Final Report of the Kosciuszko Wild Horse Scientific Advisory Panel

Advice to assist in preparation of the Kosciuszko National Park 2020 Wild Horse Management Plan

September 2020

This report was prepared by the Kosciuszko Wild Horse Scientific Advisory Panel (SAP).

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Executive Summary

The Kosciuszko National Park (KNP) Wild Horse Scientific Advisory Panel (SAP) reviewed previous management plans for wild horses in KNP and management strategies used for other populations of wild horses, as well as the most recent literature on horse ecological impacts and control methodology, in addition to KNP site visits, with a view to providing scientific advice to the Minister and NPWS to assist in the preparation of a new Wild Horse Management Plan.

A reduction in wild horse distribution and density is required to minimise the considerable negative impact that wild horses are having on the natural values of KNP. However, as the precise quantitative relationships between horse density and negative impact across different areas of the park are not fully understood, a target population size is not advised. Rather, an adaptive management strategy is recommended with continual monitoring of performance against objectives and adjustment of actions depending on feedback from monitoring.

The SAP recommends that the new management plan should follow the International Consensus Guidelines for Ethical Wildlife Control, which incorporates modifying human practices, justification for control, clear and achievable outcome-based objectives, optimising animal welfare, social acceptability, systematic planning, and decision making based on specifics rather than labels.

The systematic planning recommended by the SAP comprises strategies for:

- identifying a horse population that will not diminish environmental values
- identifying management zones
- monitoring of the horse population
- monitoring impacts including environmental, Aboriginal heritage and horse welfare
- a decision-making process in choosing control methods for different zones and circumstances
- assessing the animal welfare impacts of control methods, with an adaptive management plan to prioritise the use of methods that have the least negative impact on animal welfare

Suggestions have been made where community involvement can be incorporated into each of these stages.

The advice aims to ultimately achieve environmentally sustainable populations of genetically viable heritage horse populations, managed with control methods that have the least negative impacts on animal welfare, with a management program that is socially acceptable and incorporates ongoing community involvement.

1. Introduction

The wild horse population in KNP has substantially expanded, both in distribution and density, during the last 30 years (Cairns 2019; Cairns and Robertson 2015; Walter 2003; Dawson 2009; Dyring 1990). This has been associated with increased concern for the negative impact on natural and cultural values (see Appendix 1 for further detail).

The SAP was formed to provide scientific advice to assist in the preparation of a new wild horse management plan. Members of the SAP are keen to ensure that the new plan will result in ethical and effective management of wild horses in KNP, ensuring the protection of natural values while also protecting the heritage value of the wild horses. The SAP has worked alongside the Community Advisory Panel (CAP) to listen to their views, address their questions and concerns, and incorporate their local knowledge and expertise. This report describes work conducted by the SAP to review available scientific and other information to provide advice that will contribute to the preparation of a successful KNP wild horse management plan.

SAP members reviewed the 2008 KNP Horse Management Plan and the 2016 KNP Draft Wild Horse Management Plan (Appendix 2) and the accompanying 2016 Independent Technical Reference Group Final Report and control method humaneness assessments (Appendix 3), as well as more recent scientific documents. Previous management plans for wild horses in Kosciuszko National Park (KNP) and management strategies used for other populations of wild horses were considered to identify reasons for failure or success (Appendix 2).

2. Recommendations by the SAP

Based on these reviews, the SAP has developed recommendations for wild horse management in KNP which follow the International Consensus Principles for Ethical Wildlife Control (Dubois et al. 2017). Specific recommendations are made with regards to estimating horse population densities, estimating environmental impacts of horse populations, horse control methods for reducing negative environmental impacts, animal welfare impacts and decision making within control methods, impacts on Aboriginal heritage, and community engagement.

2.1. Ethical Management Decision Making

To ensure that the new wild horse management plan is based on sound ethics, the SAP proposes that the new management plan follows the 'International Consensus Principles for Ethical Wildlife Control' (Dubois et al. 2017), and incorporates a 'One Welfare' framework (Pinillos 2016; Fawcett et al. 2018), in addition to aligning with the principles of 'Fraser's Practical Ethic' (Fraser 2012; Fawcett et al. 2018), and 'Conservation Welfare' (Beausoleil et al. 2018; Beausoleil 2020), which are summarised in Appendix 3.

The International Consensus Principles for Ethical Wildlife Control

1. Modifying human practices

The SAP has carefully considered each negative impact related to horses in KNP (danger to people at campgrounds, road traffic accident risks, and negative environmental/cultural heritage impacts; (summarised in Appendix 1) and evaluated first whether the impact can be mitigated by modifying human practices. The predominant negative impacts from wild horses that are not able to be further mitigated by modifying human practices are those of negative environmental and Aboriginal heritage impacts, and in restricted areas, road traffic accident risk and risk to people at campgrounds. Thus, further action for managing these negative impacts is required.

2. Justification for control

Justification for the need for increased management of wild horses in KNP is based on scientific evidence of the rapidly growing horse population in KNP, and the environmental degradation to which horses are contributing (see Appendix 1.2). There is a lack of robust evidence regarding the precise relationship between negative environmental impacts and horse densities, across different habitats. Consequently, the identification of what would be an environmentally 'sustainable' population of horses is imprecise. We define 'environmentally sustainable population' as a population size at which there are no or negligible, negative environmental impacts. The SAP, therefore, proposes rigorous monitoring during horse management to determine the relationship between horse density and negative impacts, and be able to identify such environmentally sustainable populations for different regions. Details of proposed monitoring are outlined below (as well as in greater detail in Appendix 5). Further, based on optimal welfare outcomes for wild horses, the SAP recommends against inaction on implementing horse population reduction as inadequately managed wild horse populations are likely to have a large proportion of horses with poor welfare as their numbers exceed available food, and horses are pushed out into woodland areas of the park where food availability is limited.

Horse populations in KNP also have impacts on other aspects of the park, including Aboriginal and European Australian heritage (see Appendix 1.3 for discussion of the impacts of horse populations on Aboriginal heritage). The heritage value of the horses and the importance of horses to community members are recognised. Nonetheless, of high importance are also other species, unique aspects of the environment, ecosystems functions, and Aboriginal heritage. The 2020 Wild Horse Management Plan should, therefore, seek to reach a balance in protecting all these assets and reach compromises between conflicting values.

3. Clear and achievable outcome-based objectives

The SAP advises that the wild horse management plan has clear and achievable outcome-based objectives, i.e. adaptive management (Allan & Stankey 2009), as outlined in the below sections of this report. As such, the SAP advises rigorous monitoring throughout management including of environmental impacts and horse population demographics and welfare. The SAP recommends that management is adaptive based on lessons learnt from ongoing monitoring, as is detailed below. The end goal is to reach an environmentally sustainable population of wild horses in KNP.

4. Animal welfare

The need for more systematic evaluations of the welfare outcomes in Australian horse management was recently identified by Scasta et al. (2020). Thus, the SAP recommends welfare outcomes of control methods be empirically evaluated. Management methods used should cause the least animal welfare harms to the least number of animals. To identify those methods, systematic scientific evaluation of the possible animal welfare harms is required (see sections 2.2.6, 2.2.7 and Appendix 3).

5. Social acceptability

No wild horse management program will be successful if it is not socially acceptable (Howard et al. 2019, see Scasta et al. 2020 for a recent review of the social issues faced by wild horse managers). Social acceptability is dependent on education, transparency, and trust (Scasta et al. 2020). Having a management plan that follows the described ethical frameworks will hopefully instil transparency and public trust in the plan. Incorporating a strong program of environmental impact and animal welfare impact monitoring, with adaptive management informed by empirically assessed results, should further increase trust and transparency. Ongoing community involvement in the management plan will further help to ensure wider social acceptability. Community involvement in monitoring may instil greater transparency and trust in the data being used to guide horse management. Areas where community engagement can be incorporated into management are identified in each respective section and community engagement recommendations further summarised in section 2.2.8. Previous lack of true community engagement was identified by the SAP as a reason for the failure of previous management plans.

It must be acknowledged, however, that different people have different values; successful coexistence in any society is dependent on mutual trust and respect among people with different views and values, as well as those people with similar views and values. Successful and ethical management is thus further dependent on understanding and appreciating alternative views and values to reach compromises that strike a balance between these alternate views. It is also important that representative views of the broader community are considered, and not just those of the most vocal minority groups. The SAP recommends that communications specialists with knowledge and experience of gaining social license to operate with animal management issues are engaged. It is vital that a strategy is developed for effective communication with, and education of, the broader public, and that misinformation disseminated on social media, and mainstream media is effectively mitigated. For example, misinformation/misinterpretation among the public regarding population estimates and reproductive control has been identified as a social issue hindering effective horse management (Scasta et al. 2020). Thus, providing easily understandable information regarding management actions and the scientific justification for those actions to the public may improve community support of management actions (see Supplementary Material for some examples of lay explanations of the science behind management decisions).

6. Systematic planning

The SAP recommends that the management plan is systematic and adaptive to most effectively minimise negative environmental impacts of horses while optimising welfare outcomes of horse management. The recommended systematic planning comprises strategies for identifying an environmentally sustainable horse population, identifying management zones and horse heritage areas, monitoring of the horse population, monitoring environmental impacts and Aboriginal heritage, a process for decision making in choosing control methods for different zones and circumstances, and assessing the animal welfare impacts of control methods, with an adaptive management plan to prioritise the use of methods that have the least negative impact on animal welfare. The SAP recommendations for this are detailed below (section 2.2).

7. Decision making by specifics rather than labels

The SAP recommends an evidence-based management program, as already highlighted in principles 1-6. The steps being followed in developing the management program would be the same for any wildlife species where management is required as based on scientific evidence. Management decisions are therefore not being suggested based on horses being an introduced species or based on any groups of people having a bias against horses. The heritage value of wild horses in KNP and the importance of the horses to elements of the local and wider community are recognised. The SAP seeks to introduce a management plan that will achieve a balance, to reach an environmentally sustainable population of wild horses, protecting the heritage value of the horses whilst also protecting and retaining other values of KNP.

2.2. Systematic Planning

2.2.1 Recommended strategy for identifying environmentally sustainable horse populations

As the precise quantitative relationships between horse density and negative impact across different areas of the park are not fully understood, a target population size is not advised. Rather, an adaptive management strategy is recommended with continual monitoring of performance against objectives and adjustment of actions depending on feedback from monitoring. As part of adaptive management, controlled experimental studies (e.g. Lenehan 2011) should be conducted during management activities to better assess the changes in environmental impacts as horse densities are reduced. This will inform the horse densities that can be retained whilst minimising negative impacts. Preliminary targets for specific zones could be determined based on historic data of horse densities at a time when there was little evidence of negative impacts.

The SAP recommended strategy for identifying environmentally sustainable horse populations includes the following steps:

1. Define environmental and Aboriginal heritage impact.

This should include measurements of water quality, vegetation and faunal biodiversity and abundance, stream morphology, and Aboriginal archaeological surveys. More detailed methodology will need to be developed and included in the final plan. See section 2.2.3 below and Appendix 5 for specific monitoring methodology recommendations.

2. Define horse management zones.

Starting with the already defined management zones developed in the 2016 Plan, incorporate new information regarding areas of high conservation concern and value, high Aboriginal and European Australian heritage value, and habitat suitability for horses, other herbivores, and key endangered species, to further refine management zones (section 2.2.1, Appendix 4).

3. Set preliminary horse density targets within each zone.

Preliminary horse density targets should be guided by current estimated densities within each zone, and past densities when there was little evidence of negative impact (these targets will be refined as the adaptive management process continues).

5. Establish monitoring sites.

Monitoring sites within each management zone (sampling all habitat types) should be selected. At each site record indices of abundance/activity of horse (section 2.2.2, Appendix 5.1) and other grazing species (e.g. deer, pig), and record the *a priori* selected environmental and Aboriginal impacts at each site (section 2.2.3 and 2.2.4, Appendix 5). This will provide data on horse densities and impacts, prior to commencing management; monitoring should continue as management proceeds.

6. Initiate horse population control

Starting with horse reduction zones (section 2.2.1, Appendix 4), begin horse control, initially targeting areas of highest environmental and Aboriginal heritage concern within the zone. Trial initially recommended control methods and monitor efficacy, practicality, and welfare outcomes (section 2.2.6, 2.2.7, Appendix 3) to inform how management can best proceed in other zones.

7. Assess the relationship between reduction in horse density and negative impacts to inform sustainable horse densities in each region within zones

Resurvey sites for horse densities and impacts regularly once or twice per year as management progresses. Conduct water, vegetation, and faunal surveys (e.g. spring, autumn or summer, depending on the species involved) per year to assess recovery (Appendix 5.2). More frequent surveying is likely unnecessary due to the time lapse required for recovery (i.e. vegetation and fauna will require a period of time to respond to the change in horse density and recover).

8. Adjust density as necessary to reach a sustainable target density

As management progresses, scientific monitoring of environmental impact, horse density, and horse welfare (all discussed above) will enable an environmentally ‘sustainable’ target density to be determined.

2.2.2 Management Zones Recommendations

The 2016 Plan identified five types of horse management zone types: prevention; elimination; containment and population reduction; key environmental asset protection; and public safety. See 2016 Plan for further detail regarding each of these management zone types.

Working with these zones, the SAP considered the subsequent changes to reported negative horse impact up to 2020 and the damage caused by the 2019-2020 fires (Adaminaby Complex, Dunns Road, Marys Hill, and Rolling Ground Fires) to indicate three areas where immediate horse management should be prioritised. Boundaries were revised after discussions with NPWS and the CAP based on operational and heritage considerations.

Three management zones are proposed for the northeastern section of the park where fire damage has been severe and wild horse populations are at high densities (Figure 1). The rationale is that the post-fire recovery of the vegetation and its dependent native fauna may be hindered by the high horse densities that have become established in this area of the park, especially over the last decade (see Appendix 4). Additionally, there is a need to protect environmental assets that are currently being negatively impacted by horse activity (see Appendix 4). Horses also need to be managed in places where collisions between motor vehicles and horses pose a significant safety risk to humans and horses.

Zone 2 has additionally been identified to incorporate an area of potential horse heritage value in the Kiandra region. This population of horses is important to the local communities, and individual horses are well known through the work of local photographers. Anecdotal evidence from the community suggests that this population was reduced during the 2019-2020 fires. Therefore the SAP recommends that the Kiandra region be utilised as the key region for a pilot community engagement study (detailed in section 2.2.8) prior to further management planning for this region.

Beyond the three zones identified above as priorities, the SAP recommends the management zones and types specified by the 2016 Plan be incorporated in the 2020 Plan, while acknowledging that these may be refined through the adaptive management process. Additional horse subpopulations of particular community value should be identified and included in the consideration of management zones. Further detail should be provided for the justification for each zone to improve transparency (as per Appendix 4).

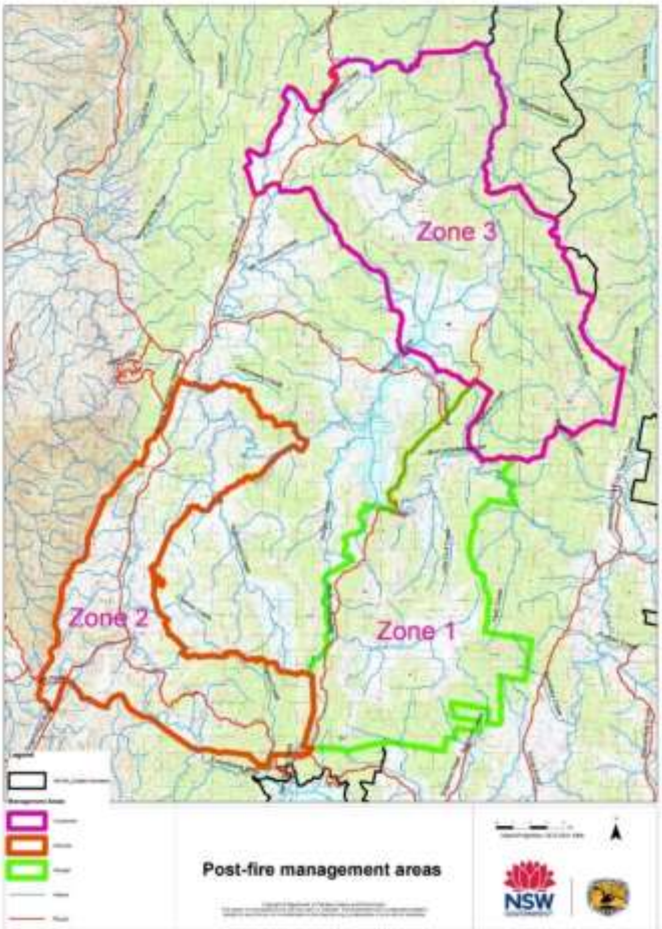

Figure 1. Priority post-fire management zones recommended by the SAP.

2.2.3 Horse Population Monitoring Recommendations

To monitor the effectiveness of horse management on a KNP wide scale, the SAP recommends that existing aerial line-transect surveys are maintained for a KNP wide population estimate (Cairns and Robertson 2015, Cairns 2019). The scientific methodology used in these surveys is scientifically robust and has provided accurate estimates of the horse population within the survey area at the time of the survey (see Supplementary Material 1.1 for background information). While the methodology of the aerial count should be maintained to allow for comparison across years of sampling, improvements that can be made include attaching video cameras and/or thermal cameras alongside human observers. Eventually, drones may replace helicopter surveys, but further development of this new technology is required.

A study of the movement behaviour of horses during an aerial survey should be conducted to measure the influence of flushing horses from one transect to the next. Satellite tracking of collared horses on the edges of the survey area would be valuable to help provide estimates of movements during aerial surveys and control operations.

The SAP recognises there are some parts of the community in disagreement with the KNP wide population estimates. Community engagement in population surveys, in addition to further education regarding the methodology (e.g. Supplementary material 1.1), may help address this issue. This is likely to remain a challenge given the complexity of performing large scale population estimates in a scientific manner. The SAP emphasises that management decisions should not be directly based on the KNP wide population estimates, but rather on environmental impact monitoring (see 2.2.4

below) and smaller scale population estimates within management zones. While aerial surveys provide an estimate of the entire horse population across KNP, there is a need for greater use of population estimates at smaller scales. The relationship between horse densities and environmental impact will likely differ for different ecosystems within the park (Appendix 1) and thus within the different management zones. Determining this precise relationship for each management zone is crucial. To obtain these smaller scale population estimates, we recommend the following methods:

- Line-transect dung count surveys
- Dung DNA sampling (genetic analysis)
- Aerial line-transect surveys using drones
- Ground surveys (line-transect and mark-recapture)
- Camera traps

Detailed methodology for each of these methods, and opportunities for community involvement, are provided in Appendix 5.1. Smaller scale population estimates within management zones will not only be more useful for directing immediate management, but estimates at this scale will be more likely to achieve community agreement. Therefore, the SAP recommends that the main focus for population estimates is shifted to smaller scale estimates within management zones.

For management zones where horse populations will be retained, horse welfare and genetic health will need to be monitored as part of the identification and maintenance of a genetically viable healthy horse population. However, as the population in KNP is not currently considered a small population and subpopulations are not geographically isolated, the SAP does not see genetic diversity within the population as an immediate concern. Genetic work as described in Appendix 5 should provide further information in this regard. Regular genetic monitoring would be required to monitor for evidence of declining genetic health over time. If this arises, management strategies would need to be altered accordingly. Additional genetic analyses may be used to identify horses outside of the park that would be suitable to introduce into these heritage herds to genetically reinvigorate the population (see National Research Council 2013 for detailed discussion of managing genetic viability in horse populations).

2.2.4 Environmental Impact Monitoring Recommendations

The SAP recommends that horse management goals be focused on reducing negative impact rather than a target population size, as was also advised by the ITRG in 2016. To achieve these goals, negative environmental impacts need to be identified and monitored to ensure that horse population reduction efforts are having the desired outcome.

Several methodologies have been developed to assess the negative impacts of wild horses on different ecosystems (e.g. Cherubin et al. 2019; Robertson et al. 2019; Thiele & Prober 1999; Tolsma & Shannon 2018; Worboys et al. 2018). The SAP review of horse impacts in KNP indicates that high densities of horses have the greatest negative impact on waterways and bogs (see Appendix 1.2). Growing horse populations can also have negative impacts on key endangered species, directly and indirectly through loss of habitat (Appendix 1.2). Thus, these impacts should also be a focus of monitoring effort. The SAP recommends monitoring include the following areas.

- Vegetation. Monitoring to include changes to vegetation structure and composition, weed abundance, endangered flora abundance, proportion of trampled or eaten vegetation.
- Stream morphology. Monitoring to include water quality, water turbidity, stream bank morphology, degree of pugging.
- Key endangered fauna. Monitoring to include presence and/or abundance of Corroboree Frogs (especially Northern species *Pseudophryne pengilleyi*), Broad-

toothed rats (*Mastacomys fuscus*), and other key species, and impacts on the habitat of these species.

Further detailed recommendations regarding methodology for each of the above areas are provided in Appendix 5.2. Opportunities for community engagement should also be identified.

With reductions in horse densities, it is likely that not only will negative environmental impact be mitigated, but some positive impacts may be identified at moderate or low horse densities in some management zones (e.g. Fahnestock & Detling 1999, Austrheim & Eriksson 2001, Ostermann-Kelm et al. 2009, Stroh et al. 2012). Alternatively, even at very low horse densities, unacceptable negative environmental impacts may remain in some management zones. An adaptive management process as described here will inform either situation.

2.2.5 Aboriginal Heritage Monitoring Recommendations

The impact of horse populations on Aboriginal heritage has been woefully understudied in KNP and across Australia (see Appendix 5.3). The SAP recommends that NPWS take this opportunity to examine the impacts of horses on Aboriginal heritage and evaluate how best to preserve Aboriginal heritage into the future. The SAP understands that NPWS have also engaged an anthropologist to undertake indigenous community engagement, and that a separate advisory report will also arise from this.

The effect of wild horses on Aboriginal heritage objects and places is hypothesised to be detrimental over the long term, even if short-term observations do not see large or obvious changes in site integrity (see Appendix 5.3). There are no known studies that address the issue of the effect of horses on hunter-gatherer archaeology. Therefore, as well as contributing to the effective management of KNP, the initiation of such study would represent a potential contribution to knowledge that would be of international importance.

Monitoring the effect of horses on Aboriginal heritage will require approaches predicated on the range of Aboriginal site types likely to be encountered in KNP by wild horses (Appendix 5.3).

The broad approaches should be enacted in each of the designated management zones and should encompass:

- Archaeological survey of known/suspected areas of higher horse density to determine the presence of archaeological material and horse impact (direct or indirect) thereon.

- Investigation of known key locations within KNP of high Aboriginal archaeological/heritage significance to assess potential impacts of horses, or their exacerbation of disturbance partly or wholly attributable to other factors.

- Design of controlled experimental locations that would allow measurement of the impact of horses on prevalent site types (see Appendix 5 for more detailed methodology).

At monitoring locations, an inventory should be undertaken of potential Aboriginal food plant resources and note of any impact to these by horses.

A further area on which to focus will be the potential effect of managing the horses on Aboriginal objects. For example, the creation of even temporary yards has potential to create a congregation of horses that might not normally occur there - and a consequent degree of scuffage and topsoil disturbance that could break and displace artefacts. Similar effects could be hypothesised if horses were to be buried in pits or roads/tracks needed to be constructed or upgraded to allow for trucks to remove captured horses. Each proposed measure for horse control should be assessed for its potential to disturb archaeological material.

2.2.6 Control Methods Recommendations

Available control methods

Rehoming and reproductive control are the only ‘non-lethal’ options of wild horse management - noting that rehoming can terminate in lethal control in some circumstances as some horses removed for rehoming may subsequently end up at sale yards and/or knackeries. Reproductive control does not reduce the population substantially or in a short period of time (see Supplementary Material 2 for an explanation of how reproductive control influences population size versus growth rates). Therefore, of these two methods, only removal for rehoming has the potential to reduce the population in the short-medium term. Figure 1.2 illustrates that when locations are truck accessible for live transport of horses out of the park and there are rehoming opportunities, then passively trapping or mustering horses for removal and rehoming is the preferred method as this has the widest community acceptance. Community involvement in rehoming efforts has the potential to increase the success of rehoming captured horses. Many people have gained considerably from their partnership with rehomed wild horses and there are many examples of horses being successfully rehomed. However, it should be noted that there is little information available on the welfare outcomes of rehoming, and on the welfare impacts of the domestication, training and rehoming processes. There is the potential for significant adverse welfare outcomes during this process, in addition to the potential for a lethal end outcome that may also be associated with significant negative animal welfare impacts. Strict conditions for rehoming should therefore be in place to increase the likelihood of acceptable animal welfare outcomes. Furthermore, research is advised to obtain further information about the welfare impacts of the rehoming process and end outcomes of rehomed horses.

There are, however, often limited rehoming opportunities, necessitating additional methods for reducing the population, of which there are only lethal methods available (Table 1). These methods are also necessary for locations that are either not truck accessible, or do not have truck access suitable for live horse transport (e.g. very long, rough, bumpy, and/or hilly tracks). Some lethal control methods require capture of the horse first, whilst others do not (Table 1).

Table 1: Lethal methods available for population reduction

Lethal control methods requiring capture		**Lethal control methods not requiring capture**
Capture methods	**Control methods**	
Passive trapping Mustering Brumby running	Transport to abattoir or knackery Shooting in trap yard Tranquilising in trap yard followed by euthanasia with captive bolt or lethal injection	Ground shooting Aerial shooting

The SAP recognises that some sections of the community strongly oppose lethal control methods but at the current time it is unlikely for successful management to be achieved without them. The primary objective should be achieving an environmentally and genetically sustainable horse population that can be managed without the need for ongoing lethal control methods. By utilising lethal control at this stage, fewer horses will be impacted in the long term than if ineffective management continues and the population continues to rise. Therefore, at the current time, when rehoming possibilities are exhausted, lethal control methods are advised, focusing on those methods with the least detriment to animal welfare.

For lethal control, the worst welfare outcomes are likely to be those where there are multiple stages (e.g. trapping, mustering, loading and transport, holding periods) prior to death, and those where death is associated with more extreme or prolonged anxiety/fear and/or pain. **It should be noted that ALL methods have the potential for moderate to extreme adverse welfare outcomes,** and so reducing negative welfare outcomes relies on adhering to strict conditions and protocols upon which each method is used. Furthermore, assessment and auditing of actual animal welfare outcomes, and alteration of methods accordingly, is required to continually strive for the lowest negative welfare impacts.

