Mammal Trapping

Wildlife Management, Animal Welfare & International Standards

Edited by

Gilbert Proulx

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Mammal Trapping

Wildlife Management, Animal Welfare & International Standards

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EDITED BY

Gilbert Proulx, PhD

Director of Science
Alpha Wildlife Research & Management

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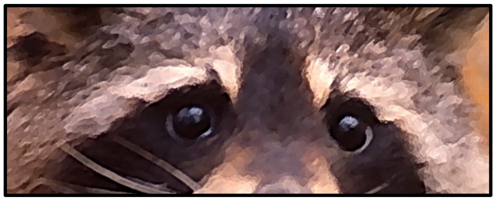
Preface



"CONCERNED"

An animal captured for several hours in a restraining trap, injured and anxious, is certainly concerned about its fate. Wildlife scientists are concerned with the welfare of mammals captured in either killing or restraining trapping systems. This is because animals may suffer hours in killing neck snares, or starve to death in restraining traps that are irregularly checked by trappers. Naturalists are also concerned about the welfare of trapped mammals, and this is not new. In his 1926 book entitled *Animals,* naturalist Ernest Thompson Seton reported about the horror of a steel trap set with a spring pole that jerks the game into the air and keeps it hanging by a leg through long days and nights in all types of weathers, and the lack of "humanity" of steel traps to capture grey wolves (*Canis lupus*). Since the early 1900s, many organizations have tried to reform trapping, mainly because of their concerns about the welfare of trapped animals. Also, in 1989, I pointed out with my co-author Morley Barrett that the issue of "humaneness" has surfaced generation after generation, and now "inbred animal activists" fight against "inbred wildlife biologists" who support steel leghold traps.

It is out of concern for the welfare of trapped mammals that Alpha Wildlife Research & Management (AWRM) held its first symposium on mammal trapping in 1997 in Edmonton, Alberta, Canada. This was an opportunity for scientists to discuss advancements in mammal trapping technology and describe protocols used to assess the welfare of trapped animals. This was followed by the release of the book *Mammal Trapping* in 1999, which I edited. Unfortunately, little of this information was retained by governments officials and the fur trade industry when they developed the Agreement on International Humane Trapping Standards (AIHTS), which was signed by the European Community, Canada and Russia. Such standards were vehemently criticized by many wildlife professionals over the years, and in 2020, a few colleagues and I pointed out that the AIHTS did not represent state-of-the-art trapping technology when it was signed in 1997, and it definitely failed to properly address animal welfare in trapping. Individuals involved in pest control and fur trapping dismissed or downplayed the concerns raised by professionals, naturalists and conservation organizations about mammal trapping, and claimed that all these people were unrealistic and unpractical.

Concerns about mammal trapping have not been resolved with the release of international standards in 1997, and Alpha Wildlife Summits (a Division of AWRM) organized a virtual symposium on mammal trapping in November 2021 to discuss issues related to wildlife management, animal welfare, and international standards. The Summit brought together leading scientists from around the world who submitted manuscripts that were peer-reviewed and corrected before their presentation at the Summit.

History and concerns about wildlife management, animal welfare and standards are addressed in the first 10 chapters of this book. In Chapter 1, I review the various aspects of trapping through a series of questions explaining how trapping has been, and continues to be, necessary in wildlife research and management, and for the subsistence and wellbeing of various communities. This chapter also reviews the performance thresholds of trap standards, capture efficiency and selectivity, and alternative methods to trapping. In Chapter 2, animal welfare concerns associated with the capture of Northern river otters (*Lontra canadensis*) are reviewed, along with a critical assessment of Best Management Practices in the USA. Chapters 3 and

4 relate to animal trap testing in Europe, and stress the importance of animal-based scientific protocols to improve animal welfare. Efforts to improve animal welfare and trapping technology in Australia are discussed in Chapters 5 and 6. A range of recent legislative and technological advances, all aimed at improving the culture and practices of trappers in Australia, are presented. Chapter 7 includes a discussion of the term *humane*, and a review of the magnitude of poor welfare in snared animals. While the AIHTS standards are known to be inadequate to ensure proper animal welfare in trapped mammals, their lack of implementation in Canada is stressed in Chapter 8. Also, Chapters 9 and 10 point out that traps used in urban and sub-urban areas may be highly unselective and inhumane, thus endangering the wellbeing of pets and wild animals in general.

While capture efficiency is an important aspect of mammal trapping, Chapter 11 gives an example of a situation where elevated wariness by black-backed jackals (*Canis mesomelas*) as a behavioural adaptation, particularly by older animals, may impact on long-term lethal control practices on farmlands in Africa. This study suggests that the potential impacts of continued lethal control on the behaviour of jackals and other mesocarnivores need to be acknowledged and managed to avoid selecting for compensatory life history traits that may intensify conflicts with small-livestock farmers. Chapter 12 describes a series of modifications to trapping systems to improve their humaneness, and suggests new technology that should be considered to enhance animal welfare in restrained animals. Finally, Chapters 13 to 16 show how important it is to determine the levels of physical injuries, and behavioural and physiological changes, to properly assess restraining trap systems. These reviews and studies show that there is sufficient knowledge and technology to assess restraining traps on the basis of behaviour, physiology (stress), and molecular biology.

