Chapter 6

Improving Animal Welfare Outcomes for Live-Trapped Terrestrial Mammals in Australia

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Abstract – Terrestrial mammals have been captured by humans for many purposes for thousands of years. Traps fall into 2 broad categories: killing traps and restraining traps. Traps are used for a range of purposes depending on cultural history and country. Here we describe and apply a hierarchy of control measures derived from common Work Health and Safety protocols as a means of identifying and improving the welfare of trapped animals. It is a systematic and pragmatic approach for welfare risk assessment and decision making which, when applied, should lead to improved animal welfare outcomes for trapped animals. Within each of 4 controls in the hierarchy, we expand on the considerations that should be made by research and pest control trappers, with a focus on practices in Australia. These considerations include decisions on which trap to use, where to set them, how to set them, checking schedules and handling of trapped animals. We also make recommendations about education, training and engagement of trappers to improve and maximise the welfare outcomes of trapped animals.

Introduction

Terrestrial mammals from across the globe are often captured or trapped for a variety of purposes including harvest, lethal control, conservation, rescue, translocation, livestock and human health, and research. Traps are either traps that kill, e.g., snap-back traps for commensal rodents, or restraining traps that hold the live animal until released or euthanised. Live-trapping requires temporary physical confinement and restraint of the animal with some sort of device such as nets, pitfall traps, box or cage traps, leghold traps, snares, or larger fenced corrals of some sort (Tasker and Dickman 2001; Powell and Proulx 2003; Iossa *et al.* 2007). An incredible variety of trap types are used given the diversity of species targeted for trapping, ranging in size from the European pygmy shrew (*Sorex minitus*; 4 g) to African elephants (*Loxodonta africana*; 6,000 kg).

Humans have been capturing animals for millennia (Bateman 1976; Bugir *et al.* 2021), and societies have typically supported such practices as a necessary activity to obtain and secure food or clothing (e.g., hunting, crop and livestock raising; Bateman 1976). In the Northern Hemisphere, trapping has had a strong focus on fur-bearing and food provisioning, broadly under a banner of hunting. In Australasia, trapping has been focussed on introduced pest animal removal for agricultural and biodiversity asset protection (Meek *et al.*, 2022). However, integration of trapping for invasive animal control and saleable products, e.g., European wild rabbits (*Oryctolagus cuniculus*) in Australia for hat production from the felted fur and brush-tailed possums (*Trichosurus vulpecula*) in New Zealand for furs and fibre, continues, as does trapping for wild foods in New Guinea. Irrespective of culture, country or trapping intent, modern Western society expects and demands continued improvement in trapping practices. Since the 1970s, there has been increased interest in the wellbeing and welfare of trapped animals (e.g., Van Ballenberghe 1984, 2006; Proulx and Barrett 1989; Byrne *et al.* 2015), with some people calling for prohibition of such animal capture and use (e.g., People for the Ethical Treatment of Animals, https://www.peta.org/issues/wildlife/cruel-wildlife-control/cruel-wildlife-trapping/; the Furbearer Conservation project, https://furbearerconservation.com/a-world-without-trapping). Much of the opposition to animal trapping has arisen from increased community awareness of the potential harms animals can experience when captured, ranging from distress to physical injury and, sometimes, death. Trappers and regulators in many societies are now under increasing pressure to justify contemporary trapping methods and demonstrate efforts to improve the welfare of trapped animals (Littin *et al.* 2004; Littin and Mellor 2005; Sharp and Saunders 2011; Petit and Waudby 2013; Meek *et al.* 2019).

The aim of live trapping is to capture a target animal alive. Interpreting the key points of Littin *et al.* (2004) specifically for trapping for invasive animal control, we should strive for exemplary protocols and methods. Such protocols and methods would be practical to use, efficacious in removing the targets, and effective in reducing their negative impacts on the environmental or agricultural assets to be protected. From a human and environmental welfare viewpoint, protocols and methods must be safe for practitioners and other people exposed to it, and for the environment. For maximised animal welfare outcomes, the protocol and methods must be specific to the target species or individuals, and as harm-free as possible, causing the minimal achievable distress, pain and suffering. "*Although such a gold standard is difficult to achieve, we can only retain ethical credibility if we conscientiously strive to make incremental improvements towards that gold standard*" (Littin *et al.* 2004, page 1).

Trapping is not without risk and unavoidably causes some level of impact to trapped animals, whether they be target or non-target animals (Short and Reynolds 2001). Where traps and their method of deployment are designed primarily with only the target species in mind, non-targets can suffer because of their unique characteristics that differ from the target, be they anatomical, physiological or psychological (e.g., Surtees *et al.* 2019). This can also be true for individuals at different life stages within the target species. For example, sub-adult animals might be more or less resilient than adults, pregnant or lactating females might be more distressed than males while restrained, or males might be more susceptible to capture myopathy during breeding (e.g., small Dasyurids; Barker 1978).

Some level of distress and injury is unavoidable even in the most humane traps because most animals experience distress from restraint when captured regardless of trap type (e.g., White *et al.* 1991; Fowler 1995). These include behavioural, biochemical and physiological changes that occur while trapped (e.g., Van Ballenberghe 1984; Kreeger 1988), or transient oedema and bruising caused by compression of trapped limbs (Kreeger *et al.* 1990; Fleming *et al.* 1998; Schütz *et al.* 2006). Most trappers and regulators are aware of these realities and have long sought to improve both equipment and techniques (e.g., Short and Reynolds 2001; Reagan *et al.* 2002; Grisham *et al.* 2015;) to achieve the ultimate aim of maximum efficacy, efficiency, target specificity and humaneness (e.g., Mowat *et al.* 1994; Meek *et al.*1995; Fleming *et al.* 1998). However, contention and disagreement continue to surround the acceptability of various trapping techniques because of continued impacts on animals (Littin *et al.* 2004; Littin and Mellor 2005). Widespread misunderstanding of the trapping process contributes to this disagreement, and can be inadvertently fuelled by trappers or regulators failing to provide a suitable training and certification framework or failing to suitably articulate details of trapping processes to all stakeholders.

Multiple variables interact to produce a trapping outcome, including but not limited to: trap type and features; location and placement; season and timing; technique including attractants and lures; and the physical and behavioural characteristics of the target animal. Every outcome can then be assessed by any human observer. The latter can be especially problematic, depending on each individual observer's value system, preconceptions and the practical knowledge they possess.

To manage both the real and perceived impacts of live-trapping on animals, it is useful to apply a 'hierarchy of control measures' approach, similar to modern Workplace Health and Safety or occupational health and safety practices (e.g., Safe Work Australia 2018; Safework NSW 2019), to refine and improve animal trapping (Figure 1). There are four components to the assessment of risks and their management in workplace health and safety protocols used in modern workplaces: (1) elimination of hazards; (2) engineering solutions to reduce hazards, which include design modifications, technological substitutions, and isolating a person from a hazard; (3) execution solutions, which includes administration of procedures, and; (4) education and training of staff, including the mandating of personal protective equipment that is of a standard that eliminates or reduces the hazard to the individual worker. We propose that 4 similar steps be taken to improve welfare standards for trapped animals in trapping programs. These we discuss and demonstrate in a trapping welfare context, then we expand upon 10 issues for consideration in a trapping program to minimise adverse animal welfare outcomes. We further demonstrate their application through case studies of Australian mammals of different sizes.

