pays over US$50M annually to keep unwanted feral horses in paddocks (Garrott 2018) because of the prohibition of culling, and limited rehoming options. Effective management has been similarly restricted in the south-eastern Australian states of New South Wales (NSW) and Victoria because politicians have banned aerial culling, and in NSW, legislated to keep feral horses in Australia's premier alpine national park, Kosciuszko (Barilaro 2018).

Here, we summarize research addressing the impacts of feral horses on Alpine National Park in Victoria, Kosciuszko National Park in NSW and Namadgi National Park in the Australian Capital Territory (referred to as alpine parks hereafter), with particular emphasis on papers presented at the Kosciuszko Science Conference held at the Australian Academy of Science, Canberra, Australia, in November 2018. Some of those papers are expanded upon in this special edition of EMR (Beeton & Johnson 2019; Cherubin *et al.* 2019; Driscoll 2019; Schulz *et al.* 2019; Ward-Jones *et al.* 2019; Williams 2019; Wright *et al.* 2019). The evidence of negative impacts is compelling and the research into effective control measures indicates that aerial culling will need to be part of the management mix. We therefore examine the case for aerial culling, including evaluating the ethical and social context. When we do this, the barriers to culling appear to be unfounded. We urge governments to follow an evidence-based approach to managing these protected areas for nature conservation by using an effective range of management methods to rapidly reduce feral horse numbers to levels where the ecosystems can begin to recover.

Impacts, the evidence

Multiple lines of evidence based on large datasets show that feral horses damage vegetation structure, degrade stream morphology and threaten alpine bog communities (Hope 2018; Porfirio & Mackey 2018; Tolsma *et al.* 2018; Cherubin *et al.* 2019; Wright *et al.* 2019). Feral horse impacts are widespread, as demonstrated by remote sensing research (Porfirio *et al.* 2017) and very large field studies, each encompassing more than 150 plots (Schulz *et al.* 2019; Wright *et al.* 2019). Historically, plant species have been exposed to substantial geographic and environmental range reductions, with some pushed to near extinction, when domestic stock was the major threat (Venn & Williams 2018). Feral horses are likely to have

Figure 1. Fresh incision and trampled banks on Gurrangorambla Creek, Kosciuszko National Park, will threaten peatlands upstream as the fen drains (Hope 2018). Peat soils build up at a rate of about 1 m every 3000 years, so soil systems like these will take thousands of years to fully recover from feral horse damage caused over a few decades.

similar impacts across ecosystems (Venn & Williams 2018; Cherubin *et al.* 2019). These observations are consistent with evidence from Europe, North America, South America and New Zealand, where a global meta-analysis of studies with >250 observations reported 34% declines of plant biomass, 32% declines of soil stability and 15% decline of plant abundance when horses are present, with feral horses causing an overall decline of environmental quality of 16% (Eldridge *et al.* 2018).

In addition to impacts on plant species and ecosystems, damage to water courses has implications for water quality. The Australian Alps are a vital source of water on a dry continent. They yield about 29% of the average surface water of the Murray – Darling Rivers, a basin that is of great environmental and socio-economic significance. Damage by horses to alpine moss bogs and riparian zones is degrading water quality and increasing variability in rates of water flow from mountain catchments (Pittock & Finlayson 2018). This change in water regime is caused in part by degradation of peat soils, which store water and slowly release it. Peat soils take thousands of years to build up but can be quickly degraded by hard-hooved livestock and feral horses (Fig. 1) (Hope 2018). They were part of a multi-million dollar restoration programme after cattle and sheep were removed from Kosciuszko (Costin 2018; Good & Johnston 2019), but now that investment in recovery is being undone by feral horses (Hope 2018).