The prerequisites for the development of state-of-the-art mammal trapping standards that would address most of the concerns voiced aby the scientific community and the public are provided in Chapter 17. These prerequisites include many of the concepts and solutions presented in Chapters 1 to 16, provides improved criteria for the assessment of killing and restraining trap systems, address the lack of information associated with the use of submersion trappings systems, and properly address trap checking times, efficiency and selectivity. The standard operating procedures to implement the prerequisites of Chapter 17 are provided in Chapter 18 for killing trap systems, and Chapter 19 for restraining trap systems.

Throughout its chapters, this book provides the most current information to improve mammal trapping technology and animal welfare, thoroughly quantifies the assessment of all mechanical trapping systems, and addresses many of the issues and concerns associated with mammal trapping. I believe that this book provides realistic solutions to address concerns voiced by the scientific community and the public about mammal trapping and the sound stewardship of wildlife resources.

Gilbert Proulx, Editor
April 2022

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Chapter 1

The Five Ws of Mammal Trapping

Gilbert PROULX
Alpha Wildlife Research & Management Ltd., 229 Lilac Terrace, Sherwood Park, Alberta, T8H 1W3, Canada. Email: gproulx@alphawildlife.ca

Abstract − In this paper, I review questions about the 5 Ws − Who, What, When, Where, and Why − of mammal trapping that I judge significant to better understand the pros and cons of mammal trapping: who traps mammals and who objects to such activities; who is responsible for professional and ethical mammal trapping; what is mammal trapping, the performance thresholds of standards, capture efficiency, and selectivity; what alternatives can be used to mammal trapping; why mammal trapping is necessary; why mammal trapping is controversial; when mammal trapping should be allowed; when concerns about mammal trapping will stop; where trapping should occur; and where we should focus our attention in mammal trapping. This review points out that there is recurrent questioning about the necessity of mammal trapping and the welfare of trapped animals. On the basis of this review, I recommend the use of a decision process to justify mammal trapping in 5 categories: sustenance, research, human-wildlife conflict, fur trapping, and wildlife management. I suggest that the common denominator for all these mammal trapping categories is the necessity to use state-of-the-art trapping technology and species-selective trapping systems.

Introduction

More than 2,000 years ago, humans trapped mammals for food and clothing, and probably to protect their families from predators (Proulx 1999a). The early trapping devices were relatively crude, and consisted of snares, deadfalls and pitfalls that were not selective and likely did not kill animals quickly. In those days, the welfare of captured animals was not a concern − people trapped for their survival.

Today, many people still trap mammals as a way of life or a recreational activity, to control nuisance animals or predators, to sell furs, glands or skulls, to implement specific wildlife management programs, or to carry out research on populations and habitats. However, mammal trapping is a source of concern for the public and wildlife professionals. While current standards such as those of the International Organization for Standardization (ISO 1999a,b) and the Agreement on International Humane Trapping Standards (AIHTS; ECGCGRF 1997) do not reflect state-of-the-art trapping technology and poorly address animal welfare issues (Proulx *et al.* 2020), the public continues to wonder about mammal trapping, wildlife conservation, and the treatment of animals (Bekoff 2002; McLaren *et al.* 2007).

In order to understand the benefits as well as the drawbacks of mammal trapping, it is important to review mammal trapping in the context of its history and today's influences and events. Therefore, in this paper, I review questions about the 5 Ws − Who, What, When, Where, and Why − of mammal trapping. There is no limit to the number of questions that may be asked under these categories. I focused on those that I heard or discussed the most often in more than 45 yrs as a field wildlife biologist, trapper, researcher, and manager.

Who

Many people trap animals, and many others object to animal trapping. In wildlife conservation, it is essential to understand diverging views and biases vis-à-vis trapping, animal welfare, and trade in order to develop sound wildlife management programs.

Who traps mammals?

Indigenous peoples

The technology and use of restraining and killing traps (e.g., snares, deadfalls, slab-ice and stone traps) to capture mammals is well documented historically in Africa (Wadley 2010), Europe (Charles 2002), and North America (McGee 1987; Wright 1987; Shaffer *et al.* 1996). In Canada, subsistence harvesting regimes remain important to some Aboriginal peoples, particularly those living in the isolated regions of the north. These Aboriginal communities prefer these lifestyles (Standing Committee on Aboriginal Affairs and Northern Development [SCAAND] 1986) where the traditional bush lifestyle does not merely represent a symbolic heritage, but rather survives as lived experience (Nelson *et al.* 2005). However, wage employment, a wide range of consumer goods, and more and more Aboriginal people moving to cities are among the factors that caused a significant decrease in trapping among Indigenous peoples (Nelson *et al.* 2005). Stabler *et al.* (1990) and George *et al.* (1995) suggested that many northern Native communities in Canada were best characterised in terms of a mixed economy, one in which people 'going in between' reflects the complementarities of the wage-based economy and the hunter-gatherer economy. Greater participation in fur trapping is best explained by the lack of alternative employment opportunities (Stabler *et al.* 1990). Many Indigenous trappers may therefore be recorded as fur trappers (see below), but their participation in the fur industry may not be consistent from year to year. Subsistence trapping (snaring) is also an important activity carried out by villagers in some African countries (Ntiamoa-Baidu 1997; Noss 2008). Elsewhere, a few Aboriginal communities also adapted to new available resources such as the brushtail possum (*Trichosurus vulpecula*), a primarily herbivorous arboreal marsupial that was introduced into New Zealand from its Native Australia in 1858 to establish a fur trade and has since become widespread and abundant (Cowan 2005). The fur and skins of the possum now represent a valuable economic resource to small, predominantly rural Māori (Indigenous people of New Zealand) communities (Jones *et al.* 2012).