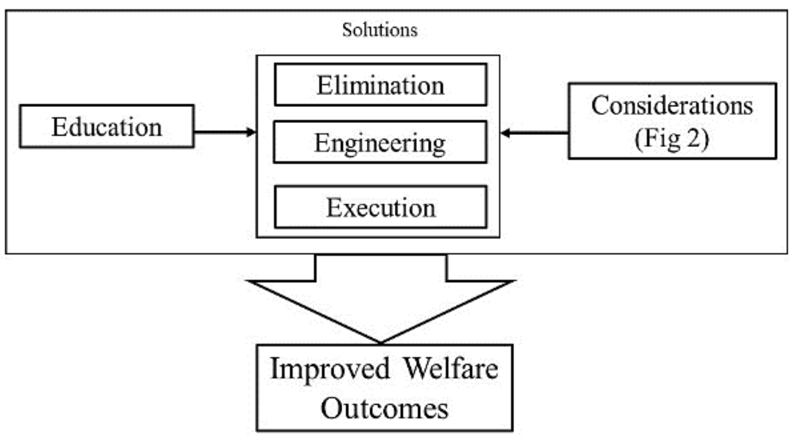

Figure 1. A conceptual model using the four Es and associated considerations for improving the welfare of trapped animals.

Our aim is to deconstruct and explicitly discuss each of the various considerations involved in trapping target animals in relation to a hierarchy of control measures, with the goal of helping trappers, critics, regulatory authorities and other concerned stakeholders to better identify the source of any arising animal welfare issues and the potential points of intervention to mitigate and overcome them. Though we focus on terrestrial mammals and use Australian mammals in many of our examples, this process is broadly applicable to the safe and less harmful capture of any animal.

Hierarchy of control measures

Our hierarchy of control measures for improving the welfare outcomes for trapped animals consists of 4 'E' solutions: (1) Elimination, (2) Engineering, (3) Execution and (4) Education (Figure 1). In the fourth solution, we include training, certification, extension and active engagement of trappers and other stakeholders to ensure aspiration towards better welfare standards and continual improvement. Additionally, broader scale education is necessary to raise awareness of the solutions and improvements required to address misconceptions that may be held by the public. Throughout the process of using the four Es to ensure the best possible welfare outcomes for trapped animals, several considerations and logical steps allow for the best trap selection, the best placement of the trap in the field, the best timing for trapping, and the best checking and handling protocols (Figure 2).

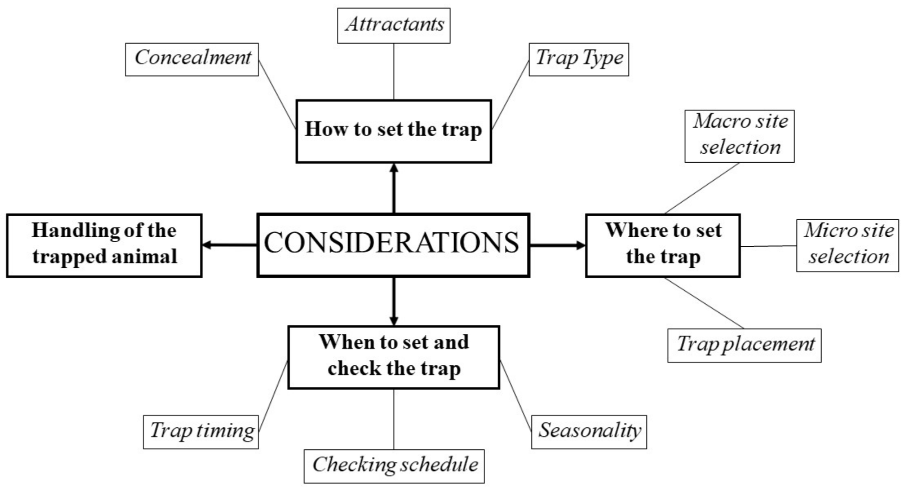

Figure 2. Factors that must be considered for practical improvements to the welfare of trapped animals.

Elimination

Firstly, it must be decided if the physical trapping of an animal is really necessary for the management purpose (Littin *et al.* 2004). For example, trapping for lethal control might be eliminated if the target animal can be physically excluded from an area to be protected by fencing (e.g., Moseby and Read 2006; Trinkel *et al.* 2016), by keeping guardian animals (Andelt and Hopper 2000; van Bommel and Johnson 2012), or by using poisoned baiting or shooting. Each of these is not without animal welfare consequences (Allen *et al.* 2019; Marks *et al.* 2000; Smith *et al.* 2020), but it can be helpful to consider whether or not trapping is necessarily required to achieve the management objectives in the first place.

Wildlife population estimation often relies on capture-mark-recapture methods, where animals are captured and marked in a permanent way, released and then either recaptured or resighted (Pollock *et al.* 1990; Alpizar-Jara and Pollock 1996). Capture might be avoided using less or non-intrusive remote sensing, for example, camera traps (Meek *et al.* 2014), drones (Hodgson *et al.* 2018), or aerial infrared imagery (Kinzel *et al.* 2006). Trapping should never be considered where it is not required or where factors such as a lack of aptitude, training and experience of potential operators are present (see Education solutions, below).

Table 1. Common trap types and their welfare features.

Trap type	Target species	Common welfare features
Pitfall traps	Small mammals, reptiles	• Depth tailored to exceed the jumping height of target animals, but not too deep that it will cause serious injuries from falling. • Bedding, shade, floating and weatherproof material placed in the bottom of the pit to allow animals to avoid unfavourable weather conditions.
Box traps	Small mammals	• Sufficient space to enable animals to stand and turn around. Trap hinges placed on the outside of the trap to avoid injuring captured animals. • Solid sides to protect from wind, rain and sun, and to hide trapped animals from predators. • Air vents along the top and the bottom. • Food typically provided. • Bedding.
Cage traps	Medium-sized mammals	• Treadle plates used instead of hooks. • Spacing between bars or mesh to discourage animals from attempting to squeeze their head through the mesh • Sufficient space to enable animals to stand and turn around. • Soft or flexible panel options • Food and water can be provided.
Soft-catch leghold traps		• Sufficient length of chain to enable animal to move around, but short enough to prevent high-speed tugging. • Crush-proof swivels to prevent limbs from twisting and fracturing during struggles. • Chain springs to act as a shock absorber and prevent dislocations. • Horizontally offset jaws the prevent lacerations and excessive compression of the foot. • Rubber pads applied to jaws, or smooth and broad jaws to prevent lacerations to the trapped foot.
Soft-catch foothold traps	Small to large carnivores	• Sufficient length of chain to enable animal to move around, but short enough to prevent high-speed tugging. • Crush-proof swivels to prevent limbs from twisting and fracturing during struggles. • Chain springs to act as a shock absorber and prevent dislocations. • Chain attachment to the centre of the baseplate and not the side, to prevent fractures. • Rounded, offset jaws the prevent lacerations and excessive compression of the foot. • Rubber pads applied to jaws, or smooth and broad jaws to prevent lacerations to the trapped foot. • Smaller jaw height when closed to prevent animals being caught too high on the leg.
Corral traps	Large herbivores	• Various door or gate styles to suit target species. • Food and water typically provided. • Usually catches whole groups of animals, and not just single animals. • Spacing between bars to discourage animals from attempting to squeeze their head through the mesh • Sufficient space to enable animals to stand and turn around.

Engineering solutions

Design

The second consideration is the type of trap to be used, and the most appropriate size and specific features of that trap. A systematic approach has been to first identify animal welfare issues for both target and non-target or bi-catch animals, and devise technical solutions. Proposing use of the right trap for the target animal and the outcome required (e.g., food and clothing acquisition, crop and livestock protection, or collaring for movement research) might sound trite, but trappers often use what is available, culturally acceptable, or traditionally used, which may not be the most appropriate trap (Meek *et al.*, 2022). Animal welfare can be subjugated to pragmatism or perception and tradition when a suitable trap with better animal welfare outcomes but equivalent efficacy and efficiency might be available but not used (Meek *et al.* 2019). Trappers must be aware of better alternatives before they can make such choices, highlighting the necessity of an education solution (see below).

