Animal Welfare Assessment of Feral Horse Aerial Shooting

Kosciuszko National Park, 2023

EXECUTIVE SUMMARY

This report describes an independent animal welfare assessment of a preliminary aerial shooting program targeting feral horses (*Equus caballus*) in Kosciuszko National Park. Field observations were performed by two independent veterinarians of 277 horses that were targeted for shooting over two days in November 2023. Parameters relevant to animal welfare were quantified, including the duration of procedures, and the frequency of adverse animal welfare events (including non-fatal wounding). Ground-based inspections were used for a subset of 43 horses that were assessed immediately (median of 3 minutes) after shooting. These inspections allowed examination for insensibility and death, and characterisation of the number and location of bullet wounds. Of all horses pursued, 97% were killed, with 3% escaping without being shot at. No feral horses observed were non-fatally wounded. The median time for combined helicopter pressure and pursuit was 84 seconds, and the median time to insensibility from shooting was 5 seconds. Repeat shooting was performed consistently, with an mean of 7.5 shots fired at each horse, and 98% of bullet wounds were found in the thorax. While acknowledging the preliminary nature of this assessment, animal welfare outcomes were comparable to past investigations of aerial shooting, with a notable absence of adverse animal welfare events and a comparatively high number of shots fired per animal. With respect to indirect animal welfare impacts imposed on other wild animals inhabiting the same environment, the use of lead-free ammunition eliminated the risk of lead poisoning in wildlife scavenging horse carcasses.

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1.1. Introduction

Populations of feral equids, horses (*Equus caballus*) and donkeys (*Equus asinus*), reach high densities on conservation estate outside of their native range in many parts of the world. Such populations are found in Australia (Tulloch and Ritchie 2020), as well as North America (Scasta *et al.* 2018), South America (Zalba and Cozzani 2004), and New Zealand (Linklater *et al.* 2004). There is growing recognition of risks that overabundant feral equid populations pose, including reducing environmental quality (Eldridge *et al.* 2020), competing with native wildlife for limited resources (Hall *et al.* 2016), and being involved in vehicle collisions (Zabek *et al.* 2016).

Due to these impacts, some feral horse populations are subject to population control measures (Berman *et al.* 2023). When sustainable population levels are pursued, methods intended to be non-lethal are often applied, including mustering and trapping to allow horses to be kept in captivity or domesticated (Scasta *et al.* 2021), and fertility control (Grams *et al.* 2022). It should be noted that these methods can still have lethal consequences for some animals (Scasta 2020). Lethal methods applied include transporting mustered or trapped horses to abattoirs for slaughter (Dobbie *et al.* 1993), aerial (helicopter-based) shooting (Hampton *et al.* 2017), trapping and killing (sometimes referred to as 'euthanasia') (Braysher and Arman 2014), and ground-based shooting (Sharp 2016). However, many of these lethal practices are opposed by sections of human communities (Scasta *et al.* 2020). As a result, despite their negative impacts, and unlike most invasive animal species, many feral horse populations are not subject to effective population control (Ward *et al.* 2016). One place in which feral horse population management has been scrutinised is the alpine environment of south-eastern Australia, the 'Australian Alps' (Driscoll *et al.* 2019).

The current distribution of feral horses in the Australian Alps spans over 1.6 million hectares, and includes Alpine National Park in Victoria, Kosciuszko National Park in New South Wales, and Namadgi National Park in the Australian Capital Territory (Beeton and Johnson 2019). In these unique ecosystems, feral horses cause biodiversity impacts in sensitive wetland environments of high ecological value. These include impacts on fauna, such as degradation of the habitat of the critically endangered northern corroboree frog (*Pseudophryne pengilleyi*) (Foster and Scheele 2019), and impacts on flora, soil and invertebrates (Ward-Jones *et al.* 2019). It has been argued that feral horse numbers should be rapidly reduced to levels where these ecosystems can begin to recover (Driscoll *et al.* 2019). However, effective feral horse population control has remained elusive in much of the Australian Alps. The killing of horses is a particularly difficult and emotive issue in this bioregion, when compared to northern and central Australia (Hampton *et al.* 2017), with interested parties working from vastly differing perspectives (Beeton and Johnson 2019). Determined opposition to the killing or removal of feral horses has cited numerous arguments (Castelló and Santiago-Ávila 2022), including prominent concern for animal welfare impacts (Chapple 2005).