Feral horses also have negative impacts on native animals. For example, feral horses eliminate local populations of Broad-toothed Rats (*Mastacomys fuscus*) (Schulz *et al.* 2019), probably through indirect impacts on vegetation (Eldridge *et al.* 2019). In southern Kosciuszko, invertebrate abundance was almost twice as high in fenced woodland plots compared with areas exposed to overgrazing (Ward-Jones *et al.* 2019). By altering vegetation structure, feral horses also likely reduce the abundance of Alpine Water Skink (*Eulamprus kosciuskoi*) (Cherubin *et al.* 2019), Northern Corroboree Frog (*Pseudophryne pengilleyi*), Mountain Pygmy Possum (*Burramys parvus*), Stocky Galaxias (a native fish, *Galaxias tantangara*), Alpine She Oak Skink (*Cyclodomorphus praealtus*) and, if shrubs are severely impacted, the Guthega Skink (*Liopholis*

Table 1. Relationships between native animal habitat needs and known feral horse damage

Species	What horses do	Evidence of horse impact	What species needs	Inference	Reference
Stocky Galaxias	Increase sedimentation	Paull (2018); Wright *et al.* (2019)	Sediment-free boulder and cobble stream habitats	Siltation caused by feral horses could destroy multiple home ranges throughout this species remaining distribution	Allan and Lintermans (2018)
Northern Corroboree Frog	Destroy sphagnum moss and reduce vegetation depth to below the mean depth of nests in horse free areas	Evans (2018); Foster and Scheele (2018)	Deep moss and grass litter to build nests where eggs are laid.	Horse damage is a threat, increasing risk of egg desiccation, interruption of breeding, undermining reintroduction programmes	Evans (2018); Scheele and Foster (2018)
Alpine She Oak Skink	Damage to grasses and other palatable species through grazing and trampling, increase bare ground	de Bie and Vesk (2014); Newsome *et al.* (2004); Whinam and Comfort (1996)	Tussock grasslands with sufficient native grass cover to provide protection from predators and thermal extremes	Horses increase bare ground and reduce grass cover, increasing predation risk and reducing thermal buffering, ultimately reducing habitat suitability.	Green and Osborne (2012); Sato *et al.* (2014a,b)
Alpine Water Skink	Destroy sphagnum moss, reduce vegetation cover, change dominant vegetation, damage waterbodies	Cherubin *et al.* (2019); Evans (2018); Wright *et al.* (2019)	Sphagnum moss beds, permanent waterbodies	Horses will drive habitat degradation causing this species to decline	Cherubin *et al.* (2019)
Guthega Skink	Reduce shrub cover and height, increase bare ground	de Bie and Vesk (2014); Whinam *et al.* (1994)	Rocky heathland and woodland areas that contain large rocks, shrub cover but low ground layer density/ exposed substrates	Minor horse incursions could increase exposed substrates and basking opportunities. However, extensive horse impacts will reduce shrub cover, degrading habitat.	Atkins *et al.* (2015); Green and Osborne (2012); Sato *et al.* (2014a)
Broad-toothed Rat	Reduce shrub and grass cover, height and density	Cherubin *et al.* (2019); Schulz *et al.* (2019)	Grasses and shrubs for runways, food, insulation in winter, protection from feral predators	Horses will destroy grass runways and compete for food. Could also increase predation rates and habitat fragmentation	Cherubin *et al.* (2019); Schulz *et al.* (2019)
Mountain Pygmy Possum	Increase sedimentation, trample shrubs	Cherubin *et al.* (2019); Paull (2018); Wright *et al.* (2019)	Deep boulder fields, shrubs for protection from predators and to create space below the snow	Horses will degrade habitat, reduce food resources and shelter	Bates (2018)

guthega) (Table 1). Feral horses can compete with native herbivores for food (Scasta *et al.* 2016; Schulz *et al.* 2019) and water (Gooch *et al.* 2017) and can destroy burrows of native mammals (Ward-Fear *et al.* 2017). In Australia, there is some evidence that native mammals, including kangaroos and wallabies, can be displaced or reduced in numbers by feral horses (Nimmo & Miller 2007). This suite of evidence that horses negatively impact wildlife is supported by similar studies and patterns elsewhere in the world (Nimmo & Miller 2007).