Ethical decision-making on control methods

Welfare impacts of management are a key consideration in choosing management techniques. It should be noted that, in line with current recommendations, the SAP does not advise using the term 'humane' since this is a vague non-specific term that incorporates ethical values in addition to animal welfare impacts, and thus is open to variable interpretations (Hampton et al 2020 *in press*). Rather the SAP recommends using the term 'welfare impact', or more specifically 'negative welfare impact' as this is very specifically referring to the welfare impacts on the animal, which can be assessed scientifically and objectively (more detail in Appendix 3).

A range of management options will be needed to accommodate different variables, such as whether the location is a heritage area, whether it is truck accessible, truck accessible for live horses, whether carcasses need to be removed if horses are shot and what carcass disposal options are available, herd sizes, herd approachability, the terrain and habitat. Different methods will be better suited to different locations depending on these variables (see Figure 2). Additional variables such as efficacy, cost, practicality, operator safety, target specificity, environmental impact, and public acceptability also require consideration (Table 2).

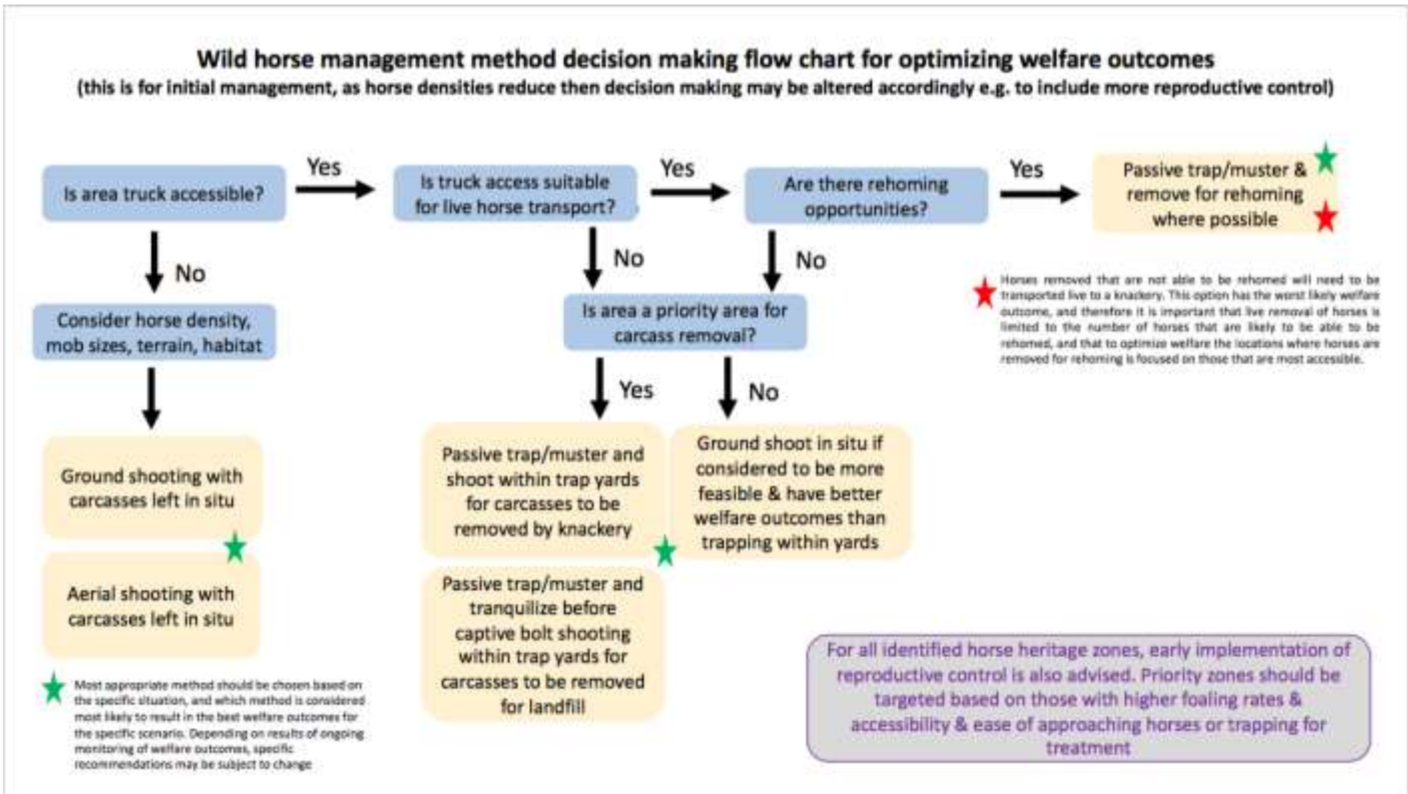

Figure 2. Wild horse management method decision making flow chart

Table 2. Variables other than horse welfare impacts that influence control method recommendations for specific areas

Rate of horse removal required for mitigating negative environmental impacts & preserving heritage populations
Truck accessibility (live horses vs carcasses)
Carcass disposal options
Herd characteristics – size, approachability
Environment characteristics – terrain, habitat type, weather conditions
Efficacy & cost
Practicality & safety issues
Potential welfare impacts on non-target species
Practicality

The actual animal welfare outcomes of the available control methods as applied in KNP has never been formally assessed. Formal studies of actual animal welfare outcomes for euthanasia of horses in trap yards and ground shooting have never been performed. Only one published study of animal welfare outcomes of aerial shooting in horses has to date been carried out (Hampton et al. 2017). Therefore, there is insufficient evidence upon which to base firm recommendations for one lethal control method above another. Consequently, rather than making firm recommendations regarding lethal control methods, the SAP advises choosing future control methods, based on preliminary pilot studies of animal welfare outcomes with a range of available options, as outlined below.

Development and refinement of Standard Operating Procedures (SOPs), and auditing of animal welfare outcomes, should be performed with ongoing involvement from the SAP/newly appointed steering committee and/or additional veterinarians as required, who have specific animal welfare expertise (e.g. MANZCVS in animal welfare and/or animal welfare PhD) in addition to experience in wild horse management.

Recommended selection of control methods based on welfare impacts

1. The ITRG assessments should be used as a starting point (see Appendix 3). From these assessments, management options could be identified where there is high confidence of severe/extreme welfare impacts, and these management options should not be considered or should be a last resort with additional investigation into how welfare impacts could be further mitigated. These assessments also enable identification of specific stages of a management option that may have severe welfare impacts and thus should be avoided (e.g. options that includes separation of and/or mixing of mobs, or involve withholding food and water for > 12 hours). This may not preclude the whole management technique but may mean aspects of the technique need to be improved for welfare impacts to be acceptably reduced

2. SOPs for current methods of capture and population reduction should be reviewed to identify areas where animal welfare outcomes may be able to be further improved. Some management options (e.g. shooting in yards, tranquilising in yards prior to captive bolt or pentobarbitone euthanasia) were not assessed by the ITRG as no SOPs had been developed at that time. SOPs should be developed for **all** available methods, utilising expert advice, and theoretical animal welfare assessments made.

3. Any methods deemed worthy of further consideration based on likely acceptable animal welfare outcomes from theoretical welfare assessments should undergo pilot studies to assess the actual animal-based measures of welfare impacts (as recommended by Hampton et al. 2016; further information in Appendix 3). Results can then inform best future management options and/or further refine management techniques to further reduce welfare impacts – a critical aspect of ensuring acceptable animal welfare outcomes.

4. Every stage of each control method needs to be considered. Many management techniques first require capture of horses and the welfare impacts of this process need to be considered in addition to the welfare impacts of post-capture control methods. Management options with fewer stages (e.g. that does not require capture of horses) are likely to have less negative welfare impacts (see ITRG humanness assessment report).

5. A welfare assessment framework should be devised specifically for each stage of each management option (see 2.2.7, Appendix 3).

6. Consideration also should be given to the welfare impacts on remaining horses, as well as impacts on other species (e.g. indirect effects of large-scale mustering on other species).

Recommendations for control methods that should undergo further evaluation

In line with the above, the following methods for capturing and lethal control should be further evaluated for implementation in appropriate circumstances (considering variables in Table 1.2) with potential alterations to any existing SOPs to further minimise negative welfare impacts (further info Appendix 3). There may be opportunity for community involvement with some capture methods.

- Capture
  - Passive trapping (suggested alterations to existing SOP in Appendix 3)
  - Mustering (either aerial or ground) of small groups of horses performed over hours, in small areas (maximum 2 km)
  - Brumby running
    - Note that this capture method had the highest negative welfare impacts in the ITRG assessment. However, this was based on a SOP from Victoria, and there is potential for many of the negative impacts associated with this method to be mitigated (see Appendix 3). Where substantial welfare impacts can be acceptably mitigated in the development of an alternative SOP, this method could be trialled under strict conditions with actual monitoring of animal welfare outcomes.
- Lethal control
  - Capture followed by transport (of maximum 6 hours) for slaughter at an animal welfare-audited knackery (See Appendix 3).
    - Note that this is only recommended where transport out of the park was performed with a view to rehoming, and was possible to transport the horses out of the park with minimal negative welfare impacts, but where rehoming did not eventuate.
  - Capture followed by euthanasia at the trap site
    - This should be undertaken when no rehoming options are available, or where it is not possible to transport the horses out of the park for rehoming without unacceptable negative welfare impacts (e.g. if journey out of the park is a long and turbulent journey).
    - Various options are available for euthanasia at trap site and the SAP advises that all these options are further evaluated to identify which has the least negative welfare impacts in specific circumstances.
      - Tranquilising (dart or hand injection) followed by captive bolt shooting
      - Tranquilising (dart or hand injection) followed by lethal injection
      - Tranquilising (dart or hand injection) followed by shooting with a firearm
      - Shooting with a firearm without prior tranquillisation
        - Recommendations for trials and further guidelines on minimising negative welfare impacts associated with these options are detailed in Appendix 3.
  - Shooting with a firearm without prior capture
    - Options include ground and aerial shooting
    - The SAP recognises that some sections of the community are strongly opposed to shooting, particularly without prior capture. Methods not requiring prior capture of horses (such as these methods) will likely have less welfare impacts, provided that the control method is carried out according to strict protocols with auditing of animal welfare outcomes (see Appendix 3).
    - The SAP would only recommend use of any of these methods in very specific circumstances, and only if preliminary trials demonstrated better animal welfare outcomes than achieved with other methods that require prior capture.
    - Shooting methods may be particularly preferable for locations where horse density, habitat, and terrain are not favourable for mustering or trapping of horses, and removing from the park.

- More detailed recommendations of important considerations in SOPs and animal welfare auditing recommendations for these control methods are included in Appendix 3. The SAP recommend trialling of both methods under strict conditions to determine animal welfare outcomes, with the ongoing method used to be that with the least negative impacts on animal welfare, alongside consideration of other variables as outlined above.

Recommendations of methods that should not be further considered

- Capture by mustering of large groups, over a period of days, over long distances outside of their home ranges
  - This is in line with ITRG assessments, based on negative impacts associated with mixing of herds, and time period without rest, food and water (see Appendix 3 for further detail).
- Slaughter at abattoirs (see Appendix 3 for discussion of the difference between abattoirs & knackeries)
  - Due to the limited number of abattoirs that process horses, this requires long-distance travel.
  - Due to the number of animals and different species being processed at abattoirs, and the method of killing (captive bolt in a conscious horse), extreme negative welfare outcomes are likely to occur, particularly as independent animal welfare auditing has not previously been permitted (see Appendix 3 for further detail).
- Slaughter at knackeries that requires > 6 hours transport and/or where independent animal welfare auditing is not permitted, or where audits reveal unacceptable animal welfare outcomes.
- Relocation requiring > 12 hours transport without rest, food and water
  - Risks of dehydration, gut stasis, muscle fatigue and delayed urination will be significantly increased for journeys beyond 6 hours without rest, food and water, so journeys of less than 6 hours (without rest/food/water) are advised, with the shorter journeys being preferable. No journey should exceed a maximum of 12 hours without rest, food and water (see Appendix 3 for further detail)
- Relocating wild horses from ‘more sensitive’ to ‘less sensitive’ areas of the park
  - Based on currently available evidence, this would be expected to have a low success rate with poor welfare outcomes, in addition to exacerbating negative environmental impacts in ‘less sensitive’ areas of the park (see Appendix 3 for further detail).
- Establishment of large off park holding facilities to allow more time for rehoming
  - Based on the experience of this practice in the USA, this is unlikely to be successful in increasing rehoming. Further, the SAP is highly concerned about the negative welfare impacts of longer term holding of horses, ability to provide appropriate care in this setting, and increased difficulty in decision making around these horses when no rehoming opportunities are identified.

Rate of population reduction

An issue in past horse management plans has been a failure to consistently remove horses at the rate required to reduce the population. To reduce the horse population size in specific areas, it will be necessary to remove a greater number of horses each year than are produced through reproduction and immigration; the number of horses that need to be removed will vary from year to year. When the population size is substantially reduced, horse breeding is likely to increase because under good conditions at low density, the age at first breeding in mares decreases and the frequency of foaling and foal survival increases (Grange et al. 2009), resulting in more rapid birth rates and higher juvenile recruitment rates (see Supplementary Material 2). This would result in a greater number of horses needing to be removed per year to continue reducing overall numbers (see Appendix 6 for further explanation). Monitoring at each site is required to determine whether the rate of removal is sufficient.

Reproductive control recommendations

Reproductive control alone will not reduce the population substantially in a short-medium timeframe (see Appendix 6 & Supplementary Material 2). However, once the population has been reduced to a lower level, reproductive control may then assist in maintaining this population level, therefore reducing or removing the ongoing requirements for lethal control methods. Earlier implementation of reproductive control trials may be desirable within heritage areas. In particular, the SAP recommends that the Kiandra population be further assessed as an initial early trial site for reproductive control. As the SAP has recommended that this population be used as a key area for a community engagement pilot study, the collection of horse population and demographic data required to instigate a reproductive control program would already be underway. If the population is found to have already been reduced from the 2019-2020 fires, and the horses in this population are already more habituated to human presence, then this may be the ideal location for an early reproductive control trial.

The SAP has discussed a range of reproductive control methods for potential trialling (see Appendix 6). It is important to note that no reproductive control method developed yet is highly effective, easily delivered, affordable, and does not alter the behaviour or physiology in some way (Kane 2018; see Appendix 6 for further detail). Criteria for selecting reproductive control methods are: delivery method, availability, efficacy, duration of effect, and potential physiological and behavioural side effects (see Appendix 6 for a review of each currently available method for mares). Currently, the most efficacious immunocontraceptive vaccines for horses are PZP and GonaCon (see Appendix 5). Neither are licensed for use, nor available, in Australia at the current time. SAP recommends that NPWS submit applications for APVMA approval for the importation and use of both of these immunocontraceptives.

Preliminary studies of approachability and flight distances of horses in various locations in KNP have suggested that only a minority of horses in KNP can be approached close enough for safe and effective dart administration of immunocontraceptives. The SAP recommends that data are collected on horses in management zones identified for horse retention (e.g. Kiandra horses in zone 2 – see section 2.2.1) in regard to approachability/flight distance, band sizes, sex ratios, reproductive rates, and identification of individuals. Once preliminary data have been obtained, further plans can then be made (see Appendix 6 for more detailed proposed steps of implementation). Efficacy and choice of possible immunocontraceptive agents are increased if hand injection is used. Therefore, at least in the initial stages, administration would require horses to be trapped first. The SAP also recommends consideration of trialling other reproductive control methods, such as Intrauterine Devices (Appendix 6). A new oocyte growth factor immunocontraceptive is also currently under investigation in the USA, and the SAP has read the researchers preliminary summary. It has yet to be concluded as to whether this will be an effective immunocontrapetive, but the SAP advise following this research and consideration be given to incorporating this into future reproductive control trials if the opportunity arises.

The SAP advises that any such reproductive control programs are developed by biologists and veterinarians in conjunction with NPWS with involvement of community members where appropriate. There is much expertise within Australia that can be drawn upon including within the SAP, and also outside of the SAP with a range of veterinary reproductive specialists with specific expertise in equine reproductive control, reproductive biologists, and wild horse researchers, in addition to veterinary darting experts. Some community groups have also acquired experience from overseas reproductive control programs. There are several opportunities for community involvement in obtaining essential demographic data for reproductive control, including recording the number of mares, stallions, sub-adults (1 to 2-year-old) and foals (< 1 year old) in subpopulations and identifying individual band and horse characteristics to assist in reproductive control planning.

Please see Appendix 6 for further background information and recommendations.

2.2.7 Animal Welfare Monitoring Recommendations

As outlined in section 2.2.6, theoretical animal welfare assessments should first be performed for each method, using the SOP for that method, and incorporating both best- and worst-case scenarios (as per ITRG assessments 2016). For those methods that are deemed to have likely acceptable animal welfare outcomes based on the theoretical assessment, then trials of the methods with assessment and monitoring of actual animal welfare outcomes should be performed. There are currently very limited data on actual animal welfare outcomes for all of the available methods.

For those management options that require multiple stages (e.g. capture, loading and transport, holding), welfare impacts need to be assessed for each stage of management. In assessing negative welfare impacts, both the **severity and duration** of the impact need to be assessed.

Use of The Five Domains Model for assessing welfare is recommended (Mellor & Reid 1994, Beausoleil & Mellor 2015, Mellor & Beausoleil 2015, Mellor 2017, Harvey et al 2020). The Five Domains Model comprises four interacting physical/functional domains of welfare; ‘nutrition’, ‘environment’, ‘health’ and ‘behaviour’, and ‘mental state’ (affective/mental experience). Following measurement of resource and animal-based indices within each physical domain, the anticipated negative or positive affective consequences are cautiously assigned to Domain 5. It is these experiences that contribute to descriptions of the animal’s welfare state.

A welfare assessment framework should be specifically devised for each stage of each management option. This should include assessment of impacts within each physical domain, for example:

Domain 1: Restricted food/water

- Time without access to any food
- Time without access to foraging and grazing
- Time without access to water

Domain 2: Environmental challenge

- Degree & duration of physical exertion during high ambient temperatures
- Duration of holding in high ambient temperatures without shade
- Duration of holding in low ambient temperatures without shelter
- Presence and duration of shivering (mild/moderate/severe)
- Presence and duration of sweating (mild/moderate/severe)

Domain 3: Health challenges

- Presence of wounds
- Presence of injuries
- Presence of lameness
- Sickness behaviours: e.g. colic signs, non-ambulatory, inappetence, separation from other horses

Domain 4: Behaviour challenges/restrictions

- Time and severity of restricted normal behaviours
- Time and severity of restricted positive social interactions (e.g. separation from mob members), and increased negative social interactions (e.g. fighting)
- Time and severity of flight behaviour e.g. during musters or helicopter chases

Additionally, welfare impacts associated with methods of lethal control need to be considered separately, to objectively assess measures that indirectly relate to the degree and duration of anxiety and/or pain prior to death. It is a common misconception that non-lethal methods cause less severe animal welfare harms than lethal methods, but this is not always the case (Dubois et al. 2017, Beausoleil et al. 2018, Beausoleil 2020, Hampton et al. 2016). Lethal methods can have less animal welfare impacts if death is instantaneous, particularly if prior capture is not required. The term 'euthanasia' means a 'good' death, i.e. one associated with minimal anxiety and/or pain. This is clearly desirable in comparison to a death that may involve substantial anxiety and/or pain. The following are examples of key measures that can be assessed (Aebischer et al. 2014, Hampton et al. 2017, Stokke et al. 2018):

- Time to unconsciousness following gunshot
- Time to death following gunshot
- Distance moved between gunshot and loss of consciousness
- Presence of non-fatal wounding
- For aerial shooting, helicopter chase time

Finally, where environmentally sustainable populations of horses are being retained in the park, monitoring of the welfare of these horses is advised. Population densities, that are too high for the food available within a particular habitat, may have poor welfare associated with malnutrition. Methods for monitoring welfare in free-roaming wild horses have been previously described (Harvey et al. 2020). In some regions with very poor nutrition, sustainable populations may not be advisable based on welfare grounds.

Refer to Appendix 3 and Supplementary Material 4 for more information regarding ethical decision making and welfare in horse management.

2.2.8 Community Engagement Recommendations

Due to the adaptive nature of the recommendations being made by the SAP, with the need for substantial ongoing monitoring of horse populations, environmental and Aboriginal heritage impacts, and animal welfare impacts of control methods, engagement of a scientific and community steering committee is advised to assist in successfully implementing and executing the management plan. With a scientific and community committee working together on an ongoing basis, the management plan is much more likely to be successful.

The SAP considers that true community engagement is critical to the success of horse management in KNP, and that a lack of true community engagement is one key reason for failures of previous management plans. Recommendations have been made within sections above where there are opportunities for community involvement. This may occur across a range of management zones. In particular, the SAP recommends that in the early stages, the Kiandra region within Zone 2 is used as a key area for an initial pilot community engagement program. The reasons for choosing the Kiandra area for this are outlined in section 2.2.2. This community engagement program could involve detailed horse population monitoring including local-scale population estimates, collection of population demographic data, systematic evaluation of the heritage value of the horses in this region, individual identification of horses, assessment of horse approachability (to inform future management options), monitoring of horse welfare, and potential genetic monitoring. Involvement in environmental impact and aboriginal heritage monitoring would also be a key feature. Once initial data is collected, optimal management decisions can then be made for this region in collaboration with the community groups. The SAP also suggests that the Kiandra herd might also be an ideal population for instigating a reproductive control trial early on in the course of implementing the new management plan (see Reproductive Control Recommendations in Section 2.2.6). The results and success of this pilot community engagement program can be used to inform further community engagement programs within other management zones as management progresses.

Appendix 1. Review of Horse Population and Impacts

1.1 Horse Population and Demography

It is clear that horse numbers within KNP have increased over the last 40 years. In the late 1980s, there were several hundred wild horses in KNP (Dyring 1990). Based on an aerial survey in 2001, there were at least 5,200 wild horses in KNP (NPWS 2008). After the 2003 bushfires the wild horse population estimate dropped to 2,300 (NPWS 2008). By 2009, there were an estimated 7,700 wild horses in the same area surveyed by helicopter in 2001 and 2003 (Dawson 2009). In response to criticism of the aerial survey methods by some community sectors, as well as to improve the precision, accuracy, and Work Health and Safety of the survey methodology, a new survey design was developed (Cairns 2015). This survey in 2014 produced an estimate of 9,200 horses (Cairns & Robertson 2015) within the area surveyed. The 2014 survey methodology was repeated in 2019, providing an estimate of nearly 20,000 horses in the surveyed part of KNP (Cairns 2019). While the methods used in all aerial surveys since 2001 are scientifically robust (refer to Supplementary Material for further information), estimating the growth rate of the horse population is confounded by the changing methodology from 2009 to 2014 (see ITRG 2016 for further discussion). Also the number of horses within the survey area will change between surveys due to the combined influence of reproduction, immigration, deaths, capture and removal, and emigration. Nevertheless, the changes in population estimates derive from aerial surveys between 2001 and 2019 show clearly the numbers and density of wild horses have been growing substantially within the surveyed areas in KNP.

Counts from helicopter in the open grassland areas of north KNP between 1998 and 2013 by NPWS showed horses were increasing at 23% per year (75 to 1674 horses). The number of horses in north KNP increased from 3,255 in 2014 to 15,687 in 2019, a rate of increase of 37 % per annum (see below for explanation). The annual rate of increase in horse population size depends on how close the population is to the carrying capacity (see Supplementary Material for further explanation), ranging from about 20-23% per year when population size is low, down theoretically to 0% when the population is at carrying capacity (Garrott et al. 1991). The high rate of increase suggests the population is not yet near carrying capacity and may continue to increase at a rate of 20-23% until density-dependent factors (e.g. resource availability) reduce this rate of increase. The rate of increase in north KNP between 2014 and 2019 is above the biologically possible rate of reproduction (Garrott et al. 1991). The likely explanation for this is that there is considerable movement of horses between surveyed and unsurveyed areas that is not accounted for in the survey methodology (Cairns 2019). When horses move between survey areas, this may affect the apparent rates of population growth in a particular surveyed area. The helicopter surveys of north KNP and Big Boggy conducted by NPWS in 2015 provide useful information to this regard; it was observed that an increase in density occurred as conditions became drier, while reductions in density occurred when seasons were wetter (OEH 2016). Thus, horses may be moving into the survey area and onto the moister habitats during dry times and spreading out during wetter conditions. These conclusions are based on a cursory evaluation of the relationship between cumulative rainfall residual and horse density, and thus require further empirical investigation.

1.2 Environmental Impact

The environmental impacts of wild horses, both worldwide and in Australia, were comprehensively reviewed by the ITRG in 2016. Since then there has been a surge in research activity documenting various aspects of the impact of wild horses in the Australian Alps (Worboys et al., 2018). This recent work reinforces the ITRG conclusion that wild horses cause considerable negative impacts on the environmental values of KNP and therefore need to be managed to reduce those impacts. The SAP agrees with the ITRG that most research, including recent studies, are correlative and inferences can be improved by controlled, manipulative, experimental measurement of impacts (Hone 2007).

This can be achieved as part of the management programme to better measure the progress of control operations with respect to minimising negative impacts. The SAP concludes, as did the ITRG, that there is a need to emphasise the importance of measuring environmental impact (instead of just horse numbers) over time, given that reducing negative impact is the ultimate aim of the management plan.

The negative environmental impacts of wild horses have been of concern since the 1950s (Costin 1954) but their impacts were not examined scientifically until the late 1980s (Dyring 1990). Horses can have negative environmental impacts, especially along trails and at stream crossings, through soil compaction and erosion (Dyring 1990; Robertson et al. 2019; Kauffmann & Krueger 1984; Hope et al. 2012; Whinam & Hope 2005). 20–50 passes by unshod horses are sufficient for dry soil compaction to occur (Dyring 1990). This means that a group of four horses would only need to travel along the same route twice a day for five days to cause significant compaction. Dyring (1990) found that soil erosion is greater on compacted tracks than non-compacted soils. In wet, peaty areas, erosion occurs through runoff and soil displacement to the side of trails as hooves sink deeply into wet soil (Marshall & Holmes 1979, cited in Dyring 1991; Lance et al. 1989). The negative impacts along trails also include changes in plant species diversity and cover. While these impacts are of concern, trails often cover less than 1% of a specific region. More work is required to measure compaction and indirect impact on flora and fauna away from trails in Australia, as has been measured in North America (Beever et al. 2003).