Over the past two decades, the attention devoted to animal welfare in wildlife management has increased markedly (Sekar and Shiller 2020). Mammalian species considered to be charismatic such as horses have been the focus of disproportionate global wildlife welfare scrutiny (Scasta *et al.* 2020), and this pattern has extended to feral horses in the Australian Alps (Harvey *et al.* 2020, 2021, 2023). Indeed, in addition to damage mitigation, another reason for reducing the abundance of feral horse populations has emerged in recent years: 'welfare interventions' in circumstances where animals have depleted food or water resources (Driscoll *et al.* 2019). Despite the heightening concern for the welfare of feral horses, there have been few empirical studies assessing the impacts of methods that may be used for population reduction, such as aerial shooting (Hampton *et al.* 2017).

Animal welfare concerns relating to shooting programs pertain to the animals shot at directly (Ryeng and Larsen 2021), conspecifics in the immediate vicinity, e.g. dependent offspring (King *et al.* 2023), non-target species that may be accidentally shot (Blanco *et al.* 2019), and scavengers that feed on shot carcasses (Hampton *et al.* 2022b). Most animal welfare studies of shooting methods have focused on animals directly shot at and have relied on the quantification of several metrics, including the proportion of animals non-fatally wounded (hit but not killed), the proportion of animals shot that are rendered immediately insensible (especially for 'head-shooting'; e.g. for seals) (Ryeng and Larsen 2021), the average duration from shooting to insensibility, and anatomical locations of bullet wounds (Urquhart and McKendrick 2006). A 2017 study quantified these parameters for aerial shooting for feral horses (Hampton *et al.* 2017), but in flat, arid and sparsely treed environments in central Australia.

Here, the outcomes of a preliminary aerial shooting program run in Kosciuszko National Park in November 2023 are described.

1.2. Methods

Observational data collection from a preliminary operational control program was supported by an Animal Ethics Committee (AEC) licence from Murdoch University (O3103/19).

1.2.1. Rationale for the assessment

To allow transparent demonstration of animal welfare outcomes, an independent animal welfare assessment was conducted. Two veterinarians, who were independent of the shooting program (i.e. not members of the shooting team or employees of the managing agency) collected ante-mortem (before death) and post-mortem (after death) data from all animals shot. The independence of the observers from the shooting team and the managing agency was considered important to provide an unbiased assessment of the program to stakeholders and the general public (Greene *et al.* 2011, 2013). The findings of the assessment were also intended to be used to facilitate refinement of the procedural documents guiding the operation (if deemed necessary), before final approval for broadscale use, following the precautionary approach outlined in Hampton *et al.* (2021). This was an observational assessment of an operational control program, and hence, data collection had to be compatible with operational parameters.

1.2.2. Field sites

Shooting events were observed over two days in November 2023 at sites in the southern section of Kosciuszko National Park, in southeastern New South Wales, Australia. The shooting sites were within Australia's Snowy Mountains region, and elevation ranges from 1150–1917 m above sea level (McCarthy *et al.* 2023). The region is mountainous, and 32% of the area has a slope of 18° or greater (NSW Department of Planning and Environment 2021). Vegetation in the area is dominated by eucalypt woodlands with tussock grass, fern and shrubby understoreys, and wet open tussock grasslands (Office of Environment & Heritage 2017), and has extensive creek and river systems with multiple tributaries (McCarthy *et al.* 2023). Operations were limited to times when weather conditions were favourable (wind <15 km/h and no rain). (NSW Department of Planning and Environment 2021).

1.2.3. Procedural documents

The program was intended to be conducted in accordance with the recently-developed and agency-specific standard operating procedure 'Aerial shooting – preliminary program: wild horse control standard operating procedure' (NSW National Parks and Wildlife Service 2023), hereafter 'the SOP'. The SOP stipulates aircraft, firearm, ammunition, and staff training minimum requirements, and prescribes shooting practices. Briefly, mandatory repeat shooting is required, with at least two shots fired into each animal, with at least one of these in the thorax (NSW National Parks and Wildlife Service 2023). A fly-back procedure is also prescribed to confirm that any animal that has been shot is confirmed to be dead. If there is any uncertainty, the SOP prescribes that further 'insurance' shots should be directed into the thorax. The assessment was intended to provide 'ground-truthing' data to guide future refinement of the SOP under the iterative approach recommended by Hampton *et al.* (2021).