Fur trappers

In North America, the fur trade is more than 600 years old. It is considered an important industry by trapper organizations because it involves thousands of participants (Association of Fish and Wildlife Agencies 2015; Fur Institute of Canada 2019) and contributes to a country's Gross National Income. For example, in Canada, in 2009-2010, 730,915 pelts generated nearly $ 15 millions CAD (Statistics Canada 2010). However, the industry is down with large quantities of furs that are sold at low prices or simply unsold (CBC News 2020; Trapping Today 2020). As is the case with Indigenous peoples, a high portion of licensed trappers may not engage in trapping (Dorendorf *et al.* 2016), and fur harvest is largely influenced by economic factors, e.g., pelt price (Gregory *et al.* 2019). Some people consider that trappers are "weekend warriors", i.e., trapping is a hobby and they go out once a week to check traps and snares (Rocky Mountain Outpost 2016). Nevertheless, in North America, trapping remains a serious pursuit for a group of participants who trap primarily as a valued component of an outdoor lifestyle, maintaining tradition and a utilitarian outdoor activity (e.g., Todd and Boggess 1987; Zwick *et al.* 2002). However, relative to other forms of land use, the market value of fur is small, almost insignificant (Adamowicz and Condon 1987).

Trappers represent a socio-political force that may be used to protect wilderness areas from industrial development (Proulx and Barrett 1991). However, contrary to claims made by some people and organizations (e.g., Alberta Trappers' Association 2019; BC Trappers Association 2021; Molvar 2021), trappers are not wildlife managers. Fur harvesting is only one tool among others used by wildlife biologists to monitor and manage wild animal populations (see Wildlife Management below). Generally, trappers do not monitor the status of populations, natality and mortality rates, age and sex ratios, and home ranges (which may encompass many traplines) vs. habitat changes. Trappers do not address management intricacies associated with species reintroduction programs, species at risk, and new taxonomic classifications. Monitoring changes in furbearer populations and harvest levels, as well as factors contributing to these changes, is necessary to make sound management decisions (Dorendorf *et al.* 2016). However, previous studies have repeatedly found that fur values play a key role in trapper participation (Siemer *et al.* 1994; Elsken-Lacy *et al.* 1999; Gehrt *et al.* 2002; Ahlers *et al.* 2016; Gregory *et al.* 2019). Effective wildlife management is not a part-time activity; it requires consistent, reliable, and factual information about populations and habitats. Wildlife population analyses and wildlife management programs should be re-assessed on a yearly basis, independently of fluctuations in pelt values or other economic factors associated with fur harvests. While wildlife managers take into consideration human activities, they must protect native biodiversity (individuals, species, populations, ecosystems) and the ecological functions and processes that maintain biodiversity (Paquet and Darimont 2010). These are hardly the activities of fur trappers.

Fur trappers are also active in Europe and some are well organized (Union Nationale des Associations de Piégeurs Agréés de France 2019; Hunters of Europe 2021). However, trapping statistics and research appear limited to occasional data on the efficiency of catching animals (e.g., Díaz-Ruiz *et al.* 2010; Short *et al.* 2012).

Pest and predator controllers

Trapping is used extensively in the removal of animals that impact on the wellbeing of human populations, their property, and their activities (Meyer 1991). In urban areas, farms and ranches, commensal species of rats and mice can reach high densities (Corrigan 2001; Witmer and Proulx 2010) that can result in increased cases of rodent-borne disease transmission to humans (e.g., Hjelle and Glass 2000). In agricultural regions, fossorial rodents such as northern pocket gophers (*Thomomys talpoides*) may seriously reduce the annual productivity of hay fields, and must be controlled through trapping (Proulx 1997).

Pest control is not limited to rodents, however, and can include carnivores, which may also be trapped and vaccinated against diseases such as rabies (Rosatte *et al.* 1990). In Australia, most trappers surveyed by Meek *et al.* (2018) categorised themselves as professional trappers, split more or less evenly between government employees and non-government contractors. Their main work is associated with the control of wild dogs (*Canis lupus familiaris*) and red foxes (*Vulpes vulpes*). In many regions of Australia, dingoes (variously referred to as *Canis dingo*, *C. familiaris*, and C. *lupus dingo*; van Eeden *et al.* 2019) and other wild dogs have been largely eradicated to accommodate sheep (*Ovis aries*) production (Fleming *et al.* 2001). Trapping is also used to remove stoats (*Mustela erminea*) and other predators of many forest birds in New Zealand (Dilks *et al.* 2003).

In some circumstances, predator control may be necessary to remove carnivores feeding on people or endangered species (Proulx 2018a). While some pest controllers may also be fur trappers, many of them belong to organizations such as the Canadian Pest Management Association and the National Pest Management Association.

Scientific Researchers

Mammal trapping is vital to scientific research and management as it allows wildlife biologists to collect information on population dynamics, health, and genetics. Mammal trapping may be used to assess the general distribution of a species and better understand habitat selection by animals (Proulx and Barrett 1991). Captured animals may be equipped with radio-transmitters (Fuller and Fuller 2012), behavioural, physiological, and environmental sensors (Whitford and Klimley 2019), and even cameras to better study their behaviours and environments (Watanabe *et al.* 2006; Patel *et al.* 2017).