Many types of traps exist, but they are not equally suitable for catching all types of animals. Even for a single species, there can be many different trap types to choose from, and even the same trap type can have a variety of minor modifications that can make a large difference to animal welfare outcomes (Table 1). For example, foothold traps used to capture mid-sized canids such as dingoes (*Canis familiaris*, ~16 kg), coyotes (*C. latrans*, ~11 kg), black-backed jackals (*C. mesomelas*, ~8 kg), or European red foxes (*Vulpes vulpes*, ~5 kg) include Victor SoftCatch®#3, and Jake™ or Bridger traps (Minnesota Trapline Products, Inc.). Each of these come in various sizes suitable for each of these species (Meek *et al.* 2022).

Besides their general mechanism being one where the animal stands on a plate and the spring-loaded jaws close on the foot, several other more subtle features are important for determining the welfare outcomes of using such traps. These include the number and size of jaw springs, presence of a chain spring, presence of swivels, chain length and where it attaches to the trap, trigger mechanism, adjustable pan tension, presence of rubber pads or offset jaws and whether or not those jaws have sharp or smooth edges. How the trap is tethered or fixed in its placement is also an important consideration. Each of these and other features are intended to help achieve the ultimate aim of catching and holding the target animal in the least harmful way possible.

Once the most appropriate trap is chosen there is always room for further improvement, particularly of the design (e.g., Kreeger *et al.* 1990; White *et al.* 1991; Meek *et al.* 1995). The most obvious solutions are to modify existing traps by removing hazards for target animals, such as removing the teeth on steel-jawed leghold traps and replacing them with rubber pads (York *et al.* 1999a,b). Adding physical barriers to prevent non-target animals entering tunnel traps can reduce impacts on protected species (Short and Reynolds 2001). For restraining traps used in the culling of invasive animals, devices such as 'trap alerts' that send messages via SMS or radio to a trapper when a trap has been triggered (Woodford and Robley 2011; Meek *et al.* 2021), tranquilizer tabs (Balser 1965; Sahr and Knowlton 2000), and lethal trap devices (Meek *et al.* 2018a; Meek *et al.* 2019) attached to traps, can all reduce stress and suffering to trapped animals by reducing the time it is restrained and exposed to environmental stressors.

Identifying missing trap features that, if added, would help improve animal welfare outcomes may be one way of resolving animal welfare concerns, mandating minimum standards for trap types is one way that trapping regulators can ensure that trapping is conducted in the best way possible (Proulx *et al.*, 2022a,b,c), and trappers can assist this effort by maintaining the functionality of all trap features in good working order.

Substitution

Substituting one trap design for another to achieve better welfare outcomes often depends on the target animal and the suite of potentially susceptible non-targets. If one of the concerns about trapping is the frequency and severity of trapping injuries, then a useful way to reduce injury rates is to carefully consider the type, size and features of the trap that may be contributing to or impacting upon observed welfare outcomes. Reducing the size of a given trap type might also assist (especially for foothold traps), as may reducing the space between wire bars in a cage trap. Changing one trap type for another trap type may be one way of improving animal welfare. For example, replacing foothold traps with cage traps to capture feral cats (*Felis catus*) may have better welfare outcomes for accidentally caught sympatric predators and scavengers, such as birds of prey, spotted-tailed quolls (*Dasyurus maculatus*) and varanids. The morphology of cat limbs, temperament and behavioural response when captured by legs or feet might lead to more injuries than restraint in a cage from which they can later be released unharmed (Sharp and Saunders 2011). If lures or attractants are used, these can be tailored to increase the chances of capturing the desired target while repelling or having a neutral effect on non-targets.

In Australia, macropods are common in areas where predators are trapped using leghold and foothold traps. Large traps such as the modified Lane's Ace used for trapping dingoes, sometimes capture kangaroos and wallabies (Fleming *et al.* 1998), which are susceptible to capture myopathy (Shepherd *et al.* 1988; McMahon *et al.* 2013). By substituting these for smaller traps with a smaller jaw spread, many captures of macropods can be avoided as their foot and lower leg is ejected when the trap is triggered because of gross morphological differences to canids.

Execution solutions

Here we describe a generalised process for successfully trapping terrestrial mammals in ways that produce the best welfare outcomes (Figure 2). These considerations are arranged within 4 categories: (1) where to set the trap, (2) how to set the trap, (3) when to set and check the trap, and (4) handling of the trapped animal, assuming that trappers have already established which animal they are targeting and proceeded through the aforementioned elimination and engineering steps.

Where to set the trap

Macro-site selection – One consideration towards safely catching an animal is macro-site selection, or deciding where trapping will be undertaken. This could be a national park or conservation reserve, a large game farm, a livestock ranch, a suburban backyard, or urban garden. Whether or not trapping needs to occur in a given area often depends on the purpose of trapping. If trapping is undertaken to acquire large numbers of predators, e.g., dingoes, then attempting to trap them in urban gardens (where few exist) is unlikely to be sustainable, and trapping them in a large wilderness area of some sort may be the only sensible choice. Conversely, if trapping aims to remove a problematic brushtail possum from inhabiting the roof cavity of a residential house in Australia, then trapping in nearby bushland is unlikely to be as successful as trapping in and around the affected house. Thus, macro-site selection is often determined by the distribution and density of the target animals and the objectives of the trapping program, with trappers often having little flexibility in self-determination of macro-site selection. However, within the distribution of the target species, macro-site selection is still a choice, which makes it the first place that trappers might begin to consider potential animal welfare improvements.

Macro-site selection is also an important step influencing the target specificity of a trap or the frequency of non-target captures. If one of the concerns about trapping is that too many non-target species are being captured, then trapping at a different site might be one way to address this concern. Macro-site selection also has a strong influence on the required frequency of trap checking (discussed below), and selection of a site should include consideration of any access constraints that may affect how frequently traps can be checked. If one of the concerns about trapping is that too many animals are suffering unacceptable welfare impacts because they remain in traps for too long, due to access constraints at the site, then trapping at an alternative site with greater access (i.e., more roads, tracks and trails) might be one way of improving animal welfare. Ultimately, macro-site selection is a key step in determining the success, efficacy, and sustainability of a trapping program, in addition to being a key determinant of non-target target captures, the required frequency of trap checking, and other related welfare issues. Macro-site selection can also be one way of reducing risk to humans and avoiding unnecessary human interference with trapping programs.

Micro-site selection – The next consideration for safely catching an animal is micro-site selection, or deciding where the trap should be placed within the broader area. This could be at a waterpoint, a crossroad, under a tree, a cave or nest entrance, along a trail or animal pad, at a food source, or at a hole in a fence. Potential micro-sites where traps can be placed are infinite, and depend almost entirely on the biology and behaviour of extant target and non-target species. For example, if the target animal is water-limited and must drink each day (such as feral pigs or hogs *Sus scrofa*), then trapping around water sources may be a successful micro-site. If the target animal is one that regularly follows animal trails or pads through the landscape (such as dingoes), then setting traps along such trails may be the most effective. Micro-site selection is arguably one of the most important choices trappers can make to determine the outcomes of a trapping program.

Much like macro-site selection, micro-site selection has a strong influence on the numbers of target and non-target animals captured. Poor micro site-selection is not always a problem for the welfare of target species because it may simply mean that fewer target animals will be captured, however, it can affect target species in some instances. For example, placing foothold traps at the base of a tree or fence post might cause the animal to become entangled, disabling the welfare features of traps (e.g., swivels, springs) and facilitating greater incidences of broken or dislocated limbs (Fleming *et al.* 1998; Kreeger *et al.* 1990).