It is worth noting that there is also an Australian national SOP for the aerial shooting of feral horses (Sharp 2011), but this more general document was not the focus for this operation. The terrain and vegetation types typical of Kosciuszko National Park (see section 1.2.2.) are generally thought to create challenges for aerial shooting. The national SOP do not advocate aerial shooting in sloping areas or in areas with extensive vegetation cover (Sharp 2011), two unavoidable aspects of operating in Kosciuszko National Park. In addition, use of lead-based ammunition is not mentioned in the national SOP, but was identified as a priority in the recently-developed SOP (NSW National Parks and Wildlife Service 2023) in order to minimise negative impacts on wildlife scavengers (Sonne *et al.* 2019).

1.2.4. Shooting method

There were two shooting helicopters flying concurrently for all shooting sessions. A third helicopter was also used in the vicinity to facilitate post-mortem inspection of shot feral horses by an external animal welfare advocacy organisation. The third (non-shooting) helicopter was occasionally used as a 'spotter' to identify feral horses in the shooting zones, and communicate their location to the shooting teams, but was only used in this spotting capacity when staff from the animal welfare advocacy organisation were not on board.

Aerial shooting was conducted according to the Feral Animal Aerial Shooting Team (FAAST) Manual (NSW National Parks and Wildlife Service 2020). The aircraft were Airbus H125 (previously designated the AS350) Écureuil ('Squirrel') helicopters (Airbus, Marignane, France), with the pilots accredited by FAAST to conduct aerial shooting. The ammunition used was .308 Winchester® cartridges factory-loaded with 150-grain copper (lead-free) Sako Powerhead Blade® polymer-tipped monolithic bullets (Sako, Riihimäki, Finland). The firearms used were FN SCAR®-H semi-automatic rifles chambered in 7.62 × 51 mm NATO (Fabrique National Herstal, Herstal, Belgium), and fitted with non-magnified Aimpoint® red-dot scopes (Aimpoint, Manassas, USA).

A trained air observer sat alongside the pilot to search for flying hazards, ensure that the aircraft targeted feral horses were inside the designated shoot areas, and record the locations of kills on a tablet (McCarthy *et al.* 2023). Four shooters were involved in the operation and alternated after each shooting run. The shooters were FAAST-accredited with 2–15 years of aerial shooting experience, and all had extensive recent experience with ground-based shooting of feral horses in the same environment. The shooter sat in the rear, directly behind the pilot. An independent observer sat in the rear left, alongside the shooter. On detecting a group of feral horses in a designated shoot area, the shooter and pilot communicated until the aircraft was positioned such that a safe and effective shot could be taken by the shooter. Shooting was conducted in approximately two-hour intervals ('runs'), between which the helicopter was refuelled and additional ammunition loaded into the aircraft. A maximum of eight hours of shooting was conducted on each day.

1.2.5. Ante-mortem observations

Methodology for the assessment was similar to that used in recent assessment of aerial shooting for control of introduced deer in Australia (Hampton *et al.* 2022a; Bradshaw *et al.* 2023; Cox *et al.* 2023). The observers recorded ante-mortem and post-mortem data for all shooting events that occurred during the two days of the assessment. Observations were made for all feral horses that were identified as being within a designated shooting zone and targeted for shooting. From each shooting event, the observer recorded the following data: the number of shots fired at each animal, whether shots hit animals, whether shot animals died or escaped wounded, the apparent time to insensibility for shot animals, and whether killed animals were found.

Helicopter-based observations were made by an independent veterinarian ('observer') seated in a shooting helicopter. All pursuit and shooting events that could be clearly seen by the observer were recorded. The number of feral horses seen and shot, and the times that elapsed between these events, were spoken into a hand-held voice recorder, as per Hampton *et al.* (2022a). Group size was defined as the number of animals initially seen together before shooting began (Pople *et al.* 1998). As for other gregarious ungulate species, assigning group size was occasionally ambiguous, particularly when social groups of feral horses either split or merged. In these cases, each group sighted was assumed to be a new group rather than a subgroup from a previously sighted larger group, as per Hampton *et al.* (2022a).