Relative impacts of deer and feral horses

Opponents of effective feral horse control often point to deer as the bigger threat to biota and water quality but, in areas where feral horses are abundant, recent evidence demonstrates that this is not the case. Data from more than 100 plots in treeless drainage lines across the alpine parks show that deer and pigs made no substantive contribution to the horse-related damage that was measured (Wright *et al.* 2019). Similarly, using 150 plots across 30 sites spanning a range of horse density in northern Kosciuszko National Park, Eldridge *et al.* (2019) found no evidence of deer dung, and pig dung was found at only five plots. The reports of researchers studying vegetation and bogs (Tolsma *et al.* 2018; Hope 2018 #11363;Ward-Jones *et al.* 2019), frogs (Foster & Scheele 2018), fish (Allan & Lintermans 2018), reptiles and small mammals (Cherubin *et al.* 2019) all showed that feral horses were the sole or major cause of environmental damage across their study areas.

While deer and pigs are major pests in the Australian Alps, there are control programmes in place, including aerial and ground shooting, baiting and trapping, aimed at limiting population expansion (OEH 2012). In contrast, this suite of effective controls is not applied to feral horses and the population is expanding (Cairns & Robertson 2015). Horses generally do not behaviourally interact with deer (Salter & Hudson 1980), and their diets usually overlap very little (Scasta *et al.* 2016), leading to the prediction that major reduction of horse numbers would not facilitate more rapid deer expansion. Nevertheless, managing all threats from introduced herbivores is important across the alpine parks.

Damage is cumulative

Critical evidence suggests that even low numbers of horses cause damage to accumulate because ecosystem recovery is very slow. Although there are only 109 horses in the 320 km^2 survey area of the Bogong High Plains in Victoria (Curran 2018), even this small number is causing ongoing degradation (Tolsma *et al.* 2018). Using repeated surveys of sites over a five- to ten-year period, Tolsma *et al.* (2018) reported increasing damage to soils and vegetation. Evidence that damage occurs at low horse densities has also been reported from New Zealand (Rogers 1991) and the USA (Cran *et al.* 1997). We speculate that if an order of magnitude fewer horses could allow ecosystems to recover (~0.034 horses/km^2), then horse numbers would need to be reduced to <120 widely dispersed animals within the parts of Kosciuszko National Park that are currently occupied (~3450 km^2).

The evidence of horse impacts, evidence that deer are not the main problem in horse-occupied areas, and evidence that damage is cumulative at low densities provides a powerful, science-based case for rapidly reducing feral horse numbers to levels where damage no longer accumulates and ecosystems can be restored and recover.

How should feral horse numbers be reduced and controlled?

Beeton and Johnson (2019) examine the consequences of feral horse management policies that include or exclude aerial culling. They demonstrate that aerial culling is needed to reduce feral horse populations and minimize costs and welfare concerns, consistent with conclusions drawn from an earlier population model (Driscoll & Banks 2014) (see Appendices S1 and S2). That these two very different, independent approaches to modelling horse populations led to the same conclusion, that aerial culling needs to be part of the management mix, provides confidence that those conclusions are robust (also see Dobbie *et al.* 1993).

The trapping and mustering scenario considered by Beeton and Johnson (2019) includes removing 1700 horses per year, a number far in excess of what has been achieved in actual trapping programmes in NSW or Victoria. Even with such large numbers removed, the model revealed that trapping had little impact on overall population size because trapping is limited to accessible areas. This suggests that if more money was spent to greatly increase the number of horses trapped and removed, horse populations would not be effectively controlled in many areas.

Rehoming has been advocated as a solution to over-abundant feral horses. However, the Kosciuszko trapping programme between 2002 and 2015 only managed to rehome 18% of trapped feral horses, the rest went to the abattoir (OEH 2016a). In the USA, such programmes have also failed to control horse numbers and now face a critical tipping point; within six years, population numbers will grow beyond what can feasibly be managed (Garrott 2018). The experience from the USA indicates that rehoming programmes are expensive and ineffective for controlling horse numbers. Ultimately, when feral horse populations are large, they must initially be culled to control numbers and prevent environmental degradation (Garrott 2018).