Poor micro-site selection also increases the likelihood that non-target animals will be captured, creating welfare impacts that would otherwise be avoided if better micro-sites had been selected. For example, placement of a foothold trap behind a log crossing a trail used my multiple species is likely to be triggered by the most common species present (e.g., livestock, herbivores), which may not be the target species (e.g., red foxes). Capturing a non-target animal not only causes unnecessary harm to that animal, but it also prevents target animals from being captured in that trap, reducing the efficacy of the trapping program. If one of the concerns about trapping is that too few target animals and too many non-target animals are being captured, then improving micro-site selection can be an effective way of reducing these animal welfare impacts. Improving micro-site selection requires sound knowledge of the fine-scale behaviours of animals present at the site, which is only gained through experience. Experienced trappers familiar with the behaviour of target species are usually very capable of identifying appropriate micro-sites suitable for trapping, and should share this knowledge with novice trappers to ensure that animal welfare is maximised over time. To gain experience, it is best that a novice trapper has a period of industrial placement with a mentor (See Education solutions below, and Meek *et al.* 2022).

How to set the trap

Trap placement – Traps should be cleaned, sterilised and checked that they are in proper working order before use. After this has been completed, another consideration for safely catching an animal is trap placement, or setting the trap in the particular manner likely to catch, hold, or restrain the animal in the intended way. For example, foothold traps should be placed with the intent to catch animals on one of their front feet, with the jaws closing on the front and back of the foot, and not from the sides, which can lead to an awkward and uncomfortable grip on the foot. Pan tension and trigger speed should also be checked and adjusted to maximise the chances of capturing target animals and avoiding non-target animals. Cage traps or corral traps should be placed in a way that makes it easier for the target animals to enter the open door or gates. Box traps can also be placed in a way that discourages non-target animals from tampering with the trap, such as securing it to the ground or facing the door towards a tree. While macro-site selection is about the general area where trapping is conducted, and micro-site selection is about the locations where animals are expected to visit or move through, trap placement is about where, exactly, the trap is placed at the micro-site to maximise the chances of catching the target animal in the intended way while minimising the chances of non-target captures or tampering.

Appropriate trap placement also requires a high level of experience and knowledge of animal behaviour and morphology. For example, a foothold trap placed too far from where the animal will likely stand while investigating attractants (see below) will mean that the animal will not stand in the trap and trigger it, or will stand on the jaw of the trap and not the pan, discovering the concealed trap and thereby avoiding capture. Alternatively, poor trap placement may result in animals getting caught in the locking wings of the trap where the rubber pads do not reach, rather than across the foot as intended, causing lacerations. A cage trap placed in a manner that makes it difficult or less intuitive to be captured may result in the animal attempting to remove the attractant through the rear wall of the trap, rather than entering the trap from the open door at the front. It is impossible to predict and plan for all possible ways that all extant animals may approach the trap and be captured, and some level of imperfect captures and their resultant animal welfare harms may still occur. But, with practice and experience, small refinements to trap placement can greatly improve the welfare outcomes for target and non-target animals alike.

Concealment – A further consideration for safely catching an animal is concealment of the trap, or concealment of the fact that the trap is indeed a trap. Foothold traps, for example, are typically concealed just below the surface of the ground so that animals are less aware of the trap when they place their foot or feet near it while investigating scent or other attractants used by the trapper. Other trap types, indeed most traps, cannot be concealed in this way and are visually observable by animals. In these cases, concealment of the trap means making the trap appear as though it is a safe, innocuous, even inviting device that presents no risk to the animal. This may require, for example, pre-baiting, covering a cage trap with branches and leaves, and/or holding a trap door open to make the trap entrance appear safe and welcoming. For some trapping applications, the target species may be so interested in the attractant that concealment of the trap is not even necessary.

Concealment primarily affects the efficacy of trapping programs at catching the target animal, but concealment can also be an animal welfare issue when it increases non-target captures. Failing to properly conceal foothold traps may increase the hazard to non-target animals like birds (Durham 1981). Tampering with traps can also be a 'welfare concern' for humans, and for this reason, warning signage is often used to notify people of the presence of traps that may be unsafe for inexperienced people to tamper with. Concealment can also affect animal welfare by providing shade to captured animals. When used in this way, it is not intended to hide the trap from the animal, but to protect captured animals from extreme environmental conditions, e.g., very cold or warm temperatures. Whether or not concealment is necessary is context-dependent, but it can be an important factor influencing animal welfare outcomes in some situations.

<u>Attractants</u> − Another consideration for safely catching an animal is the use of attractants to encourage the target animal to approach and enter the trap. Attractants or lures should be target-specific and unattractive to non-target animals, or potentially even dissuade non-targets from entering. The type or nature of attractants is also infinite, and can include olfactory, visual, or audio attractants. Common attractants for small mammals include grains such as oats, rice or wheat, which are often mixed with peanut butter to form a small, aromatic bait ball (Calaby and Wimbush 1964). Common attractants for scavenging carnivores include fermented or rotten meat, or the carcass of a deceased animal. Territorial carnivores are often attracted with pungent urine, faeces, or the scent glands from other carnivores (Fournier 2011). Large herbivores may be attracted with lucerne or other forage hay or salt supplements. Useful attractants are not limited to substances intentionally placed by trappers at the micro-site, but also include landscape features that are 'naturally occurring' such as log piles, holes in fences, water sources, or animal trails. Some trappers also use various techniques to 'call' animals. For example, the sound of a distressed prey animal can be used to attract predators, or the sound of a mating call can be used to attract unsuspecting mates or rivals. In each case, the chosen attractant is intended to elicit a desired behaviour that will increase the chances of catching the animals; for example, some attractants are intended to persuade the animal to consume something, whereas others are intended to persuade the animal to urinate or roll.

From an animal welfare perspective, the type of attractant used is important because it has a strong influence on which animals are captured – targets or non-targets. One frequent animal welfare concern arising from the use of attractants is the capture of non-target scavengers whenever a food-based attractant is used. When trapping dingoes with foothold traps, for example, use of food-based attractants can increase capture rates of non-target lace monitors (*Varanus varius*), brush turkeys (*Alectura lathami*) or brushtail possums, all of which are more likely to suffer injuries in traps intended for large canids. In this case, capturing dingoes may require preferential use of urine-based attractants which are not as attractive to such non-targets. Instead, a trapper may avoid olfactory attractants altogether and use an audio or visual attractant. The allure of attractants also varies temporally when, for example, food-based attractants are used at a time when preferred prey abundance is high. Furthermore, animals can become both habituated to attractants (i.e., 'trap-happy') or repelled by attractants (i.e., 'trap-shy'). For each of these reasons, it is important to regularly consider the types of attractants used and their influence on target and non-target captures.

When to set and check the trap

<u>Seasonality</u> − One other consideration for safely catching an animal is seasonality, or consideration of the time of year that trapping is being undertaken. Many species exhibit strong seasonal patterns in behaviour. For example, reptiles may hibernate in winter or juveniles of many species become present and trappable in spring. Seasonality affects the suite of target and non-target species that may be trappable, the size of the individuals, and the welfare of those species once captured. For example, some non-target species that frequently enter traps may not be present at certain times of year, so trapping at these times may reduce non-target captures. Trapping at times when lactating females are present may prevent such females from feeding their young, indirectly harming and potentially killing animals that were not even trapped. Trapping

in extreme temperatures may also place captured animals at extreme risk of hypo- or hyperthermia. In each of these cases, changing the seasonality of trapping programs may reduce or even eliminate animal welfare concerns. This may not be possible given the objectives of the trapping program, but it can be a simple and useful way to improve the animal welfare outcomes of trapping in many situations.