KNP contains the most extensive peatlands in the Australian Alps. These ecosystems are unique in Australia and are more sensitive to the impacts of large hard hooved herbivores than other ecosystems (see Worboys et al. 2018). Studies specifically in the Kosciuszko ecosystem show a variety of negative impacts in wetlands. Among the chief threatening processes impacting peat communities in the Australian Alps is physical damage by trampling (e.g. from large hoofed animals), which leads to loss of vegetation cover and altered hydrology and channelling of water (McDougall & Walsh 2002; Hope et al. 2012). Near wetlands and bogs this is linked to declines in sphagnum and sedges, increased erosion, and increased probability of wetland draining, which in turn will negatively affect soft plants (e.g. sphagnum moss) and fauna with specific requirements for well-aerated soils (Dyring 1990; Hope et al. 2012; Rogers 1991).

Negative impacts of horses on bogs and waterways are probably the greatest concern in KNP, particularly because they are important habitats for a range of Commonwealth and State threatened species (summarised in Robertson et al. 2019). Broad-toothed rats (*Mastacomys fuscus*), for example, depend on these habitats and evidence suggests these habitats are being degraded due to the negative impacts associated with a high density of horses (Cherubin et al. 2019; Schulz et al. 2019). While these data are correlative and the inference is weak, differences in rat abundance were attributed to grazing of the tussocks and trampling of the inter-tussock spaces (Schulz 2019). Damage to Sphagnum moss bogs also threatens the Northern Corroboree Frog (*Pseudophryne pengilleyi*) as these habitats are critical to breeding for these frogs (Evans 2018; Scheele and Foster 2018). Habitat loss arising from horses could also threaten the Mountain Pygmy Possum (*Burramys parvus*) by exposing them to fox predation (OEH 2013); however further investigation is required to determine the nature of negative impacts on these species.

While it is clear that horses at a high density have a significant negative environmental impact, the precise relationship between horse density and negative impacts specific to different areas in KNP is not yet known. There may even be positive environmental impacts of horses, at least when their densities are low. Positive impacts observed under light grazing regimes in drier areas could include recycling of nutrients and maintenance of patchy habitat and improve floristic diversity (Menard et al. 2002). For example, higher plant species diversity was maintained by wild horse grazing in the Australian Alps (Wild and Poll 2012; Williams et al. 2014). Horse and cattle grazing is beneficial for an endangered daisy in Tasmania (Gilfedder and Kirkpatrick 1994). The potential benefits of horses, such as reducing fire severity, are not supported by studies of cattle grazing in the Alps (Williams et al. 2006; Williamson et al. 2014) but more thorough studies specifically assessing fuel reduction by horses in grassland are required. The 2016 ITRG acknowledged that there are potentially both positive and negative impacts from horses but concluded that positive impacts are not supported so far by science in the Australian Alps. Monitoring of wild horse control, if designed in a controlled experiment, will confirm or refute this.

1.3 Aboriginal Heritage

The Aboriginal heritage of KNP is referred to in both the 2006 and 2016 Management Plans and widely acknowledged to be diverse and abundant. Traditional connections to the area are strong among the Traditional Owner descendants, as attested in several consultation and planning documents (Sullivan and Lennon 2003, Melville et al. 2015, but also see below extracts of Local Aboriginal Land Council correspondence). Flood pioneered archaeological research in the high country (Flood 1973, 1980), suggesting seasonal occupation built around the abundance of Bogong Moths. Aboriginal occupation at Birrigai Rockshelter in the northern Namadgi foothills has been dated to ~25,000 years before present (Flood et al 1987) and site Y258 in the Yarrangobilly caves area has evidence of visitation between 9,700 and 9,120 years ago (Aplin et al. 2010). Further north on the margins of the high-country, occupation in the Wee Jasper area has been dated to ~14,000 years ago (Theden-Ringl 2016, 2018). Recent work in the Namadgi high country (e.g. Gudgenby, Bobeyan) demonstrates "people were actively utilising the Namadgi high country from almost 8,000 years ago" (Theden Ringl 2016). Since Flood's initial work, further studies have contributed to a refinement of our knowledge of Aboriginal occupation in KNP, although very few have had fully alpine areas as a basis for study. Commercial heritage studies for environmental assessments have been undertaken in selected high-pressure areas, and these often find evidence of Aboriginal occupation. As a consequence, there are numerous sites recorded around recreational facilities and associated tracks and infrastructure. These are mostly scatters of stone artefacts of varying density (e.g. Geering 1982, Paton and Macfarlane 1988, Feary and Niemoller 2015). The most recent work occurring in KNP has been heritage assessment related to the Snowy-Hydro II project, where artefact concentrations and isolated artefacts were found at 44 locations, and test excavation yielded 2,306 stone artefacts from 180 50cm x 50cm widely spaced excavation squares (Dibden 2018).

Certain areas in KNP contain relatively dense archaeological material, indicating intensive occupation: c.f. Paton and Macfarlane (1988): 246 artefacts at 39 artefacts/m^3 and potential 2 million at the one site; Kamminga et al. (1989): 661 artefacts from test excavation at Lake Crackenback resort with deposit dated to ~4000 before present; Dibden (2018): 2306 artefacts at an average of 51 artefacts/m^2, up to 524 artefacts/m^2. Kamminga (1992) postulated that the Thredbo valley was a major thoroughfare for Aboriginal people moving into the higher mountain peaks from ceremonial grounds at Kalkite and the Wollondibby valley and the base of Mount Crackenback; those sites can be expected to occur throughout the valley (Kamminga 1992). He interpreted the archaeology of the Thredbo valley as a continuous archaeological site, comprising many activity areas and postulated that flaking of quartz pebbles at locations along the valley floor and lower slopes over millennia have produced a high background count of flaking debitage. Dibden concluded a similar pattern at Lobs Hole (Dibden 2018), noting the presence of numerous identifiable individual 'flaking floors'[1]. The importance of the presence of these features for the purposes of this report is to demonstrate the potential for relatively intact archaeological signatures to be extant in KNP. These signatures can include quite dense clusters of archaeological material and a relatively small disturbance footprint (e.g. horses) has the potential to disturb a large number of Aboriginal objects (see also Plates 1-3 below).

At the time of preparing this report, there are a total of 1003 Aboriginal sites recorded in KNP (see Table 3)[2]. Some of the recorded site locations have more than one feature recorded - for example, to observe an artefact scatter at the same location as a scarred tree is relatively common. The vast majority (90.6%) of these registered places are related to the occurrence of stone artefacts, or their potential to occur. These sites occur throughout the park and their recorded locations will be in large measure due to cultural heritage assessments of proposed development projects or park

[1] A flaking floor is a cluster of stone artefacts produced in one session of flaking stone - it is usually dense and will cover anything up to ~3m^2, but can be larger (see plate 3, this appendix).
[2] ESRI .shp file provided by Mr D.Gordon to Douglas Williams 15/06/2020.

works. They are generally located close to watercourses/sources, but also on more level ground in more elevated locations (ridge crests and saddles, high plains). As might be expected, modified trees have a similar distribution to open artefact scatters, being remnants of everyday living activities.

'Ceremonial Ring' sites occur mainly in the northern end of the park, where higher horse populations occur. This type of site, if remaining extant, would be particularly vulnerable to trampling and scuffage. Stone arrangements are also vulnerable to disturbance through the movement of stones in the arrangement by trampling or kicking. While these sites are found at various locations in the park, they can also cluster at localised landscapes - for example, three stone arrangements recorded in 350m ~11km east of Lake Tantangara.

Table 3. Aboriginal Sites Registered on the AHIMS database in KNP at 15/06/2020.

Site Type	**Description**	**%. records**
Artefact Scatter or Isolated artefact	Surface stone artefacts in clusters or in isolation.	81.20
Potential Archaeological Deposit	An area where stone artefacts may occur below the ground surface, sometimes recorded in associating with a scatter, but not exclusively so.	9.40
Modified tree	Tree from which bark was removed for a utilitarian purpose (container, shield, shelter, canoe) - commonly called a scarred tree, or where designs were cut into the heartwood to designate an important place - commonly called a carved tree.	6.20
Burial	An interment of human remains.	0.60
Ceremonial Ring (stone or earth)	Sometimes called a 'Bora Ring', a raised earth or stone ring used in ceremonies.	0.50
Grinding Grooves	Ground patches or grooves, mainly where stone hatchets were sharpened, sometimes spears.	0.30
Habitation Structure	The remains of an aboriginal dwelling such as a gunyah, but could also be on the record as a historical structure (e.g. a shepherd's hut), or a rock shelter,	0.50
Shell	Culturally transported o accumulated shell	0.08
Stone Arrangement	Stones arranged into a pattern or design.	0.73
Stone Quarry	A source of stone exploited by Aboriginal people, normally for material to make stone artefacts.	0.33
Resource and Gathering	Location of a natural resource other than stone (e.g. location of a bush food or medicine plant	0.08
Art (Pigment or engraved)	As described.	0.08
TOTAL		**100.00**

Plate 1. Artefacts from one 50cm x 50cm test excavation square at Lobs Hole (Dibden 2018:147)

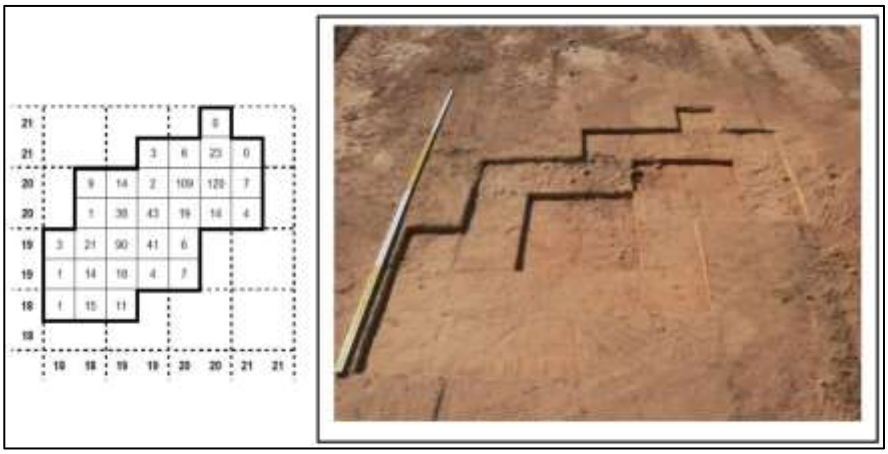

Plate 2. Example 1 of extent of stone artefact flaking floor (Williams 2008:102). Each small square is 50cm x 50cm. Numbers in squares are numbers of artefacts

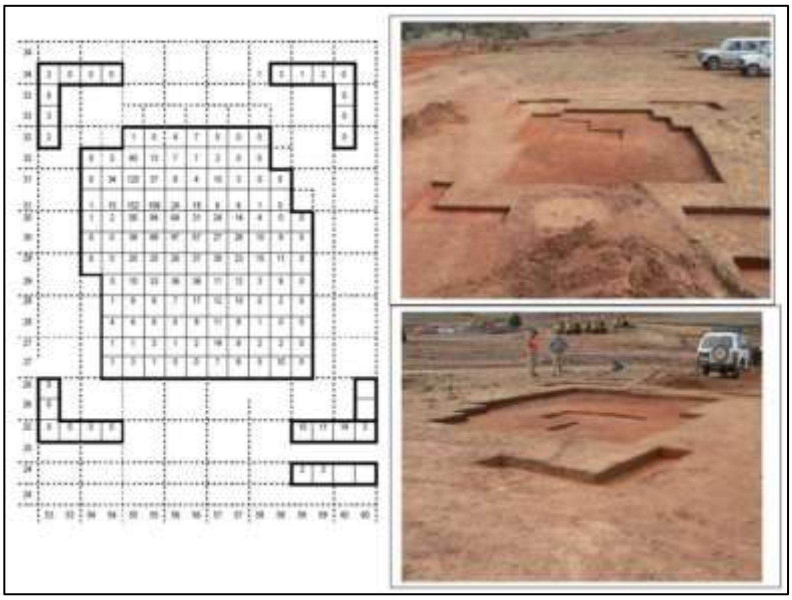

Plate 3. Example 2 of extensive stone artefact flaking floor (Williams 2008:105). Each small square is 50cm x 50cm. Numbers in squares are numbers of artefacts.

It should be noted that site recordings are denser where specific projects have required intensive survey and further investigation; this density of archaeological material might be found in many of the highland and alpine valleys if they were afforded investigation, which has not yet occurred. In dissected upland topography, a significant relationship has been demonstrated between the density of archaeological material and low slope and proximity to water (Cochrane et al. 2013, Dibden 2018).

Other archaeological site types found in the region are human burials. Archaeologically recorded (Feary 1996) and ethnographically noted (Helms 1895), quarries where stone materials were obtained, scarred trees, and occupation sites, such as rock shelters. Ceremonial sites, such as earth rings and stone arrangements, have also been noted. A more complete summary can be found on the Australian heritage Database (AHC 2008).

There has not been time to research the level of immersion of the local Aboriginal people in the pastoral industry of the high country, but references exist that would bear collation and examination (e.g. Wesson 1994, Young et al. 2000, Young 2005) it is certainly a subject worth study. Initial discussion with Ngarigo Traditional Owners highlights the complexity of the issue, for example, “the wild horse issue is … complex for us as our forefathers were renowned horseman on that Country yet still cared for and held and performed Cultural Obligation and Responsibilities for that Country” (White, pers. Comm. 2020).

In other areas of Australia, Aboriginal people found ready work in this industry as stockmen, drovers and shearers, and indeed excellent horsemen. Aboriginal women found employ as domestic staff. The CAP and SAP are referred to the 2015 ‘competing values study’ (Melville et al. 2015), which considered the question of horses and Indigenous Tradition at the National Level. The assessment concluded that any relationship between Aboriginal people and horses in KNP did not meet the threshold of National Significance (Melville et al. 2015), although they also note that ‘there are historical and contemporary heritage values held by members of Indigenous tribe and clan groups associated with the Alps and KNP that can be considered under other criteria, given the well-documented roles of Aboriginal people in contributing to the pastoral development of the region’. Along the same lines, it was also noted by Sullivan and Lennon (2003) that ‘values associated with the contact period and post-contact Aboriginal life and history of the KNP landscape, including items from the pastoral era, are of potential significance, [could not] be identified because the required research [had] not taken place [at the time the study was completed]’.

Overall, concerns expressed in consultative studies suggest an overriding interest in the conservation of native species, native environments, and sites of significance above post-European Aboriginal heritage values. Recent (2020) consultation of Aboriginal communities with responsibility for land including KNP demonstrates a widely held view that protection of natural and cultural heritage should be prioritised over the retention of wild horses, as attested in the following extracts of letters to the NSW Minister for the Environment:

> The Bega LALC holds the view that the feral horses in the [KNP] negatively impact and threaten Indigenous heritage and cultural values...These values developed over millennia must not be lost through the trampling of feral horses and the destruction of precious life-giving waterways must stop…Indigenous heritage and culture are of greater significance than the plague of…feral horses that are decimating significant cultural landscapes in the [KNP]. Effective feral horse population controls should be implemented immediately to reduce the numbers and the ongoing future management of the mountains must protect Indigenous heritage and culture, so that it can be passed on to all Australians.
>
> Glenn Willcox, CEO, Bega LALC

> The KNP is the birthplace of streams and waterways that give life to the country and form part of the shared heritage for [all] Australians …The brumbies are relics of colonisation…The reality is that a romanticisation of these animals prevails over living

> Aboriginal culture and heritage and that parts of this landscape are so fragile and of such cultural significance to Indigenous people that they are in danger of being lost forever... We urge the authorities to hear our voice as we speak as one and undertake an urgent and humane culling program to preserve country and areas of cultural significance. Future management of these areas must protect Indigenous places so we are able to pass on our stories to all Australians.
>
> Craig Mills, A/CEO, Twofold Bay Aboriginal Corporation

> We are concerned that feral horses are impacting on the source of the Murrumbidgee River. This river is extremely significant to the Wiradjuri and Wolgalu people, both spiritually and culturally. I have seen the damage that horses have caused on the spring at the very beginning of this important river. We would like to see the horses removed from this fragile and important area.
>
> Sue Bolger, CEO, Brungle Tumut Local Aboriginal Land Council

> Indigenous people have lived in the Snowy Mountains for thousands of years. The mountains are unique and very important to Aboriginal Heritage and Culture. There is no other place like them on earth. The environment contains the only representation of many endangered species and it is being disregarded. Our culture is also unique because of the environment and the dreaming that has been given to us. Both are in danger of extinction and both must be protected. Feral horses are destroying our heritage and erasing our culture….The destruction of thousands and thousands of years of Indigenous heritage and culture, must not be lost through the trampling of feral horses. The destruction of our precious life-giving waterways must stop…Our heritage and culture are of greater significance than the plague of ever-increasing feral horses that are decimating our sacred mountains... We ask that we are respected and that the culling of feral horses begins immediately, and that culling is carried out to the degree that it is effective and results in the preservation Indigenous places. The ongoing future management of the mountains must protect our heritage and culture, so that we are able to pass on our stories to all Australians.
>
> B.J. Cruse, Board Chair, Eden Local Aboriginal Land Council

These extracts demonstrate several important points with regard to Aboriginal heritage considerations. Firstly, they eloquently express a connection to the land and environment beyond the somewhat narrow view of archaeological sites. The waterways (in particular), the landscape features, flora and fauna all interconnect in a holistic consideration of 'heritage'. Secondly, there is an exceedingly generous desire to share knowledge of that heritage with all Australians. Finally, and crucially, they express a fear that the ability to preserve and share aspects of their heritage is being lost through damage being done by feral horses.

Legislative Protection

In NSW Aboriginal Objects and Places are protected by the provisions of the *National Parks and Wildlife Act* (NSW) *1974* (as amended) (The Act). The following sections are particularly relevant:

- **Section 3**. The Act binds the Crown, with respect to NSW and "in all its other capacities"
- **Section 85 (2) (a).** The Chief Executive is responsible for the '*proper care, preservation and protection* of any Aboriginal Object or Aboriginal Place on any land reserved under [the Act].

- **Section 86 (1)-(8).** A person must not harm or desecrate Aboriginal objects or Aboriginal places - knowingly or unknowingly, though being guilty of knowing harm carries higher penalties.
    - Under the Act, harm is defined as any act or omission that:
        - (a) destroys, defaces or damages the object or place, or
        - (b) in relation to an object--moves the object from the land on which it had been situated, or
        - (c) is specified by the regulations, or
        - (d) ***causes or permits*** the object or place to be harmed in a manner referred to in paragraph (a), (b) or (c)
- **Section 87 and 87A**. There are exemptions from harm to Aboriginal Objects and Places under s.86, mainly:
    - If harm is permitted by an Aboriginal Heritage Impact Permit (AHIP)
    - If harm occurs during certain emergency activities
    - If harm is inadvertent and the person has exercised *due diligence* prior to undertaking the action.
- **Section 90**. Harm may be authorised by an Aboriginal Heritage Impact Permit.

In NSW there is currently no threshold of significance applied to the Aboriginal Objects or Places protected by the Act. - it is an offence to CAUSE or PERMIT destruction, defacement or damage to even one artefact however small or 'insignificant'. Permitting horses to proliferate unchecked or unmanaged in locations where Aboriginal Objects occur might be regarded as contra to these provisions and intent.

Impact of Wild Horses on Aboriginal Heritage

Unchecked numbers of horses in KNP have the potential to cause irreversible damage to Aboriginal heritage places in KNP. Aboriginal heritage places/values fall into a number of categories for the purposes of management in KNP. While Aboriginal people might rightly regard these as a continuum of values embedded in the overall landscape ('country'), these might be summarised as:

- Archaeological
- Natural
- Historical

Archaeological Resources

Aboriginal archaeological resources occur under, on, and above the ground. As indicated, the most common type of archaeological site is a scatter or cluster of stone artefacts. These sites are where Aboriginal people discarded stone artefacts in the course of either manufacture or general living activities. Table 4 (below) is a very preliminary summary of archaeological site types that might be expected in KNP and potential impacts from horses.

An important feature to note about archaeological resources, in comparison to many other ecological and environmental variables, is that once disturbed or destroyed, there is no way of it being undisturbed or undestroyed; there are no methods of regeneration. So, while environmentally degraded areas might regenerate following de-stocking or erosion control, the archaeology within it remains compromised. Archaeological research of open sites depends largely on the study of spatial relationships of elements within sites. When that spatial relationship is disturbed, it cannot be reestablished. This potential for damage is referred to in several planning documents, but there has not yet been a dedicated study on the impact of wild horses on Aboriginal heritage places. For example, the ‘Feral Horse Impacts: The Kosciuszko Science Conference’ (Worboys et al 2018) contains no assessment of the impact of horses on Aboriginal heritage. Given the demonstrated relationship between low slope, presence of water and high density of archaeological material (Cochrane et al. 2013, Dibden 2018), and given this mix of topography will also be highly attractive to horses, horse congregation likely has a negative impact on Aboriginal archaeological sites. However, to the best of our knowledge, there is no study of the effect of wild horses on Aboriginal archaeological sites. Such a study should commence as soon as possible.

Table 4. Archaeological Site Types Expected in KNP and Potential/Predicted damage from horses

Site Type	**Frequency of occurrence**	**Predicted location**	**Vulnerable to**	**Predicted Likelihood of damage**
Isolated stone artefacts (1 in isolation, say 100m from any other)	Very high	Flats, low to moderate slopes nearly anywhere	Breakage, moderate movement.	Low where horse groups are small. Moderate where groups are large and/or traffic is high or repeated
Sparse artefact scatters/simple sites (2-20)	Very high	Flats, low to moderate slopes nearly anywhere. Increasing likelihood closer to water	Breakage, moderate movement,	Low where horse groups are small. Moderate to high where groups are large and/or traffic is high or repeated, subsurface artefacts/site structure may be compromised where soil churning occurs. Consequent erosion/deflation is also a threat to site integrity
Dense artefact clusters/complex sites	Moderate	Flats and low slopes close to water, moderate to large plateaux or other wider level to gently sloping area in dissected topography,	Breakage, artefact movement, site deposit deflation or churning (loss of integrity)	Moderate to high, environmental factors leading to site location are also very attractive for horses. | Accumulation of horses leads to accumulation of impacts - churning of artefact bearing deposit, loss of site integrity, deflation/erosion.
Human Burials	Low	Creek flats	Erosion (destabilised banks), crushing	Overall low, as site frequency is low, but potentially high if encountered.
Scarred trees	Low	Almost anywhere, more frequent near water/environments that support larger trees	Rubbing, root destabilisation	Overall low, as genuine scarred trees are rare (or rarely recorded), but where they do occur, they will be old and potentially susceptible to external pressures. Often scarred trees are dead (standing or fallen), where they have not been destroyed by fires. Horses rubbing against a dead tree or destabilising around the roots of a dead standing tree would hasten deterioration

Rock shelters and caves	Low	Karst systems (caves) or large granite boulders forming shelters between	Erosion.	Overall low, no known karst formations where horses can shelter, and granite shelters are usually too low for horses to enter. However, numbers of horses sheltering around granite boulders could destabilise soil and cause external erosion, allowing for the erosion of internal deposit. Flat areas around granite boulders were also occupied, people using boulders as a windbreak. Horse treadage could potentially disturb significant archaeological deposit in some locations
Stone quarries	Low (but unknown and unresearched)	Anywhere useful stone sources occur	Breakage, artefact movement, erosion,	Overall low, quarries are rarely recorded so unlikely to be encountered. Their locations are also geologically specific rather than determined by day to day survival and comfort requirements. On balance, it might be predicted that quarries might occur in locations generally unattractive for horses (rocky outcrops), but not exclusively so.
Rock Art	Low	Caves, overhangs and granite boulders	Rubbing art off walls	Very low potential for impact due to very low potential for occurrence.
Stone Arrangements	Low	Level to gently sloping ground in secluded harder to reach locations	Displacement of stones, loss of patterning.	Very low, based on the rarity of these sites in the knowledge database, but also a low level of investigation. A high impact could be predicted if horses congregate at the location of a stone arrangement
Axe grinding grooves	Low	Where suitable stone occurs (sedimentary, mainly sandstone, but also granite in rare instances)	Wear, breakage	Overall low. Grinding grooves would not be expected to occur with frequency and would be resilient to an extent. However, any that did occur would be of high significance.

Natural Aboriginal Heritage Resources

This category of heritage might include the full gamut of environmental variables, including bush foods and medicines, water quality, and non-economic species with cultural significance (e.g. Corrobboree frog, Pygmy possum). While ecological and environmental conservation measures will conserve these values, the Aboriginal cultural element/connection to these resources should be more explicitly referenced as part of their value. Bushfood and bush medicines should be a particular focus of research, documentation, and monitoring for impacts (both negative and positive) by horses. The importance of this range of heritage values is demonstrated by ubiquitous opinion provided by four Local Aboriginal Land Councils surrounding and including KNP (see extracts above).

Historical Heritage

This phase of Aboriginal heritage is that of the European contact and post-contact period, and may indeed include a connection to horses and the pastoral industry. It may also include components of archaeological sites where there is material evidence of the adoption of European material culture into traditional Aboriginal life (e.g. glass flaked artefacts). Connections to this phase of Aboriginal history may be intangible and would bear research in terms of the impacts the removal of wild horses would have on the strength of community memory.

Appendix 2. Review of Past Plans

2.1 2003 Plan

Horse Management Plan: For the Alpine Area of Kosciuszko National Park January 2003 – January 2005 (20 pages)

Preparation of the 2003 Horse Management Plan commenced in the year 2000. The importance of involving the community was recognised. A Wild Horse Management Steering Committee was established, and the committee was "*instrumental in developing the draft plan*".

The primary objectives were:

- *"To conserve and protect the natural values of the Kosciuszko alpine area (above the treeline – approximately 1850 metres) by removing horses and to ensure the alpine area remains free from horse impacts; and*
- *To minimise the likelihood of horses causing a traffic hazard on the Alpine Way."*

The 2003 Plan examined the range of horse management methods available, including immobilisation using tranquillisers, fertility control, fencing, shooting and capture and removal methods. The plan proposed to trial trapping, roping and mustering (using horse riders) and these methods were to be evaluated, *"for their effectiveness in humanely removing horses from the alpine area and reducing environmental impacts."*

"To measure changes over time and responses to the implementation of management strategies, four sites that exhibit existing impacts from horses were chosen for monitoring." Monitoring sites included: Little Tin Mines Creek, Cascades Hut and the Big Boggy. At each site, there was to be an assessment of vegetation, water quality, horse population and the environmental impact of the removal process. Exclusion fenced areas (10 m x 10m) were to be built at each site.

A goal of the plan was to reduce horse numbers and collect information to allow NPWS to modify and improve management techniques as appropriate, i.e. adaptive management. The population was estimated to be 1400 in south Kosciuszko. They estimated that a removal rate of 100 horses per year would reduce the population to 800 horses in 30 years. A removal rate of 150 horses would reduce the southern population to 850 horses in eight years. There was no mention of north Kosciusko although since the total population for KNP was reported to be 2300, and 1400 were in south Kosciuszko, there must have been around 1000 in north Kosciusko at that time.