Fertility control is often suggested as a way to managing feral horse numbers (Kirkpatrick *et al.* 2011). However, the most effective way to manage horse populations is by reducing adult

survival rather than manipulating reproduction (Dawson & Hone 2012). Recently, Hobbs and Hinds (2018) considered fertility methods for controlling feral horses in Australia and concluded that it would not be effective. At least half of the females need to be treated every 2–4 years, and even then, populations would not be reduced within 10 years because horses are long-lived. Effective fertility control is not possible in the alpine parks given that the population is open to immigration and has over 9000 individuals, with many animals in difficult to access areas (Cairns & Robertson 2015; OEH 2016b). Hobbs and Hinds (2018) conclude that numbers must first be reduced using methods such as shooting before fertility control could be a useful approach, but even then it would only be effective on small populations in accessible areas with minimal immigration.

Animal welfare and the ethics of aerial culling

Aerial culling has fewer animal welfare concerns than capturing and removing horses or other techniques for reducing numbers because it is fast, minimizing horse stress (Dobbie *et al.* 1993; HAP 2015). A previous aerial cull at Guy Fawkes National Park is claimed to have been inordinately cruel by people who support keeping many feral horses in national parks (Chapple 2005; Barilaro 2018). However, an independent report revealed the cull was an overwhelming success, with 606 horses killed and only one case of prolonged suffering (English 2000). In that example, feral horses were suffering and dying due to food shortages after fire and so the cull was a humane and appropriate response (English 2000; Chapple 2005).

Recent research quantifies the welfare outcomes of aerial culling in central and Western Australia (Hampton *et al.* 2017). Most feral horses (63%) were killed instantly, while 1% were non-fatally wounded. The relatively low failure rate (1% non-fatally wounded) compares favourably with standard operating procedures for abattoirs, where they aim to stun livestock on first strike of the bolt in 95% of cases (Edge 2009). While horses may suffer during a cull, the levels are well within widely accepted industry standards and can be further reduced with appropriate training and adherence to standard operating procedures (Hampton *et al.* 2017; RSPCA 2018b).

For the 37% of horses not killed instantly during aerial culling, the time to death averaged 19 seconds (range 3 seconds to four minutes) (Hampton *et al.* 2017). Such swift deaths are in contrast to prolonged deaths in grim circumstances in the wild, particularly during drought or after fire, when horses gradually die of starvation and thirst (English 2000; Becker 2018; Garrott 2018). Horses can also become trapped above the snowline, including at the aptly named Dead Horse Gap in Kosciuszko NP (Driscoll & Banks 2014). Unlike native animals, feral horses have been placed in the alpine parks by people and allowed to multiply to their thousands by ineffective management. We therefore argue that feral horse suffering cannot be dismissed as just a natural process in the wild; people are directly responsible, and ethically culpable for feral horses being in situations where they face extreme suffering and death.

A complete ethical equation considers the balance between the mostly instantaneous death of aerial culling against: (i) the prolonged suffering of horses in the alpine parks, especially at times of stress; (ii) the suffering of native animals affected by the horses and; (iii) the ethics of damage to water catchments and threatened ecosystems, and increasing the risk that species will become extinct (Fraser & MacRae 2011; Fraser 2012). For example, the Australian endemic Broad-toothed Rat is formally listed as a Vulnerable species with a targeted strategy for management (OEH 2017). However, their numbers are expected to decline through increased predation after horses destroy their habitat (Cherubin *et al.* 2019; Schulz *et al.* 2019). Such deaths and declines are likely to involve suffering for these animals and lead to local population extinctions (Schulz *et al.* 2019). The additional threats posed by feral horses place this already threatened species at higher risk of extinction. This example helps to illustrate a framework for thinking clearly about the ethics of feral horse management (Fig. 2). Reservations about aerial culling must be weighed against being complicit in mass horse starvation, suffering and death of native animals, and potentially irreversible loss of high-quality water catchments and native ecosystems and species.