Trap timing – Another consideration for safely catching an animal is trap timing or consideration of the time of day that trapping is undertaken. Many species have regular daily patterns of activity which can be exploited to increase trapping success, and also useful for minimising undesirable welfare outcomes. For example, crepuscular or nocturnal animals might be better trapped in the late afternoon or during the night when they are most active. For these species, opening traps just before sunset and closing them after checking each morning would minimise non-target captures of sympatric diurnal species, and reduce instances of heat stress resulting from animals being restrained in traps over the hottest part of the day.

Considerations of trap timing can also refer to trapping during extreme weather conditions (such as heatwaves, fire events or flooding), or not trapping over weekends when traps may be more likely to be encountered or tampered with by the public. Unlike seasonality, which is a long-term consideration of the best time to trap the target species, trap timing is a much finer time scale and decisions on trap timing may vary on a day-to-day or even hour-by-hour basis. Deciding to delay trapping by a day can have the potential to considerably improve welfare outcomes; for example, trapping rodents in wet, cold weather can result in high mortality from hypothermia, where trapping the following day under improved weather conditions may have no mortality events at all. This welfare consideration is harder to predict or prepare for in advance, but thresholds for when trapping should be delayed can be determined prior to active trapping, and for the most part decisions on delaying trapping should err on the side of caution. Avoiding the scheduling of inflexible trapping periods can assist this effort.

Checking schedule – The next consideration for more humanely trapping animals is trap checking times, or the frequency that traps are checked and times of day that those traps are checked. Trap checking schedules that leave animals in traps for excessive periods lead to prolonged suffering and risk or exposure or predation. Conversely, too frequent checking can disrupt target animal movements and result in poor capture success. In the case of foothold trapping, where traps cannot be visited within 24 h due to vast distances, like those in some Australian landscapes, toxins or trap alerts should be used or the trapline could be subdivided into sections which are trapped in intervals. Consideration must also be given to how many animals are likely to be captured in the whole trapping array, and whether or not this will delay the checking of other traps that might contain animals. Do not set so many traps that captured animals cannot be processed within a reasonable timeframe. It may be necessary to review the trap array early in the program if traps cannot be serviced within acceptable time frames, or increase the number of personnel involved in the trapping program. Most jurisdictions have requirements mandating the maximum periods of time animals can be restrained, and animals cannot be left without food, water and shelter for longer than 24 h, so checking at least once every day is also legal best practice.

Handling trapped animals

The final consideration towards safely catching an animal is how the trapped animal is handled. After the initial capture period, the entry of a human into the trapped animal's purview is probably the most stressful time for the animal. It cannot escape from the approaching 'threat' and injuries potentially occur as it tries to do so. If the animal is to be euthanised for control, then this should be done in a way that minimises the duration of the animal's struggles. More detail on processes recommended for the trapping and euthanising of pest vertebrates can be found in published codes of practice and standard operating procedures (Sharp 2012; 2016; Proulx *et al.*, 2022b,c).

When live trapping for later release, the approach of humans and subsequent handling will cause the animal distress because it involves more prolonged physical contact. Consultation of standard operating procedures, recommended wildlife management practices and codes of practice will enlighten trappers about the minimum expected welfare standards for handling trapped animals for research and conservation, and the tools and strategies to minimise adverse welfare outcomes (e.g., Petit and Waudby 2013; Waudby *et al.* in press). Detailed requirements will also be outlined in animal care and ethics approvals and associated standard operating procedures that must be attained when any animal is being captured for research. In practice, the handling of animals should be done with confidence, calmness, care, compassion, and prompt execution.

Education

Education, extension and engagement of trappers and the public are probably the most important components of improved animal welfare in trapping because it is through these activities that the benefits of elimination, engineering and execution are facilitated and realised. Here we briefly discuss aspects of education and specifically trapper training, and extension and community engagement actions that help with improving the welfare of trapped animals (more detail for foothold trapping education and training is provided in Meek *et al.* 2022). For trapping to keep pace with community expectations and for the public to be accepting of trapping practices, their awareness of the realities of trapping needs to be raised through education and extension. Likewise, for trappers to maintain currency and social license, they need to be aware of community expectations, including the legislative requirements of their trade. This can be included in training programs.

Training, certification and licensing

Trapper training, certification and licensing takes many forms throughout Australian jurisdictions. In some States, untrained and unqualified people can undertake trapping programs with no formal recognition of their animal welfare obligations. These usually take form in 3 categories; professional trapping contractors/employees, farmers and farm labourers, and the general public. While inhumane treatment of pests using traps is recognised in animal welfare legislation across the country (Hampton and Hyndman 2019; Meek *et al.* 2021), many people using traps are unaware of the legal requirements surrounding this practice. Professional trappers have increasingly been required to undertake formal training courses to become certified, although there are no consistencies across the nation in regard to training requirements despite a nationally accredited training course being available through registered training organisations (Meek *et al.* 2022). Diverse training courses are available throughout jurisdictions for farmers and farm labourers, but again, there is no national consistency in the certification process. The absence of trapping certification in Australia results in any member of the community being able to purchase trapping equipment and commence trapping without any instruction, awareness of the best animal welfare practices, or demonstrated competency.

Introducing a more formal framework around trapping in Australia is crucial to improving animal welfare outcomes from trapping practices and securing the future use of this tool for management and research. However, this approach will have varying support from the trapping fraternity. Meek *et al.* (2018b) surveyed Australian foothold trappers and reported that they generally agreed that a standardised approach to trapping legislation was preferred, although there was little support for a formal licensing system. A legal framework for trapping is consistent with international standards and aspirations for humane trapping (Proulx *et al.* 2020).

Extension and engagement – In addition to the education of trappers and those who manage them (above), it is vital that stakeholders in animal management, funding bodies and regulatory authorities have a sound understanding of best trapping practice as a wildlife management technique. This has not always been a key focus in managing trapping programs, leading to perceptions of secrecy that can be readily interpreted as trappers 'having something to hide'. Negative perceptions or criticism quickly fill an information void and spread readily, so it is in the interest of trappers and the organisations or industries that rely upon trapping to be proactive in engaging with the broader public.

Posting photos or videos of trapped animals on websites or via social media platforms is often counter-productive to positive extension and engagement. Although it represents key aspects of trapping, most audiences typically lack important context that help them understand why and how that situation has occurred. The same outcomes can result when members of the public unexpectedly encounter trappers at work, occasionally leading to conflict.

Consequently, when trapping for research or control, we have found it useful to call public meetings in advance of trapping programs to talk through key aspects of Elimination, Engineering, Execution and

Education with the local community. In conjunction with these, we normally provide information about the objectives and reason for the trapping program, contact details, social media and/or website details about the program, including information on what to do if trapped animals are encountered. At a broader level, for agencies or authorities intending on implementing trapping to achieve wildlife management goals, appropriately scaled, proactive extension and engagement is vital to maximise understanding, acceptance and support (Hampton *et al.* 2020). Providing documents that outline the decision-making process, such as the Conservation Risk Assessments used to justify wildlife control activities (NSW National Parks & Wildlife Service 2020), is one possible approach.