Community consultation at workshops and information sessions determined that "*management of feral horses is a very polarised issue"* with views ranging from total eradication to the view that "*horses have heritage value and should be retained in national parks*".

There was discussion about ground and aerial shooting. Some members of the Wild Horse Management Steering Committee were "*adamant that they would never endorse shooting as an acceptable option.*"

There was agreement that:

- The alpine area of Kosciuszko is a unique environment which must be protected from the impacts of horses.
- Control methods must be humane.
- Management of horses shouldn't be limited to the alpine area but should be extended across the entire park.

Achievements

- The Plan was implemented.
- Used estimation of total population size and recent ecological information (Michelle Dawson's PhD).
- Planned to monitor environmental impact and the benefits of control.
- Used community members and community consultation to prepare the Plan.
- Used a simple population model to predict the change in population size depending on the removal rate.
- Removed 206 horses from 2002 to 2007 with 64 horses being removed from November 2006 to February 2007 (NPWS 2008).

Performance with regard to objectives

- Horses continued to increase in the Alpine area (NPWS 2008; NPWS 2016).
- Horses are still a traffic hazard on the Alpine Way (NPWS 2016).

2.2 2008 Plan

Kosciuszko National Park Horse Management Plan December 2008 (36 Pages)

"In 2006 a Plan of Management for Kosciuszko National Park was formally adopted and one of its objectives is to reduce the distribution and abundance of introduced animal species found in the Park. The Plan of Management called for the exclusion of horses from key areas and for a Feral Horse Management Plan to be prepared for the whole of the Park." (NPWS 2008)

The 2008 Plan was part of the response to the commitment in the 2006 Plan of Management for Kosciuszko National Park. As with the 2003 Horse Management Plan, a Horse Management Community Steering Group assisted with the preparation of the 2008 Plan.

"*The Steering Group examined the range of horse management methods available, including fertility control, fencing, shooting and capture and removal methods and some of the issues associated with each of the methods in the document. After reviewing the different methods, the Steering Group recognised that different techniques are best suited to different situations depending on issues such as mob size, geography and season. The Group agreed that as with any vertebrate pest program, a combination of different techniques will give the most effective result." (NPWS 2008)*

The objective of the 2008 Horse Management Plan for Kosciuszko National Park is to exclude horses from:

- the Main Range Management Unit;
- the Yarrangobilly Management Unit;
- the Cooleman Plain Management Unit;
- Safety risk areas such as highways;
- Areas of the park where horses have not been or have only recently been recorded (e.g. Jagungal);
- Areas of the park adjoining other Australian Alps national parks and reserves; and
- Feeder areas for all management units.

"*To measure changes over time and how our management strategies are working, we will have an environmental monitoring program in areas across the Park. This program will involve assessing vegetation and water quality at 4 sites that show signs of existing impacts from horses within the proposed horse control areas."* (NPWS 2008)

Achievements

- Plan was implemented.
- Used estimation of total population size and ecological information (Michelle Dawson's PhD).
- Identified where horses were to be removed completely.
- Planned to monitor environmental impact at four sites.
- Planned to established photo monitoring points.
- Planned to monitor impact on cultural heritage.
- Planned to train staff in the appropriate methods of trapping and removal.
- Planned to involve RSPCA.
- Used community members and community consultation to prepare the Plan.
- Removed 2977 horses from 2008 to 2016 (ITRG 2016; NPWS 2008; NPWS 2016).

Performance with regard to objectives

- Horses continued to expand their distribution and abundance (NPWS 2008; NPWS 2016).
- Horses have not been completely removed from any of the areas identified for elimination.
- Horses are still a traffic hazard on the Alpine Way and along the Snowy Mountains Highway (NPWS 2016).

2.3 2016 Plan

2016 Draft Wild Horse Management Plan (47 pages)

The SAP members conducted a detailed review of this draft plan and prepared advice on how to address issues.

The 2016 Draft Wild Horse Management Plan had three objectives:

1. *To reduce the impacts of wild horses on the natural and cultural heritage values of Kosciuszko National Park by reducing the overall population of wild horses using a range of cost-effective and humane control measures.*
2. *To reduce and mitigate the risk of adverse wild horse interactions or incidents with park visitors and the public more generally.*
3. *To involve the community in the ongoing management of wild horses in Kosciuszko National Park through active participation in research, monitoring, and control programs where possible.*

Key strategies to achieve these objectives was to reduce the wild horse population from 6000 to less than 3000 horses in five to 10 years; and to reduce the population to 600 (400–800) horses within 20 years.

Achievements

- Used estimation of total population size and available scientific information via the Independent Technical Reference Group (ITRG 2016).
- Reviewed 2008 Horse Management Plan.
- Assessed the national cultural heritage values associated with the Kosciuszko National Park wild horse population (Context 2015).
- The heritage value of horses was acknowledged.
- Accepted the ITRG advice that complete eradication is not achievable.
- Used community members and community consultation to prepare the Plan.
- Planned to involve community groups in ongoing management through active participation in research, monitoring and control programs.
- Identified zones where horses were to be removed completely.
- Defined Management Zones, Prevention, Elimination, Containment and Population Reduction, Key Environmental Asset Protection.
- Where horses were to remain, the plan was to adjust or determine densities of horses based on acceptable levels of impact.
- Planned to use Adaptive Management.
- Acknowledged there were significant knowledge gaps and with the help of the ITRG recommended research required.
- Planned to establish a scientific panel to design a wild horse survey methodology that quantifies the environmental damage caused by wild horses, in addition to estimating total wild horse numbers.

Performance with regard to objectives

- Was not implemented

Note on Community Engagement

The community must be truly included in the preparation and implementation of the Plan. Past management plans have all attempted some form of community involvement (Melville et al 2015), but true engagement appears to have not been achieved. Past efforts include consultation, education, workshops, information sessions, online surveys, and “consideration of community views”. A lack of involvement of community representatives in the preparation of the management plan is considered to have contributed in part to the failures of past Plans.

Detailed Review of 2016 Plan

The SAP reviewed the 2016 KNP Draft Wild Horse Management Plan and the accompanying Final report of the Independent Technical Reference Group in detail. There are many gaps in scientific knowledge identified by the ITRG and the SAP. SAP members considered the use of unpublished data and local expert knowledge to help fill some of these gaps. Still, the collection of the most useful new information will need to be by incorporating scientific experimentation into the management plan. Integrating science with management is termed ‘adaptive management’, which was the approach also recommended by the ITRG.

Table 5 (below) lists detailed issues, describes the problems identified by SAP members, and suggests possible solutions.

Table 5. SAP review of 2016 Plan

Issue	Problem	Solution
The Management Plan, the ITRG Report and SAP advice	The ITRG advice was not sufficiently incorporated into the 2016 Plan. The Plan should have been a ‘stand-alone’ document, with the ITRG 2016 review providing ‘supporting information’. It should not be necessary for someone to read the ITRG review, unless they desire to do so.	The SAP will ensure information from the ITRG 2016 Report along with more recent scientific and other evidence is incorporated in the 2020 Plan.
Basis for the plan	The conceptual basis for the 2016 Plan acceptable, but it is implicit rather than explicit.	The logical sequence should be explicitly stated as follows: • There are many wild horses in KNP and other nearby areas • These horses have been and are causing significant negative environmental impacts and risk • Therefore, numbers of horses should be reduced • There is spatial variation in horse density, impacts of various kinds, cultural value, and practicalities of reducing horse numbers (and hence density) • Therefore, KNP (and other nearby areas) should be divided into different areas that are subject to various horse management regimes (e.g. prevention, elimination, etc.)
Supporting evidence	Many statements lack appropriate substantiation, and the plan therefore is not scientifically adequate. No information or citation is provided to support many assertions.	Need to be transparent about where information is lacking. Information can be published or unpublished from personal observation, but the source of the information must be supplied. SAP to provide citations, identify sources of unpublished information, and make sure it is clearly stated where there is uncertainty, for 2020 Plan.
Strategy to reduce the population from 6000 to 600.	No strong justification or explanation for selection of the reduction from 6000 to 600. This antagonised horse protection groups and they were mobilised against the plan.	The ITRG 2016 report stated: *“The outcomes of management would ideally be monitored primarily through the effects on agreed impact measures or thresholds of concern, rather than just on horse numbers or densities”*. This statement from the ITRG report is consistent with recommendations from “Managing Vertebrate Pests: Feral

Issue	Problem	Solution
	Insufficient support presented that reducing the population size to 600 horses (the key tactic) will have the desired positive effects.	Horses" (Dobbie et al. 1993) and the SAP. Less focus given to a concrete ultimate goal number and more emphasis is given to reduction of negative impacts. The main goal should be to minimise the negative impact and maximise positive impact. The overriding goal needs to be one that all key stakeholder groups are happy with (a common goal).
Vagueness regarding control methods to be used	'The decision on when and where one or more of the seven methods … will be employed will be determined by NPWS based on a range of considerations, including [a list of conditions' (page 25 KNP 2016 Plan). Vagueness/lack of transparency here may be a point of concern for opponents.	The new plan needs to be much more explicit what methods will be used where and what initial targets in, say, the first 5 years would be. While it is not necessary to detail the exact operating procedures of each method, providing greater detail of how control methods will be selected may strengthen support of the plan. Incorporate welfare impact assessment into decision making. People may be less worried, having the knowledge that animal welfare outcomes are to be assessed and transparently reported before progression of the plan.
Monitoring horse welfare	Little mention of monitoring horse welfare	As density increases, and environmental impacts increase, horse welfare may reduce. Severe welfare impacts can occur in self-limiting/resource limiting populations, so there are good welfare arguments for keeping population densities lower. There are also specific habitats where there are more horse welfare issues due to lack of nutrition (e.g. the lower snowy region) (Harvey unpublished data). There will be positive welfare impacts for the remaining horses caused by reduction in horse density and negative welfare impacts if too many horses remain. Thus, monitoring of horse condition is required. Set 'welfare targets', such as what % of the local population should not be below a BCS of 3/9 for example, so if > 60% have a BCS > 3/9 it is an indicator that the population needs to be further reduced (Harvey et al. 2020).
Evidence for environmental impact	The plan makes statements such as 'the preference for grassland and heath habitat is likely to eventually alter the ecology (page 16)'. Everyone should be concerned that the removal of 1000's of horses is based on 'likely eventually alter'. 'Snow patch herb fields need protection from introduced mammals (Williams 2005)'. No data to support more specific role of horses. It is possible that adverse impacts of horses reflect their abundance, and this could guide management, but no relevant information is presented. Such information is therefore much needed. It is clear that wild horses adversely affect various natural values of KNP, but it is not clear how to integrate this information into park management. For example, the nature, extent, and spatial distribution of such	Update references with new/more relevant research which can then be used to strengthen language such as 'likely eventually alter'. For example, studies such as (Wild et al. 2012) that exclude horses but not macropods. Other recent and relevant literature to include (Cherubin et al. 2019; Robertson et al., 2019) and all studies presented in (Worboys et al. 2018) which are specific to wild horses in Australian Alps. The conclusions from the existing evidence of environmental impact will need to be presented. This evidence will need to be improved upon substantially to ensure the cost, effort, and horse welfare impact of horse removal activities will be certain to produce real benefits to the environment in KNP. While it is clear that horses have a negative impact, a criticism that is often raised is the lack of data demonstrating horse impacts independent of other species. The 2020 Plan should take the opportunity to fill this knowledge gap. The 2020 Plan should involve Adaptive Management where performance of work to reduce horse

Issue	Problem	Solution
	impacts are not described, making it impossible to know where to aim to reduce any impacts. ITRG 2016 Report: "controlled experimental studies are rare, and most rely on a correlational approach and are often complicated by the presence of other herbivores (Beever & Brussard 2000). This issue is not acknowledged in 2016 Plan.	density is measured by controlled experiments measuring changes in environmental impact. Adaptive Management "learning by doing" is required. That is, management monitored scientifically.
Impact terminology	There is inconsistent use of impact, adverse impact, and damage. Need to acknowledge that there are positive and negative environmental impacts and not assume all impact is negative. In some places, impact is written where negative (adverse) impact or damage should be written.	Refer to impact as positive or negative impact consistently throughout. Acknowledge the possibility that there could be positive impact.
Positive environmental impact	The ITRG and horse opponents believe there is no scientific support for the presence of positive environmental impacts caused by horses. There is, however, some support for the hypothesis that some native plants or animals may benefit from the presence of horses, particularly if horse density is moderate.	There are a reasonable number of studies that have found positive impacts of wild horses overseas (Soriano 1991; Zalba and Cozzani 2004; Loydi and Zalba 2008) and in Australia (Wild and Poll 2012, Williams et al. 2014) and there are theoretical reasons to expect positive impact at moderate grazing density (Connell 1978). Experimentation measuring impact at a variety of densities is required to prove or discount the presence of any positive impact.
Separating impact of horses from other animals and from natural factors	Little information provided regarding the impacts and control measures of other grazing species. While it is clear that horses can have negative impact, a criticism that is often raised by opponents of horse control is the lack of data demonstrating horse impacts independent of other species.	Acknowledge that other species have negative impacts and specify the control measures undertaken to mitigate their negative impacts. Monitoring must include measurement of other things that may cause environmental impact. Deer/pig dung or hoof print counts, rabbit/hare pellet counts, camera trap indices for all species. Control of these species needs to accompany the horse removal activities. If other animals such as deer, pigs, rabbits, foxes, cats or dogs are present, and not managed as well the removal of horses may have no benefits to native plants, animals, or soil.
Aboriginal cultural heritage	The 2016 Plan does not consider or address the issues of managing Aboriginal Cultural heritage to a sufficient extent. The description of the three management regions touches only once on cultural heritage (the central region), and the management strategies/priorities do not include any strategic assessment of the likelihood of horses causing damage to archaeological sites. It is an omission that none of the actions specified in the five proposed management zones include actions specific to understanding the effect of horses on archaeological sites. This might have been particularly important in management of the 'containment zones'	A process for considering the effect of management actions on Aboriginal cultural heritage should be included in the revised plan. One particular aspect of managing horses that has not received consideration is the potential impact of management actions/techniques on Aboriginal cultural heritage places. Consider for example trapping or corralling. The installation of fences capable of holding horses requires posts inserted into the ground surface, this and related construction has potential to disturb Aboriginal objects. The accumulation of horses in a fenced area has potential to concentrate considerable numbers of horses in one location, and as a result, exacerbate trampling damage to Aboriginal Objects.

Issue	Problem	Solution
How much reduction in horse density is required	It is clear that where there are too many horses there is considerable negative impact. Most agree that a reduction in numbers is necessary, but the level of reduction required is unknown. No research conducted so far helps to determine this level.	The historical densities and impacts from photos or expert knowledge might, to some extent, help determine a starting goal for density reduction. This goal will be different for different management zones. Refining the appropriate density that is most suitable for the various management zones must be determined by monitoring horse impacts. Sites selected for monitoring must be sufficient in number to represent each management zone. Monitoring methods must be detailed enough to allow identification of acceptable target horse densities.
Movement between neighboring properties and between areas within the park	It is believed that the relatively high numbers and densities of horses in adjoining areas have been a factor in the movement of horses into the alpine area and expansion in some areas. Any management within the park might be made less effective by lack of management (or growth-positive management) in the adjoining properties. There is no clear plan as to how the park will deal with neighbouring landowners.	Assessment of neighbouring areas to determine population sizes and perhaps radiotelemetry is required to determine how much movement there is into and out of the park. At the very least home range sizes need to be determined by radio-tracking. Include some discussion regarding how much connectivity occurs between the four park populations as well as from outside the park (if known). Provide a plan for mitigating incursion to areas of where removals are being undertaken.
Horse Impact on Fire	Common claim from horse protectionists is that horses reduce fire intensity or spread by reducing fuel (ITRG Report). Horses are also accused of increasing the vulnerability of peat to fire by drying out the swampy areas. There is a lack of information about the impact of horses on bush fire fuel and the impact of bush fires on horses. There is also little information on the impact on horse welfare caused by bush fires. There is little consideration to the response after a bush fire, e.g. take advantage and further reduce density? Will there be greater impact of horses on native wildlife because of the fire and limited resources?	Identify where fire has damaged peat and show that the drying caused by horses was a contributing factor. Keep horses out of areas threatened by this process. It is assumed that horses have the same impact as cattle in that by eating predominantly grass they increase the number of flammable shrubs. Where has this happened and has it been documented? Presumably, there should be a correlation between horse density and increases in shrub density and then fire frequency or severity. Include other studies such as the report on fires in the Alps (Zylstra 2006) that suggests that the increased burning by European settlers changed the vegetation to make it more fire-prone not the influence of introduced ungulates. Furthermore, Walter (2003) found that horses were not congregating in unburnt areas after the 2003 fires. A better understanding of the relationship between bush fires, horses, and horse impacts will help inform the proper response to bush fires.

Issue	Problem	Solution
Community Engagement	While the 2016 Plan made an effort to engage community groups, many still feel that their views have been ignored and this likely contributed to the upheaval of the Plan. In the ITRG 2016 Report, Appendix B: Stakeholder submissions to the ITRG on horses in KNP, there were four stakeholder types identified (Groups A to D). Groups A and D are the extremes. Group A thinks there is no management required, and Group D believe eradication is required. The conflict between these groups polarises the issue, and the moderate stakeholders move one way or the other.	The SAP considers the conflict between these groups prevents sensible management. Group D activities provoke Group A and vice versa. The only way to achieve sensible management (reduction in horse numbers and reduction in negative impact whilst also protecting the horse heritage values) is for these groups to have a common goal and work together. Group A needs to be convinced that management is required. Group D needs to be satisfied with less than eradication. The whole plan needs to be owned and accepted by the major interest groups. These groups need to be involved in the preparation of the plan from the start. The objective proposed in 2016 to involve the community in ongoing management should be expanded to include involvement in the preparation of the plan. This is happening using the CAP working with the SAP. The CAP appears to represent key community interest groups.
Involving the community in ongoing management	There has been a lack of acceptance by the community of horse population estimates. This is in part due to their opinion that there is a lack of transparency in how these estimates are obtained.	Mobilising groups of volunteers to assist in quantifying important Kosciuszko-specific demographic parameters (i.e. death rates, lifespans, foal rates, foal mortality, sex ratios) as the population is reduced may be a good area for community engagement. Using volunteers to identify animals and monitor foaling rates has been successfully used for some populations of wild horses in the USA (e.g. Baker et al., 2018; BLM staff, pers. comm). However, this may not always be feasible due to practical constraints relating to park conditions. Community involvement in heritage herd identification. There are herds for which the public know individual horses and are very attached to them. This would include some areas of Long Plain, Tantangara, Kiandra, some areas down Barry Way such as around the Pinch etc. These may be herds where reproductive control is considered earlier on, as these horses are also more likely to be more habituated to people and thus easier to identify and capture or dart. It is these populations that are most known to the public and horse lobby groups. How these populations are managed will impact the most on how these groups/public feel about the plan.
Legislation	Legislation is interpreted differently by different people. Many believe that horses should not be in national parks. They appear unaware that this is not written into legislation. This needs to be made clear. Many believe the Wild Horse Heritage Act prioritises horses over natural values and that lethal control has been banned. This is also not the case and needs to be made clear.	The National Parks and Wildlife Act 1974 No 80 requires conservation of habitat, ecosystems and ecosystem processes and biological diversity at the community, species and genetic levels and identification and mitigation of threatening processes. The new Wild Horse Heritage Act wording should also be included so that it clarifies that it does not prioritize horses over natural values and that lethal control is **not** legislated against. Where there is a conflict between the new Wild Horse Heritage Act and the National Parks and Wildlife Act 1974 the Wild Horse Heritage Act will prevail but there is unlikely to be significant conflict particularly regarding prioritizing horses over natural values. What happens in areas where horses have been retained and managed for heritage reasons and there is still significant negative impact on natural values?

Issue	Problem	Solution
Horse biology	Information regarding horse biology should be relevant, but such relevance is unclear in the 2016 Plan. Highly relevant would be the rate of population increase and how this varies with circumstances, but no such information is provided. Ecological information is essential for determining how many horses need to be removed to reduce or maintain populations at desirable densities. There are better references available than those used and better information. There is considerable published and unpublished information directly relevant to the Australian Alps. This needs to be incorporated in the plan.	Greater detail is required of how horse biology will be considered in the plan. For example: which horses will be targeted for removals? Mares rather than stallion should be targeted to reduce population growth rates. Will the entire band be removed together? Will mares with foals be released? Horses are trapped and travel much more calmly when with their social unit. Removal of the whole band versus select horses in a band will have both implications for the effectiveness of the removal and the welfare impacts of removal. Removal of bachelor groups may reduce adverse interactions with park visitors but will have little impact on reducing population growth rates. An understanding of reproductive rates, survival rates, social behaviour, and movement patterns is necessary for complete removal of horses from some areas and for maintaining populations at certain densities. Demographic data such as survival rates (age-specific if possible), reproductive rates, age structure, and sex ratios should be obtained where possible for each management zone within KNP so that possible rates of increase at different densities can be predicted and how they might change as horses are removed. Useful information can be found in Australian published studies (Dawson 2005, Dawson and Hone 2012, Zabek 2015, Zabek, Berman et al. 2016). Some statements to be revised, properly cited, or specified for KNP. For example, page 11 states ‘Mares are able to foal at one to two years of age and usually raise one foal every two years (Dobbie & Berman 1992; Wagoner 1977)’ and page 11 states “it is likely that horses in Kosciuszko National Park would have longer lifespans than wild horses in other parts of Australia due to the more favourable conditions.” These statements may not be true for the KNP population and should be assessed. For example, while mares can foal at 1 to 2, it is uncommon for mares under 3 years of age to foal, and furthermore, mares do not reach full reproductive potential until 5 years of age (Berger, 1986; Feist & McCullough, 1975; Goodloe et al., 2000; Linklater et al., 2004; Scorolli & Cazorla, 2010). This has in fact been quantified for the Alps: ‘No 2-year-old females were observed with young (Dawson & Hone, 2012)’. Furthermore, Dawson & Hone’s (2012) findings demonstrate annual adult survival that is lower than many other populations (however this is compared globally; not specified in comparison to the rest of Australia). Thus, the assertion that lifespans are longer should be supported or rephrased to be less assertive.
Horse distribution maps	Various figures in the Draft WHMP indicate where horses occur, but the basis for such illustrations is unclear. The figures presumably indicate horse presence/ absence rather than horse abundance, but should be specified. More informative if variation in horse abundance indicated.	If the raw data from the broad-scale aerial surveys includes coordinates for each group of horses counted, then kernel analysis could produce “hot spot” relative density maps (see Zabek 2015).

Issue	Problem	Solution
Management zones	It is not sufficiently clear how and why the different management areas were chosen. It is reasonably obvious to select areas that apparently lack horses at present as 'prevention' areas, but otherwise designation of management areas is unclear. Identifying areas of horse retention, prevention, and elimination is a strength of the 2016 plan, but the plan does not provide transparency as to how management zones were selected. What are the specific control methods to be used for each management region?	Provide more detail of how management zones were selected to improve transparency. This is clearly a point of concern among community members. Include the current population estimates after the new survey in each of these regions to have a clearer picture of how many horses in each region need to be removed. Specify which control methods will be used in each management region or outline how methods will be chosen. This will reassure opponents that lethal control will not be the only method used in elimination zones
Reduction in horse numbers in management zones	Numbers of horses present in each management zone and the numbers that need to be removed from each zone are not known.	Analysis of the aerial survey data or more detailed existing surveys (Camera Traps, horse counts, dung counts) may provide the size of populations within management areas. These initial estimates should be improved by detailed surveys (Camera traps, DNA from dung, dung density). These should be done before and after removal operations to provide measurement to ensure that it is known whether a sufficient number is being removed or not.
Target densities	Proposed target wild horse population densities have no justification. It is not clear, in particular, why horse density should be lower than 0.4 per sq. km in one area and lower than 0.2 per sq. km in another. It is also unclear whether such target horse densities might be achievable.	If these target densities are to remain in the report, then the basis for their selection needs to be included.
Sustainable horse population	The number of horses retained for heritage values must be large enough so that there are no inbreeding problems or risk of extinction due to bush fire or other catastrophes.	Since the park's aim includes maintaining a 'sustainable' population of horses in the park, quantification of the genetic diversity may be required at some point to ensure genetic diversity of residual horse populations is maintained.
Trapping	Can this method remove enough horses? How much can trapping be increased from previous plans?	The highest number per year was around 600 horses. Is it possible to increase the density of trap sites? Passive trapping using electric fencing has proven successful where lure trapping is not an option. This method may be useful for removal of the last relatively untrappable horses in areas where exclusion is required.
Ground and Aerial Mustering	Is this a real option? If large numbers of horses are captured how will they be processed? What are the risks for horse welfare and people's safety?	Do a trial. Horses can be transported out for rehoming where opportunities exist. Where lethal control is required explore the possibility of field processing for meat so carcasses are removed and utilised.
Ground shooting	Further information on how ground shooting will be carried out required.	If trapping/mustering and rehoming fails to remove a sufficient number of horses, ground shooting may be required in some areas. Where this is used it is important to shoot the entire social group in a quick time period. Critical that horses are not non-fatally wounded. Ensure well-trained and experienced shooters are employed. They must know how to determine which horse in a group is shot first so that the others stay around. It is important not to take a shot if there is any uncertainty that the shot will be accurate. A drone may be useful to help the shooter approach the group during daylight, but thermal imaging can be very effective at enabling close approaches at night-time without horses being spooked.

Issue	Problem	Solution
Aerial shooting	Aerial shooting not included as social licence is not available in NSW and the use of this method may jeopardise its use in other parts of Australia. Horse protection groups are unlikely to support the use of aerial shooting. What should be done with carcasses?	In some areas with limited accessibility, then as a last resort aerial shooting may be required in some circumstances. Horse protection groups should be involved in designing a trial. Animal welfare outcomes would need strict monitoring.