Four time-to-event parameters were quantified from the voice recordings. The pursuit phase of aerial shooting, generally referred to as 'chase time' (Bradshaw *et al.* 2023; Cox *et al.* 2023), was split into two components: a) 'pressure time', during which the animals are visible but the chopper sits at high elevation waiting for them to move into a suitable shooting area, and b) traditional chase time, when the helicopter moves as close as possible to the target animals to facilitate close-range shooting. This division was made as past work involving aerial capture of large ungulates in Kosciuszko National Park has indicated that helicopter pursuit phase is complicated by steep slopes, inundated low-lying areas, densely treed areas and public use spaces (McCarthy *et al.* 2023).

Hence, pressure time (PT) was the interval between when feral horses were sighted within an allowable shooting area, and when the shooting helicopter flew in low and fast to allow close-range shooting, including the time required for feral horses to move away from shooting zone boundaries, public access trails, campsites, huts or waterways (McCarthy *et al.* 2023). Chase time (CT; seconds) was the interval between the onset of escape behaviour (animals beginning to run in response to helicopter disturbance) and the first shot being fired at each individual animal. Time to insensibility (TTI; seconds) was the duration between the first shooting event and insensibility (i.e. the moment the animal became recumbent and ceased moving). This parameter has also been termed ‘time to incapacitation’ (Cox *et al.* 2023) and ‘time to death’ (TTD) (Hampton *et al.* 2014) in previous aerial shooting studies. However, helicopter-based observations do not necessarily detect animals that are hit and rendered insensible but return to consciousness (i.e. that are rendered temporarily insensible but do not die) (Hampton *et al.* 2017). Finally, total time (TT) was the total duration of stress imposed by helicopter shooting, beginning at the onset of the helicopter approaching a group of feral horses, and ending with insensibility, i.e. PT + CT + TTI.

1.2.6. Ground-based inspections

A limitation of traditional approaches to animal welfare assessment in shooting studies, and especially aerial shooting studies, is that animals can only be observed remotely (Bradshaw *et al.* 2023; Cox *et al.* 2023). This means that insensibility and death must be presumed, rather than confirmed directly. In contrast, some ground-based shooting studies have employed a veterinarian to record the presence or absence of a heartbeat via thoracic auscultation with a stethoscope, within seconds of shooting, e.g. for Philippine deer (*Rusa marianna*) shot on the Pacific island of Guam (DeNicola *et al.* 2019). In addition, ground-based inspections of carcasses that occur hours after shooting do not necessarily detect animals that are hit and regain mobility, or animals that are killed, but that take minutes to hours to die (Hampton *et al.* 2014). As a consequence, past estimates of the frequency of non-fatal wounding relying on delayed ground-based inspections of carcasses have been proposed only as minimum estimates (Hampton *et al.* 2017).

For these reasons, a subset of shot and insensible feral horses were subjected to ground-based inspection. These animals were subjected to examination as soon as the observers could approach their body. Animals were opportunistically chosen for ground-based inspection, and this option was only available for feral horses that were killed in relatively flat and open areas in which pilots were confident that they could safely land, and when fly-back procedures for other shot feral horses in a social group had been completed. This limitation dictated that horse subjected to ground-based inspection were always the last 1–2 horses shot in a social group, or horses that were observed alone (i.e. a social group size of 1). This approach meant that animal welfare assessments did not interfere with normal shooting procedures.

Once a shooting helicopter had landed in the immediate vicinity of a recently shot feral horse, the observers walked to the animal as quickly as possible. The observers assessed whether recumbent horses were insensible (via testing of corneal and palpebral reflexes) and dead (presence or absence of a heartbeat and breathing via thoracic auscultation with a stethoscope), as per DeNicola *et al.* (2019). Each dead horse was then sexed (by external genitalia) and aged (adult or juvenile) by body size. The observers then recorded the location and number of bullet wound tracts. Locations of bullet wounds were recorded via external inspection of carcasses following typical methodology (Hampton *et al.* 2022a). The locations of bullet wound tracts were assigned on the basis of the anatomical zone (head, neck, thorax, abdomen and limbs) displaying the most ballistic pathology (Urquhart and McKendrick 2006).