Exemplification case studies

Trapping of rodent-sized mammals: small box trapping

Australasia has a predominance of small marsupials and rodents, some of which are introduced and invasive. These range in size from a few grams, e.g., small carnivorous dasyurids like the long tailed planigale (*Planigale ingrami*, females ~4 g) to the largest rodent, the Bosavi woolly rat (*Mallomys* spp.), of the New Guinea highlands (1.5 kg). Pest rodents, e.g., ship rat (*Rattus rattus*) and house mouse (*Mus musculus*), can be trapped with snap-back kill traps, but live trapping of native rodents is often undertaken for research and conservation in small box or cage traps; their use is the topic of this case study.

Which trap to use

Trapping small, native mammals in Australia is only permissible for research or conservation; native species cannot be trapped for fur or consumption and use of products. All native wildlife is protected under various jurisdictional legislation and can only be live-trapped. As a result, the only kill traps permissible for small mammals are snap back traps strictly for control of introduced pest rodents like ship rat and house mouse. Australian terrestrial native species from the small dasyurids up to bandicoots (Peramelidae) weighing <2 kg are caught using small aluminium box traps and other trap types such as pitfall traps. Similar traps are used globally for this size class of mammals. Three types are used most widely including Elliot (size A and B), Sherman (size E, A and F), and Longworth traps. Choosing the most appropriate trap design to suit the target species and investigation is very important and will depend on the species targeted. Sound project design and planning are inter-related (Ripley 1980), with implementation and subsequent optimal animal welfare results. While bandicoots can be caught in small box traps, there are inherent risks with using them for this genus; primarily that adults can be too large for the trap and this risks injury. Choosing a larger size box trap where bandicoots are the target species should be considered in the risk assessment. Similarly, from a capture efficacy perspective, using a B size Elliot trap for a *Planigale* spp. (12g) survey would be an inappropriate sampling method. Striking the balance between capture efficacy and specificity, and animal welfare is judicious.

When to trap

Planning to conduct trapping for Australian wildlife must adhere to strict animal ethics approvals and licensing from various jurisdictional agencies; the general public is prohibited from trapping native wildlife in Australia. Decision making around timing of trapping should recognise a range of factors that may result in adverse effects on target species if ignored (Waudby *et al.* in press).

Assessing the level of risk when capturing animals with pouch young, on the teat or in a burrow should be front of mind. Holding a female that is rearing young in any form may result in adverse effects on the litter if she cannot return to feed them in a timely manner. Therefore, avoiding the breeding season to limit this risk is advisable. If this is not an option, then more frequent trap checking maybe necessary (Tasker and Dickman 2001; Petit and Waudby 2013). Physiology of the animal including life history must be considered to minimise the chance of catching animals that may be at risk during certain times of year. As an example, *Antechinus* spp. populations undergo a male population semelparity where they spend the last few weeks of their life repeatedly copulating until they become so diseased and immunocompromised that they all die. Trapping during this time can result in considerable trap deaths because animals do not have the fitness to endure being caught in a trap overnight.

Where to trap
Foldable box traps are often deployed in transects or grids; the ideal spacing depends on the species, habitat, habitat complexity-structure, and research question(s) being addressed. Prior to setting traps, consideration must be given to checking each day and the routine and staff available to check and remove animals from traps each morning. Setting too many traps with too few people may put some species at risk of prolonged exposure and death. Setting a number of box traps to suit the site with the appropriate level of resources to check the traps must be estimated prior to undertaking trap deployment. In some cases, a revision of the survey design maybe required if trap servicing is unexpectedly longer than planned, including closing and removing traps completely. Closed box traps can still catch some animals, therefore leaving box traps with doors closed is insufficient to remove the risk of a forced entry by some species.

Choosing where to deploy trap transects and grids must recognise the logistics and servicing traps and the associated risk to the health and wellbeing of capture fauna. Setting traps in steep and inaccessible terrain may result in increased trap checking times, or allow traps with captured animals to be dislodged by predators and competitors and tumble-down slopes. Furthermore, the placement of traps should be targeted towards optimising capture success of the study animal (Gurnell and Langbein 1983) while ensuring protection from extremes of weather. Placing traps in the open, away from woody debris and vegetation may expose animals to heat, rain and wind. Given that most box traps are constructed of aluminium, these traps can act like a refrigerator causing excessive stress to trapped animals. Placement must ensure the trap is on solid ground to prevent premature door closure from trap instability and catching an animal before it is fully inside, thereby stripping the flesh off the tail (Petit and Waudby 2013). Setting them on the morning shade side of woody debris in summer and on the un-shaded side in winter will assist with controlling for internal trap temperatures. Setting traps in micro-sites to limit exposure from un-expected rainfall should all be included in the decision process for each trap placement.

How to trap
Traps should be inspected ahead of deployment for malfunctioning, sharp edges and faults that may either cause injury or compromise capture efficacy. Box traps can become damaged by captured animals, during transport or through long term use. Compromised traps should be repaired or replaced.

To ensure the least discomfort to trapped animals as possible, every trap should contain bedding material to assist with the animal controlling its body temperature (Petit and Waudby 2013). A small mammal laying only on aluminium is unacceptable in harsh environments and appropriate bedding material should be included (Waudby *et al.* in press). Materials such as coconut fibre provide good insulating qualities (Green and Osborne 1981; Meek *et al.* 2006), can be made into a bed by the animal and repels some scats and allows urine to sieve through the material, unlike cotton wool which quickly becomes soiled and can become tangled in the animal's appendages. Engineering solutions may also be considered to assist with protecting animals similar to the extended Elliot A+ trap design (Meek and Elliott 1995) that provides more space for placing trap bedding to help protect nesting animals.

It is advisable to consider the type of bait to attract the animal and also to consider the bait as an overnight food resource. For some species, it maybe be worth considering adding multiple food groups (high energy items) to a bait to both attract and feed the trapped animal. Conversely, using a bait type that may attract unwanted predators can result in trap interference or predation of trapped prey species, which may be avoidable. Where unexpected weather is likely, it is important that plastic bags or equivalent shelter (Petit and Waudby 2013) are available to keep animals dry and minimise ingress of water from squalls. Ultimately, if conditions are likely to pose a significant risk to animals during a program, then traps must be deactivated until work can be resumed. Trapping duration is often 3-4 nights (Tasker and Dickman 2001), although where additional trapping effort is required, it is recommended that traps be closed on night 3 to enable recaptured animals to recover (Tasker and Dickman 2001).

Handling the trapped animal
Checking traps must be done as soon as possible after sunrise each day and in some cases where animal ethics approvals require it, or where diurnally active animals are caught, trap checking or opening may be necessary in the afternoon before sunset. Handling of animals in box traps should only be undertaken by

people that have been trained or are being supervised. Removing animals from box traps should be swift and done so as not to harm the animal. The preferred method is to empty the animal into a plastic or calico bag for handling (Petit and Waudby 2013), but this depends on the practitioner and animal species. Handling must be done quietly and gently always in recognition of the sensitivity of the animal to handling and using a level of restrictive force commensurate with the size and health of the animal. Taking morphology measurements, tagging collaring and collecting DNA must be done promptly to enable the animal to return to its shelter. Taking un-necessary measurements and extending handling time should be avoided. Upon completion, animals should ideally be placed back at the site they were trapped or at least within several metres to ensure they return to familiar habitat and do not face competition or predation.

Cage trapping of medium-sized Australian animals

The largest terrestrial herbivores in Australasia are macropods (up to 80 kg), but most Australian mammals are small- to medium-sized animals when compared to those on other continents. Here we use trapping of yellow-footed rock-wallabies (*Petrogale xanthopus*), which are medium-sized macropods associated with rock piles in the arid zone of Australia, as the case study species for cage or box trapping of Australian animals of ~2–10 kg. Welfare outcomes are greatly improved through application of the hierarchy (Figure 1), followed by deliberation of the considerations (Figure 2). As a result of trial and error and more recent welfare evaluations, cage traps of various types are the most commonly used method to capture wallabies for research and conservation (Waudby *et al.* in press). Therefore, this case study expands on trapping using cage traps to emphasise welfare considerations and how to deal with them.