Review of ITRG Humaneness Assessment

SAP members reviewed the humaneness assessments from the ITRG 2016 report. The ITRG developed a separate impressive panel of scientists with animal welfare expertise to develop a humaneness assessment of a range of horse management methods. The report used a well-established published model previously developed for comparing the relative humanness of pest control methods. Assessments were based on the Five Domains Model for assessing welfare (nutrition, environment, health/injury, behaviour, mental status; see Appendix 3 for more detail). The assessments were made based on available evidence in the literature, and where this was not available, expert opinion/experience (panel of 9 experts specifically created for the humaneness assessments) was used (acknowledging that there was some subjectivity). Assessments were not based on actual measures of welfare impacts during any management activities. There were two parts of the assessment:

- Part A assessed the impact of all methods and duration of impact;
    - The welfare impact in each domain was assigned a grade on a scale of ‘no impact’ to ‘extreme impact’, and then an overall welfare impact grade was derived from these 5 grades.
- Part B assessed only lethal methods assessing the impact of the actual killing method (Part A assesses impacts up until the point of killing, e.g. trapping, mustering)
    - The level and duration of suffering during the actual killing process were assigned a grade.

A scoring matrix (based on previously published humanness assessment model) was then used to assign an overall welfare impact grade to each method specified within the 2008 management plan. Most methods have multiple stages; for example, passive trapping, followed by loading and transport, followed by a holding period, followed by loading and transport to rehoming facility or knackery. The welfare impact of each stage in multi-stage control methods was assessed separately. All options with multiple stages are more likely to overall have more significant negative welfare impacts. For example, rehoming may end in positive welfare impacts, but can also result in negative welfare impacts with more stages, and still end in a knackery death. Assessments were based on Standard Operating Procedures and Codes of Practice, so an assumption was made in the assessments that each method would be carried out according to ‘best practice’. It was acknowledged that auditing of processes would need to be performed to ensure best practice was adhered to. Final humaneness scores incorporated the severity and duration of welfare impacts, so a severe impact of short duration could end up with the same score as a mild impact of long duration.

Management methods assessed:

- Passive trapping
- Helicopter mustering within a 2km area (not pushed out of home range)

    - Roping/brumby running
    - On-site euthanasia in trap yards
        - Only Part B was assessed since there was no SOP for euthanasia within trap yards. Considerations need to include separation of individuals, partitioning, visual barriers, sound suppressors, handling, chemical restraint, firearm vs captive bolt euthanasia
        - Detailed SOP incorporating these needed before welfare impact assessment could be performed
    - Removal for domestication and rehoming - assessed loading and transport for short (< 4 hrs) and long (> 15hrs) journeys.
        - Domestication process itself couldn't be assessed as details of practices and outcomes would be needed from rehoming groups
    - Removal for slaughter – assessed loading and transport for short (< 4 hrs) and long (> 15 hrs) journeys
    - Lairage and slaughter – assessment performed for both slaughter at abattoir and slaughter at knackery
    - Ground shooting – 2 assessments performed based on head and chest shots, and also assessment of impacts on surviving herd members.
        - No published studies to base assessments on so this was based on expert opinion, assumed higher wounding rates than aerial shooting because assumed harder to approach horses from the ground
    - Aerial shooting – 2 assessments based on best case scenario (< 1 min chase and rendered unconscious after the first shot) and scenario 2 (> 5 min chase and 2 shots needed to render unconscious)
    - Immunocontraception - only effects of actual treatment assessed
        - Welfare impacts of administration (e.g. trapping or darting) not included
    - Fencing

The ITRG also highlighted that their assessments could be used to inform recommendations for how improvements may be able to be made within the various methods in order to reduce welfare impacts. For example, if water and shade/shelter were able to be provided in trap yards then this could reduce the welfare impacts of passive trapping. Details of all processes in the humaneness assessment and overall scores can be found in the ITRG report on assessing the humaneness of horse management methods.

In summary: Methods with the lowest welfare impacts were passive trapping, mustering of small groups (large groups were different and associated with more severe welfare impacts), short journeys, aerial shooting scenario 1, followed by ground shooting with a headshot of small groups or individuals

Advantages and limitations of ITRG humanness assessments

Advantages:

- Assessments were based on available evidence in the literature at the time and expert opinion/experience within the panel

- The assessments enable transparent assessment of the welfare impacts associated with a range of management methods enabling a comparison of the various methods

Limitations:

- Assessments are theoretical
- Assessments depend on having a precise SOP for the proposed method
- Assumption that best practice/SOP is adhered to
- Assessments do not utilise actual animal-based measures of welfare
- The model has the limitation in producing overall scores, but some aspects are not directly comparable, e.g. a severe welfare impact of short duration is not the same as a low welfare impact of long duration.
- Assessments are overly simplified, since, in reality, the welfare impacts associated with each method will vary depending on many variables such as terrain, habitat type, horse density, mob sizes, weather, time of year, personnel expertise etc. (See supplementary info on humane management).
- Not all possible management techniques were assessed. For example, the welfare impacts of euthanasia in trap yards, and impacts of no management were not assessed.

Appendix 3. Ethical Wild Horse Management & Improving Welfare Outcomes

Ethical decision making

As outlined in the main body of the report as well as Supplementary Material 4, the SAP advise following the 7 Principles of Ethical Wildlife Control, from the International Consensus Guidelines (Dubois et al 2017). Furthermore, following **'Fraser's practical ethic'** (Fraser 2012; Fawcett et al. 2018) can further help to guide ethical decision making in wild horse management. This also incorporates a '**One Welfare'** framework (Pinillos 2016; Fawcett et al. 2018), to seek to maximise the wellbeing of animals, the environment, and people.

'Fraser's practical ethic' comprises the following 4 principles:

1. **To provide good lives for the animals in our care**

   KNP is home to many species, and we should be mindful of the welfare of all species, and how some species may impact on others. The SAP advise a management plan that optimises the welfare of horses in KNP, and also the survival and welfare of other species, particularly those that are currently threatened.

2. **To treat suffering with compassion**

   Compassion is required for all species and appropriate management of the impacts of wild horses on other species is required. In doing so, unnecessary suffering should not be caused during wild horse management, and the SAP advise management methods are adopted that have the least impacts on animal welfare. There are also times that wild horses may need to be euthanised to terminate their own suffering whether that be through injury, disease or malnutrition.

3. **To be mindful of unseen harm**

   Unseen harms may include harms that horses are causing to other species in the park or may also be harms to horses themselves (for example malnutrition, illness & injuries) which may be greater if they are left unmanaged. The biggest welfare risk to horses, with no natural predator other than humans, is if their population continues to rise, it only becomes limited by food availability, and so malnutrition and starvation become a significant welfare issue. This can often be an unseen harm since those horses that are most vulnerable tend be living in more densely bushed habitats where they are consequently less likely to be seen by humans. Unseen harms can also result from management interventions. It is critical that unnecessary harm is not caused during management. Therefore, management methods with the least negative impacts on animal welfare should be employed, with ongoing welfare assessments and auditing, and alternation of management practices as necessary to ensure that unnecessary harms are minimised.

4. **To protect the life-sustaining processes and balances of nature**
   The key end aim of the new wild horse management plan is to reach a sustainable population of horses whilst protecting the other values of the park, life-sustaining processes and balances of nature.

Finally, **Conservation welfare** is a new discipline applying animal welfare ethic to conservation activities. This is a consequentialist ethic similar to utilitarianism, according to which the right action is the one that results in the greatest good for the greatest number. In practice, this equates to minimising harms to animals and maximining benefits of any harms caused. Conservation welfare applies scientific methods to inform an understanding of what harms and benefits animals might experience with different conservation activities, how they may be mitigated, and how this information can be used to inform decision making about what management actions are morally and ethically permissible. The SAP advise that the new management plan follows the principles of Conservation Welfare (Beausoleil et al. 2018; Beausoleil 2020).

Reducing welfare impacts associated with different management methods

The main body of the report addresses how welfare impacts can be assessed. The following summarises what welfare impacts occur with different stages of management options, and further considerations for how some of these impacts may be mitigated. For any method where welfare impacts are severe, and cannot be substantially mitigated, then this method should not be used. **This section is intended to be read alongside the IRTG humaneness assessment report.**

Methods of capturing horses

Passive trapping

The ITRG assessment scored passive trapping as the capture method with the least negative welfare impacts, although it still scored a moderate impact for a duration of hours, with an overall score of 5 (See IRTG humaneness assessment report). Considering that some of these impacts may also be further mitigated, passive trapping is the method of capturing horses that is most likely to have the least negative welfare impacts, and this is the preferred method for capture.

Impacts in Domain 1 (Food or water restriction) can be reduced if water is safely provided within trap yards. Water should not be restricted for more than 12 hours (particularly if mares are lactating). Consideration should be given to the feasibility of also providing hay within trap yards at the time the trap is set to reduce the duration of food restriction. Impacts in Domain 2 (environmental challenge) may be reduced by having trap yards in sheltered areas where possible. Provision of hay would further reduce the impacts of cold conditions. Thermal stress in hot conditions will be reduced if shade is available, and further reduced if water is available. Assessment of horses for presence and severity of shivering or excessive sweating will provide more information regarding thermal challenges during trapping, to highlight whether further mitigation of these challenges is required.

Impacts in domain 3 (disease, injuries) can occur; injuries are rare, and risks can be reduced by trap design and maintaining family groups within trap yards. It should be noted that horses may commonly have pre-existing illness (e.g. related to malnutrition, gastrointestinal parasitism, mineral deficiencies) that may become apparent following trapping (but is not caused by trapping). Impacts in domain 4 (behaviour) can be reduced if bonded groups do not become separated, and if personnel are careful to cause minimal disruption upon arrival for processing the horses, spending a little time to habituate the horses to human presence. Impacts in Domain 5 (mental status: anxiety, fear, thirst, hunger, hypo/hyperthermia) are reduced by addressing impacts in domains 1-4.

Mustering

The ITRG assessment scored mustering as another capture method with the likely least negative welfare impacts, although it still scored a moderate impact for a duration of hours, with an overall score of 5. Further, this was only when mustering was of small groups of horses performed over hours. If larger groups of horses are mustered over days, then welfare impacts will be greater (score 6). This also assumed mustering within a small area (i.e. maximum of 2km) so that horses are not pushed outside of their home range, and assuming up to 4 bands are mustered. If more horses were mustered, over a longer period, and/or over longer distances then welfare impacts would be expected to be greater. Therefore, mustering of smaller numbers of horses (1-2 bands) over hours, and not outside of their home range is advised. Mustering larger groups of horses (especially > 4 bands) over days, and/or moving them outside of their home range is not advised. If more than one band is being mustered, yards need to be able to appropriately separate bands maintaining family groups together. Food and water need to be provided in yards. Horses should be mustered slowly to reduce the negative impacts of exertion and risks of injury. Impacts once yarded can be similarly reduced as for passive trapping. Horses should not be without water and food for > 12 hours.

Brumby running

The ITRG assessment scored brumby running as the capture method with the highest negative welfare impacts, with a severe impact for a duration of hours, with an overall score of 7. Scoring was based on Parks Victoria SOP. Welfare impacts were classed as severe because horses may be without food and water for > 24 hours, they may experience heat stress during exertion, and potentially hypothermia if tied up for a long period during cold weather. Prolonged or excessive exertion can cause myopathy, neck ropes can cause injuries and interference with breathing, pursuit can cause injuries, the bands are disrupted, and horses separated from their family groups, captured horses may be tied up for 24 hours and be apart from other horses. Foals can also become separated from bands during the chase with subsequent extreme welfare impacts.

There is the potential for many of these impacts to be mitigated if strict protocols are followed, which would include a limitation on the pursuit time and tie-up time, that individual horses should not be left alone without another horse, horses should not be more than 12 hours without water (or not more than 6 hours without water if horses are sweating excessively), or food, neck ropes should not cause injury or interference with breathing, and bands containing young foals should not be targeted. Measurement/auditing of actual measures of animal welfare impacts has not been previously performed and would be advised for any pilot program before deciding if continuation of brumby running was acceptable on welfare grounds.

All these are simply methods of capturing horses, and need to be followed by further stages which may include the following:

Transport

There are significant potential welfare risks associated with transporting horses, even those that are acclimatised to the transportation process. These risks are heightened with wild horses that are not acclimatised to the transportation process. The most common and important complications are those related to dehydration and muscle fatigue (Doherty 1997, Friend 2000, 2001, Weeks et al. 2012, Padalino 2015).

Dehydration occurs through water deprivation during (and sometimes proceeding) transportation but is further exacerbated by higher ambient temperatures, the occurrence of diarrhoea which may be associated with transport stress, and increased sweating which can occur with anxiety and fear. Lactating mares, mares in the 3rd trimester of pregnancy, and foals < 6 months of age have higher water requirements and are therefore at an increased risk of dehydration during transportation. Dehydration can also lead to serious metabolic complications, reduced renal function, large colon impaction and laminitis (Padalino 2015). Severity of dehydration relates predominantly to journey duration, fear and environmental challenge with thermal stress described at ambient temperatures > 30 degrees C (Weeks et al 2012). Horses can tolerate water deprivation for longer periods in cool weather, but in hot weather, severe dehydration may occur with water deprivation of > 8 hours (Friend 2001).

Due to change in routine and confinement, wild horses are also more likely to have already had reduced food and water intake prior to transport, and are likely to take longer to eat and drink upon arriving at their destination. Therefore, it can be anticipated that these complications would occur in journeys of shorter duration when compared to domestic horses.

The muscular effort and physical exertion required for a horse to balance in a moving vehicle is similar to that of moderate exercise. Many physiological changes may occur during transportation including tachycardia, diarrhoea, increased cortisol, increased muscle enzymes and lactate, fluid and electrolyte imbalances, shipping fever, azoturia, reduced immune function, and physical effects such as weight loss and behavioural changes (Doherty et al. 1997). Horses can develop life-threatening levels of fatigue after 24 hours of exertion, but even after 8 hours horses have been reported to fatigue to the point of lying down in the truck, risking also getting trampled and injured (Friend 2001).

Additional transport stressors include separation from herd members, forced proximity to unfamiliar horses, exposure to pathogens, restraint of normal activities, forced adoption of an abnormal posture, extremes in temperature, reduced ventilation (Friend 2001), and lack of REM sleep (Weeks et al. 2012). Oxidative stress has also been shown to occur with 8-hour road journeys (Padalino 2015). Respiratory disease and weight loss are also common during long journeys. Significant weight loss is reported to occur even just after 6 hours of transport, mainly due to dehydration.

The IRTG scored welfare impacts of short journeys (< 4 hours) as overall moderate impact with a score of 5, and long journeys (> 15 hours) as an overall severe welfare impact, with a score of 7.

Every effort should be made to reduce the duration of journeys during which horses are not receiving rest, food and water. It is recommended that rest periods of 30 minutes are required every 4-6 hours to enable horses to urinate and drink (Weeks et al. 2012, Padalino et al. 2015). In many Codes of Transport, it is deemed acceptable to remove access to food and water for up to 8 hours (Padalino 2015).

The Australian Animal Welfare Standards and Guidelines - Land Transport of Livestock (http://www.animalwelfarestandards.net.au/land-transport/) stipulate maximum journey durations of 24 hours for horses > 6 months of age, and 12 hours for foals and lactating mares. However, additional considerations are needed after 12 hours off water for horses > 6 months of age, and after 8 hours off water for foals and lactating mares, and 5 hours in pregnant mares in their 3rd trimester.

Additional considerations include body condition, assessing the horses for temperature abnormalities, diarrhoea, lethargy and injuries.

Most horse transport guidelines are written with domestic, handled horses in mind, and wild unhandled horses pose additional difficulties in assessing horses while on the truck, provide food and water, or unload for rest. The SAP recommends reducing the maximum duration of journeys accordingly.

Risks of dehydration, gut stasis, muscle fatigue and delayed urination will be significantly increased for journeys beyond 6 hours without rest, food and water, so journeys of less than 6 hours (without rest/food/water) are advised, with the shorter journeys being preferable. Transport of foals, lactating mares and mares in their 3rd trimester of pregnancy should not travel for more than 6 hours without rest, food and water. If a journey is expected to exceed 6-8 hours, consideration should be given to body condition, period prior to travel without food and water, ambient temperature, presence of sweating and/or diarrhoea No journey should exceed a maximum of 12 hours without rest, food and water.

Slaughter

Slaughter requires further transportation and lairage. Overall due to combined welfare impacts of different stages, transport and slaughter has the worst potential welfare outcomes out of the lethal control methods. There are also important differences between slaughter in abattoirs vs knackeries and these are also regulated differently, and so will be addressed separately. The processes in abattoirs and welfare problems associated with horse slaughter have been described in detail (Harvey 2020). Abattoirs are licensed to slaughter animals for human consumption, whilst knackeries slaughter animals for pet food and other by-products, such as hides and bone meal. Since the market for horsemeat for human consumption is small and based overseas, all horses slaughtered for human consumption are done so at abattoirs licensed for exporting meat, of which there are 2 in Australia (Queensland and South Australia). Abattoirs and knackeries are regulated differently. Export abattoirs operate under both federal legislation, and requirements of the importing country, which includes EU legislation that incorporates some animal welfare regulations. There are specific requirements for export abattoirs under EU legislation such as requiring a veterinarian to be on-site, and a designated animal welfare officer to be present when animals are unloaded on arrival. Conversely, knackeries are state-regulated and have no requirements for a veterinarian or animal welfare officer, are audited much less frequently, if at all, and have no formal requirements for specific animal welfare audits.

Lairage and slaughter in an abattoir

The ITRG assessed lairage as mild welfare impacts, and the slaughter process up until the point of inducing insensibility being moderate impacts, with overall scores of 5 and 4 respectively. The method of rendering horses insensible in an abattoir is stunning with a captive bolt. When placed correctly insensibility occurs very rapidly. In this case, if they do not regain consciousness prior to death then there should be no suffering. However, problematically, the stunning success rate is unknown. A captive bolt only causes localised brain trauma and concussion, and to achieve insensibility, very accurate placement and positioning of the captive bolt gun is absolutely critical, and the gun needs to be held firmly over the intended site. If there is any error in placement when the gun is fired, it will cause extreme pain without inducing unconsciousness, and a further shot is immediately required. The brain of the horse is surprisingly small (about the size of a grapefruit), within a large skull, and so it can be challenging to achieve accurate placement, especially if there is any movement of the head. When fully conscious, most horses will tend to raise their head if they are anxious or an unfamiliar object is advanced towards their head, and this makes correct height and angling of the captive bolt even more challenging. Thus, in wild unhandled horses, accurate placement of the captive bolt gun is particularly challenging, and a higher than normal rate of ineffective first shots may be anticipated. Further, due to the number of animals being processed at an abattoir, and the size of the facilities, it is an inherently stressful environment for a wild horse.

Lairage and slaughter in a knackery

There are no animal welfare regulations for knackeries. However, that is not to say that animal welfare standards aren't high in some knackeries. Knackeries and much smaller and process much fewer animals than abattoirs, and therefore it is more likely that staff will be familiar with managing horses, and the environment is likely to be inherently less stressful. There are many more knackeries throughout Australia and therefore travel duration will also be much shorter. Knackeries may use a captive bolt or firearms. The advantage of a firearm is that it doesn't need to be held firmly against the horse's head, and instant death is more likely to be achieved. Some knackeries may allow independent animal welfare auditing.

Given the inherent potential welfare problems associated with slaughtering horses in abattoirs, combined with the long transport duration, the SAP does not advise slaughter of horses in abattoirs. Given that not all horses removed from KNP will be able to be rehomed, the slaughter of a small number of horses is unavoidable. The SAP advise the minimum number of horses possible should be slaughtered. When this occurs, the duration of travel without rest, food and water should not exceed 6 hours. Only knackeries that allow independent auditing of animal welfare outcomes should be used.

Euthanasia in trap yards

Euthanasia in trap yards has not been previously performed in NSW and so there is no existing SOP for these methods. Euthanasia in trap yards has the potential to have much less negative welfare impacts given that it avoids transport and horses will be habituated to the environment. It can be performed in the following ways:

- Tranquilising (dart or hand injection) followed by captive bolt shooting
- Tranquilising (dart or hand injection) followed by lethal injection
- Tranquilising (dart or hand injection) followed by shooting with a firearm
- Shooting with a firearm without prior tranquillisation

All of these methods have the potential to cause very rapid insensibility and death with no suffering. Tranquilising prior to applying lethal control has the advantages of keeping the horse still and reducing anxiety when the lethal method is applied, thereby minimising suffering. However, the disadvantage is that the process of tranquilising adds another stage where welfare impacts can occur, such as anxiety/fear and injuries. A veterinarian is also required to prescribe and oversea use of tranquillisers. The SAP advises trials of all these methods to identify the ones with the least negative welfare impacts.

Factors that require consideration in how to minimise anxiety and fear, and maximise the chance of instantaneous death, include separation of individuals, partitioning, visual barriers and sound suppressors for firearms.

Shooting with a firearm without prior capture

Due to the welfare impacts associated capturing horses, lethal methods that don't require prior capture are most likely to have the best welfare outcomes. However, they also have the potential for extreme negative welfare impacts. Aerial shooting, but not ground shooting, has been previously assessed in horses. These methods are only be recommended in the following circumstances:

- o Where there is a very low likelihood of significant animal welfare impacts, based on careful assessments of the points outlined above by the ITRG. An updated SOP would be advised, to incorporate these recommendations within the SOP to be used

- Use of extremely experienced shooters
- Where other methods are either not feasible, or more likely to be associated with higher animal welfare impacts (e.g. inaccessible locations or large numbers of horses in one area)
- Where a defined proportion/number of horses in the particular population are to be shot (i.e. indiscriminate use would not be recommended)
- Where animal welfare outcomes are monitored and results used for recommendations to further improve animal welfare outcomes, i.e. the initial recommendation would only be for a trial and targets for key welfare parameters such as chase time, instantaneous death rate, rate of non-fatal wounding etc, would be set. If targets considered to represent acceptable animal welfare outcomes could not be achieved, then continued use of the method would not be recommended.

More details about integrating ethics and animal welfare, and commonly asked Q&As about lethal control are detailed in Supplementary Material 4.

Appendix 4. Management Zones

Justification for horse management zones – starting in post-fire zones

Following the very large fires of December 2019 - February 2020, three priority locations in northern KNP have been identified by OEH with advice from the SAP for immediate horse management. The rationale is that the post-fire recovery of the vegetation and its dependent native fauna may be hindered by the high horse densities that have become established in the three identified areas of the park, especially over the last decade. Additionally, there is a need to protect significant scientific assets that are currently being damaged by horse activity, independent to the impact of the recent fires. Horses also need to be managed in places where collisions between motor vehicles and horses pose a significant safety risk to humans. Three Management Zones are proposed for the north-eastern section of the park where fire damage has been severe and wild horse populations are already at high densities. The Zones also include areas where horses pose a greater risk to motorists. They total 58,200 Ha or nearly 12% of the area of the park.

Similar zones were already identified in the 2016 Plan based on observed significant changes to the geomorphology (streams, soil cover, wetlands, and limestone karst) and ecology (floristics of grasslands, native rodents and invertebrates, bog and fen communities) and the desire to limit the spread of horses into new areas of the park. The SAP considered the subsequent changes to the reported negative impact of horses up to 2020 and the damage caused by the 2019-2020 fires (Adaminaby Complex, Dunns Road, Marys Hill, and Rolling Ground Fires) to indicate three zones where horse management should be focused to assist in the post-fire recovery and serve as a starting point for horse control efforts. After a review of the zones proposed by the SAP, NPWS recommended minor changes to the boundaries based on operational considerations. Boundaries were moved to align with a nearby track/trail or waterway (where it exists) so that boundaries are easier to identify on the ground.

After the 2019 bushfires, members of the SAP have only inspected the area near the Snowy Mts Highway and the link road to Cabramurra, but adequate information has been provided by NPWS and other sources. Our information is that horse mortality associated with the fires has been relatively minor and that horses remain active across the area, with little effect on the total population. However, it is acknowledged that community concerns and collection of horse data suggest that there could be significant horse loses in particular in the Kiandra area of Zone 2 and thus this should be further evaluated prior to management in this specific region.

Identification of Management Zones

Zone 1 Nungar Plain and south to the Snowy Mts Hwy. This zone corresponds to an area that was designated for horse elimination in the 2016 Draft Management Plan. This area extends south along Pockets Saddle Road from 5 km north of the Port Phillip Trail intersection, crossing the Murrumbidgee River downstream of Tantangara Reservoir south along Kellys and Nungar Creeks to the Snowy Mountains Highway at Gang Creek. Then east and north along the eastern park boundary to the north of the Murrumbidgee River the northwest on the spur west of Paytens Creek to the Pocket Saddle Road.

The southern part of the zone is forested and has a low horse population, thus making horse eradication feasible for this zone. It includes Nungar Plain, an upland open plain at 1340 m altitude which has extensive specialized grasslands (McDougall and Walsh 2002). The grasslands are of two broad types: 1) herb-rich and dominated by *Poa petrophila*, *Poa hookeri* or *Poa phillipsiana*, occurring on dry slopes and 2) species-poor and dominated by *Poa labillardierei* and/or *Austrofestuca hookeriana*, occurring on damp flats. The grasslands have high floristic richness and preserve species such as the rare daisies *Calotis pubescens* and *Taraxicum aristum* that have not been located at Kiandra or Long Plain. The plain had long-term cattle grazing until 1975 but has been recovering after the cessation of cattle grazing. If the horse population is allowed to increase, the recovery may be reversed. The growth of sedges and aquatics such as *Potamogeton cheesmanii* have occupied stream channels and the banks are well vegetated and stable, supporting riparian sedge fens. McDougall and Walsh (2002) noted significant pig damage in the grasslands, which NPWS has subsequently effectively controlled. The Nungar Plain would be regarded as having high archaeological potential. Several modified trees have been identified in this zone that should be revisited and assessed.

This zone is identified for complete removal of horses because historically, horses have been absent, or incursions have been recent. Complete removal from this area will provide buffer areas that will prevent the expansion of horse populations into areas that are currently horse free. These include land bordering the park and the area of Zone 3 lying northeast towards the ACT border.

Zone 2- Three Mile Dam. This includes an area that was originally identified as high risk for public safety but is expanded from that described in the 2016 Plan to include an area inhabited by the endangered broad-toothed rat. This area, consisting of a zone following Gang Gang Creek south across the Snowy Mountains Highway then west across the Eucumbene River to Kings Cross Road. South for 2km and west and then north along the divide between Eucumbene and the Tumut River to meet the western side of the Snowy Mountains Highway north to 1 km south of Rules Point. Then west across the Murrumbidgee River and up Dairymans Creek and down Hell Hole Creek then upstream to Hains Hut and southwest to Goandra Creek. Then southeast to the head of Wallers Creek and east over Tantangara Mt to Gang Gang Creek.

The zone is identified for an overall reduction in horse abundance to a level where traffic safety risk is minimised. Vehicle-horse collision is a significant risk. All horse groups that cross the highway should be removed to establish an initial horse-free buffer, approximately 4 km wide from the highway, be established. The reduction in horse numbers at the southern end also has the aim of preventing the spread of horses southwards into areas of the park that are currently horse free.