1.2.7. Data analysis

Frequentist descriptive statistics and 95% confidence intervals (CIs) were used to estimate the distribution of data other than time-to-event values. Bayesian statistics were used to examine time-to-event data, with 90% highest posterior density intervals (HDPIs) used to estimate credible intervals (CrIs). Survival functions were used to estimate PT, CT, TTI and TT distributions. Many TTI observations could not be assigned an exact value because the position of the observer in the helicopter prevented them from observing and definitively inferring the moment of onset of an animal's insensibility (Hampton *et al.* 2022a). In these cases, the *maximum* TTI was recorded, as the time elapsed between the first shot being taken at an animal, and that animal being sighted as immobile and insensible by the observer. In these cases, the maximum TTI was recorded (i.e. the data were interval-censored between 0 s and the recorded TTI). TTI values for censored data were imputed by sampling an interval distribution spanning the range 0: recorded TTI for the datum (Plummer 2017). Exponential survival curves were fitted to the PT, CT and TTI data, following Hampton *et al.* (2022a). TT was derived within the model as the sum of PT, CT and the observed or imputed TTI for each observation. Survival functions were then fitted to TT using a second exponential model. Methodological details for statistical analysis of time-to-event data can be found in Hampton *et al.* (2022a).

1.3. Results

1.3.1. Ante-mortem data

A total of 84 feral horse social groups were targeted, with group size ranging from 1–10, with a mean of 3.3 horses (95% CI = 2.8–3.8). Of 277 feral horses targeted and pursued, a total of 270 animals were shot at. Hence, 7 feral horses (2.5%; 95% CI = 1.2–5.1%) escaped without being shot at. The minimum group size from which a feral horse escaped was 4. All feral horses shot at were hit and killed – non-fatal wounding was not observed. All shooting outcomes are shown in **Table 1**. A total of 2032 shots were fired, ranging from 3–15 shots fired at each horse, with a mean of 7.5 shots (95% CI = 7.3–7.8). 'Insurance shots' (taken at recumbent shot horses during fly-back procedures) were fired at 30 horses (11.1%; 95% CI = 7.9–15.4%).

A total of 35 (13.0%) animals classed as 'juvenile' (yearlings or recent foals) were observed in feral horse social groups and all of these animals were shot and killed. Two very young foals (estimated age <1 week) were observed stationary and not near social groups. These animals were shot and killed, but it was not clear which social groups they had been attached to. It is possible that these isolated foals were the result of maternal abandonment (King *et al.* 2023), or may have been 'cached' by their dams, which is behaviour common in other wild ungulates (e.g. deer) (Williams and Gregonis 2015), but not described in the literature for feral horses. It is possible that these foals became separated from their dams due to the disturbance caused by shooting helicopters.

Time-to-event data revealed that PT ranged from 3 s to 3 m 20 s. Median PT was 30 s (90% credible interval (CrI) = 27–33 s). CT ranged from 0 s (no escape behaviour) to 7 m 16 s. Median CT was 54 s (90% CrI = 48–59 s). TTI ranged from 0 s (immediate insensibility) to 53 s. The proportion of censored TTI values was 0.39, and median TTI was 5 s (90% CrI = 5–6 s). Finally, TT ranged from 9 s to 9 m 20 s. Median TT was 1 m 29 s (90% CrI = 80–98 s).

