Sam Smith, intern at the NAMMCO Secretariat was tasked to carry out a literature search of hunting efficiency for terrestrial mammals. In so doing he was supervised by Kathrine Ryeng. The present document is his findings.

# OVERVIEW OF RECENT DEVELOPMENTS IN TIME-TO-DEATH REPORTING FOR HUNTED TERRESTRIAL SPECIES.

In 2005, Knudsen published a review of the criteria used to assess insensibility in hunted whales in comparison to other species. Within this review, it was noted that official criteria have only been considered when applied to humans or large whales. Following that, several studies on terrestrial species were discussed that purported to assess hunting efficiency. However, lacking in these studies were quantitative data related to insensibility and time to death (TTD).

The issue of animal welfare has been discussed at the International Whaling Commission (IWC) since the 1950's, prompting increased scrutiny of hunting methods (IWC 1959, Knudsen 2005, Gales *et al.* 2008). With a view to increasing hunt efficiency, improve animal welfare outcomes, and increase hunter safety, changes were made to hunting methods and the use of cold harpoons was largely abandoned. This effort culminated in the development of the Norwegian "Whale Grenade-99", leading to significant decreases in TTD, and increases in the Instantaneous Death Rate (IDR – the proportion of animals killed instantly during a hunt) (Øen 1995). With the increased opposition to whaling, there was even more impetus to demonstrate that this form of harvest could not only be sustainable, but also as humane as other practices that involve the slaughter of animals. Therefore, following the North Atlantic Marine Mammals Committee (NAMMCO) Committee on Hunting Methods Expert Group meetings of 2010 and 2015, it was acknowledged that a further review of the literature was necessary to see if quantitative data on TTD was available for terrestrial mammals.

After online searches of relevant journals and literature sources, there remains few quantitative assessments of hunting methods that assess time to death in terrestrial animals. However, since 2014, several papers have been published in the journals of *Wildlife Research* (Hampton et al. 2014, 2017, Hampton & Forsyth 2016), *Animal Welfare* (Hampton et al. 2015), and the *Wildlife Society Bulletin* (Hampton et al. 2016) by J. O. Hampton. This body of work was subsequently included in the author's thesis submitted for the Doctor of Philosophy degree at Murdoch University, Australia (Hampton 2017).

Hampton's thesis and associated papers discussed their findings with reference given to the extensive information on cetacean hunting methods. It was acknowledged that a framework has been developed in the hunting of large whales from which the assessment of terrestrial hunting can model (Hampton 2017). Improving animal welfare outcomes for the physical killing of animals should aim for the reduction of the duration of suffering (Lewis et al. 1997, Hampton et al. 2014). The ideal approach would be to record the time to insensibility, yet practical assessment of this is often difficult in the field. Recording TTD is therefore identified as an alternative that has been successfully implemented for cetaceans (Knudsen 2005, Brakes & Donoghue 2006). Hampton's studies have been modelled on similar criteria and methods, incorporating the parameters of TTD and IDR used to evaluate whaling efficiency.

The following sections aim to provide an overview of the recent work conducted in the assessment and evaluation of animal welfare outcomes from terrestrial shooting programs by Hampton. The thesis (Hampton 2017) contains further chapters discussing non-lethal control methods as well, yet these will not be the focus of this review. Instead, the overview will predominantly report on the evaluation of lethal control methods used, namely those using rifles for herbivore management in Australia.

## I: Quantitative analysis of animal welfare outcomes in helicopter shooting: a case study with feral dromedary camels (*Camelus dromedarius*).

### Introduction

Presented here is a summary of the paper published in *Wildlife Research* (Hampton et al. 2014). This paper addresses the animal welfare concerns arising from helicopter shooting as a method for feral camel population control. Helicopter shooting has been widely employed as a management tool for large mammals (Saunders 1993), particularly for invasive species in Australia where introduced animals such as camels are considered to be overabundant. It was noted by the authors that, while studies exist that evaluate the efficacy of the method from a population control perspective (Choquenot et al. 1999), little effort has been made to quantify the animal-welfare parameters. Further, where the practice has been discontinued, this has been largely due to public opinion shaping policy, and not whether the technique is effective (Nimmo & Miller 2007).

### Methods

The methodological approach for assessing the welfare and humaneness of helicopter shooting of camels consisted of two parts; an *ante-mortem* observation, and a *post-mortem* examination. Standard Operating Procedures (SOPs) for helicopter shooting programs are highly regulated in Australia, and those used conducted under the Australian Feral Camel Management Project (AFCMP) were required to follow these, and Civil Aviation Safety Authority regulations.