Reducing wild horse populations near popular campgrounds, such as at Three Mile Dam, is desirable as unsafe conditions have been noted with horses damaging tents, searching for food, and leaving piles of manure. NPWS advises that a small northward extension of the zone near Three Mile Dam would incorporate an existing trapping site.

A total of 86% (139 km^2) of this Zone was burnt by a very hot fire that removed the ground layer of plants and burnt into the humus layers of soils. The bare surfaces are prone to erosion and recovery to a dense and stable grassland will be a lengthy process as the seed store will have been destroyed.

Mastacomys fuscus, the Broad-toothed rat (Green et al. 2014) occurs in wet tussock grasslands and shrub bogs at Delaneys and Rocky Plain, despite a long pastoral history in the area. They are absent in areas of high horse density where grazing has removed the tall grass cover that they need. Only small patches of unburnt grass have survived in areas of former high broad-toothed rat density populations. Hence their post-fire survival and eventual recovery will require extremely low horse densities.

In this zone, horses should be excluded or removed from the most severely burnt areas and densities managed to reduce traffic risk. Fencing has been suggested as a solution, however, this would be expensive and require constant maintenance, but nevertheless should be further considered. The major riparian corridors running through the zone will have high archaeological sensitivity, including the locations of existing campgrounds (which have topography conducive to the existence of Aboriginal sites). Other locations of low slope in otherwise hilly country would be expected to exhibit a higher density of archaeological material.

In regard to Kiandra, horse removal should initially occur only at the very northern tip to provide a buffer zone to prevent horses in the Kiandra region from dispersing further north. In line with the proposal for Kiandra to form the key initial pilot study area for community engagement and reproductive control, horse removals would not occur until local population estimates and horse identifications have been performed with community involvement. The main population in the Kiandra zone is anecdotally less than 300 horses. A rigorous population and environmental impact assessment need to be carried out to empirically inform what an acceptable horse density is for this area. If substantial numbers of horses were lost in the fires, the current population may be able to be retained. This site may then be used as an initial key site for reproductive control methods (see Appendix 6) to prevent further population growth.

Zone 3 Upper Currango, Coolemon, Peppercorn and upper Long Plain. This zone lies to the north of Zone 1 and is considered an area warranting protection of karst and other key environmental assets in the 2016 Plan, as well as an area that could provide a buffer to prevent horses from moving into the ACT. This area, extending from Pocket Saddle Road south of Gurrangorambla Creek northwest across upper Currango Plain to Old Currango then to the Gurrangorambla Range and northwest to Cooinbil Hut then following the Cooinbil and Long Plain Roads to the Murrumbidgee Crossing then north along the western side of Long Plain and returning to the Long Plain Road and following it northwards to the Little Peppercorn Creek then eastwards down the creek to cross McLeod’s Ridge north of Basin Creek to the Goodradigbee River. The boundary follows the river southwards to Rolling Grounds Creek where it turns southeast up the ridge to the ACT border. It proceeds southeast from Bimberi Gap to Murrays Gap and then follows KNP/ACT border to the west of Yaouk Gap then the Park boundary south and west to the Murrumbidgee where it turns north and west on the Murrumbidgee Fire Trail to join Pockets Saddle Road.

This complex zone is identified for a reduction in horse abundance to a level that protects key environmental assets. One of these is the karst (limestone) landforms and drainage integrity of Coolemon limestone, identified as vulnerable to horse impact (Spate and Baker 2018). Horse traffic has damaged an unusual karst weathering feature at Blue Waterholes, where slabs of limestone have naturally lifted into unusual tent-like structures. Because karst processes are affected by water quality, the entire catchment leading to a karst area needs to be as undisturbed as possible and this requires very low horse densities given their tendency to break down streamlines and increase turbidity. Spate and Baker (2018) note that the Blue Waterholes area supports some rare crustaceans adapted to the calcium-rich water. The removal of around 100 horses from the Blue Waterhole area at the end of 2019 did not solve the problem of karst catchment protection as horse densities are high at the southern end of Currango Plain.

The large montane sedge fens and drainage lines of the Mosquito Creek complex in northern Currango Plain are exhibiting increasing rapid erosion over the past eight years due to high horse densities (Driscoll et al. 2019, Hope et al. 2012). These peatlands contain 3-4 m of sedge peat which has acted as a sponge and infilled streamlines so that, after heavy rain, water flowed in a sheet through the sedges and not along channels. Sediments and nutrients were trapped by the peat and high-water quality resulted. The fens are of particular importance to wildlife during drought periods and after fires, as they remain green and the sedge resprouts quickly if burnt.

The entire fen complex has been taken over with the dominant sedge (*Carex gaudichaudiana*) replacing a 40-50 cm dense sedge land. The horse traffic has cut lines across the swamps and channelization has become marked, with some channels reaching down to the erodible silty clays below the peat. Consequently, the main streams are turbid, and the fen has drained and collapsed along streamlines. Substantially reducing horse densities is required to prevent a major collapse of the peatlands with large sediment losses to the Tantangara Reservoir.

The Peppercorn Hill area, including the source area of the Murrumbidgee and Peppercorn Plain, are similarly vulnerable to wetland loss and stream bank collapse with increasing horse activity. Small streamlines are progressively eroding up slopes, and shrub bogs are showing increasing horse trackways. These areas are under pressure from high horse populations migrating from the more resilient grasslands on Long Plain to the south. An unusual flark drainage complex of small linear ponds set across the slope occurs near the Murrumbidgee source and could be at risk from trampling.

In addition to widespread open artefact scatters and concentrations, significant archaeological sites occur at several locations in his zone. A human burial has been recorded at Blue Waterholes, and a cluster of stone arrangements occurs at Mt Morgan, ~11km west of Tantangara Reservoir. Seven kilometres NNW of these stone arrangements is a ceremonial ring recording (Oldfields Ring Site). These sites should be revisited and their condition assessed.

More than 22 km^2 (9%) of this Zone was initially burnt, although another fire from the east has more recently increased the burnt area, including burning over bogs along Dunns Flat Creek (east of the Goodradigbee). The peatland has been severely altered over the past 20 years from a *Sphagnum* shrub bog to grassland by horse trampling as evidenced by remnant peats under the grass. Horses in this area can cross into the ACT over Murrays Gap, itself an extensive wetland.

Zone three will have a reasonably high archaeological sensitivity, particularly areas like Currango Plains, Long Plain and the margins of wetlands (e.g. Murrays Gap).

Because there are no natural barriers across the northern parts of Currango and Long Plains the proposed boundaries are to provide a horse-free buffer zone of approximately 2 - 4 km that would be only slowly recolonised between the key assets and groups of horses. This buffer is also the aim in the Peppercorn Creek area to prevent further spread of horses northward into an area with the last remaining populations of northern corroboree frogs. NPWS suggest that extending the boundary westwards out to Peter’s Hut on Long Plain (Murrumbidgee River) will allow the inclusion of 4 x existing trap sites, as these trap sites are the only ones with access over winter.

Within Zone 3 the question is what horse densities are environmentally sustainable such that the environmental damage can be reversed, and particular regions and herds within zone 3 that may have horse heritage value. Monitoring of the karst and fen water quality should provide a sensitive measure of stream erosion that will indicate if damage is continuing at various levels of horse densities. In addition to horse management, the zone will require rigorous control of deer and pig activity.

Appendix 5. Monitoring Methodology

5. 1 Monitoring Horse Populations

Below are more detailed recommendations for estimating horse numbers and their impacts.

Dung counts

- 1. *Distance*: Run a 200 m string line out and peg it tight and straight. Have an observer walk along the string line and call out when dung is seen from the string line. Another person with a tape measure measures the perpendicular distance to the centre of each dung deposit and records it. Only dung seen by the observer on the string line should be recorded. To calculate horse density using distance with an acceptable Coefficient of Variation, at least 80 dung points need to be recorded. The length of transect or number of transects needs to be increased if not enough dung is present. A simple strip transect may be sufficient under time constraints, at least for areas with low dung density.
- 2. *Strip*: Run two more string lines parallel to the first 200 m string line, 5 m either side making a 10 m wide strip 200 m long (Butler et al. UTAS *in preparation*). Search this strip and count every location with horse dung. Repeat the dung counts in each habitat.
- 3. Drive along tracks, recording the location of horse dung deposits (if time permits, record age: fresh (green or black) or old (brown or grey), stallion pile or single defecation). That will provide a broad-scale view of horse activity along vehicle tracks and the extent of the horse distribution. Select sections of vehicle tracks for more detailed sampling. Clear dung off these sections of road/track, record dung deposited in a set timeframe after clearing and before the control operation commences and then repeat clearing and recording after the horse control operation. Sections of the road should be chosen both close to where horse removals are being conducted and also far away from the control operations in a similar country where there are similar dung densities prior to control activities.
- Quadcopter drones can be trialled for use in dung counts. This could be more efficient than walking transects so a greater number of sites could be surveyed in more remote areas. Dung can be seen on drone video and can potentially be recognised by computer, which would require trials.

DNA samples from dung

- Collect samples of fresh (green or black) dung with a view to testing for horse DNA. This can provide an accurate estimate using genetic tags for individuals and mark-recapture estimation of actual numbers of horses in the area where dung is collected (see NHS 2014).

Ground Counts

- Twice a year (beginning and end of breeding season), count horses from vehicle or horseback (same tracks each time), recording at the very least, the number of foals and the total number of horses in each social group. Record the number of mares, stallions, sub-adults (1 to 2-year-old) and foals (< 1 year old) if time permits. This level of detail takes longer and may not be possible for NPWS staff, but community members may be able to do this. Also record identifying characteristics if time permits (community groups may have time and interest) to allow mark-recapture calculations. If possible, all areas in KNP with access should be covered. Staff and community members should be involved, and the observer noted. Apps are available on smartphones to do this quickly. Community counts on horseback would increase the area surveyed off vehicle roads and tracks. Data needs to be separated into community or NPWS staff records to control any biases.

Drone surveys

The SAP recommends that drone technology be trailed to replace the groups of people and transport devices and to record visual information that can be used to assess horse populations.

Specifically, we imagine surveys of horses (and other species such as pigs & deer) using drones and associated computer software configured as follows:

- Drone flies along pre-determined transect lines at a constant and relatively low height above the ground
- Drone has downward-facing cameras that record in normal light and infrared
- Camera settings (e.g. aperture, focal length, filter) will need to be adjusted to provide best-possible information, and then used consistently to enable appropriate comparisons
- All recorded information can be transmitted to a base in real-time and distributed from there
- Computer software can determine when and where a camera records an animal, estimates the distance of the animal from the transect line that is directly below the drone, and saves a sequence of photos for each such animal
- Computer software can be tested to determine if additional information about each recorded animal, such as species (e.g. horse, pig, deer, kangaroo) can be recorded
- Otherwise, each sequence of photos can be examined by a human for appropriate interpretation (e.g. species, sex-age class, behaviour)

Such information could then be analysed to obtain estimates of horse density using standard methods for 'variable distance transect counts'. However, it should be noted that it is necessary to assume that any animal that is directly below the drone is certain to be detected and that the likelihood of detection falls off with increasing distance from the transect line in accordance with a particular mathematical function (e.g. Gaussian or Normal).

Such estimates of horse density may then be compared with other measures of horse abundance (e.g. dung) and with various environmental attributes. This should lead, amongst other things, to evaluations of relationships between horse numbers and environmental impacts.

Implementing what we here propose will require funding to support (at least) the following:

- Purchase & maintenance of drones and associated equipment
- Computer & software
- Personnel (operate drones; operate computer software, including statistical analysis; interpret results; document results and conclusions; prepare scientific manuscripts)
- Scientific publications: this project would be novel and exciting research

Community involvement in horse monitoring

- Community counts on horseback or on foot could increase the area surveyed off vehicle roads and tracks.
    - Consideration should be made to potential biases introduced by surveying on horseback versus on foot.
- Community involvement in dung count estimates.
- The SAP advises that community monitoring occurs alongside park staff monitoring to control for potential biases in count data obtained by community members versus park staff.
- Community identification of individual band and horse characteristics to allow mark-recapture calculations and assist in future management (e.g. reproductive control). Apps are available on smartphones to do this quickly.

Monitoring genetic diversity

At the population level, genetic diversity can be measured as the mean number of variants of a gene (alleles) or as the proportion of individuals that have different variants of a gene (heterozygosity) (see National Research Council 2013). Inbreeding coefficients (the probability that genes at a randomly chosen location are identical by descent) is also a useful measure. There are no published genetic studies on the wild horses in KNP. Thus, baseline genetic diversity is unknown and thus, the effect of reducing the population on genetic diversity and health is not known. To indicate the genetic health of the current population, analysis for allelic diversity, heterozygosity, and inbreeding coefficients should be performed from genetic testing of samples collected from gathered horses. Recording the occurrence of genetic diseases and conditions could further provide an indicator of the genetic health of a population. The National Research Council (2013) discussion of maintaining genetic diversity in horse populations in their report to the Bureau of Land Management (BLM) provides further information on this topic.

5.2 Monitoring Environmental Impact

Methodology can be modelled from recent studies, such as those of Wild et al. (2012), Cherubin et al. (2019), and Robertson et al. (2019). For example:

- Selection of sites that are similar in landscape, soil type, habitat, and other factors that can potentially influence environmental impact measures. Select sites in each treatment (horses absent, horses removed, horses reduced, horses unmanaged).
- At each site, walk 200 m to the east, 50 m to the north, 200 m to the west then 50 m to the south and end up at starting point. Record the number of metres of impact (grazing, pugging, trampling) along the total 500 m.
    - Faunal survey can include recording the number of skinks observed, the length of each broad-toothed rat runway and the number of broad-toothed rat scats in each runway, wombat burrows, wombat scats, pig diggings, horse dung within 5 m either side, rabbit pills, deer pellets and cattle dung.
- At waterways, run a 50 m tape out along one bank. At 0, 10, 20, 30 and 40 m, record water depth, flow rate, siltation (percent cover and depth), turbidity, bank slope and height, and % veg cover. Each 10 m section of the creek, record the metres of bank disturbed and the likely animal causing it based on the most recent hoof prints, dung etc. This makes 5 x 10 m sections of the bank on either side.
    - It is also important to walk a longer section of the creek (200 m to 1 km) recording the length of bank disturbed to determine how representative the 50 m section is.

5.3 Monitoring Aboriginal Heritage Impact

Open Artefact Scatters/PADs

Controlled experiments at locations that would allow measurement of the impact of horses on prevalent site types, predominantly stone artefact clusters should be undertaken. Where possible these locations should be in complimentary locations to stations established for monitoring other variables. Foreseeable horse impacts might be breakage and displacement (either directly or through erosion/deflation). These potential effects could be measured through the creation of 'model' sites where change is measured over time. To replicate artefact clusters an initial method could be the use of metal tags (or something as simple as metal washers of different sizes), painted high vis, numbered and placed in pre-recorded locations. Where specimens were not observable, subsequent inspections to employ a metal detector to attempt to find them, and their movement thus able to be measured in relation to a pre-recorded datum (and/or differential GPS to sub centimetre accuracy).

Potential breakage could be measured through the creation of replica stone artefacts by a modern stone worker and inclusion in replica-controlled clusters.

A complementary approach would be to select several places in KNP where horses are known to frequent known Aboriginal open sites, and implement a regime of monitoring site/artefact condition, both through recording artefact condition and distribution and also measuring proxies of archaeological site condition (ground exposure, deflation/erosion).

Other Aboriginal Heritage places

As indicated in Appendix 1.3., open artefact scatters and PADs comprise the vast majority of sites in KNP, and can occur at nearly any location of low slope. The less common/more significant known places in KNP should be subject to a program of revisitation and re-recording to determine current condition and what (if any) factors are causing their deterioration. Determinations should be made at each of these sites regarding the necessity/feasibility of installing mechanisms to exclude horses. Assessment of the effectiveness of control measures on intangible cultural heritage is a less straightforward process but may be achievable through repeated surveys of Traditional Owner participants taken to particular monitoring locations and/or provided data on environmental changes. Such a process of recording and analysing changes in individual opinion would be best undertaken by a qualified anthropologist.

Appendix 6. Reproductive Control

Reproductive control alone will not reduce the population substantially in a short-medium time period. However, for populations already at a low density or once the population has been reduced to a lower level, then reproductive control may assist in maintaining this population level, therefore reducing or removing the ongoing requirements for lethal control methods.

Reproductive control is most effective in maintaining medium-sized populations (100-300 horses). For horse populations to be retained, such as the Kiandra horses, reproductive control could be used early on to maintain a population growth rate to be as close to zero as possible. It is important to note that no reproductive control method yet developed is highly effective, easily delivered, affordable, and does not alter the behaviour or physiology in some way (Kane 2018). Criteria for selecting reproductive control methods are delivery method, availability, efficacy, duration of effect, and potential physiological and behavioural side effects (see below for a review of each currently available method for mares). Currently, the most efficacious immunocontraceptive vaccines for horses are PZP and GonaCon (see below).

The size of the population would need to be determined by the density at which negative impacts are mitigated or considered acceptable. The applicably of reproductive controls would be determined by the ability to apply the control at the level necessary to achieve the goal (e.g. maintain the size or significantly reduce the number of removals required) and the cost of achieving that.

Steps to implement reproductive control program (adapted from Kirkpatrick & Frank 2005):

1) Identify goal
    a. Target density and locations, e.g. acceptable density regarding negative impacts
2) Gather information on the target population
    a. More accurate population counts
    b. Identification of bands and individuals
    c. Identify the rates of immigration and emigration

3) Assess feasibility of treatment(s)
    a. Selection of reproductive control method(s)
    b. Develop methodology for administration
        i. Vaccine by hand or other procedure (IUD or surgical) will require:
            1. Site for gathering
            2. Methodology for gathering
            3. Methodology for administration
            4. Infrastructure for administration
        ii. Vaccine by darting will require:
            1. Testing approachability of horses
            2. Estimate the daily number that can be darted
            3. Methodology for keeping track of darted mares
    c. Develop methodology for monitoring
        i. Monitoring treated mares' fertility and for any adverse side effects
4) Statistical modelling to inform the feasibility of using reproductive control to maintain this density, using the specific demographic data collected if possible
    a. Estimate number of mares to be treated
    b. Estimate the frequency of treatments
    c. Estimated effort: time and financial cost

If modelling shows reproductive control would be effective at reducing the population's growth rate to near zero (or enough to significantly reduce the frequency of removals required), and trials show the effort required is possible, then can go ahead with a plan to implement in that sub-population.

Some of the reasons why reproductive control could be less effective than planned

1. Reproductive control is not as effective in populations open to immigration (Ransom et al. 2014b). In an open population, new animals can come in from other populations and contribute to population growth. If no new animals are entering the population, more than half of the females must be treated to achieve a moderate reduction in growth rate (Ransom et al. 2014b). However, in open populations, where immigration can compensate for lower birth rate, more than 80% of females need to be treated (Hobbs & Hinds 2018; Ransom et al. 2014b). The sub-populations in KNP are open to immigration from other zones and treating more than 80% of mares would be a challenge.
2. Non-treated mares may compensate for the reduced breeding of their peers by producing more foals, meaning treatment may need to be more aggressively applied to achieve the same goal as time progresses. When fewer mares are foaling overall, there would be less competition for resources and mares will be in better condition. Non-treated mares may then start producing foals more frequently (e.g. each year) and those foals might be more likely to survive, thus increasing fecundity and juvenile survival (Kirkpatrick & Turner 2008). The rates used in the initial modelling to determine how many mares to treat would then be too low and more mares would need to be treated to achieve the same outcome.
3. Regarding immunocontraceptives, vaccines are generally less effective in the wild than in captivity (Miller et al. 2013; Powers et al. 2014). This is likely due to wild animals generally having lower immune response than captive animals, due to poor nutrition and more parasites and disease (Miller et al. 2013). If the body condition of the animals being vaccinated is low, there may be lower efficacy of the vaccine (Powers et al. 2014). Furthermore, immunocontraceptive vaccines, like all vaccines, have variation in how effective they are in each individual since immune function varies among individuals (Miller et al. 2013). There would be a portion of mares that will not respond to the vaccine, and depending on if this is a trait that is inherited by the daughters, the number of mares in a population who

won't respond to the vaccine could increase since these are the mares producing the next generation of females (Asa & Porton 2005; Massei et al. 2014).

Table 4 provides information on each of the reproductive control methods currently available globally for use in horses. Only methods for controlling reproduction in mares were considered, as male reproductive control in horses is far less effective as it would require nearly 100% of stallions to be made infertile (Bomford 1990; Eagle et al. 1993; Garrott & Siniff 1992; see Supplementary Material 3 for further discussion).

Table 4. Review of current reproductive control methods.

	PZP vaccines			**GnRH vaccines**			**Surgical sterilization**	**IUD**
	PZP-22	Spay-Vac	ZonaStat-H	GonCon	Improvac	Equity		
How effective treatment is at preventing pregnancy	>85% for 2 years; 50% in 3rd year. 2 to 4-year booster= efficacy for 3 years.	50-100% for 3 years (1st year 83-100%)	55-70% for 1 year; Up to 90% if booster at 2-4 weeks	40-94% for 4 years. Booster in 4th year = 91% for 5 years (still evaluating for 6 years +)	< 50%; 1 year or less; requires 2 doses, 4 weeks apart	<50%; 1 year; requires 3 doses, 4 weeks apart	100%; treating only 30% of mares can reduce foaling	Potentially 80-100% but can be expelled: More recent formulation, no expulsion in domestic trials
Delivery	By hand or dart, Hand more effective, darting less effective	By hand	By hand or dart	By hand or dart (Hand more effective) Current trialling of a remote delivery	By hand (dart probably possible)	By hand	Capture and restrain	Capture and restrain
Delivery time	Minimum of 1-3 months prior to breeding activity			Applied near the end of the breeding season for effects to occur after subsequent season			When not pregnant	When not pregnant
Ongoing management requirements	Every 1-2 years	Every 1-3 years	Every year	Every 4-6 years potentially; optimal schedule still being tested	Every 6-12 month	Every 6-12 years	None	Reapplication of expelled IUDs
Issues with delivery	Requires gathers and recognition of individuals High individual variability			Requires gathers and recognition individuals High individual variability			Requires gathers – need to be held for a week to	Requires gathers in a tight time window when non-pregnant

	Darting requires ability to approach within 40 meters			Darting requires ability to approach within 40 meters			ensure no medical issues	
Side effects – immediate physical	Uterine edemia; mild injection site reactions Little adverse effects if accidentally dosed more often Mild darting site reactions – more grievous injuries if darting inaccurate			Mild injection site reaction Little adverse effects if accidentally dosed more often Mild darting site reactions – more grievous injuries if darting inaccurate			Potential for infection – 2% mortality	Mild to moderate endometris; no long-term effects
Side effects- behaviour	Oestrous behaviour continues Increased agonistic and reproductive behaviour; Extended breeding season Decreased band stability			Suppresses oestrous behaviour Effects on band stability			Not demonstrated but limited tests	Maintain normal breeding behaviours
Safe during pregnancy	Yes			Yes, but may induce abortion in early pregnancy			No	No
Reversible	Yes, but long term (5 years) may induce permanent infertility			Yes, but long term (4 years) may induce permanent infertility (may also induce infertility in first dose for some individuals)			No	Yes
Cost	25 $USD per dose; additional costs with administration	24-35 $USD per dose; additional costs with administration	21-56 $USD per dose – need 2 for full efficacy; additional costs with administration	2-10 $USD; additional costs involved with administration	Approx. 4 $USD per dose; additional costs involved with administration	Approx. 200 $USD per dose; additional costs involved with administration	150 $USD includes vet costs	100-200 $USD for device plus vet costs
Availability	Must be made in AUS – is not currently. Would require formulation optimization and trials before ready for wild-scale administration			In process of being registered	Yes	Yes	Yes	Yes
Ecological feedback	Selection for non-responders Improved body condition and lifespan may affect fecundity Effects on band dynamics			Selection for non-responders Improved body condition and lifespan may affect fecundity Effects on band dynamics			Reduces genetic diversity as there is no reversibility	Improved body condition and lifespan may affect fecundity

Relevant references	(Bechert et al., 2013; Jones & Nuñez, 2019; Killian et al., 2006; Killian et al., 2008; Kirkpatrick et al., 2012; Kirkpatrick & Turner, 2003, 2007, 2008; Nuñez et al., 2010; Roelle et al., 2017; Roelle & Ransom, 2009; Rutberg et al., 2017; Turner Jr et al., 2007; Turner et al., 2008)	(Baker et al., 2018; Gray et al., 2010; Killian et al., 2004; Killian et al., 2008; Ransom et al., 2010; Ransom et al., 2014a)	(Botha et al., 2008; Donovan et al., 2013; Imboden et al., 2006; Schulman et al., 2013)	(Ealy et al., 2010)	(Collins & Kasbohm, 2017)	(Killian et al., 2006; Killian et al., 2004; Killian et al., 2008)

In addition to the above reproductive control methods, the BLM is currently developing a new immunocontraceptive, Oocyte Growth Factor (OGF) vaccine, which may safely prevent pregnancy for up to three years or longer from a single dose. Such vaccines prevent the growth of the oocyte (see Mauldin et al. 2007). This would have an advantage over current immunocontraceptives as it may only require a single dose versus two. However, the effectiveness is not yet known, and vaccination trials are currently underway in the USA (BLM).

Supplementary Material

1. SAP responses to CAP questions

Below are the written responses the SAP have provided to questions that have been posed by the CAP throughout the process of compiling this report. They have been included in this report as they are questions other members of the public may also have. These responses had been prepared for viewing by the CAP independent to this report and therefore, there is some repetition with the above report.

1) Quantitative methodology for measuring environmental impact – how, what and where? Include way to correlate numbers with impact

Environmental impact can be defined as any change to the environment, whether adverse (negative) or beneficial (positive), wholly or partially resulting from the activities of wild horses.

Why measure environmental impact of wild horses?

The goal of any horse management plan for KNP should be to mitigate identified negative impacts. While there is ample evidence to indicate that a large horse population in KNP has negative environmental impacts, the relationship between horse densities and these impacts are currently unknown. Since the goal is to mitigate these negative impacts, there is a need to measure the environmental impact of wild horses and the relationship between impact and horse density in KNP. In doing so, management will be able to a) assess whether reducing horse densities is having the desired outcome of reducing negative impacts and b) determine at which horse density the negative environmental impacts are at an acceptable level for the different areas of the park.