1.3.2. Ground-based inspection

A total of 43 feral horses were selected for ground-based inspection immediately after shooting. The median time elapsed between the final shot being fired at an animal and when it was inspected was 3 m 27 s. All inspected horses had no corneal or palpebral reflexes, breathing or heartbeat at the time of inspection. Four horses were observed agonal gasping as they were approached, but all four had no heartbeat or breathing detectable. Agonal gasps (also known as agonal breathing) are involuntary movements that commonly occur soon after death in animals, see DeNicola *et al.* (2019). It was not unexpected to detect agonal gasping in some killed animals, and all horses displaying this were inspected within 110 s of final shooting. The sex ratio of inspected animals was slightly male-biased (53:47). Of 285 bullet wound tracts detected, 279 (97.9%; 95% CI = 95.5–99.0%) were found to predominantly affect the thorax, with the remaining bullet wounds found in the cranium (n = 1), neck (n = 1), abdomen (n = 3) and forelimb (n = 1). All horses inspected on the ground had ≥3 bullet wounds in the thorax. Most bullet wounds either produced an exit wound, or the deformed (mushroomed) bullet was palpable underneath the skin on the far side of the animal, see Stokke *et al.* (2017). Characterisation of the fate of all bullets was not possible due to the large numbers of intersecting bullet wound tracts in most inspected animals.

Table 1. Summary of ante-mortem data collected from aerial shooting of feral horses (*Equus caballus*) in Kosciuszko National Park, November 2023.

Category	Sample size (*n*)	Probability (95% CI)
Animals pursued	277	–
Animals shot at	270	0.97 (0.95–0.99)
Animals hit by shots	270	0.97 (0.95–0.99)
Animals killed	270	0.97 (0.95–0.99)
Animals escaping without being shot at	7	0.03 (0.01–0.05)
Animals escaping unwounded after being shot at (missed)	0	0 (0–0.01)
Animals escaping wounded	0	0 (0–0.01)

1.4. Discussion

Animal welfare outcomes documented in this assessment were typical of previously examined professional aerial shooting operations, but were notable for an absence of adverse animal events, likely influenced by a deliberate 'overkill' policy which resulted in a comparatively high number of shots fired at each animal.

Non-fatal wounding is considered the worst animal welfare outcome for any shooting operation because it causes protracted (but unmeasured) suffering (Aebischer *et al.* 2014). Concerns about the frequency of non-fatal wounding have driven much of the hesitancy around aerial shooting of feral horses in New South Wales in the past two decades (English 2000). Non-fatal wounding was not observed in this assessment. In comparison, non-fatal wounding has been detected in a minority of animals in several previous aerial shooting assessments (Hampton *et al.* 2014, 2017, 2022a). This is an important finding as a rigorous methodology was employed to assess the occurrence of non-fatal wounding in this assessment – namely, by landing as soon as possible and as close as possible to immobile horses, and testing whether they were insensible and dead. We could safely conduct this assessment for 43 (16%) of the shot horses, and all of these animals were confirmed dead. Importantly, these checks were performed at a median of 3 minutes after the final shot was taken at the horse. It is unlikely that animals could be inspected more quickly in an aerial shooting program, given the need to safely land the helicopter close to a shot animal, and then safely exit the helicopter and locate the shot animal.

Ground-based inspection results suggest that the feral horses for which post-mortem inspections were not performed were all likely to have been dead. More generally, this finding indicates that ante-mortem observations of insensible shot animals generally equates to death under this protocol. However, this finding does not indicate that non-fatal wounding could not occur in aerial shooting of horses under this protocol, only that it does not occur at a frequency that was detected in our sample of 270 shot animals. The slight male bias in horses subjected to ground-based inspection likely reflects the over-representation of solo adult stallions (i.e. a social group size of 1), which were easier to inspect without interfering with normal shooting procedures. The presence of very young (<1 week old) foals at the time of year that the program took place created animal welfare risks. Whether abandoned or cached, the presence of very young animals that are completely dependent on maternal support considerably raises the risk of orphaned animals suffering protracted deaths (King *et al.* 2023). All dependent foals detected were shot and killed in this assessment.

Time to insensibility values were comparable to several aerial shooting methods that have previously been assessed. However, there is an important distinction in this context between species commonly culled via using the thorax ('chest') as the primary anatomical target, and using the cranium ('head') as the primary anatomical target (Urquhart and McKendrick 2006). Due to the imprecision inherent to shooting at moving targets from a moving platform, chest-shooting is much more commonly attempted from an aerial platform. For example, chest shooting is typically used for fallow deer (*Dama dama*) (Hampton *et al.* 2022a; Bradshaw *et al.* 2023; Cox *et al.* 2023), chital deer (*Axis axis*) (Hampton *et al.* 2022a), and feral pigs (*Sus scrofa*) (Cox *et al.* 2023). In contrast, head-shooting is rarely used, e.g. feral camels (*Camelus dromedarius*) (Hampton *et al.* 2014), and sometimes, feral horses in flat and sparsely vegetated desert areas (Hampton *et al.* 2017). With chest-shooting, very few animals are rendered immediately insensible (Stokke *et al.* 2018), hence animal welfare metrics such as 'instantaneous death rate' (Smith and Ryeng 2022) are not typically quantified. For comparison, reported median TTI values ranged from 17–37 s in three programs targeting species of introduced deer found in Australia (Hampton *et al.* 2022a). Median TTI (described as 'time to incapacitation') was 11.5 s for feral pigs and 11.0 s for fallow deer in the study of Cox *et al.* (2023).