Two Robinson® 44 helicopters (Robinson Helicopter Co. Torrance, California, USA) were used in the shooting operations. Shooting was conducted from one helicopter, with the other making observations and recordings while flying approx. 30m above the other. Two types of firearms were used in the operations; the M1A (Springfield Armory, Geneseo, Illinois, USA) and the LR-.308 (DPMS Panther Arms, St Cloud, Michigan, USA). Both were semi-automatic, firing 0.308 Winchester® ammunition, and the target area on the animal was either the cranium or thorax. (Hampton et al. 2014). Repeat shooting is required in Australia and as such, a ‘fly-back’ procedure was performed as detailed along with further SOPs in Sharp (2012).

*Ante-mortem* observations were performed by recording the interval between the first shot impacting the animal, and the moment at which the animal fell to the ground and did not move (Lewis et al. 1997). This time was recorded as the TTD, yet it was noted that as physiological responses could not be measured, there is a chance that this measure merely represents a time to insensibility. However, it was also mentioned that with the requirement for repeat shooting, it is unlikely that animals will return to sensibility (Knudsen & Øen 2003, Sharp 2012), therefore making this assessment of TTD representative of the duration of animal suffering.

*Post-mortem* observations were conducted for a separate series of shooting operations. These were conducted by veterinarians within four hours of shooting. Animals were initially assessed for signs indicating a non-instantaneous death. These included blood-trails, evidence of paddling or thrashing, and any disturbance to the substrate in which their carcass was found. Further examinations were conducted to assess the gross pathology of vital organs, the damage sustained by non-target organs, and the location and direction of bullet-tract wounds. Shots to the cranium, thorax and cervical spine were considered fatal (Urquhart & McKendrick 2006, Cockram et al. 2011).

## Results

The results of the *ante-mortem* operation described 192 camels, 83% (95% CI: 77-88%) of which were shown to have died instantly (Table 1.). The TTD ranged from 0s to 242s, with a mean TTD of 4s. 32 animals were not considered to have been killed instantaneously and have a mean TTD of 22s (±11s).

**Table 1.** Summary of results obtained through *ante-mortem* observations by (Hampton et al. 2014). Mean Time-to-death (TTD, given in seconds) and Instantaneous Death Rate (IDR) is given for 192 camels shot in a helicopter shooting operation.

| Parameter | *n* | Mean | 95% CI (lower) | 95% CI (upper) |
|---|---|---|---|---|
| **TTD** (all)/s | 192 | 4.00 | 1.00 | 6.00 |
| **IDR** | 192 | 0.83 | 0.77 | 0.88 |
| **TTD** (non-instantaneous)/s | 32 | 22.00 | 11.00 | 33.00 |

*Post-mortem* observations were conducted on a total of 715 animals, three of which were found to still be alive upon examination, and thus a wounding rate of 0.4% was given. This is similar to the Struck-and-Lost parameter given in the assessment of the hunting efficiency for marine mammals, yet struck-and-lost may include animals that were killed instantly (Kestin 1995, Knudsen 2005, Hampton 2017). From initial observations of the animal upon inspection, from the gross pathologies of vital organs, bullet wound locations and bullet-hole tracts, an IDR of 77% (95% CI: 74-80%) was inferred. Although inferences of TTD and IDR from *post-mortems* should be treated with caution, This IDR is very close to the above stated IDR given for the *ante-mortem* observations (Table 1.).

## Discussion

Further statistical analysis found strong support for the shooter's identity to have affected the proportion of animals rendered instantaneously dead (Hampton et al. 2014). Shooter training, experience, skill, and selection for the operations will likely impact any animal welfare outcomes on an individual basis. Furthermore, vegetation was found to be a factor in reducing the likelihood of achieving improved IDRs. It was also noted by the authors that the stability of the platform, and the need to hit a moving target would likely act as a barrier to improved welfare outcomes. Likewise, harpoon operation, sea conditions, and angle of the shot in minke whale (*Balaenoptera* a*cutorostrata*) are known factors influencing the efficiency of whaling operations (Kestin 1995, NAMMCO 2015). As such, NAMMCO provides a manual to skippers in recognition of the optimum outcomes for animal welfare during the hunts; "NAMMCO Instruction manual for the maintenance and use of weaponry and equipment deployed in hunting of baleen whales in NAMMCO member countries" (Øen 2015).