After an initial period of investment to reduce feral horse numbers, the cost of ongoing control would be relatively small. Instead of more than 600 new feral horses added to the population each year in Kosciuszko alone (assuming a conservative 10% annual increase on 6000 horses), there would only be a small number to remove to prevent populations expanding again. Ongoing costs would include catchment restoration (Good & Johnston 2019). Ongoing control is a very standard practice and is why the Australian Capital Territory has remained largely feral horse free (ACT Government 2007). The nature of pest species control is undergoing a technological revolution at the moment (Campbell *et al.* 2015; Jurdak *et al.* 2015; Naz & Saver 2016). It is therefore foreseeable that applications of current technology, let alone new technology, will reduce the cost of control, increase effectiveness and further reduce animal suffering if governments choose to invest in this area.

Is culling acceptable to most Australians?

Aerial culling is used to manage feral horses in Western Australia, the Northern Territory, Queensland, and the

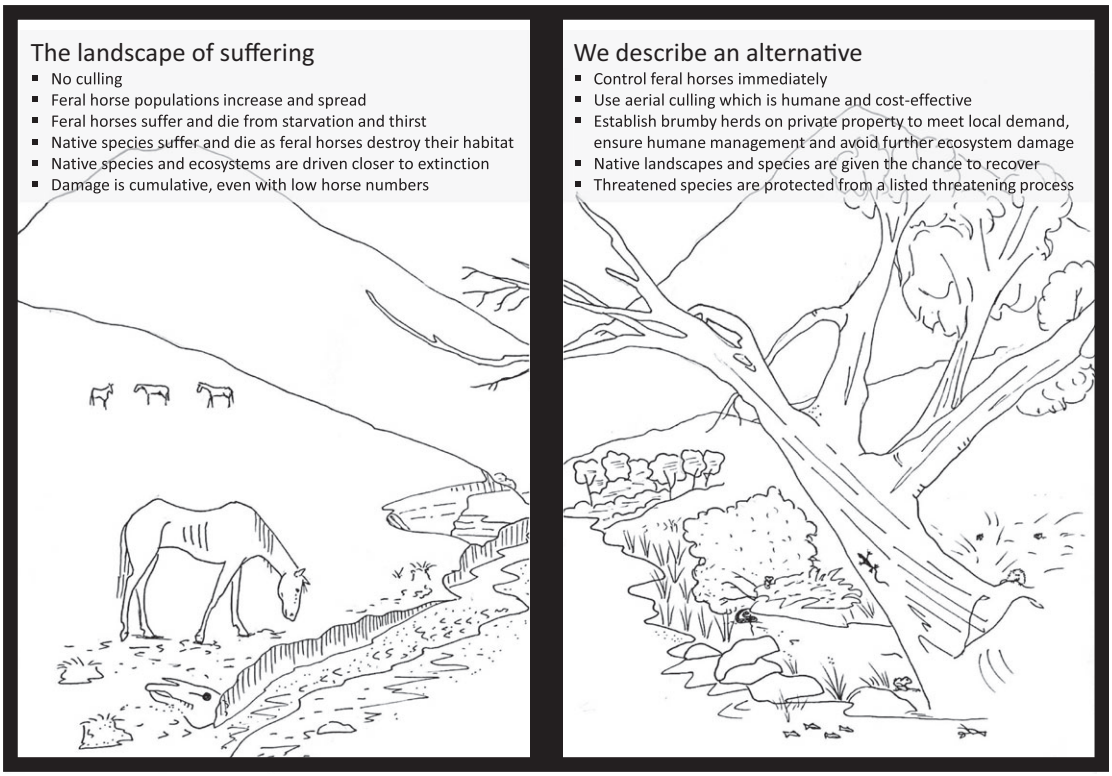

Figure 2. Managing feral horse populations when they reach large numbers in remote areas requires a conscious ethical trade-off between the quantified welfare impacts of culling and other control measures against (1) suffering of feral horses in the wild during drought and after fire; (2) suffering of native animals that are impacted by feral horses, and; (3) the ethics of driving species and ecosystems that are already critically endangered, closer to extinction. Taking these factors into account makes a compelling case for choosing to include aerial culling among the acceptable management approaches.