While there is valuable information contained in existing studies regarding how horses negatively impact the environment, improvements are required in experimental design to determine the relationship between horse density and impact; much of the previous research is correlative. Furthermore, exclusion studies (where large herbivores are fenced out of an area) may exaggerate the impact of horses due to confounding effects of other herbivores. Additionally, there may be some positive impacts, such as greater vegetation diversity. Impact, therefore, needs to be measured using controlled, manipulative experimental design.

What and how should be measured?

Horse density: horses densities need to be measured at a smaller scale in the different areas of the park to allow for the current horse density and any subsequent changes in horse densities to be linked to the current state and any subsequent changes to focal environmental impacts. Horse densities can be estimated with drone surveys, ground counts, dung counts, camera traps

Negative environmental impacts: Some of the environmental impacts that can be measured include trampled vegetation, eaten vegetation, change to vegetation structure and species composition/diversity, widened streams, broken stream bank, water quality, erosion along horse paths, change in native species abundance and distribution, change in native animal habitat quality (e.g. Dyring 1990, Thiele and Prober 1999, Beever and Brussard 2000, Prober and Thiele 2007, Beever, Tausch et al. 2008, Tolsma 2009, Wild and Poll 2012, Tolsma and Shannon 2018, Worboys, Driscoll et al. 2018, Robertson, Wright et al. 2019).

Where should it be measured?

In all management zones and different habitat types. The relationship between horse densities and negative environmental impact will likely differ for different habitat types. For example, alpine and subalpine habitats are likely more sensitive to even small numbers of horses than lower grassland habitats.

Correlate numbers with environmental impact: Suggested strategy

Using the experimental design described below, i.e. an adaptive management process, the impact of horses can be measured at different horse densities in different areas of the park and measured through time as density varies. If the negative environmental impacts measured (above) are reduced as horse densities are lowered (by control activates and verified by smaller-scale horse population estimates), that is good evidence that those negative impacts were caused, at least in part, by horses and management actions that lower densities are having the desired outcomes of mitigating negative impacts.

To identify environmentally acceptable horse populations will include the following steps:

1. Define environmental impact, as described above. Also define impact on Aboriginal heritage.
2. Define horse management zones. Starting with the already defined management zones developed in the 2016 Plan, incorporate new information regarding areas of high conservation concern and value, high Aboriginal and European Australian heritage, and habitat suitability for key endangered species to further refine management zones.
3. Set preliminary horse density targets within each zone. Preliminary horse density targets to be guided by the current estimated densities within each zone, and past densities when there was little evidence of negative impact (which can be informed by historic records). These targets will be refined as the adaptive management process continues.
4. Establish monitoring sites. Monitoring sites within each management zone (sampling all habitat types) to be selected. At each site record indices of abundance/activity of horse (dung counts, horse counts, etc.) and other grazing species (e.g. deer, pig), and record the selected impact variables at each site. This will provide data on horse densities and impacts, prior to commencing management, and monitoring should continue as management proceeds.
5. Initiate horse population management. Starting with horse reduction zones, begin horse control, initially targeting areas of highest environmental and Aboriginal heritage concern within the zone.
6. Assess the effect of the reduction in horse density on negative impacts. Resurvey sites for horse densities and impacts regularly once or twice per year as management progresses.
7. Adjust density as necessary to reach an acceptable target density. As management progresses, monitoring of environmental impact and horse density will enable an environmentally acceptable density to be determined.

2) *Using drones for population monitoring and mustering: Using drones to conduct an annual population survey over the entire park. Same methodology as the Alps survey. Drone replaces human observers. Data available in real-time to the community.*

Drones can sometimes be more accurate and precise than human observers for some situations but not for others. For example, drones have been shown to be more accurate and precise than ground observations by humans in estimating bird and large mammal populations, but less so than human observers in helicopters in estimating macropod densities (Guo et al. 2018, Hodgson et al. 2018, Gentle et al. 2019). But drones cannot always distinguish between species (Guo et al. 2018, Gentle et al. 2019). Moreover, the costs of labour for drone piloting and data processing can be more expensive than aerial helicopter surveys (Gentle et al. 2019).

At this stage it is unlikely that drones will be able to completely replace helicopters for surveys of the whole Alps, however, they may be useful for smaller-scale surveys of management zones.

Trials will need to be run to test drone capability for distinguishing between pigs, deer and horses and compare their accuracy and cost with other methods of population monitoring.

It should also be noted that the drone obtained data will still need to be statistically assessed. This means that horses counted in live-streamed footage do not equal the population estimate.

3) *Types of effective and practical exclusion fencing*

Exclusion fencing can be an effective tool to protect areas of high conservation value from threats posed by pest species and has been commonly used in Australia; for example, fencing can exclude herbivores to control erosion of streams and water supplies by preventing trampling, and regenerate vegetation by preventing grazing (Hayward et al. 2009; Kota et al. 2010). However, fence construction is laborious, expensive, and can present some unintended adverse effects: for example, blocking water sources limits water access for wildlife, non-native and native (Boone and Coughenour 2001), and can result in high mortality since animals can become dehydrated or entangled in fencing (e.g. Caughley et al. 1987; Hoare 1992; Mbaiwa et al. 2006). If some streamlines and water holes are to be fenced off to prevent horse access, there must be other water access options for horses and other animals in the area.

Some questions should be addressed prior to construction of fencing (adapted Hayward et al. 2009).

A. Will a fence provide benefits that outweigh both financial and ecological cost, including wildlife access? Exclusion fencing for introduced species in Australia costs between US$6700 and $9500 per km (Moseby et al. 2006).

B. Is on-going maintenance of fencing possible and practical? Once constructed, fences require annual monitoring and maintenance, thereby increasing financial costs.

C. Any failure in maintenance of fencing could have serious consequences such as entrapment in damaged fencing, and entrapment within the exclusion area (e.g. if this is a road, consequences would be very serious)

D. Will the fence solve the identified problem and will the problem be resolved? In the context of KNP, will the horses (and presumably other large, non-native mammals) causing the unwanted impacts to be eliminated or reduced to a density where impacts are acceptable so that fences do not have to be permanently maintained?

E. Will exclusion fencing from one area, increase negative impacts on an adjacent area?

F. Fencing introduces the opportunity to exclude other damaging animals such as pigs and goats, though it may be difficult to do so without excluding desirable animals such as kangaroos and wallabies. Fence design varies according to what animals are to be confined. Horses may be relatively easy to keep out with fencing while including native mammals, but may not effectively exclude pigs (Choquenot et al. 1996), goats (Parkes et al. 1996), or deer (VerCauteren et al. 2006).

G. Animal welfare impacts (some mentioned above) – blocking access to a range of resources for both the intended and unintended species, which may include water, food, con-specifics and potential mates, shade/shelter, escape from predators, escape from adverse environmental conditions (e.g. snow, fire), other potential negative impacts by altering home range, injuries and mortalities by entanglement in fencing, trapping within exclusion area if fencing fails

H. How will tampering of fencing (e.g. by illegal hunters) be prevented?

I. Will the establishment and maintenance of fencing have a detrimental effect on Aboriginal sites?

In conclusion, fencing may be an effective method to protect sensitive areas on a small-scale from horses. However, because we do not know the financial costs and practical constraints associated with fencing in certain areas of KNP, above considerations will need to be assessed before determining whether fencing is a feasible option in a specific area.

4) *Significance of wild horses to Aboriginal cultural heritage.*

Horses can have an impact on Aboriginal heritage. However, what these impacts have not been well-studied. For example, there is at present no known study of the effect of horses on Aboriginal archaeological sites in Australia. It is important therefore to establish baseline information on the effect of large, hard hoofed animals on Aboriginal sites in the region. Such information could be gathered as part of a suite of data built into holistic monitoring programs but also might require consideration of existing models of artefact accumulation for the high country and have certain dedicated monitoring locations

The impact of horses on Aboriginal heritage should be incorporated into the above strategy and may include the following:

- Archaeological survey of known/suspected areas of higher horse density with a view to the initial determination of the presence of archaeological material and horse impact (direct or indirect) thereon.

- Investigation of known key locations within KNP of high Aboriginal archaeological/heritage significance to assess potential impacts of horses, or their exacerbation of disturbance partly or wholly attributable to other factors.

- Design of controlled experimental locations that would allow measurement of the impact of horses on prevalent site types (see Appendix 5 for more detailed methodology).

- At monitoring locations, an inventory should be undertaken of potential Aboriginal food plant resources and any impact by horses.

5) *Significant conservation areas where horses should be eliminated or reduced? Inc. threatened species*

As identified by the ITRG and the Kosciuszko Science Conference, horses have the greatest impact in alpine ecosystems, in particular to the Commonwealth-listed Alpine Sphagnum Bogs and Associated Fens Endangered Ecological Community (Robertson et al. 2019) and unique karst systems of geological significance (Spate et al. 2018). Alpine and sub-alpine peatlands provide important habitat for a range of Commonwealth and/or State-listed threatened species including the Alpine Water Skink, Northern Corroboree Frog, and Broad-toothed rat among a variety of others (Cherubin et al. 2019; Worboys et al. 2018). These are areas in which even very low densities of horses are believed to cause considerable damage (Worboys et al. 2018). Sphagnum bogs, karst areas, and preferred habitats of sensitive endangered species would likely be the best areas for complete removal and exclusion of horses to provide the greatest positive ecological outcomes. The alpine and subalpine wetlands are listed as “Sphagnum bogs and associated fens” under the Commonwealth EPBC Act and the larger subalpine fens under NSW listed “Montane Peatlands and Swamps”. The karst areas are registered with NSW PWS for protection. The ITRG found that all groups interviewed agreed to exclusion of horses from above the tree line and in the Main Range in general. This is reflected in zones proposed in the 2016 Plan.

There are also areas in the park of high Aboriginal heritage, although further work is required to identify which areas of greatest concern. A high correlation is predicted between places where wild horses congregate, particularly in wet weather, and the location of larger more dense clusters of surface and subsurface archaeological material (more significant sites). These areas may occur within or peripheral to the areas of ecological sensitivity identified above but will also occur with frequency throughout the park.

6) Where are the heritage areas where horses should remain?

The SAP does not have particular expertise in this field, but valuable information is available in the National cultural heritage values assessment & conflicting values discussion report: 'The Wild Horse Population of Kosciuszko National Park' undertaken by Context Pty Ltd in 2015 and Jenny Dyring's Master's thesis.

Heritage areas are likely to be Kiandra, Byadbo, Long Plain-Coolemon and possibly the lower Indeegoodbee and other lower altitude drier grasslands which were formerly cattle grazing leases. Management of these populations will need to estimate the current population density and the associated impacts. Once an acceptable population size has been estimated with regard to negative impacts, the retained horse population can be managed with a mixture of removals and reproductive control.

Below are quotes from the National cultural heritage values assessment & conflicting values discussion report: 'The Wild Horse Population Kosciuszko National Park' by Context Pty Ltd in 2015.

"From the 1830s and 1840 when the Monaro and Snowy Mountains district was first settled, the occasional Thoroughbred and other breeds escaped from pastoralists, overlanders, or stockmen, or became lost, and inter-mixed with a growing wild horse population. A wild horse population was established in the Mt Kosciuszko area by the 1850s and probably by the 1840s. In 1861, during the ascent from Kiandra of Mount Inchcliffe, near Thredbo, the members of the climbing expedition sighted 'immense herds of wild horses, which would be impossible to break in' (Age 1861). The presence of 'immense herds' would suggest that the horses were well established in the mountain environment at that time." (Context 2015).

"There are various accounts of horses accidentally escaping at Mt Kosciuszko, including the horse/s belonging to Georg von Neumayer's scientific expedition of 1869. Domesticated horses were also intentionally released into the wild at Mt Kosciuszko from at least c.1900 by graziers and stockmen in order to 'improve' the wild horse population with fresh stock. Whereas in other pastoral districts of NSW the wild horses were culled on a large scale, the difficult terrain of the mountainous area of Kosciuszko provided a place of refuge for escaped and wild horses. By the 1890s, the wild horse population was probably greater in the Alps than in the Riverina and other districts. In 1890, Richard Helms noted 'A great number of unowned horses are found all over the ranges' (cited in Slattery 1998)."

7) Feasibility of mustering or brumby running with regard to animal welfare

The SAP has prepared some advice for reducing welfare impacts associated with different management methods, and so in addition to giving specific advice on mustering, have opted to also share advice being provided on passive trapping and brumby running, from the perspective of optimising welfare outcomes, and some general information on assessing welfare during methods of capturing horses. The preliminary evaluations of welfare impacts were based on the ITRG humaneness assessment report, and so it is advised that this is also referred to. The following summarizes what welfare impacts occur with different methods of capturing horses, and further considerations for how some of these impacts may be mitigated. For any method where welfare impacts are considered to be severe, and unable to be substantially mitigated, then this method is not advised.

Mustering

The ITRG assessment scored mustering as another capture method with the likely least negative welfare impacts, although it still scored a moderate impact for a duration of hours, with an overall score of 5. Further, this was only when mustering was of small groups of horses performed over hours. If larger groups of horses are mustered over days, then welfare impacts will be greater (score 6). This also assumed mustering within a small area (i.e. maximum of 2 km) so that horses are not pushed outside of their home range, and assuming up to 4 mobs are mustered. If more horses were mustered, over a longer period, and/or over longer distances then welfare impacts would be expected to be greater. Therefore, mustering of smaller numbers of horses (1-2 mobs) over hours, and not outside of their home range is advised. Mustering larger groups of horses (especially > 4 mobs) over days, and/or moving them outside of their home range is not advised. If more than one mob is being mustered, yards need to be able to appropriately separate mobs maintaining family groups together. Food and water must be provided in yards. Horses should be mustered slowly to reduce the negative impacts of exertion and risks of injury. Impacts once yarded can be similarly reduced as for passive trapping. Horses should not be without water and food for > 12 hours.

Brumby running

The ITRG assessment scored brumby running as the capture method with the highest negative welfare impacts, with a severe impact for a duration of hours, with an overall score of 7. Scoring was based on Parks Victoria Standard Operating Protocol (SOP). Welfare impacts were classed as severe because horses may be without food and water for > 24 hours, they may experience heat stress during exertion, and potentially hypothermia if tied up for a long period during cold weather. Prolonged or excessive exertion can cause myopathy, neck ropes can cause injuries and interference with breathing, pursuit can cause injuries, the bands are disrupted, and horses separated from their family groups, captured horses may be tied up for 24 hours or more and be apart from other horses. Foals can also become separated from bands during the chase with subsequent extreme welfare impacts.

There is the potential for many of these impacts to be mitigated if strict protocols are followed, which would include a limitation on the pursuit time and tie-up time, that individual horses should not be left alone without another horse, horses should not be more than 12 hours without water (or not more than 6 hours without water if horses are sweating excessively), or food, neck ropes should not cause injury or interference with breathing, and bands containing young foals should not be targeted. Measurement/auditing of actual measures of animal welfare impacts has not been previously performed and would be advised for any pilot program before deciding if continuation of brumby running was acceptable on welfare grounds. The SAP recommends that where substantial welfare impacts can be acceptably mitigated in the development of an alternative SOP, that this method could be trialled under strict conditions with actual monitoring of animal welfare outcomes.

8) *Brumby Mare rates of reproduction per annum (i.e. how many foals is a mare likely to have in any 5-year window) i.e. it must be a less than 1 for every year to allow for infertility etc*

In population studies of wild horses, this is usually quoted as ‘fecundity’ which is the number of females born per adult female per year, across the population. If food isn’t limited, fecundity is usually relatively stable across most wild horse populations, at around 0.4 in most published studies. This means on average, each adult mare has one foal every 2 years (or more precisely 4 foals over 10 years). Fecundity will vary however between individual mares with age, fecundity increases up to 5-6 years of age and foaling rates remain on average a foal every 2 years until the age of 15-18 years. Mares also produce fewer foals when they are in poorer body condition.

Since the number of foals that a mare produced over time is dependent on her body condition, which depends on how much food is available, this means, as the population grows larger, there is less food available for each mare, each mare is likely to be in poorer body condition and will likely have more years between each foal. This also means that when the population grows smaller (e.g. if horses are being removed from the population by management), each mare will be in better body condition and will be more likely to have a foal every other year, or even every year.

In the Australian Alps, population demographics were studied in detail by Dawson & Hone and over 3 sites (Big Boggy, Cowombat, Currango) fecundity varied from 0.24 and 0.21 at Big Boggy and Cowombat flat, to 0.31 at Currango plain. This is an average of one foal approx. every 3 years; or 3 foals every 10 years. There have been other more recent observations at Cooleman Plain suggesting that mares were on average having one foal every two years (Andrea Harvey, pers. obs).

In summary, depending on how good the season/habitat is in terms of food availability and how high the population density already is in an area, over a 5-year period, each adult mare will likely to have on average 2 foals. In a good season in good habitat (such as Northern KNP) they certainly can have a foal every year. In very bad seasons, poor habitats (such as some parts of Southern KNP), or at very high densities, they may only have a foal every 3 or 4 years. Because foaling rates can vary with population density, the rate of foaling will likely change as horse control methods are undertaken.

9) *What is the survival rate for Brumby Foals, e.g. must be some disease, colic, health issues*

In most wild horse populations without predators, foal survival is quite high. Survival for 0-2 year-olds is reported at being about 90% across most studies. In KNP, there are no predators of foals (dingoes or wild dogs may occasionally predate foals but evidence suggests this does not occur frequently), so that the most important factor influencing foal mortality is the amount of food available (which influences both the food available for the juveniles and the condition of mothers and their ability to produce milk).

In Dawson & Hone’s study in the Australian Alps, average survival of 0-2 year-olds was 83 – 90% across the 3 study sites. In a more recent study at Cooleman Plain and Cowombat flat, foal survival appeared to be > 90% with monitoring over a 2-year period (Andrea Harvey, pers. obs). Moreover, since the proportion of foals and yearling was the same, foal survival was also likely high before these 2 years of observation.

10) *What is the average life expectancy of a wild horse in this climate?*

Life expectancy of a wild horse depends largely on the habitat, climate, and food availability. This means the life expectancy of horses in KNP is likely to differ within the different habitat types in the park and over time between good and bad seasons. Studies of most wild horse populations, including Dawson & Hone's study in the Australian Alps, have shown high adult survival (> 90%), but haven’t specifically looked at life expectancy as this would require very long-term studies. This is a bit of a knowledge gap here. Some data from Northern KNP has been collected from ageing dentition of skulls found in the park, and ageing horses that have been removed from the park by dentition. Although not a precise measure of life expectancy, this offers some information on the ages of horses in KNP. Very few horses have been estimated at > 10 years of age, which may suggest that life expectancy is relatively short compared to domestic horses. We did find one skull of a horse well over 20 years old. However, this does need to be interpreted with caution; only a very small number of skulls were found and the cause of death was not known. The age of horses removed from the park is likely to be biased towards younger horses as older horses tend to be more ‘trap shy’. We would expect life expectancy to be longer in northern KNP where food availability is higher, but this has not been tested. Life expectancy may also be shortened due to intestinal disorders associated with chronic gastrointestinal parasitism but there is no definitive information about this.

11) *Explanation on the survey model analysis (how do they get 15,000 horses out of 1200 actual counted?)*

Estimates of wild animal numbers are just that … estimates… because we can rarely record and count every animal. The KNP horse population estimates are obtained using a technique called distance sampling. This technique first estimates animal density and then converts to animal number by simply multiplying the estimated density (e.g. animals per ha) by the size of the area involved (e.g. in ha).

Suppose a friend (or fiend!) evenly scatters matchsticks across an area of your backyard lawn, telling you the boundaries of the area, but without telling you how many matches were scattered. Suppose also that these matches could sense your presence, if nearby, and were mobile, by virtue of little legs. Then imagine that your task is to estimate the density of matches and hence the total number of them within the demarcated area of lawn. This would be conceptually analogous to first estimating horse density within a certain area, and then extrapolating to estimate total horse abundance in this area. In this situation, estimating match density is plagued by the following two fundamental problems: it is increasingly difficult for an observer to detect a match with increasing distance between match and observer; matches may respond to observer presence by moving towards (i.e. attraction) or away (i.e. repulsion, which would be the case for horses).

The standard method for estimating match-stick density would be the transect-distance approach. In this case, one moves along a line (called the 'transect line'), possibly while walking but probably better on one's hands and knees, noting every match that is observed and estimating the distance between match and transect line. Statisticians have devised ways to convert such data into density estimates. Important assumptions here are that close to the transect line (e.g. perhaps about 20 cm either side, if the observer is crawling along) any match is certain to be detected, and that the likelihood of detection declines with increasing distance between match and transect line. This latter relationship can be estimated statistically: transect-distance data are converted into estimates of match density using computer software such as the program '*Distance*'.

This approach can be applied to estimating horse density through observations made either by people in helicopters or through recorded images from a drone. In either case, observations are made along transect lines with estimates of the distance between observed horse and the transect line. In either case, it must be assumed that horses relatively close to the transect line are certain to be detected and recorded. Estimates of horse density can then be converted into estimates of total horse population size for the relevant area, just by multiplying estimated density by the size of the area involved.

12) *Feasibility of using translocation as a control method*

Relocating animals with home range fidelity is generally a low success strategy because a) animals often return to where they were removed from and b) relocated animals suffer high mortality and thus a poor welfare outcome.

Relocated individuals often return to their home ranges, even when 100's km away (Fischer & Lindenmayer 2000; Linnell et al. 1997). Although horses don't defend territories, they show relatively high fidelity for home ranges (Cameron et al., 2001; Linklater et al., 2000). After large scale gathers, released horses will quickly return to their home range when possible (Berman pers. obs., Pirtle pers. obs. and pers. comm. with NPS and BLM staff). Depending on where bands are relocated to within KNP, it could be quite easy for them to return, potentially crossing roads to do so and presenting potential hazards and negative welfare outcomes for the horses.

Relocated animals tend to face high rates of mortality, in part, from harassment from residents or naivety of the new environments (Craven et al. 1998; Fischer & Lindenmayer 2000). Relocated animals tend to be harassed, excluded, and even killed by resident individuals. Horse bands often have overlapping home ranges and are familiar with neighbouring bands (Cameron et al. 2001; Linklater et al. 2000). Relocated bands into areas with established bands might face high levels of harassment and exclusion from prime resources by the other bands. Furthermore, relocated animals have no knowledge of reliable food and water sources throughout the season. In an extreme example, wild mares in Queensland that were moved from prime to less prime habitats, all either died or were in very poor body condition within 2 months (Hampson et al. 2011). The difference between areas in the park would not be as extreme but in drought conditions, naïve bands could face more difficulties in finding sufficient resources.

Relocating horses to 'less sensitive' areas on the park, even if successful, would only exacerbate the negative impacts on those 'less sensitive' areas. 'Less sensitive' areas would need to be identified and it would need to be determined that the environment could cope with additional, potentially hundreds, of horses. In conclusion, relocating horses within the park is likely to be an inefficient strategy with potentially poor welfare outcomes.

13) *Numbers required for a genetically viable population*

There is no magic minimum number at which a population can be considered infinitely viable (i.e. will maintain genetic viability indefinitely). How 'genetically viable' the population is will depend not only on the size of the population but also on how genetically diverse the population is already and how often it is infused with new genetic material (i.e. new animals immigrating into the population).

There are no current published genetic studies on wild horses in KNP, although we have been in touch with a geneticist recently with a view to such work commencing. This means baseline genetic diversity is currently unknown, so the effect of reducing the population on genetic diversity is not known. However, the population in KNP currently is not a small nor isolated population and thus there is little imminent risk of inbreeding and consequences to genetic health. This means that protecting genetic diversity of horses in KNP is not an immediate concern. However, genetic diversity can be routinely monitored as management progresses to ensure genetic health is maintained.

At the population level, genetic diversity can be measured as the mean number of variants of a gene (alleles) or as the proportion of individuals that have different variants of a gene (heterozygosity) (see National Research Council 2013). Inbreeding coefficients (the probability that genes at a randomly chosen location are identical by descent) is also a useful measure. To provide a measure of the genetic health of the current population, analysis for allelic diversity, heterozygosity, and inbreeding coefficients could be performed from genetic testing of samples collected from gathered horses. Recording the occurrence of genetic diseases and conditions could provide an indicator of the genetic health of a population as control measures are implemented and the population density reduced. If there is an indication of compromised genetic health, additional genetic analyses can identify horses managed outside of the park (e.g. in neighbouring parks/reserves) that could be suitable to introduce into these heritage herds to genetically reinvigorate the population (see National Research Council 2013 for a more detailed discussion of managing genetic viability in horse populations).

2. Estimating Population Size

Zen and the art of estimating wild animal numbers

Introduction to estimating wild animal numbers

Estimates of wild animal numbers are just that … estimates… because we can rarely record and count every animal.

Estimates of wild animal numbers will have inherent associated error, because many factors vary outside of our knowledge or control. However, it is often possible to also estimate the magnitude of such error and to be able to state, for example, that it is 95% likely that the number of animals within a certain area lies between one number and another (e.g., between 1,000 and 1,200). Such a range would be described as our 95% confidence interval.

We can decrease the size of the confidence interval, and hence be more confident in our estimates of animal numbers, by repeating procedures, and combining more and more data. If, for example, we were trying to estimate the number of horses within a particular area, then counting horses along 100 different transects or paths would be better than having just 50. In other words, the larger the sample size the better.

In estimating the number of animals in a certain area, we might aim to estimate this directly, or first estimate animal density and then convert to animal number by simply multiplying the estimated density (e.g., animals per ha) by the size of the area involved (e.g., in ha). We shall explain these two approaches below.

Direct estimate of the number of animals in a certain area

This task is conceptually similar to trying to estimate the number of marbles in a large jar, which is opaque except for a few clear windows on the side. These windows are like vantage spots, from each of which can be seen a few marbles. So, we know that there are marbles in the jar, but we have little or no idea as to how many marbles there are.

The first thing we would do is give the jar a shake or two, so that the marbles are well mixed with no biases in distribution (e.g., slightly larger ones nearer to the top and smaller ones toward the bottom, or perhaps vice versa).

The second thing to do is to remove a random sample of marbles from the jar. If the marbles are well mixed, we could just tip some out from the top. Otherwise, we would need to take marbles from throughout the jar, taking care not to create biases by inadvertently tending to pick one kind of marble over another. Here the aim is to get a sample of marbles that is 'random' with respect to any inherent differences amongst marbles.

Thirdly, we would mark each marble in the sample, perhaps with a dot of paint, count them (call the number 'n'), return them to the jar, and give the jar a few more shakes, to completely mix them up again. Marbles that were included in the sample could then be distinguished in the hand from other marbles in the jar.