Wildlife managers

The management of furbearers involves the manipulation of their populations and their habitats (Wolfe and Chapman 1987). It is carried out by wildlife biologists who develop programs to monitor the biological status of each species and maintain viable populations of each species. In jurisdictions where fur harvesting and animal control occur, programs may aim to optimize the harvest of the furbearer resource when furs are in prime, and avoid overexploitation, minimize animal damage, and provide the public with recreational, economical and ecological benefits (Proulx and Barrett 1991).

People of all walks of life

Most urban and sub-urban dwellers use traps to remove commensal rodents that invade their property. Of course, most of them have no training in trapping, and they reluctantly capture mice and rats in snap-traps (many of them being disposable single-use traps) purchased at their local hardware store.

Who objects to mammal trapping?

Mammal trapping is a highly controversial invasive activity that often results in the death of captured animals. Also, it has been the subject of constant criticism since the 1900s by both the public and the scientific world.

Animal welfare and animal rights organizations

Organized campaigns against the use of leghold traps and opposition to trapping originated in the USA in the 1920s (Gerstell 1985) and in Canada in the 1940s (SCAAND 1986). Since the 1950s, hundreds of new animal welfare and animal rights organizations have developed and represent a major challenge to the wild fur industry (Barrett *et al.* 1988). Unfortunately, pro-trapping agencies fail to differentiate animal welfare groups from animal rights organizations (see White *et al.* 2020). While these organizations may express anti-trapping sentiments, there is a major difference in their agenda.

Animal welfare organizations are concerned with the welfare of animals. They object to trapping systems which cause undue pain and suffering to captured animals by causing serious injuries, or involving long periods of distress before death. The Canadian Association for Humane Trapping, Humane Canada, and regional humane societies, are all part of such organizations. These organizations have played a vital role in changing public and political attitudes towards the treatment of animals.

Animal rights organizations are against any form of animal use. Such organizations condemn trapping but also hunting and fishing, the use of animals as companions, for food (livestock, dairy, eggs, etc.), or work (e.g., guide or security dogs) (Proulx and Barrett 1991). Most animal rights advocates believe that animals are entitled to the same basic legal rights as human beings (Singer 1975; Regan 1985). Organizations such as Coalition to Abolish the Fur Trade (2018), Animal Defense League of Canada (2021), Animal Rights Coalition (2021), PETA (2021), and many more argue that all forms of trapping are obsolete, cruel, and unnecessary for wildlife management or human requirements.

Compassionate conservation, consequentialist conservation, and animal welfare

Compassionate conservation is an interdisciplinary field which promotes the treatment of all wildlife with respect, justice, and compassion (The Centre for Compassionate Conservation University of Technology 2019). With the guiding principles of first, do no harm, individuals matter, inclusivity, and peaceful coexistence, compassionate conservation aims to find solutions for conservation practitioners that minimize harming wildlife. Using these guideline principles, wildlife management and research programs encompassing the capture, handling, killing, or translocation of animals may not be acceptable (The Centre for Compassionate Conservation University of Technology 2019). Hayward *et al.* (2019) and Beausoleil (2020) pointed out that, while compassionate conservationists favour non-invasive and non-lethal strategies for achieving conservation goals, such strategies may not be adequate to address conflicts that are detrimental to people or other animals, or when non-harmful ways of avoiding those impacts are not currently available. Applications of deontology (theory that suggests actions are good or bad according to a clear set of rules and forms of virtue ethics including animal rights and compassionate conservation) to conservation and other human activities have been prominent in opposing animal killing.

The welfare of individuals and the ethical treatment of animals are part of conservation biology (Paquet and Darimont 2010; Brook *et al.* 2015). Also, both wildlife management and animal welfare share similar ethical origins in that both have been traditionally underpinned by consequentialist ethics, emphasizing the importance of an action's consequences over other ethical considerations such as moral rules, character traits or rights (Hampton *et al.* 2019). Under consequentialist approaches, contentious actions such as killing are considered ethically permissible if, when compared to alternative actions, they deliver a better balance of positive versus negative welfare effects (Gamborg *et al.* 2012; Dubois *et al.* 2017, Hampton *et al.* 2019). Animal welfare is incredibly important to conservation but, ironically, compassionate conservation does not offer the best welfare outcomes to animals and is often ineffective in achieving conservation goals (Hayward *et al.* 2019).

The philosophy of compassionate conservationists should not be confounded with the views of wildlife professionals who have expressed their concerns about undue pain and suffering in mammal trapping. For example, wildlife professionals have expressed their concerns about animal welfare regarding improper trapping regulations (Proulx and Rodtka 2019), unacceptable trapping devices (Proulx *et al.* 2015, Virgós et al 2016), and poor standards (Iossa *et al.* 2007; Powell and Proulx 2003; Proulx *et al.* 2020).

Who is responsible for professional and ethical mammal trapping?