Australian Capital Territory (Driscoll 2018b). Public submissions on proposed feral horse management methods in Victoria found over 80% support for using shooting as a control method (Parks Victoria 2018). The Royal Society for the Prevention of Cruelty to Animals (RSPCA) supports aerial culling that adheres to standard operating procedures for controlling feral horses (RSPCA 2018b). Such wide application and support emphasize that aerial culling can be acceptable to the general public throughout Australia, when the facts of the matter are fairly and openly considered and publicized: culling is cost-effective, can be implemented humanely, and the consequences of inaction are severe (Fig. 2).

Killing horses and other livestock is part of routine management by the farming and horse racing industries. For example, in Australia approximately 9000 horses are killed every year in abattoirs, with about half of those coming from the racing industry (Doughty 2008; RSPCA 2018a). On average, one horse is killed every three days on Australian race tracks (Safi 2015). Further, during drought or disease outbreaks, livestock are shot, often in large numbers, to minimize suffering and protect farm productivity (Westbury 2000; Thornber *et al.* 2014; Wakatama & Regan 2018). These widely applied and accepted practices suggest that the extreme policies of not culling feral horses in Victoria and NSW are out of step with industry and societal norms.

Cultural associations have been used as objections to culling. Much of this is based on conceptual affiliations of feral horses with Australian bushlore and early settler identity, as depicted in an iconic poem, novels and two movies, as well as real events, notably the opening ceremony of the 2000 Sydney Olympic Games, and the use of horses in the First World War (Barilaro 2018). However, there are no records indicating that feral horses from the alpine parks were sent to war (Context 2015). At that time, rather than war steeds, feral horses were universally regarded as pests, treated brutally, and considered suitable only for the export meat industry (Context 2015; Gibson 2015). Most 'walers', the breed of horse widely exported from Australia throughout much of the 19th and 20th centuries, were bred on farms around the country, with no particular association to the alpine parks areas (Context 2015). Regarding the Sydney Olympics, Australian stock horses, bred in studs, were used at the opening

ceremony, not animals captured from alpine parks. Consequently, cultural grounds are no justification for allowing unchecked growth of feral horse populations (Context 2015). Further, cultural aspects of brumbies from regions around the alpine parks can be maintained with, for example, herds held on private property. This was the successful solution to feral horse management for South Australia's Coffin Bay National Park (CBBPS 2018).

Although claims about cultural values of feral horses have dominated debate and policy, there are other highly important cultural issues that are at stake: the value of our nationally iconic high mountain ecosystems for a wide range of economic, ecological, cultural and aesthetic reasons (Slattery 2018) (Fig. 3). The facts about animal welfare, culture and environmental impacts have not been appropriately translated and communicated, and an extreme point of view has been able to fill the void left by inadequate education and leadership (Nimmo & Miller 2007). There is a long and strong history of support for protection of alpine areas by scientists and citizen conservation bodies (Williams 2019) as well as growing numbers of summer tourists. This too concerns powerful cultural ideas about managing uniquely Australian places for their better protection, both for their intrinsic values and for health and well-being of ordinary citizens (Slattery 2010). It is likely that most of the Australian public supports such cultural connections with the mountains, but this alternative set of images and arguments has been greatly underplayed in the feral horse management issue (Axford & Brown 2013).

Priorities and knowledge gaps

Priority research is difficult to define in a volatile and contested political context. If national parks are protected by reducing feral horse populations to a size where damage no longer accumulates, alongside programmes to tackle deer and pigs, then research into impacts and methods for localized protection will not be needed. Research budgets and effort could then be allocated to developing new efficient ways of preventing feral horse population growth, for tackling other invasive pests, and improving conservation, restoration and catchment management.