The extensive use of repeat shooting likely made an important contribution to the observed animal welfare outcomes. Repeat shooting was performed for all animals, with a mean of 7.5 shots fired at each horse, and was done so relatively accurately, with 98% of these bullet wounds found in the thorax. Aerial shooting commonly produces bullet wounds in anatomical structures adjacent to the target area (in this case, the thorax). Due to animals being shot from behind as they run, shots that target the thorax also commonly involve the anterior abdomen (Hampton *et al.* 2016). The frequency of these non-target-zone bullet wounds are typically higher in small species. For example, in one fallow deer program, 50% of animals had ≥1 bullet wound in the neck (Hampton *et al.* 2022a). Fewer bullet wounds were found in inspected horses (mean of 6.6) than were fired at each horse (mean of 7.5). This discrepancy likely reflects some combination of: 1) a sub-set of 43 animals contributing data to the former metric, whereas 270 animals contributed data to the latter, 2) a minority of fired shots missing targeted animals entirely, and 3) failure to detect some bullet wounds during ground-based inspection. In contrast, Cox *et al.* (2023) reported medians of 3.0 and

2.5 shots fired per feral pig and fallow deer, respectively. Hampton *et al.* (2022a) reported means of 2.6 and 1.4 bullet wound tracts per fallow deer and chital deer, respectively.

The use of monolithic copper bullets resulted in extensive penetration of horse tissues, with the majority of bullets (although unquantified) either producing exit wounds or being palpable underneath the skin on the far side of the animal. This is an important consideration, as non-bonded soft-point lead-based bullets tend to penetrate far less than monolithic copper bullets (Gremse *et al.* 2014). Non-bonded soft-point lead-based bullets were used for the shooting of feral horse in Guy Fawkes National Park in the year 2000, and that program resulted in the non-fatal wounding of at least one animal (English 2000).

While this was a preliminary assessment with a relatively small sample size (<300) (Hampton *et al.* 2019), animal welfare outcomes were comparable to the only peer-reviewed assessment of feral horse aerial shooting (Hampton *et al.* 2017). In that study, time-to-event metrics were predictably lower, given that the operations were performed in flat and treeless sites in central Australia. Median chase time (equivalent to combined PT and CT as defined in this assessment) was 42 s, and median TT was 52 s. However, there was a higher frequency of adverse animal events, with seven (1.1%) horses found alive (non-fatally wounded) at the time of ground-based inspections, and each horse had a mean of 2.4 bullet wounds. In comparison, the duration of procedures was longer in the current assessment, but non-fatal wounding was not observed, and the mean number of bullet wound tracts in killed feral horses (6.6) was ~3 × that reported (2.4) by Hampton *et al.* (2017).

Finally, lead-free ammunition was used in the program examined, eliminating the risk of lead poisoning in wildlife scavenging on these carcasses (Pay *et al.* 2021). In the context of Kosciuszko National Park, there are several species of native scavenger that may otherwise be indirectly harmed through ingestion of lead fragments in shot horses. These include wedge-tailed eagles (*Aquila audax*), and corvids such as ravens (*Corvus* spp.) (Woodford *et al.* 2020).

1.5. Conclusions

Independent assessment of this program indicated that animal welfare outcomes were comparable to other assessed aerial shooting programs. Comparison with other feral horse control methods was outside of the scope of this report. Given the absence of observed adverse animal events, and the relatively brief duration of procedures, the draft SOP that guided this operation appears to be fit-for-purpose for aerial shooting of this species in this habitat type.

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