From a political point of view, government wildlife agencies establish rules and regulations relative to fur trapping. At the scientific level, organizations such as the Canadian Council on Animal Care (CCAC; 2003, 2020), the Animal (Scientific procedures) Act in the United Kingdom (Her Majesty's Stationery Office 2006), the American Association of Zoo Veterinarians (2006), the American Society of Mammalogists (Sikes *et al.* 2011), the American Veterinary Medical Association (2013), and the Australian and New Zealand Council for the Care of Animals in Research and Teaching (2017) provide guidelines for the proper use of animals in research institutions. At the international level, trade standards such as ISO (1999a,b) and AIHTS (ECGCGRF 1997) have been established to address animal welfare in trapping, but they have been highly criticized because they are fur trade-oriented standards, which are not representative of state-of-the-art trapping technology, and fail to properly address the welfare of captured animals (Iossa et al 2007; Powell and Proulx 2003; Proulx *et al.* 2020). When everything is considered, professional and ethical mammal trapping has resulted from the commitment of a core group of scientists who have been personally and professionally concerned with the welfare of animals, and trap research and development − see references to researchers who have been involved in the development of trapping devices in Proulx (1999b), Schemnitz (2005), and Proulx *et al.* (2012, 2020) − and concerned citizens who applied pressure on governments to ban unacceptable traps and find alternatives (Stevens and Proulx 2022).

What

Mammal trapping consists of mechanical devices set in a specific way to capture animals. The components of traps and trapping systems, and the parameters used to determine if a trap is adequate or not for the capture of mammals, are complex.

What is mammal trapping?

Mammal trapping corresponds to the physical capture of animals in traps, snares, boxes, nets, or other mechanical devices. It involves the use of:

- *Restraining traps*: devices used to live-capture mammals. These include cage or box traps, foothold traps, foot/leg snare, cable restraints (neck snares with a modified lock design to stop the noose from tightening), and nets (Proulx *et al.* 2012).
- *Killing traps*: devices used to kill mammals. These include snap traps (mousetraps), planar traps, rotating-jaw traps, killing box traps, manual or power killing neck snares, restraining traps set to slide underwater, and submarine traps (Proulx *et al.* 2012).
- *Trapping systems*: trapping devices with all their parts (trigger configuration and mechanism, springs, closing jaws or striking bar, etc.), sets (construction and location), and baits or lures (Proulx *et al.* 2020).

What is an animal welfare performance threshold?

In today's world, where animal welfare is an important issue for the scientific community (Brook *et al.* 2015; Dubois *et al.* 2017) and the public (van Eeden *et al.* 2017), restraining and killing traps should meet the highest animal welfare standards, and trap standards should be raised as developments on trapping technology allow (Proulx *et al.* 2020). Responsible professionals must strive continuously to improve traps to work more efficiently, more selectively, more humanely, and more safely for both animals and people.

Performance thresholds for killing traps are based on the time period to irreversible loss of consciousness in struck animals. Once consciousness has been lost, animals do not feel pain. The most stringent criterion used to date for the acceptation of killing traps requires that traps render at least 70% of target animals irreversibly unconscious in less than 3 min (Proulx *et al.* 2012, 2020). In the AIHTS standards, traps must render at least 49% of target animals irreversibly unconscious within a time period that changes with species size but is 5 min for the majority of furbearer species (Proulx *et al.* 2020).

Performance thresholds for restraining traps are based on injury-scoring systems, most of which correspond to pathological changes in captured animals (Proulx 1999a). The most stringent criterion used to date for the acceptation of restraining traps requires that traps hold at least 70% of animals for a maximum of 24 h with less than 50 points scored for physical injury, i.e., without severe injuries that could decrease the survival of released animals (Proulx *et al.* 2012, 2020). In the AIHTS standards, performance level is 57% (Proulx *et al.* 2020).

Proulx *et al.* (2020) recommended that performance level corresponds to a minimum number of animals meeting the acceptation criterion. Also, the evaluation criterion for restraining traps should not be based on mean cumulative injury scores as in White *et al.* (2020), because mean scores are affected by extreme individual values; in other words, many low values can mask the presence of an unacceptable number of high injury scores. While a minimum performance of 70% is superior to AIHTS standards, Proulx *et al.* (2020) considered that this minimum performance level was inadequate and should be further improved. New international trapping standards are currently proposed to meet state-of-the-art trapping technology and improve animal welfare in captured animals (Proulx *et al.* 2022). With these new standards, killing traps should render at least 85% of animals unconscious in less than 90 sec for mid-sized mammals, and less than 30 sec for small mammals (Proulx *et al.* 2022). Standards for restraining trap systems also include new performance criteria including physiological and behavioural changes caused by trapping (Proulx *et al.* 2022).

What is capture efficiency?

Capture efficiency is the rate at which a trap catches a target species, and is usually expressed as the number of captures/100 trap-nights. A trap-night is 1 trap set for 1 night. Trap testing in the field may involve comparing the capture efficiency of test traps to that of control traps, i.e., most popular traps among trappers of a region (e.g., Barrett *et al.* 1989). Many factors affect trap efficiency, such as trap type, trap set, bait and lure, number of traps per unit area, visitation rate, trappers' experience and trap use learning curve, and environmental conditions (Pawlina and Proulx 1999). Weakened springs (Gruver *et al.* 1996), distorted components (Warburton 1982), and poorly made traps (Linhart *et al.* 1986) also affect trap performance. Further, the species assemblage and relative species abundance in test areas may vary among regions, and some abundant non-target species in a particular region may be more attracted to test traps than control traps, and vice versa, thus biasing the true assessment of capture efficiency (Proulx *et al.* 2020). If traps are located diffusely over large areas, they may be absent from small home-ranges (Gehrt and Fritzell 1996). If males and females have home ranges of different sizes, trap density will affect the sex ratio of captured animals (King and Powell 2007), and when changing resources lead to changes in the sizes of home ranges, capture efficiency changes (Smith *et al.* 1994). Also, males and females often behave differently towards traps and sets (Gehrt and Fritzell 1996). Some animals become trap-shy after initial capture, while others become trap-happy (Pawlina and Proulx 1999). Resident or dominant individuals may intimidate intruders or subordinates with their scent marks, affecting capture rate (Pawlina and Proulx 1999). The development of traps with high performance level must ensure that capture-efficiency is as high as that of control traps to meet the objective(s) of any trapping program.