Repeat shooting has been stated by some to be the product of ineffective first shots, and therefore as an indication of non-humane killing (see Daoust et al. 2013, Butterworth & Richardson 2014). However, as per regional regulations and SOPs (Hampton et al. 2014, 2017), and practices routinely carried out by hunters (Knudsen 2005), the assumption that a secondary shot equates to poor welfare outcomes is not warranted. Indeed, the present study states an average of 2.4 bullet-wounds tracts were present in camels from *post-mortem* observations, even with the inferred 77% IDR.

This study provides the first quantitative evaluation of the animal welfare outcomes for helicopter shooting of a large terrestrial mammal. This is also one of the only studies to produce time-to-death values for terrestrial wildlife shooting, and as such, builds upon the extensive body of work previously conducted in cetacean hunts. It demonstrates that animal welfare outcomes can be judged by a combination of *anti*- and *post-mortem* observations which, when combined, give a wealth of information regarding the humaneness of physical killing methods. The results of this study by Hampton et al. (2014) are comparable to the IDRs currently achieved by Norwegian minke, and Icelandic fin whale hunts (82% and 84% respectively) (NAMMCO 2015). Similarly, it identifies certain variables that can influence the animal welfare outcomes of hunts, the likes of which are analogous to those observed in whaling operations.

## II: A simple quantitative method for assessing animal welfare outcomes in terrestrial wildlife shooting: The European rabbit as a case study

**&**

## III: Improving Animal Welfare in Wildlife Shooting: The Importance of Projectile Energy

### Introduction and Methods

The following papers describe the application of terrestrial wildlife shooting on European rabbits (*Oryctolagus cuniculus*). Hampton et al. (2015) assessed the welfare aspects of shooting programs used in population control. It combines *ante*- and *post-mortem* observations and examinations to infer the humaneness of hunting methods. This follows the benchmark parameters developed and established for the study of cetacean hunting methods, such as the recording of time-to-death (TTD), instantaneous death rate (IDR), and *post-mortem* analysis of location of shot (Kestin 1995, Øen 1995, Knudsen 2005, Gales et al. 2008, Hampton et al. 2014). Further, an analysis of Struck-and-lost rate also gives an impression of welfare outcomes for hunted marine mammals. Hampton (2014, 2015) equates this to the wounding rate (WR) obtained from some terrestrial studies. This is not strictly correct as the WR is defined as "the estimated proportion of animals shot but not killed", whereas the NAMMCO definition of Struck-and-lost incorporates all animals hit but not landed, with no indication of whether they are dead or not. Although this may seem a technicality of the different environments, an equivalence of the two terms would not account for those whales that were killed instantly but subsequently lost if, say, the harpoon becomes dislodged (Knudsen 2005, NAMMCO 2017).

Hampton et al. (2016) discusses the importance of projectile choice in improving the welfare outcomes of the shooting of European rabbits. *Ante*- and *post-mortem* observations were made for rabbits shot with two different projectile types; a low energy 40-grain .22 long rifle rimfire (.22LR) bullet, and a high energy 40-grain .222 Remington® centrefire (.222R) bullet. The muzzle energies for each were found to be 198J, and 1433J respectively. The welfare parameters, as discussed above, were contrasted for each projectile used, and conclusions made regarding best practices for improved animal welfare outcomes. Hampton et al. (2015) uses solely .22 long rifle ammunition.

These studies represent some of the few terrestrial studies reporting on *ante-mortem* parameters such as TTD and IDR. They apply the cetacean hunting methods template for assessment to the control of European rabbits, an invasive population where lethal control is considered necessary in Australia (Hampton et al. 2015). Following standard operating procedures (SOPs) as described by Sharp (2016), rabbits were shot opportunistically at night, with distance of shot recorded as an additional variable. Analysis TTD and IDR were calculated as per Hampton et al. (2014), based the framework established for cetaceans. However, for both these studies, it appears that the mean TTD reported includes those in which the TTD = 0. This differs from the studies of Hampton et al. (2014) and Norwegian reporting of TTD in minke whale *(Balaenoptera acutorostra)* hunts, where those reported as instantly dead were excluded from an average survival time reporting (NAMMCO 2015, Øen

2015). The wounding rate (WR) was defined as above; the proportion of animals that were hit but not recovered.