When to trap

Cage trapping of rock-wallabies in the arid zone is only done in the cooler months of the year to avoid heat stress in captured animals, which is a significant risk associated with trapping in the summer. Rock-wallabies are also generally much less active in the summer months due to the heat (good seasonality selection). Additionally, summer months are when the primary non-target species caught during rock-wallaby trapping are most active (lizards; typically, varanids (Varanidae) and shinglebacks *Tiliqua rugosa*). Opening traps in the afternoon and closing them during the day also mitigates these undesirable welfare outcomes, as animals are only in the traps during the night and the coolest parts of the day, and reptiles are least active at this time. Traps are also not set during rainy or unseasonably hot weather (good trap timing). A good practice is to set only 10 traps per processing team. In a best-case scenario when all traps are full, only 10 animals can be checked and processed in the time after dawn before it gets too hot. This prevents animals being in traps in the hottest parts of the day and minimises the time they spend in traps when they could be foraging or shading. Traps are also only open for 3 days, so if trap-happy individuals are caught repeatedly, they have time to recover from trapping (good checking schedule).

Where to trap

While macro-site selection is largely determined by the species' range, yellow-footed rock-wallabies in the arid zone are limited to very specific geographic formations. These formations occur both on national parks and private property, and this allows options for choosing macro-sites that are less likely to result in non-target captures (good macro site selection). Due to the heat in the arid zone, even in cooler months of the year, micro-site selection favours shaded areas, particularly under trees, or in places where the cliffs rock-wallabies use as primary habitat shield the trap from the sun for the majority of the day (good microsite selection). Choosing appropriate micro-sites (on the side of scree slopes) also reduces the opportunity for tampering by both humans (who typically walk the top of the cliffs) and non-target species such as goats (*Capra hircus*) and red kangaroos (*Osphranter rufus*). Traps are placed on ground as flat as possible and under shrubs or in nooks, where possible. These considerations of placement ensure that it is more likely to catch rock-wallabies (good trap placement), make the animal feel safer in and around the trap (good concealment), and the flat ground provides a safe and suitable place to process the animal after capture (good handling). Correct placement on flat ground also prevents a trap becoming dislodged and rolling down the slope.

How to trap
Rock-wallabies can be caught in medium sized, soft-wall treadle traps. Historical trapping of rock-wallabies occurred in large and rigid wire mesh traps; however, rock-wallabies were prone to injuries in these traps, and by replacing the rigid cage with shade-cloth and flexible wire mesh, these injuries could be mitigated. Reducing the size of the cage restricted large/fast movements by the animals, also reducing injury (i.e., good trap-type selection). Rock-wallabies are lured to the trap using a food lure, which is initially free-baited to habituate rock-wallabies to move in and out of the trap and to determine if other species such as possums, will potentially interfere with trapping efficacy for the targeted rock-wallabies. In the early stages of free baiting, rock-wallabies are drawn to the trap with an olfactory lure. This process reduces stress in the animal when active trapping. Water is also provided in the trap in a small container fixed to the wall of the trap to ensure the animal stays hydrated, which is particularly important in the arid zone (i.e., good use of attractants and good animal welfare).

Handling the trapped animals
Rock-wallabies are removed from the trap, placed in a hessian sack, and held firmly by placing them between the legs of the handler while sitting on the ground. Loud or sharp noises (clicks) are to be avoided while handling rock-wallabies. The hessian sack acts as a sensory deprivation aid, and firmly holding the animal stops struggling. Both these actions (somewhat counterintuitively) decrease heartrate and stress (D. Smith, unpublished data) in the animal by stopping escape behaviours and pacifying the animal (i.e., good handling).

Foothold trapping predators
The largest terrestrial predators on mainland Australia are dingoes and feral dogs, which are collectively referred to as wild dogs and weigh an average of 15.7 kg (Allen and Leung 2014, Fleming *et al.* 2014). They are followed by European red foxes (~5–7 kg ; Saunders *et al.* 1995) and then feral cats ($\bar{x}$ = 4.2 kg; Denny and Dickman 2010). Dingoes were brought to Australia by indigenous people about 5,000 yrs ago, and foxes and cats arrived with Europeans about 250 yrs ago. All three are considered invasive, and are targeted for lethal control in many places to protect livestock and threatened species principally from their predation, but also from the parasites and pathogens they transmit (Fleming *et al.* 2014, Woinarski *et al.* 2019). Broad-scale distribution of poisoned bait is the most common control tool used against these predators, although trapping with soft-catch foothold traps is also very common. Foothold trapping is also a standard method for capturing these species for research purposes, where the same principles apply.

Which trap to use
A variety of trap types are used to capture predators, mostly those that catch the foot or lower leg (Meek *et al.* 2022). When used for control of dingoes, these traps can be fitted with poison-laced cloths wrapped around a jaw or para-aminopropiophenone (PAPP) packaged inside a Lethal Trap Device (LTD), which dingoes chew and consume following capture (Meek *et al.* 2019). Cages are most used for feral cat capture and are sometimes used to catch foxes and dingoes, although they tend to be less effective than concealed foothold traps for these larger canids.

Choosing which foothold trap to use for the 3 predators described above is largely a personal preference of the trapper (Meek *et al.* 2019), although some jurisdictions dictate trap features which influences which trap model can be used (Meek *et al.* 2022). The objective of canid trapping in Australia is to capture the animal by the front foot (see above), and choosing a trap size that is commensurate with the morphology of the target species' foot must be considered. Setting large Bridger sized traps for foxes and feral cats may cause injuries that can be avoided by choosing smaller traps. For general trapping of the 3 species where they co-occur, traps in the size class of Victor #3 are suitable for all species, usually resulting in minimal injuries.

When to trap
Although feral cats can breed whenever resources are ample (Jones and Coman 1982; Woinarski *et al.* 2019), dingoes and foxes have an annual breeding cycle (Jones and Stevens 1988; Saunders *et al.* 1995; Cursino *et al.* 2017) where courtship and mating occur in April-May and pups are typically born in July (mid-winter). Juveniles become independent, active and trappable over the spring and summer. Dingoes,

foxes and cats can be captured at any time of the year, though greater numbers of animals are typically captured over the summer and autumn months when juveniles are dispersing and mature animals are seeking mates. Capture rates are typically the lowest in late winter and early spring. Trapping for dingoes can occur under all environmental conditions, although trapping during extreme weather should be avoided to minimise risk. Trapping can be undertaken in extremely hot weather and can be very successful at these times, particularly by trapping near water sources which dingoes must visit regularly (e.g., Allen *et al.* 2014). However, traps must be checked regularly throughout the day (e.g., Meek *et al.* 2019), including at sunrise and sunset and during the night to minimise stresses caused by thirst and exposure. Consideration must also be given to trapping during denning and whelping seasons when young maybe dependent on food and protection from adults.