What is trap selectivity?

ISO (1999a,b) defined selectivity as follows:

Selectivity = Number of captured target animals/total number of captured animals

However, Virgós *et al.* (2016) showed that the ISO definition of trap selectivity is only a simple capture proportion and therefore does not represent trap selectivity. Indices of trap selectivity should be based on algorithms which use estimates of species availability (Manly *et al.* 2002). An example of an appropriate index of trap selectivity is Savage's *W* index, a selectivity index used in different ecological applications related to the selection of resources (Manly *et al.* 2002), which can be expressed as follows:

W = Capture proportion/population proportion

where the numerator alone (*capture proportion*) corresponds to the current ISO index for trap selectivity. The denominator (*population proportion*) is that proportion of the entire population of possible trapped animals (of all species) made up of members of the target species. A value of 1.0 for *W* indicates no selectivity. Therefore, good quality information on species occurrence and their relative abundance is required to determine the selectivity of a trapping device (Virgós *et al.* 2016). The development of traps with high performance level must ensure that these traps are used in highly selective trapping systems to avoid jeopardizing wildlife communities and impacting on the persistence of species at risk.

What are the alternatives to mammal trapping?

In the past, trapping was used to capture mammals and study their distribution, habitats, health, etc. (Powell and Proulx 2003). Unquestionably, mammal trapping has significantly contributed to our understanding of mammal biology (Proulx and Do Linh San 2016). However, the capture of wild animals has the potential to cause injury and to change normal behaviour and physiology (Kreeger *et al.* 1990; Cattet *et al.* 2008; Proulx *et al.* 2012). Today, several non-invasive methods, i.e., methods which do not require the handling of animals, have been developed (Zielinski and Kucera 1995; Long and MacKay 2012; Proulx and Do Linh San 2016). The use of non-invasive methods help implement Russell and Burch's (1959) 3Rs principles − *Replace, Reduce, Refine* − and limit the pain and distress that animals are exposed to in trapping (Zemanova 2020). The following non-invasive methods may be considered depending on the objectives of the research program:

- Tracks: animal tracks may be inventoried in sand, mud or snow (Rezendes 1992; Proulx and O'Doherty 2006; Long *et al.* 2008) to determine the distribution of species at landscape and habitat levels, individuals' movements during different phenological periods, etc.
- Scats, food caches, and bait markers (Poole and Graf 1996; Schwartz and Monfort 2008; Bischof *et al.* 2016; Proulx 2016) to determine animals' distributions, habitats and food habits.
- Hair and skin (Sloane *et al.* 2000; Castro-Arellano *et al.* 2008; Wilson *et al.* 2021) to determine animals' distributions, habitats, and genetics.
- Huts, burrows, dens, and setts (Proulx and Gilbert 1984; Landa *et al.* 1998; Lara-Romero *et al.* 2012) to determine animals' distributions and habitat use.
- Foraging and feeding signs (Vowles *et al.* 2016) to determine species' distributions and habitat use.
- Scent marking and latrines (Kruuk 1978; Mijller-Schwarze and Heckman 1980) to assess the distribution of populations and estimate territory sizes.
- Cameras and videos (De Bondi *et al.* 2010; Huck and Watson 2019; Proulx and Buckland 2020) to assess habitat use and behavioural activities.
- Direct observations and spotlighting (Dixon 2003; Proulx and MacKenzie 2012).
- Questionnaire surveys and web-interface records (Proulx and Drescher 1993, Seiler *et al.* 2004; Aubry and Jagger 2006) to assess distribution, use of habitats, and human-wildlife conflicts.
- Although the collection of roadkills and carcasses from trappers is not a true non-invasive method, carcasses found along roadsides or collected from trappers or hunters, can be used to assess population structure, age and sex ratios, reproduction, genetics, etc. (Roper and Lüps 1995; Robitaille 2017).

Why

Why is mammal trapping necessary?

Mammal trapping is being justified by many explanations ranging from sustenance to health concerns among human populations, and disease prevention and management of animal populations (Proulx and Barrett 1991), to religious beliefs where humans have authority over the animal kingdom (Vantassel 2007), and to crusades to save the world from predators who would attack people, and destroy livestock and game species (Miskosky undated; Rocky Mountain Outpost 2016). Not all explanations are valid, and anecdotal and non-scientific information may lead to a misunderstanding of the role of trapping in today's world.

Trapping is necessary for socio-economic reasons. It is especially important to Aboriginal people as a source of money and food, and for clothing and handicraft (Woods 1986; Stabler *et al.* 1990; George *et al.* 1995). However, enjoyment of the outdoor experience alone is a strong motivation for Indigenous people (Nelson *et al.* 2005) as well as for non-Native people (Dorendorf *et al.* 2016).