**Results**

The results of Hampton et al. (2015) reported that rabbits fatally shot had TTDs ranging from 0 to 90 seconds, with 60% (95% CI: 50-69%) killed instantaneously (Table 2.). Out of a total of 141 animals shot at, 127 were hit with 15 individuals (12%) escaping wounded.

**Table 2.** Animal welfare parameters for shooting of European rabbits as reported in Hampton et al. (2015). Mean Time-to-death (TTD, given in seconds), Instantaneous Death Rate (IDR) and Wounding rate (WR) are given for 127 animals hit during assessment.

| *Parameter* | *Mean* | *95% CI (lower)* | *95% CI (upper)* |
|---|---|---|---|
| **TTD/s** | 12 | 8 | 16 |
| **IDR** | 0.60 | 0.50 | 0.69 |
| **WR** | 0.12 | 0.07 | 0.19 |

The second study discussing comparing projectile choice (Hampton et al. 2016) demonstrates similar *ante-mortem* results as Hampton et al. (2015) when assessing the welfare outcomes of .22LR ammunition (Table 3.). Following the assessment of .222R ammunition, it was found that welfare outcomes were substantially improved when the higher energy projectile was used. IDR was increased from 66% to 92%, while mean TTD was reduced by 8 seconds (Table 3.). WR also decreased by 4%.

**Table 3.** Comparison of projectile choice with respect to animal welfare parameters as stated in Hampton et al. (2016). Mean Time-to-death (TTD, given in seconds), Instantaneous Death Rate (IDR) and Wounding rate (WR) are given for 500 animals shot during assessment.

| *Projectile* | *n* | *Mean TTD/s* | *Mean IDR* | *Mean WR* |
|---|---|---|---|---|
| **.22 Long Rifle** | 224 | 10 (7-13) | 0.66 (0.59-0.72) | 0.06 (0.03-0.09) |
| **.222 Remington ®** | 276 | 2(1-3) | 0.92 (0.88-0.95) | 0.02 (0.00-0.03) |

*Post-mortem* observations from both studies identified bullet tract locations as Hampton et al. (2014). Shooting distance was found to be an important explanatory variable when assessing animal welfare outcomes. Increasing shooting distance decreased the probability of hitting a rabbit in one of the recommended locations defined as likely to cause instantaneous insensibility and death (Hampton et al. 2015, 2016, Sharp 2016). The SOPs stipulate a recommended shooting distance; reducing this distance as much as possible is though to improve welfare outcomes for rabbits. The comparison of projectiles also found that successful shooting of rabbits was possible at greater distances when using the .222R given the higher energy profile of this ammunition. *Post-mortem* also found that use of the .222R ammunition also increased the probability of inducing trauma in multiple anatomical zones (Hampton et al. 2016). Even when distance was controlled for following statistical analysis, the .222R ammunition were found to increase animal welfare outcomes derived from *ante-mortem* parameters over the .22LR projectiles.

## Discussion

The results obtained from studies observing the shooting of the European rabbits has demonstrated further successful use of the framework developed for hunting method assessment in marine mammals (Øen 1995, Knudsen 2005, Hampton et al. 2015, 2016). Assessment of terrestrial mammal welfare outcomes has demonstrated that a combination of *ante*- and *post-mortem* observations is able to infer parameters such as TTD, IDR and WR. Further, Hampton et al. (2016) also demonstrated the importance of projectile choice when considering welfare improvements. High energy projectiles were able to improve all welfare parameters and enabled more humane physical killing at greater distances.

The higher the wounding rate, the greater the number of animals that escape after being hit. This is widely considered the worst possible outcome of animal killing from a welfare perspective (Bradshaw & Bateson 2000, Hampton et al. 2015, 2016). The duration of suffering experienced by an animal that escapes after being hit by a projectile is unable to be quantified and could be substantial. The above study has shown that increasing the projectile energy by selecting a higher calibre can reduce the likelihood of non-lethal wounding occurring (Hampton et al. 2016). Even when controlled for distance, this equates to increased kinetic energy being transferred to the animal, followed by trauma observed in multiple critical anatomic zones as per standard operating procedures (Sharp 2016).