If aerial culling continues to be banned, communicating the imperative for action becomes a priority (Sharp *et al.* 2011). There is more than enough evidence of impacts, economic rationale and ethical and cultural analysis (Driscoll 2016, 2018a,b) to justify urgent deployment of aerial culling to rapidly reduce feral horse numbers. Having means to communicate this to a diverse public is essential. A second priority would be to evaluate the animal welfare concerns of leaving horses in the national parks and suffering of native species when horses destroy their habitat. Such information could then be weighed against the measured suffering by horses during culls (Hampton *et al.* 2017) to quantify the trade-offs and test our qualitative predictions (Fig. 2).

There is abundant research that demonstrates horses are capable of spreading a wide variety of weeds into natural areas (Loydi & Zalba 2009; Quinn *et al.* 2010). However, there is very little research on weed spread by feral horses in Australia (e.g. Ngugi *et al.* 2014) and none from the alpine parks. Weed invasion, facilitated by horses, is potentially important in the alpine parks and warrants further research attention (Nimmo & Miller 2007), including the potential for invasion through commercial trail-riders (Barros & Pickering 2014).

Conclusions

There is unequivocal evidence that feral horses are the single largest cause of widespread environmental degradation throughout their range in the alpine parks, even at low densities, and are a threat to many native species. Their impacts are reversing decades of recovery from damage caused by cattle and sheep, recovery that cost almost $10M (Good & Johnston 2019). Stream banks are being eroded, streams are becoming silted, and bogs and fens that take millennia

Figure 3. Nationally Iconic. Lake Albina, Kosciuszko National Park.

to form are being destroyed. These documented impacts justify effective and rapid horse control, to levels at which damage no longer accumulates and recovery and restoration is possible, probably <200 animals within Kosciuszko National Park.

Protecting alpine parks is particularly important because such a small proportion of NSW (9.3%) and Victoria (17%) is set aside in protected areas (http://www.environment.gov.au/land/nrs/science/capad/2016). That is, only 9.3% of the land area of NSW is nominally dedicated to the conservation of Australia's unique native plants, animals and ecosystems. This is well below global targets of 17% (CBD 2016). These small proportions already represent an enormous compromise for Australia's natural heritage. Further compromise of the ecological integrity of these protected areas, by keeping feral horses in them, is made with disregard for what is uniquely Australian, disregard for animal welfare and disregard for water supplies and quality. It is also contrary to the purpose of the protected area system and conflicts with international obligations (NRMMC 2009).

Supposed strong cultural links between feral horses and the Sydney Olympics or the ANZAC light horsemen are not supported by evidence. Tangible local cultural links to feral horses can be maintained by establishing community-supported horse populations on private property (CBBPS 2018). Feral horses need not be kept in alpine parks to meet cultural needs.

Evidence from modelling and from what has already been tried demonstrates that trapping horses cannot solve the problem alone. Trapping could be part of the solution in easily accessible areas, albeit a more expensive management option with poorer animal welfare outcomes. However, only aerial culling can reduce horse numbers rapidly, effectively, humanely and at lower cost than other methods. Culling horses from the air is widely practiced and aerial culling of feral deer, pigs and goats is common within the alpine parks. There appear to be no substantive cultural barriers to horse management using aerial culling. Based on the evidence, aerial culling needs to be included in the range of tools available to managers for controlling feral horses, and, in NSW, legislative barriers that prevent effective management of protected areas for conservation must be revoked.

Now, urgent dialogue is needed between scientists, NGOs, agencies and politicians to make feral horse control feasible and protect Australian ecosystems and species. The purpose of this special issue, as well as Worboys *et al.* (2018), is to catalyse open dialogue on a factual basis. Urgent action is needed and any delay makes the management problem and the impact on the natural environment worse as horse numbers increase and the cost of an effective response escalates.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1 Description of methods used by Driscoll and Banks (2014) in their simple population model of feral horses.

Appendix S2 Spreadsheet for modelling feral horse numbers. Adjust yellow cells only to alter scenarios.