As pointed out above, trapping is associated with the harvest of furbearers and the fur industry. Furbearer trapping is not necessary for wildlife populations to persist in their environment (Proulx 1999b). However, some species produce enough animals annually to allow the harvest of part of their populations. This is the case for beaver (*Castor canadensis*) (Patric and Webb 1953; Knudsen 1962) and muskrat (*Ondatra zibethicus*) (Errington *et al.* 1963) whose populations may reach density levels that may cause habitat deterioration. The removal of a portion of the population may actually reduce competition among animals for food and cover, and increase the chances of survival for the remaining population, particularly in winter (Proulx 1999b). On the other hand, even when regulated by wildlife agencies, trapping has had negative impacts on species such as the American marten (*Martes americana*) (Hodgman *et al.* 1994), the fisher (*Pekania pennanti*) (Lewis and Zielinski 1996), the wolverine (*Gulo gulo*) (Mowat *et al.* 2020), the endangered Iberian lynx (*Lynx pardinus*) (Virgós *et al.* 2016), and many other species. For species with low-intermediate resilience to trapping, over-exploitation, coupled with habitat destruction and low prey population levels, may result in extirpation (Banci and Proulx 1999).

Trapping is necessary to control introduced (Hodges and Nagata 2001; Keedwell *et al.* 2002) and native (Stancyk 1982; Burger 1989) predators that impact on species at risk. It is also necessary to control commensal rodents that cause economic damages to crop and livestock producers (Proulx 1997; Bradley *et al.* 2015), such as Norway rats (*Rattus norvegicus*), roof rats (*R. rattus*), Polynesian rats (also called Kiore, *R. exulans*), house mice (Mus musculus), cotton rats (*Sigmodon* spp.) and rice rats (*Oryzomys palustris*), ground squirrels (*Urocitellus* spp.), and pocket gophers (*Thomomys* spp.). Rats and mice may reach very high densities in urban settings (Witmer and Proulx 2010). Trapping often is necessary to control rodent outbreaks that can result in increased cases of rodent-borne disease (e.g., hantavirus) transmission to humans (Rodriguez-Moran *et al.* 1998), and in increased plague outbreaks (Stapp *et al.* 2009; Butler 2013). Trapping may be necessary to reduce encounters between humans and wildlife in urban areas (Smith and Engeman 2002), or to monitor and remove animals from diseased populations (Gunson *et al.* 1978; Rosatte *et al.* 1992; Hawkins *et al.* 2006).

Trapping is necessary for the management and conservation of species. Fur trappers may be employed in wildlife management programs aimed at reducing the size of some populations that are in conflict with human property or activities, or impact on the quality or quantity of habitat resources. In this case, fur trapping may be a management tool used by wildlife biologists to meet their objective. Furthermore, animal carcasses may be studied to learn more about the life history and ecology of species, i.e., the reproductive and physical conditions of the animals, and the age and sex ratios of the trapped populations. Such information is used in the analysis of population trends, which is used to improve and modify fur harvest programs (Proulx and Barrett 1991).

Knowledge on the natural history of mammals, and the status and characteristics of the majority of mammal species, could not have been acquired without the use of trapping. Although alternative methods to trapping exist to study some aspects of the biology of mammal species, trapping is still necessary to study population dynamics, equip animals with radio-collars, carry out translocation programs, and many other research activities.

Why is mammal trapping controversial?

The continued use of unacceptable trapping devices and the protection of the 'old ways' by trappers and pest controllers are largely the causes of so much controversy in mammal trapping. For example, trappers claim that killing neck snares are humane and quickly kill grey wolves (*Canis lupus*) (Rocky Mountain Outlook 2016), in spite of 40 yrs of scientific findings proving that these antiquated trapping devices cause pain and suffering (Proulx *et al.* 2015). In fact, Proulx (2018b) showed that canids captured in killing neck snares may spend hours in distress. Trappers continue to support bounty programs for the control of predators (Rocky Mountain Outlook 2016), but decades of scientific assessments have shown that these programs are ineffective in controlling predators, cause undue suffering, are non-selective, and jeopardize wildlife communities (Proulx and Rodtka 2015).

The use of antiquated technology and ineffective wildlife management programs resulted in the denunciation of trapping devices that do not meet any standards such as killing neck snares (Proulx *et al.* 2015; Proulx and Rodtka 2017), glue boards (Mason and Littin 2003), steel leghold traps (Proulx and Barrett 1989), and unselective trapping devices that endanger the persistence of species at risk (Virgós *et al.* 2016). Others have criticized trapping standards (Iossa 2007; Proulx *et al.* 2020) and regulations (Proulx and Rodtka 2019) that cause distress and undue suffering to animals, and predator control and research programs that are unjustified and unethical (Brook *et al.* 2015; Proulx and Rodtka 2015).

When

When should mammal trapping be allowed?

Trapping is a privilege; it is not a right. As stewards of the land and its resources, people should be responsible to sustain the long-term welfare of populations and individuals (Proulx and Barrett 1989, The Wildlife Society 1990; Paquet and Darimont 2010).

I believe that mammal trapping should be allowed when, and only when, the capture of animals will not impact on the persistence of populations and the welfare of individuals. In other words, if traps are unselective and risk to capture species at risk (Virgós *et al.* 2018), trapping should not be allowed. Selectivity should be species-specific − for example, traps that result in the capture of multiple furbearing species that are legal within a jurisdiction during the regulated harvest season (White *et al.* 2020) are not discriminant; they may capture many other non-furbearer species and cause havoc in wildlife communities.

If traps cause severe injuries and stress in restraining traps, or long and painful deaths, trapping should not be allowed (Proulx 2018b; Proulx *et al.* 2020). Acceptable trapping activities should minimize welfare impacts under the following domains: nutrition, environment, health, behaviour, and mental state (Mellor and Reid 1994; Sharp and Saunders 2011).