Potential drawbacks of using higher energy projectiles such as the .222R ammunition were discussed in terms of primary objective of animal killing. Given the higher cost of the .222R over the .22LR bullets (more than 10 times greater), the practicality of using more expensive methods will not suite every situation (Hampton et al. 2016). This can be comparable to the situation where the ammunition determined by experts to be the most efficient, has not always been available in the stores. This has remained a problem in several of the NAMMCO member countries (NAMMCO 1999, 2001). As an example, the collective minke whale hunt in Greenland consists of a multiple of small boats first using large calibre rifles and then attaching several hand-held harpoons to not lose the whale before killing it. This contrasts with larger, single vessels, operating explosive harpoons fired from cannons. Any hunting methods where the combined use of cold harpoons and rifles often results in prolonged TTDs and low IDRs. In this situation, the Greenlandic whalers cannot kill for instantaneous death given the whale's propensity to sink before a harpoon can be attached (NAMMCO 2010, 2015). While this has raised welfare concerns, the lack of whaling vessels, the need for food supply and the geographic isolation of communities practicing the collective hunts has limited animal welfare outcomes (NAMMCO 2015).

Furthermore, there is a concern that, although the .222R ammunition used in Hampton et al. (2016) provided improved welfare outcomes, it also damaged a greater proportion of the target animal. Therefore, if shooting is to be conducted for meat, rather than population control, animal welfare concerns may have to be balanced against the cost of the ammunition and the potential wastage of usable product. Likewise, Daoust & Cattet (2004) observed that accuracy of the shot had less impact on the probability of negative welfare outcomes if the projectile used had a higher energy profile on impact. This may be of greater benefit to wildlife population control than it would be to harvest of wildlife, given the greater potential for damage to usable meat.

Nevertheless, the discussion of projectile choice in regard to animal welfare in terrestrial shooting mirrors the improvements made to whaling operations in the 1980's and 1990's (Øen 1995, 2015, NAMMCO 2015). As parameters have been used to quantify the humane killing of animals, so the understanding of positive and negative outcomes has improved (Kestin 1995, Knudsen 2005, Hampton et al. 2015). In recognition of the work conducted in whaling operations to reduce the intensity of duration of animal suffering, the discussion in Hampton et al. (2016) turned to relevance of projectile choice. Again, quantitative data combining both *ante*- and *post-mortem* observations provide insights into the welfare outcomes of hunting methods in terrestrial shooting.

## IV: An assessment of animal welfare for the culling of peri-urban kangaroos

### Introduction

The following paper introduces the assessment of animal welfare during night shooting of peri-urban kangaroos (*Macropus sp.*). Eastern grey kangaroos (*Macropus giganteus*) are subject to population control when numbers become over abundant in proximity to human settlements (Hampton & Forsyth 2016). As with the previous studies discussed, questions surrounding the welfare aspects of this practice remain, especially as the target is a charismatic mammal endemic to Australia. Also as in previous studies, both *ante*- and *post-mortem* observations were used in the assessment, enabling the accurate quantification of IDR, TTD and WR. Furthermore, in addition to these parameters quantified for the individual animals, the duration of stress was also quantified for pouch young and conspecifics. The quantification of stress on young animals is particularly important, given that the welfare of 'orphaned' animals has previously received considerable attention (Hampton & Forsyth 2016). The assessment of flight responses of conspecifics may also have implications for animal welfare assessments in other social species.

### Methods

Shooting took place at night during June 2015 in the Australian Capital Territory. It took place in the winter months to minimise number of young-at-foot (juveniles outside the pouch) and furred pouch young, which would likely have poorer welfare during the shooting operation (Mcleod & Sharp 2014, Hampton & Forsyth 2016). A shooting team consisting of a driver, an observer and a shooter operated a modified four-wheel-drive-vehicle driven at 5-10kmph around an estate in which the shooting program was conducted. The shooter used a bolt-action rifle, using .223 Remington® calibre ammunition. The rifle was fitted with a telescopic sight and sound suppressor to reduce noise. Typically, shooting is conducted with the use of spotlights (see Hampton et al. 2015, 2016), yet for the purposes of this study, a infrared imaging technology was utilised. Once a kangaroo was spotted, the vehicle was stopped within 75m of the animal, and the marksman aimed for the cranium of the animal, as per standard operating procedures (Commonwealth of Australia 2008, Hampton et al. 2016).

Retrieval of the animals once shot occurred as soon as possible, yet multiple animals including young-at-foot sometimes shot in cohort. Females assessed for presence of pouch young, and these were euthanised through blunt-force trauma or decapitation. An independent veterinary observer recorded *ante-mortem* welfare parameters (TTD, IDR, WR), while infrared video recordings were reviewed later to assess the flight behaviour of conspecifics. Flight behaviour was defined as either the animal remaining calm and stationary after another animal in the vicinity was shot, or an alarmed flight response away from the animal that was shot. The duration of the flight response (FD) was recorded, with those that remained stationary recorded as FD = 0.