How to trap

In rural, remote or wilderness settings with low human population densities, traps are best placed at behavioural focal points such as road intersections, animal trails, high-points along ridge tops, low points (saddles) along ridge tops, creek crossings, water points, livestock corrals, or any other landscape feature where predators have been observed to frequent. Inspecting potential micro-sites for the presence of scats, scratch marks or foot prints can be a useful way to identify successful micro-sites where traps can be placed. Once such a site has been selected, traps should be placed in a manner that maximises the likelihood of catching an animal by its front foot, which may require rotating or angling the trap in a particular way to mimic the specific physical characteristics of the chosen micro-site. Attractants will often be used in association with the trap and include predator faeces- or urine-based lures or scents, and food-based attractants (depending on timing, e.g., during prey shortages). These food-based attractants can increase non-target capture rates in some circumstances, e.g., varanids. Traps should be tethered to the ground with a stake, or preferably two in loose soil. Some trappers also use heavy drags, such as logs or concrete blocks, intending for captured animals to move away a short distance from places of exposure and human interaction, but not too far that they cannot be found. These can be useful, but trapped animals have been observed to move considerable distances when drags are too light, and animals also tend to snag themselves on other landscape features and become entangled. Using drags should be avoided where possible for these reasons.

Handling the trapped animal

When dingoes, foxes and cats are being trapped for lethal control purposes, trapped animals should be euthanized by firearm with a single shot from a short distance (i.e., <10 m (Sharp and Saunders 2004a). Alternatively, if an animal is particularly active and cannot be reliably euthanized with a single shot from this distance, then the animal may be first restrained with a catch pole before euthanizing it with a single shot at point blank range with a small calibre firearm (e.g., .22 rimfire) or with a captive bolt (e.g., Blitz Kerner; Sharp and Saunders 2004b). Animals might also be euthanized by lethal injection.

When dingoes, foxes or cats are being live-trapped for later release, trapped animals should first be secured with a catch pole. Animals can then be moved to a restraining board, and their head covered by a hessian bag to ease the distress of handling and to improve handler safety. Dingoes and foxes can alternatively be physically restrained by hand and their mouth secured during processing, without the use of a restraining board or head covering. Sedatives might also be used, particularly for feral cats. Care should be taken to prevent humans from being bitten or scratched by captured animals, and care taken to prevent zoonotic pathogens. Care should also be taken not to restrict the animal's ability to breath, which is the most serious threat to animals during handling. Animals should also be inspected for any injuries before being released. Swelling of the trapped foot occurs in almost all animals but can be easily treated prior to release. Bruising also occurs at times and animals sometimes experience minor lacerations to the captured foot and the mouth obtained while struggling in the trap. These types of minor injuries are temporary and animals quickly recover. Serious injuries (e.g., simple fractures) occur very rarely, and more serious dislocations and compound fractures occur even more rarely when using soft-catch foothold traps in the manner described here (Meek *et al.* 1995; Fleming *et al.* 1998). Animals with such injuries should be euthanized to avoid infection and prolonged suffering if released. Necrosis of the tissues below the point of capture can also arise with live-trapped animals that are released (Byrne and Allen 2008). Such injuries are not observable at the time of capture and release, so re-trapped animals should be checked for such injuries. Thus, when live-trapping for later release, trappers should do all they can to check traps as often as possible and use trap types and sizes most suited to the suite of extant target animals. Most injuries occur at capture and prior to handling and, apart from swelling and bruising, can usually be avoided by careful trap type selection and placement, regular trap maintenance and trap checking.

Discussion

A great variety of terrestrial mammals are trapped for an array of purposes all over the world. Although the welfare of trapped animals has not always been a major concern historically, the welfare of trapped animals is definitely a major concern now (Dubois and Fraser 2013; Dubois *et al.* 2017). Social pressure to prohibit all forms of trapping is strong in many places, and those seeking to continue trapping must constantly be striving to improve animal welfare or risk the loss of trapping altogether. In debates surrounding the welfare and ethics of mammal trapping, we have observed a tendency to recommend prohibition of trapping before even seeking to understand the source of any welfare concerns and how these concerns might be mitigated. In other words, a concerning animal welfare harm associated with a given trapping practice might be easily overcome with a simple change to that practice, rather than prohibition of the practice altogether. In this way, trappers can still meet their animal protection or research objectives while mitigating the practice of concern.

During the 1980-1990s, considerable changes in direction took place in Australia to improve pest control practices for animal welfare benefit. In 1979, the *Prevention of Cruelty to Animals Act* was proclaimed in NSW and similar legislation was later passed in all other jurisdictions, creating a legal process for implementing change in practices. Prior to this period, foothold trapping was solely undertaken using toothed, steel-jawed traps (Meek *et al.* 1995). In the 1980s, Stevens and Brown (1987) redesigned an Aldrich foot snare from the USA to capture wild dogs and foxes, with new functions to improve animal welfare outcomes. These traps were distributed in the east coast and were mandatory in the Australian Capital Territory and Victoria for a short time before Victor SoftCatch® traps were tested (Meek *et al.* 1995) and recommended as a suitable alternative to both snares and toothed steel-jawed traps (Meek *et al.* 1995; Fleming *et al.* 1998). Other mechanisms for change have been assessed to improve welfare outcomes in Australian trapping (Marks 1996, Marks *et al.* 2004). However, there has been no formalised structure for ongoing improvement of the welfare of trapped animals in Australia.

Here we have provided a framework for identifying and mitigating animal welfare harms associated with terrestrial mammal trapping. This framework is based on the same type of process used to mitigate workplace injuries and harm to humans, and broadly involves a hierarchy of controls that are implemented to mitigate the observed risk or harm (Figure 1). After identifying an animal welfare concern such as unacceptably high injury rates or non-target capture rates, a variety of factors should be considered (Figure 2) when seeking to find ways of addressing the concern and improving animal welfare. Careful consideration of these factors will help identify potential areas of improvement and enable continued use of traps while resolving the concern. Although we have described a framework for mitigating objectively described injuries and harm, this framework does not seek to mitigate subjectively described ethical concerns about trapping animals. In other words, stakeholders will find our framework useful for identifying and mitigating harms associated with trapping, but our framework is unlikely to alleviate concerns about the moral acceptability of trapping in the first place. Discussion of these moral and ethical issues is not found here, but is present in the broader literature on wildlife management and conservation (Littin *et al.* 2004; Littin and Mellor 2005; Wallach *et al.* 2015; Dubois *et al.* 2017; Allen and Hampton 2020; Wallach *et al.* 2020; Bobier and Allen 2022).

We encourage use of our framework to improve the welfare consequences of terrestrial mammal trapping. Before a trapping program is instituted, our hierarchy of control measures can be applied to help direct the program and minimise or eliminate potential adverse animal welfare outcomes for targeted and untargeted animals. After the decision to trap has been made and the engineering solutions applied, execution solutions come into play. Each of the considerations should be scrutinised if undesired welfare outcomes are occurring during trapping programs, to see whether they are causing harm and how changes to them could alleviate negative outcomes. The final investments in improving animal welfare outcomes for trapped animals are not only improving the practice of trapping but expanding the knowledge of both trappers and the public through education, extension and engagement. Approaching the process of continual improvement in this way will reduce welfare impacts associated with trapping while enabling the continued practice of trapping.

Littin *et al.* (2004) refer to 6 major principles required for ethical pest control. We propose that these same principles are commensurate with our described hierarchy of control measures. They proposed that aims and harms must be clearly defined, control must be achievable and effective, best practice must be adopted, measures of success must be assessed, and outcomes maintained. By applying our principles of the four Es – (1) Elimination, (2) Engineering, (3) Execution and (4) Education (Figure 1) – to pest control and research using trapping, we propose that best practice and the first 4 principles described by Litten *et al.* (2004) can be achieved. That is, when efficacy is maximised, harm is minimised and trapping practices are applied to the highest standard possible, the best welfare outcomes for trapped animals accrue.

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Animal welfare and conflict of interest statement.

Because this paper is a review, no animals were handled for its production. The authors declare no conflicts of interest: the views expressed are their own and are not influenced by their employers or research funders.

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