Fourthly, we take a second random sample of marbles from the jar; it doesn't have to be the same number of marbles. We count the number in this sample, differentiating between specially marked and unmarked marbles. This gives up the proportion (call it 'p') of marked marbles in this second sample. Consequently, this approach is commonly referred to as 'capture-recapture'.

Finally, we estimate the number of marbles in the jar (call this N) by the following bit of simple mathematics:

$N=n/p$

In other words, the estimated number of marbles in the jar is the number in the first random sample divided by the proportion of marbles in the second random sample that were 'marked' as being included in the first sample.

For example, if the first sample consisted of 200 marbles (it is a big jar!) and 20% or one-fifth of the second sample were marked, and so included in the first sample, our estimate of the total number of marbles in the jar would be 200 divided by 1/5, which is the same as multiplying 200 by 5, which would equal 1,000 (yes, quite a large jar!). To check this result, you can confirm that the proportion of specially marked marbles in the jar should be 200 out of 1,000, or one fifth, which should and does correspond to the proportion of marked marbles in our second random sample.

Now, imagine that we are similarly trying to estimate the number of wild horses within an area.

In this case, the marble jar is assumed equivalent to an area within which horses mingle and move about and can be considered reasonably well mixed. It would require a somewhat more sophisticated approach if groups of stallions were in some parts of the area and mares in different parts. We would need help from the statisticians to cope with this. For now, let's assume it's not an issue.

There are a couple of ways in which we could take our first, hopefully random, sample of horses and identify animals in this sample. We could, for example, attempt to identify observed animals through patterns of colour. Or we could use DNA analysis to identify animals responsible for accumulated dung. We could assume, in either case, that the identified individuals constitute a random sample of the population. Otherwise, we would once again have to seek assistance from the statisticians.

We would similarly take a second random sample, allowing time (equivalent to shaking the marble jar) for horses to become well mixed.

We would then proceed as above, determining the proportion of individuals in the second sample that were included in the first sample (i.e. 'p').

By dividing the number of animals included in our first sample by the proportion 'p' (as above) we would estimate the total number of horses in our area of interest.

If we had several areas of interest, each corresponding to a separate sub-population of horses, we would separately carry out such calculations for each area, and then add the estimated numbers together to end up with an estimated total number for our entire area of interest.

Of course, just as in the marble example, there may be deviations from some of the simple assumptions. You should therefore not be surprised if scientific documents dealing with such capture-recapture methods for estimating horse population size seem more complicated.

This approach could give us estimates of horse numbers across different sub-populations within KNP, and hence across all of KNP.

Estimation of animal density

Suppose a friend (or fiend!) evenly scatters matchsticks across an area of your backyard lawn, telling you the boundaries of the area, but without telling you how many matches were scattered.

Suppose also that these matches could sense your presence, if nearby, and were mobile, by virtue of little legs.

Then imagine that your task is to estimate the density of matches and hence the total number of them within the demarcated area of lawn.

This would be conceptually analogous to first estimating horse density within a certain area and then extrapolating to estimate total horse abundance in this area.

In this situation, estimating match density is plagued by the following two fundamental problems: it is increasingly difficult for an observer to detect a match with increasing distance between match and observer; matches may respond to observer presence by moving towards (i.e. attraction) or away (i.e. repulsion). If you have tried observing birds, you should be well familiar with these phenomena!

The standard method for estimating match-stick density would be the transect-distance approach. In this case, one moves along a line (called the 'transect line'), possibly while walking but probably better on one's hands and knees, noting every match that is observed and estimating the distance between match and transect line. As explained below, statisticians have devised ways to convert such data into density estimates.

Important assumptions here are that close to the transect line (e.g. perhaps about 20 cm either side, if the observer is crawling along) any match is certain to be detected, and that the likelihood of detection declines with increasing distance between match and transect line. This latter relationship can either be assumed to fit a standard equation (e.g. Gaussian or Normal) or be estimated statistically.

Transect-distance data are converted into estimates of match density using computer software such as the program '*Distance*'.

This approach can be applied to estimating horse density through observations made either by people in helicopters or through recorded images from a drone. In either case, observations are made along transect lines with estimates of the distance between observed horse and the transect line. In either case, it must be assumed that horses relatively close to the transect line are certain to be detected and recorded.

Estimates of horse density can then be converted into estimates of total horse population size for the relevant area, just by multiplying estimated density by the size of the area involved.

This approach can provide estimates of horse numbers for different areas or horse sub-populations within KNP.

3. Reproductive Control: Background Information

Brief introduction to controlling population densities

Horse populations increase when horses are born or immigrate, and decrease when horses die or emigrate. This means that the population growth rate, i.e. the number of horses each year, is determined by the immigration, emigration, death, and birth rates.

We can control any population's growth rate by reducing the number of individuals entering the population each year by preventing immigration and/or reduce the birth rate or we can reduce the number of horses already in the population by relocating or culling individuals.

Reproductive control methods control population densities through altering the birth rate. Population traits that determine the birth rate include the number of females that produce offspring, i.e. the effective population size, and the number of offspring that each female produces, i.e. fecundity. The number of these offspring that are daughters and survive to sexual maturity, i.e. juvenile survival, will further influence the future birth rate. Thus, the birth rate is essentially the effective population size x fecundity x juvenile survival. To decrease the birth rate, we can reduce the effective population size (i.e. remove breeding females), reduce juvenile survival (i.e. remove foals) or reduce fecundity (i.e. reduce the number of offspring each female produces).

The method that works best (i.e. controlling immigration, emigration, deaths, or births) for **reducing** a population's density depends on aspects of the biology of the animal. Horses are long-lived with low fecundity (mares can only produce one foal per year), high juvenile survival, and low adult death rates. This means that even if all births are stopped, the population won't decrease in size any faster than the natural death rate. In the Alps, that is about 6% of adults who die each year (Dawson & Hone 2012). This means that reproductive control is not a good tool for quickly shrinking horse populations. In fact, reducing fecundity can increase adult survival since mares live longer when they are released from the stresses of having foals (Kirkpatrick & Turner 2008), making reproductive control even less effective at **reducing** population densities. The most efficient way to reduce the size of a horse population is to adjust the 'death/emigration' rate, i.e. removing individuals from the population (Barlow 1997; Dawson & Hone 2012; Fagerstone 2002).

While controlling reproduction is not an effective method for quickly reducing horse populations, it can be an effective way to maintain low densities and reduce the need for removal of horses. By making some mares infertile, we are reducing fecundity and shrinking the effective population size. The effective population size in horses is mostly determined by the number of mares, since only one stallion is needed to impregnate many mares. In terms of the population growth rate, every male is replaceable, and most are superfluous. This has two implications: firstly, reducing the effective population size means reducing the number of mares, i.e. controlling the number of stallions in the population is not an effective way of controlling birth rates. Secondly, reducing fecundity means reducing **mare** fecundity, i.e. controlling reproduction of stallions is not an effective way of reducing birth rates. Reducing reproductive rates via sterilisation of stallions would require nearly 100% of stallions to be treated (Bomford 1990; Eagle et al. 1993; Garrott & Siniff 1992). This also applies to the removal of horses to manage populations. Removing stallions does not slow the population growth rate since each band stallion you remove will be replaced by another and mares will continue to foal at the same rate.

In general, reproductive control will work best in closed populations of less than 300 horses for which all animals are identifiable, trackable, and relatively approachable/gatherable (e.g. Baker et al. 2018; Kirkpatrick & Turner 2008). This is because to administer any sort of control (vaccine, IUD, etc. see table below), we must be within touching (or darting) range of the mare. So, in general, horses need to be gathered and to some extent handled. If we are using immunocontraceptive vaccines, most need to be administered to the same mare in multiple years to be most effective, which means we need to be able to identify and recapture each treated mare. Furthermore, to ensure the treatment even worked, we need to follow each treated mare in the next season to see if she foaled and ensure no adverse welfare outcomes. This is all quite challenging to complete in large populations.

Controlling reproduction also works best in populations closed to immigration. When the population's density is reduced in an area, there is more food available, less competition, and the area becomes more attractive to dispersing individuals. In a population that we have lowered and then administer reproductive control to keep the population low, new mares will full fertility may immigrate into the lowered population, making the treatment less effective.

Initial steps for implementing a reproductive control method:

1) Identify the goal and the timeframe to achieve that objective.

We have to decide what the goal is. If it is to reduce a population from 500 to 250 within 5 years, controlling reproduction won't be effective. If it's to maintain 250 horses in an area at that density for the next 5 years, then reproductive control may be appropriate.

Because our goal is to reduce the negative impact of horses on the environment, this makes identifying the target population densities more difficult since we don't yet know at what density the negative impacts of horses are acceptable or mitigated. Thus, we don't know what our target population densities are yet and where using reproductive controls would be suitable.

2) Identify the available control method(s) that would be most suitable.

An updated summary of the available reproductive controls for mares is provided in Table 4 (above). In Australia, immunocontraceptives would have to be registered with the Australian Pesticides and Veterinary Medicines Authority (Humphrys & Lapidge 2008). Import of the vaccines might need to be sorted out with Australian Border Force. First, follow up in how achievable this is and in what timeframe before moving on. Other methods that may be useful and more quickly available: IUDs or surgical sterilisation of mares (see Appendix 6).

3) Assess whether the contraceptive could be delivered under field conditions in the chosen population.

Once we have chosen a method(s), we have to assess whether we could treat a large proportion of mares in our target population. If we are using vaccines, can we gather a sufficient number of mares and hand dart? Can we approach within 40 yards to be able to dart mares? We need to consider how will the treated mares be tracked and identified for booster vaccinations. Regardless of the methods used, we will need to follow each treated mare to determine a) if she gets pregnant after being treated and b) ensure there are no adverse welfare outcomes from being treated.

4) Determine whether the goal could be achieved in the field.

This requires modelling the effects of the control program on population dynamics (Barlow et al. 1997). Modelling can help inform what overall proportion of mares must be made infertile to achieve the goal, how frequently the treatment needs to be re-applied, and what effort would be required to achieve the target within a given timeframe. If modelling suggests that the goal can be achieved within the targeted time frame (and available budget), then we can move forward with implementing a program as informed by the modelling.

4. Humane Management of Wild Horses

The below information provides an outline of the ethical decision-making framework the SAP is recommending be followed for wild horse management in KNP. Below is a guide of decision making based on welfare outcomes of different wild horse management methods, and commonly asked Q&As regarding lethal vs. non-lethal control. This information is supplementary to the ethical decision making section in the main body of the report and Appendix 3.

Terminology

- ***Humane*** is a very subjective term and means different things to different people. Concerning population management methods, some use the word 'humane' to mean 'a method that does not cause significant animal suffering'. However, others use 'humane' to have a broader meaning, incorporating ethical values, which may include whether a method is lethal or non-lethal. Thus, some people may consider lethal control, by any method, even if there are good welfare outcomes (i.e. no suffering) not to be 'humane', but this is due to ethical values, rather than due to welfare impacts. The dictionary definition of 'humaneness' is 'characterised by tenderness, compassion and sympathy', so arguably for some people, no methods of population control would be considered humane using this definition.

    - It is important that we are clear about this, because when any of us object to a particular method of population control we need to consider whether it is because of our ethical values, or because of animal welfare impacts. These two issues should be addressed separately.
        - ***Ethical management***
        - ***Animal welfare impacts of management***

- The ITRG humaneness assessments from the 2016 draft plan (detailed in review of 2016 plan) are therefore more accurately considered as an ***'animal welfare impact assessment'***, although they did consider more than just animal welfare, by also considering whether the method was lethal or non-lethal. Lethal vs non-lethal is also problematic terminology since many methods considered non-lethal (e.g. fencing, trapping and removal, non-intervention) can also be lethal. This is further addressed below. It is also important to remember that whether a method is lethal or non-lethal doesn't necessarily impact on the animal welfare outcome; some non-lethal methods may have worse animal welfare outcomes (i.e. more suffering) than lethal methods. We will now use the term '***animal welfare impact'*** rather than 'humaneness' to clarify when we are discussing animal welfare aspects of a particular method, vs ethical views associated with a particular method. Other ethical aspects should be considered separately, but alongside, animal welfare.

- ***Ethics*** refers to the moral principles that guide our choices and behaviours to make 'the best' decisions.
    - There are many different ways of thinking about ethics, but one way is to think about ethics in terms of the consequences of a decision. 'The greatest good for the greatest number' is a maxim that is commonly recognised and accepted.
    - Sometimes the best decision may be very obvious, other times it can be really difficult to determine what the best decision is, and these situations are known as ***'ethical challenges'***.
    - Situations are often ethically challenging because the same decision that may lead to 'the best' outcome for one person, may lead to an undesirable outcome for another person, so the 'best decision' becomes less obvious.

- Thus, addressing ethically challenging situations involves weighing up the outcomes of a range of decisions for a range of ‘stakeholders’.
- Wild horse management is certainly an ethically challenging situation, and the ‘stakeholders’ that are affected by decisions are very broad including:
  - The horses themselves – as a species, population, and the welfare of individuals
  - Other animals sharing the same environment – as a species, population, and the welfare of individuals
  - The environment – as an ecosystem, and also individual aspects of the environment which might include certain features, specific plant species, soils, water systems, and other aspects such as aboriginal artefacts
  - People – the wide range of people in society with different value and views around wild horses is one of the reasons why wild horse management is so ethically challenging. In ethics, the outcome for all people needs to be considered and so even without considering the non-human stakeholders, the outcome with ‘the greatest good for the greatest number’ inevitably means that respect for different views and values is required and that compromises need to be reached to strike a balance between the range of views

Ethical decision-making in wild horse management

As many stakeholders are impacted by decisions, it is not a personal opinion that dictates what ‘the best’ decision is, but rather decision making should follow an ethical framework to ensure ‘the best’ decision is made to achieve ‘the greatest good for the greatest number’. It is recognised that the management of any wildlife can be ethically challenging for many of the same reasons highlighted above. As a consequence, a large panel of international wildlife, conservation and animal welfare experts got together to produce the ‘International Consensus Principles for Ethical Wildlife Control’, which was published in the peer-reviewed literature (Dubois et al 2017).

The SAP recommends that these principles are followed for wild horse management in KNP and following these principles form the main body of our advice. The principles are as follows:

1. ***Modifying human practices***

   Negative impacts were first evaluated as to whether the impact can be mitigated by modifying human behaviour.
2. ***Justification for control***

   Scientific evidence was evaluated to assess the population size, increase and the negative environmental impacts, as well as the horse welfare impacts of ineffective population control. Knowledge gaps were identified with recommendations for further research to define ‘sustainable populations’.
3. ***Clear and achievable outcome-based objectives***

   Adaptive management is recommended to each the end goal of environmentally sustainable populations of wild horses.
4. ***Animal welfare***

   Management methods used should cause the least harms to animal welfare to the least number of animals.
5. ***Social acceptability***

   Social acceptability is crucial, and is dependent on education, transparency and trust. Effective community engagement is required in development and execution of the management plan. Effective communication with the public and prevention of dissemination of misinformation is required.

6. ***Systematic planning***

   The recommended systematic planning comprises strategies for identifying an environmentally sustainable horse population, identifying management zones and horse heritage areas, monitoring of the horse population, monitoring environmental impacts and Aboriginal heritage, a process for decision making in choosing control methods for different zones and circumstances, and assessing the animal welfare impacts of control methods, with an adaptive management plan to prioritise the use of methods that have the least negative impact on animal welfare.

7. ***Decision making by specifics rather than labels***

   The SAP recommends an evidence-based management program in line with principles 1-6. The steps being followed in developing the management program would be the same for any wildlife species where management is required as based on scientific evidence. Management decisions are therefore not based on horses being an introduced species, or based on any particular group of people being biased against wild horses. The SAP recognises the importance of the horses to elements of the local and wider community. The SAP seeks to introduce a management plan that will achieve a balance, to reach an environmentally sustainable population of wild horses whilst also protecting and retaining other values of KNP.

'Fraser's practical ethic' is another ethical principle that is commonly applied to ethically challenging situations involving animals, in particular in a 'One Welfare' context, where it is sought to maximise the wellbeing of animals, the environment and people. ***'Conservation* Welfare**' is also a new defined discipline specifically applying animal welfare to conservation activities. These are both principles that the SAP recommend following in wild horse management, and are further detailed in Appendix 3.

Lethal vs ***non-lethal*** management

As eluded to in Appendix 3, some methods that are considered 'non-lethal', may ultimately be lethal and cause worse animal welfare impacts than other non-lethal methods. Examples here include fencing an area that may prevent access to food, water or con-specifics or result in getting trapped or injured, rehoming where the new home isn't successful and the horse may end up getting sent to a knackery, sometimes after a period of neglect or mistreatment, and may involve going through saleyards.

A non-lethal method that doesn't have severe impacts on animal welfare would always be considered preferential to a lethal method. However, there are situations where non-lethal management is not possible. The only non-lethal management options available are rehoming and reproductive control. However, there are limited rehoming opportunities compared to the number of horses that need to be removed from the park. Further, for rehoming to occur, the horses need to be in an area that is accessible for trucking out. There are many areas in KNP that are not accessible for trucking horses out. Reproductive control has the potential for reducing population increase but does not **reduce** the population in the short to medium term (see Supplementary Material 3). Therefore, where horse numbers need to be reduced to a higher degree than can be achieved with rehoming or reproductive control alone, then lethal methods are required. If used to reduce the population in the short term, the aim is then that eventually populations could be maintained with rehoming and reproductive control without the ongoing need for lethal control methods.

If lethal methods are not used, and non-lethal methods can not remove a sufficient number of horses the population of horses will continue to rise. This is not only detrimental to the environment and other animals sharing the environment, but it also becomes detrimental to the welfare of the horses themselves. With no natural predator of horses in KNP, the only thing that slows the population growth of wild horses is food availability. This means that without effective management large numbers of horses starve to death. This can occur very slowly over many months. This has much more severe welfare impacts than a quick death by shooting or lethal injection. Ineffective management is therefore unethical as many ‘stakeholders’ suffer including the environment, other animals and many individual horses themselves.

Therefore the ethics of lethal control is commonly assessed by balancing the other outcomes associated with killing or not killing the animal, i.e. animals should not be killed unnecessarily; there needs to be good justification of other positive outcomes resulting. In this case, potential positive outcomes would include environmental benefits, welfare and survival benefits to other species, and welfare benefits to remaining horses (increased resource availability and reduced competition).

There may be other ethical reasons against particular methods – for example, other concerns with shooting from the ground or air include the possibility of indiscriminately killing large numbers of animals in a short period of time, and concerns about carcasses being left in the environment. These are also very important concerns, but it is important that these are considered and addressed separately to the ethics of lethal control *per se*, and concerns about animal welfare impacts associated with the method.

When lethal control in certain circumstances is deemed justifiable, then we should ensure that the methods used, result in the least negative impacts on animal welfare (i.e. the least ‘suffering’, such as pain and fear) as possible.

Animal welfare impacts

Animal welfare is characterised as the animal’s perception of their mental state, in other words, what an animal is experiencing or feeling. It is conceptualised as the property of individuals, belonging to species considered to have the capacity for both pleasant (positive) and unpleasant (negative) mental experiences, a capacity known as sentience.

All interventions can have positive impacts on an animal’s mental experiences, or negative impacts. When we are talking about animal welfare impacts of methods of population control, we are generally talking about negative impacts on the individuals being removed from the population, although we should always be clear about that (e.g. some impacts could be positive; such as reducing a population can enable higher food availability for the remaining population, which can result in a positive animal welfare impact for the remaining population). Negative impacts associated with population management are negative mental experiences such as hunger, thirst, breathlessness, pain, fear, fatigue, weakness. These mental experiences are inferred using neurophysiological evidence and interpreting indicators of biological function and behaviour. There is a wealth of literature on this area of animal welfare science.

Animal welfare impacts are further evaluated based on the severity and duration of these negative mental experiences. On a population level, animal welfare impacts are also evaluated based on the proportion of animals experiencing negative impacts. For example, the proportion of animals experiencing injuries or dehydration. With lethal control methods, it may be the proportion of animals not experiencing instantaneous death.

Assessing animal welfare impacts, and reducing welfare impacts associated with different management options, including different methods of capturing horses, is detailed in Appendix 3. The following section aims to specifically answer some commonly asked questions surrounding lethal control methods.

Common Q&A's associated with lethal control methods

1. Why does lethal control have to be used at all, isn't this cruel?

There is sometimes confusion between 'ethics' and 'welfare impacts' when people consider cruelty. Animals should not be killed without justification (ethics) but following ethical decision making if it has been deemed justifiable that an animal should be killed (for example numbers need to be reduced and can not be done so with non-lethal methods), then it is the way in which the animal is killed that is important. If a method is 'cruel' it would suggest that it causes severe negative animal welfare impacts such as hunger, thirst, pain, fear. It is very important that when an animal is killed, whatever method is used, it is performed in a way that has the least negative impacts (or least harms) to animal welfare.

2. If lethal control has to be used what is the best method with the least animal welfare impacts?

The available ways for killing wild horses are capturing in yards and then tranquillizing before giving a lethal injection or shooting, or shooting without prior tranquilization. Alternatively, horses can be shot with a firearm without prior capture, either from the ground or from the air.
There are potential advantages and disadvantages of all these methods. Shooting *per se* is often considered by the public to be undesirable. However, when performed appropriately, it has the ability to cause instant unconsciousness and death without prior fear or pain, i.e. without significant negative welfare impacts. This can potentially have less welfare impacts than death by lethal injection.

The biggest concerns with shooting without capturing the horses first are that if a shot is inaccurate it could result in non-fatal injuries and that other horses may become anxious when one of their herd mates is shot. However, when performed under strict conditions (see Appendix 3) it would be expected that most animals would experience a very quick death, without having prior negative experiences of long durations, such as being removed from their natural environment through trapping or mustering, subjected to other steps such as being trapped and transported, or separated from their herds. Therefore there is a much lower risk of additional welfare impacts than other methods. Conversely, the main concerns with capturing horses first are that the additional step of capturing them has additional negative welfare impacts. Confining a wild horse can cause anxiety, fear, and, depending on the length of time they are confined, can impact their behaviour, ability to eat and drink, and risk injuries. Separating horses from their band mates prior to shooting may reduce the anxiety associated with being present when their herd mates are being shot, however separation from their herd could cause more anxiety. All these factors need to be carefully considered and balanced, and the method with the least harms to animal welfare chosen – this may vary between populations – sometimes better overall welfare outcomes may be achieved with capturing horses first, and in other situations, better outcomes may be achieved with shooting prior to capture.

There are many other factors that can influence the animal welfare impact of any method (detailed below), and what is important is that a carefully planned protocol is used to ensure that welfare impacts are minimized and that actual animal welfare impacts are assessed during control actions. If animal welfare impacts are found to be unacceptable then the method can be improved or discontinued. To date, no such trials have been performed with careful assessment of animal welfare impacts of these different methods to truly determined which will have the best animal welfare outcomes in different situations. Therefore, it is important that this is done to identify the methods with the best animal welfare outcomes and to continuously improve the outcomes.

3. What other factors influence the welfare outcomes other than the method used?

All methods, lethal and non-lethal, can cause mild to severe animal welfare impacts, depending on how that method is carried out and the situation that it is used in. There are many other potential variables that influence animal welfare impacts including band sizes, approachability of the horses, visibility in the environment, habitat and the terrain. Further, for example with any method of shooting, the shooter's expertise, techniques, firearm type and ammunition characteristics also all play a vitally important role.

4. When lethal control methods are used, how can it be ensured that there are good animal welfare outcomes (i.e. minimal suffering)?

Firstly, very strict Standard Operating Procedures would be in place. This provides directions for the circumstances in which the procedure can be carried out, and exactly how it is carried out. For example, a shot wouldn't be taken unless it was certain that rapid death could be achieved, and after a shot, it is always confirmed that the animal has died before moving on. NPWS shooters are highly trained professionals who are always using state of the art equipment and following the latest research in terms of the best firearms and ammunition types to ensure the best welfare outcomes.

Further, additional recommendations can be applied such as only using the most highly experienced shooters, only shooting in open areas and on flat terrain, and only small groups of horses. Finally, auditing of all control methods should be performed by animal welfare veterinarians to ensure that the best animal welfare outcomes are being achieved.

When lethal control methods are performed within the park, one big advantage is that good monitoring of animal welfare outcomes is possible, and NPWS have direct ability to determine practices that will increase the likelihood of the best animal welfare outcomes (e.g. by choosing skilled shooters, appropriate equipment and shooting configurations, and training), in addition to altering practices dependent on animal welfare outcomes. This is not possible for methods that involve removing the horses from the park, where it is then usually not possible for animal welfare outcomes to be monitored (e.g. at abattoirs) and severe animal welfare outcomes may occur without any knowledge to be able to address this. Slaughter off park would not be recommended unless processes and animal welfare outcomes can be audited by an animal welfare veterinarian.

5. Wouldn't the terrain in KNP make it difficult to shoot horses accurately without capturing them first?

KNP has extremely variable terrain from large open grasslands, to alpine heathlands, and mountainous forested areas. Habitats would need to be very closely assessed, and shooting without prior capture would only ever be advised where there would be high visibility of the horses, low risk of injury and low risk of non-fatal shots. All shooting should only be for a defined proportion/number of horses in a particular population are to be shot (i.e. indiscriminate use would not be recommended). This method is most likely to be recommended in regions where other methods are either not feasible, or more likely to be associated with higher animal welfare impacts (e.g. inaccessible locations or large numbers of horses in one area). Again, animal welfare outcomes would always be monitored, and results used for recommendations to further improve animal welfare outcomes or discontinue the method if acceptable animal welfare outcomes could not be achieved.

6. What about reports from members of the public describing horse carcasses with multiple bullet holes following shooting from the ground or air; how could these horses have died without suffering?

Standard Operating Procedures usually require that animals are shot at least twice in the cranium or thorax – this is to increase the chances of a quick death and does not mean that the first shot wasn't accurate. A shot is not taken if the shooter is not certain that the first shot will cause unconsciousness. Given the high level of training and experience of the shooters employed, it is very unusual for death to not occur with the first shot. However, it is possible to cause an animal to become unconscious with a first shot, and not dead. Once an animal is unconscious they have no feelings; they can't feel pain or fear, and so there are no impacts to their welfare once they are unconscious. However, an animal can regain consciousness if they are not dead and this would have severe animal welfare impacts. Therefore to ensure that this does not happen, it is standard operating policy to take further shots after the first one to ensure that the animal can not regain consciousness. This means that horse carcasses may have multiple bullet holes even if they experienced instantaneous death from the first shot. This is particularly common if horses are shot from the air, as part of the standard procedures is to fly back and repeat shoot all animals as an extra measure to be absolutely certain there are no horses left alive with non-fatal wounding. All deaths are therefore very rapid.

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