*Post-mortem* examinations were performed to determine the location of the bullet wounds and bullet wound tracts as per Urquhart & McKendrick (2006). This was conducted by an independent observer who also conducted an examination of the euthanised pouch-young.

### Results

During the shooting program, 136 kangaroos were shot at, with two animals escaping un-wounded. Of the 134 animals that were hit, 131 animals were rendered instantaneously insensible (Table 4.).

For the three animals not rendered immediately insensible, the median TTD recorded was 12 seconds (range = 4-81s). *Post-mortem* observations demonstrated that 98% of kangaroos had bullet-wound trauma to the brain. Young-at-foot (juveniles outside the pouch) were, when present, shot with 60s of the mother (n=17).

**Table 4.** Summary of *ante-mortem* observations of peri-urban kangaroos described by Hampton & Forsyth (2016). Animals subject to night-shooting, and observed through thermal imaging cameras by independent observers. IDR = Instantaneous death rate; WR = wounding rate (animals escaping after being hit).

| ***Parameter*** | ***n*** | ***Probability* (95% CI)** |
|---|---|---|
| Shot at | 136.00 | 1.00 |
| Hit | 134.00 | 0.99 (0.97-1.00) |
| Killed | 134.00 | 0.99 (0.97-1.00) |
| IDR | 131.00 | 0.98 (0.95-1.00) |
| WR | 0.00 | 0.00 |

66 pouch young were found in 90% of the females shot (n=72), 57 of which were described as 'unfurred'. Young marsupials without fur, and that have not yet opened their eyelids, are thought to not have sufficiently developed neurological system in order to feel pain and therefore to suffer (Mcleod & Sharp 2014, Hampton & Forsyth 2016). Young were euthanised by either blunt force trauma (furred and unfurred) or decapitation (unfurred). For sentient furred pouch young (n=9), median stress time (duration from pouch removal to insensibility) was 4 seconds (range = 1-10s). Median flight time of conspecifics was 5 seconds, with 22% of animals exhibiting no alarmed flight response. *Post-mortem* examinations confirmed that

**Discussion**

To the knowledge of the authors, this study represents the first quantified review of animal welfare outcomes in the culling of peri-urban kangaroos. It has implemented the parameters developed for cetaceans to assess hunting methods, and has produced a methodology designed to reduce bias associated with the measurement of these parameters by combining both *ante-* and *post-mortem* examinations (Kestin 1995, Øen 1995, Lewis et al. 1997, Knudsen 2005).

The results obtained show a very high percentage of animals shot and killed instantaneously (IDR=98%). This value is comparable to those obtained in abattoir slaughtering of cattle (*Bos taurus*) described by Grandin (2010), and higher than those observed in the Norwegian minke whale (*Balaenoptera acutorostrata*, 82%) hunt (NAMMCO 2015, Øen 2015). Furthermore the WR, widely considered the worst of all animal welfare outcomes (Bateson & Bradshaw 1997, Hampton & Forsyth 2016), was zero and therefore a very positive welfare outcome.

Duration of suffering for pouch-young was conserved low (median 4s), and the flight time, with a median value of 5s was also relatively low. The fact that 22% of animals exhibited no flight response at all indicates that the behaviour of conspecifics in the vicinity of targeted animals was minimally affected. A number of factors may contribute to this, namely the use of a sound suppressor, the absence of a spotlight, and the habituation of the animals to the presence of humans. These are important considerations for methods designed to improve welfare outcomes in shooting programs. The fact that the behavioural responses of conspecifics were also quantified has allowed appraisal of welfare outcomes for all animals potentially affected by shooting. This will be especially important in animals where social behaviour is perceived to be well-developed. In this study, negative welfare implications for conspecifics were accounted for in the shooting protocol, with the use of suppressors and thermal imaging cameras over spotlights. Both the sound of the shot, and the bright spotlights have been associated with negative welfare outcomes (Hampton & Forsyth 2016). For marine mammals, the duration of stress of conspecifics during hunting activities may be an important welfare concern, especially with respect to species and methods employed during the hunt.

To summarise, Hampton & Forsyth (2016) have demonstrated a quantitative approach towards assessing welfare outcomes for kangaroo culls, with respect to methods used, and the effects of conspecifics. This study has reported very low duration of suffering and stress experienced by the animals, and this has been evidenced by both *ante*- and *post-mortem* observations. The utilisation of the parameters developed for the assessment of cetacean hunts demonstrates that a quantified approach to assessing welfare outcomes has again be successfully applied to terrestrial animals using this framework. Furthermore, the observations of conspecific behaviour in the vicinity of targeted animals may indicate an area in which the assessment of marine mammal welfare could pursue in further studies.

## V: Assessment of animal welfare for helicopter shooting of feral horses

### Introduction

In this final paper, Hampton et al. (2017) provides *ante*- and *post-mortem* observations made during population control operations for feral horses (*Equus caballus*) through helicopter shooting. This follows from the initial study, Hampton et al. (2014), where the same technique used in the control of dromedary camels (*Camelus dromedarius*) was assessed. The techniques in question involved the application of the parameters, such as TTD, used to assess welfare outcomes for large cetaceans (Øen 1995). Furthermore, it has long been recognised that time-to-death is not the sole measure of the duration of suffering inflicted upon a hunted animal. The period of time in which an animal is under stress may begin long before the first shot makes contact. This is especially evident when animals are being chased, such as the present study where the shooting platform is a fast-moving helicopter. This defined ‘chase-time’ can be combined with TTD to give an overall quantification of the stress experienced in the different stages of a hunt.

### Methods

Shooting protocol was identical to those used in (Hampton et al. 2014). *Ante-mortem* observations were made using the parameters of TTD and IDR used to assess animal welfare. Unlike previous studies discussed, the present study did not state a wounding rate, instead only gave a minimum estimate of 1% inferred from *post-mortem* (Hampton et al. 2014, 2015, 2016, Hampton & Forsyth 2016). This was however not regarded as reliable since it was estimated from *post-mortem* observations alone (Hampton et al. 2017). Also incorporated into the *ante-mortem* observations was the recording of ‘Chase-time’. This was defined as the time from the onset of flight behaviour in response to the helicopter, to the time of the first shot (Linklater & Cameron 2002, Hampton et al. 2017). The value recorded here was combined the TTD to give an overall total time (TT), providing an overall representation of *ante-mortem* stress endured.

*Post-mortem* examinations were conducted by independent veterinary observers, and the anatomical location of bullet-wounds and bullet-wound tracts were recorded. Further information was also obtained as per Hampton et al. (2014), such as variables associated with shooter skill, vegetation type, and physical condition of the horses. *Post-mortem* observations dichotomised the perceived outcome; whether instantaneous death could be inferred or not.

## Results

A total of 937 animals were shot during the helicopter shooting operation. All animals that were chased by the helicopter were shot, 63% of which were regarded to have been rendered instantaneously insensible. For those that were not killed instantly (TTD > 0), the mean survival time was 19 seconds (Table 5). The range for CT and TT was equivalent, indicating that at least one individual was chased for nearly 11 minutes, before being killed instantly. The wounding rate observed was at least 1%.

**Table 5.** Summary of *ante-mortem* parameters used to infer welfare outcomes for helicopter shooting of feral horses (*Equus caballus*) as reported by (Hampton et al. 2017). CT= Chase time, TTD = Time-to-death, **TT** = Total time. CT and TT incorporate data recorded for all animals, while the values for TTD solely includes animals for which TTD was greater than zero seconds.

| Parameter | Mean/s | Median/s | Range (lower)/s | Range (upper)/s |
|---|---|---|---|---|
| CT | 73.00 | 42.00 | 2.00 | 654.00 |
| TTD (non instant) | 19.00 | 15.00 | 3.00 | 242.00 |
| TT | 80.00 | 52.00 | 2.00 | 654.00 |

*Post-mortem* observations conducted on 630 animals obtained through separate shooting operations demonstrated that the number of bullet-wound tracts ranged from 1-6. 3% of animals did not display at least one bullet-wound in either the cranium, cervical spine or thorax, and an inferred IDR of 70% was estimated from these examinations. This is slightly greater than that which was recorded during *ante-mortem* observations.

Statistical analysis of additional variables found shooter identity, as with Hampton et al. (2014), to be the most important determinant of higher IDR.

## Discussion

As with the previous studies, the present example of welfare assessment has successfully applied parameters developed for the assessment of large cetaceans in a terrestrial setting. Further, it has demonstrated similar outcomes for TTD and IDR as reported for feral camels; this is only other animal subject to helicopter shooting that has had associated welfare parameters quantified (Hampton et al. 2014). In addition to these parameters, a key development of the present study is the recording of ‘chase-time’, and thus quantifying the total duration in which the animal is subject to stress from the hunt (Table 5). This is a key aspect of addressing welfare concerns for hunted animals, and challenges the notion that it is only the physical killing methods that must be assessed. Bateson & Bradshaw (1997) analysed samples from red deer (*Cervus elaphus*) subjected to hunting with dogs, some of which were pursued across 19km of rough terrain. They found an increase in so-called ‘stress-hormones’ such as cortisol following *post-mortem* examinations. Similarly, other studies have found significant effects of hunting at the population level that can indicate strong physiological responses in species subject to heavy hunting pressure. Bryan et al. (2015) compared hair samples obtained from two populations of wolves (*Canis lupus*); one subject to heavy hunting pressure, and one where this pressure is significantly less. The study recorded higher progesterone, testosterone and cortisol levels in the samples from the heavily hunted population. It is thought that this is an indication of increased reproductive output in response to higher anthropogenic mortality. Specifically, the increased cortisol was thought to reflect social instability among the heavily hunted population, demonstrating the need for physiological effects to be accounted for in management plans for targeted animals.

With the potential for substantial physiological impacts upon hunted animals, both directly and indirectly, the quantification of chase time by Hampton et al. (2017) is an important parameter in assessing the welfare outcomes of hunts. With respect to hunts of large cetaceans, hunts vary between region in terms of methods used in the pursuit of an animal. Using a comparison of minke whale hunts (*Balaenoptera acutorostrata*) in Norway and Japan as an example, the manner in which the whales are approached has been subject to discussion (NAMMCO 2010, 2015). Norwegian vessels, once a whale has been identified, will try and estimate it's next point of surfacing and attempt to move into position along side the whale without a definite 'chase-phase' occurring in the hunt (NAMMCO 2015, Øen 2015). By contrast, Japanese offshore whaling vessels may actively pursue an animal, sometimes with the assistance of a sonar device and attempt to harpoon the animal during a fast chase (NAMMCO 2010). This difference could be of significant interest to those wishing to assess welfare outcomes in marine mammal hunts. If the duration and intensity of the chase were to be parametrised in the same way as TTD and IDR are recorded, then this will add to the developed framework for hunting methods assessment. Hampton's various papers have discussed how techniques used in the assessment of large cetaceans has been applied in terrestrial setting. The quantification of chase time in horse population management should be considered as a useful addition to the suite of parameters assessed in whaling operations.

**Summary**

The intensive study of large whale hunts led to the development of key parameters used to quantitatively assess welfare outcomes. The combination of *ante*- and *post-mortem* observations allow an accurate evaluation of the duration and intensity of suffering during the killing process (Øen 1995, Knudsen 2005, Hampton 2017). Knudsen (2005), along with NAMMCO Expert Groups have remarked upon the notable lack of studies quantifying similar parameters in the hunts of terrestrial mammals, especially with regard to time-to-death. Moreover, this is surprising given the disparity between the criticism received by whaling operations in comparison to terrestrial shooting and wildlife management programs. Working with the assessment framework developed for cetaceans, potential terrestrial studies now have a benchmark from which to assess their respective hunting methods.

The work documented by Hampton (2017) has successfully demonstrated the application of *ante-mortem* parameters such as time-to-death, instantaneous death rate, and wounding rate (a rough analogue to Struck-and Lost), in assessment of herbivore management programs. With *post-mortem* observations additionally considered, the work presents the first application of the large cetacean framework for welfare assessment.

Furthermore, the papers associated with the shooting of rabbits, kangaroos, horses and camels evaluate hunting methods, and aim to quantify additional variables associated with the improvement of animal welfare outcomes. Specifically, Hampton et al. (2016) relates TTD, IDR and WR to projectile energy and distance at which animals have been shot, while Hampton & Forsyth (2016) evaluate flight behaviour of conspecifics with regard to efforts made to reduce disturbance. While in the study of helicopter shooting of camels (Hampton et al. 2016), recognition is given to the importance of shooter identity, the use of a helicopter prompted scrutiny of the total duration of stress using this technique for wildlife control. In the study of feral horses, the authors presented the first quantification of the duration of the chase, commencing at the first observed avoidance behaviour from the helicopter shooting platform. Studies demonstrating the physiological importance of stress allow the full appreciation stress and suffering of total duration of a hunt, not just the moment of bullet or harpoon impact. It would be of interest to incorporate chase time into the assessment of marine mammal hunting methods, enabling further improvement of welfare outcomes.

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