When will concerns about mammal trapping stop?

It is likely that the issue of animal welfare in mammal trapping will never be resolved conclusively to the satisfaction of all opponents. Even with major progress, some anti-trapping groups will continue to challenge the performance standards of traps and the acceptability of some trapping systems. However, if wildlife professionals, trappers, and governments work together to develop improve trapping systems that are representative of state-of-the-art trapping technology and implement best animal welfare practices in the field, the gravity of issues raised by anti-trapping organizations will be significantly lessened.

Where

Where should mammal trapping occur?

In research, trapping may occur wherever it is necessary to sample populations; it can therefore be conducted in urban and suburban areas with retraining traps, and in the wilderness with either killing or restraining trap systems. Fur trapping should be limited to wilderness areas that are remote from urban and sub-urban areas (Villeneuve and Proulx 2022), and away from wildlife reserves to allow populations to expand from protected areas into surrounding landscapes (Proulx and Aubry 2020).

Where should we focus our attention in mammal trapping?

As pointed out by Proulx *et al.* (2020), the future of mammal trapping resides in better technology and implementation programs to ensure the wellbeing of captured animals while increasing capture-efficiency and selectivity. This means that new standards must be developed to increase performance thresholds for killing and restraining traps. These standards must include physiological and behavioural parameters to assess the adequacy of trapping systems. Trap assessment, research and development, and implementation of standards must be transparent, under the supervision of scientists with field expertise, and all findings should be published in peer-reviewed scientific journals (Proulx *et al.* 2020), trade magazines, and newspapers.

Finally, the long-term impact of trapping on wildlife populations, particularly those of carnivores, needs to be investigated. For example, trapping reproductive wolves can subdivide existing wolf territories and, thereby, increase wolf densities locally through compensatory reproduction and colonization (Ballard and Stephenson 1982; Brainerd *et al.* 2008; Hayes *et al.* 2003). The long-term effect of such changes on wildlife communities needs to be further investigated. Harvesting not only affects population size but also population dynamics, age structure, sex ratio, spacing, and likely mating patterns and foraging costs (Powell 1994). The level of resilience among species varies greatly, and many populations do not have the capability to recover from a significant reduction in numbers (Banci and Proulx 1999). Therefore, long-term comparative studies should be conducted between non-harvested and harvested furbearer populations to better understand the effects of trapping on population dynamics, structure, genetics and behaviour (Fortin et Cantin 1990; Banci and Proulx 1999; Botha *et al.* 2022).

Discussion

People of all walks of life can trap mammals, and although there is little control on the background of the trappers and the quality of trapping devices used (Proulx *et al.* 2020; Feldstein and Proulx 2022), integrating ethics, performance criteria, and common sense can ensure that trapping will be carried out without impacting on the perseverance of mammal populations, and the integrity of biodiversity and ecosystems (Powell and Proulx 2003). Today, mammal trapping is still necessary and it should be used in years to come, if only to further our knowledge of mammals' evolution, ecology, animal behaviour, physiology, parasitology, and genetics.

The major issue with trapping is the questioning about the necessity of trapping and the controversy surrounding the welfare of trapped animals. This must definitely be resolved through the use of improved trapping standards (Proulx *et al.* 2020, 2022) that would be representative of state-of-the-art trapping technology, and the implementation of effective and ethical research and management programs (Proulx 2018c).

On the basis of my review of the 5Ws of trapping, I believe that a decision process is required to justify mammal trapping (Figure 1). This process would classify trapping activities among 5 categories: sustenance, research, human-wildlife conflict, fur trapping, and wildlife management (Figure 1). While the use of trapping for sustenance among Aboriginal populations is highly justifiable, mammal trapping systems that are representative of state-of-the-art technology should still be employed. Scientific research needs to meet several assessment levels: 1) it must have a protocol that takes into account the scientific method, with an inductive portion that justifies the need for the specific research; 2) there are no alternative methods to mammal trapping to obtain the results sought by the research program; 3) the program is acceptable from an animal welfare point of view, as determined by an Animal Care & Use Committee (a group of scientists and members of the public who ensure that the highest animal welfare standards and robust scientific research are maintained; Canadian Council on Animal Care 2006); and 4) it will employ state-of-the-art trapping technology (Figure 1). Humane-wildlife conflicts may be resolved through trapping if, and only if, the capture/removal of animals will address the issues at hand (Proulx 2018a). These actions must be focused on the animals causing the problem and the exact location where conflicts occurred. In other words, using trapping in programs such as bounties where the removal of animals is unselective and not aimed at a specific problem (Proulx and Rodtka 2015), is unjustifiable. Fur trapping should be justifiable if: 1) it is selective; 2) it does not impact on species at risk; and 3) it uses only trapping systems that meet the highest standards of animal welfare (Proulx *et al.* 2022). Finally, wildlife management programs involving mammal trapping need to be based on scientific evidence and must exclusively use trapping systems that meet the highest standards (Proulx *et al.* 2022). The common denominator for all these mammal trapping categories is the necessity to use state-of-the-art trapping technology and species-selective trapping systems (Proulx *et al.* 2022). If only these trapping systems are allowed on the market and on traplines, the justification process (Figure 1) will be easily used and enforced, and the concerns of the public and the scientific community relative to the necessity of trapping and the welfare of trapped animals could be reduced.

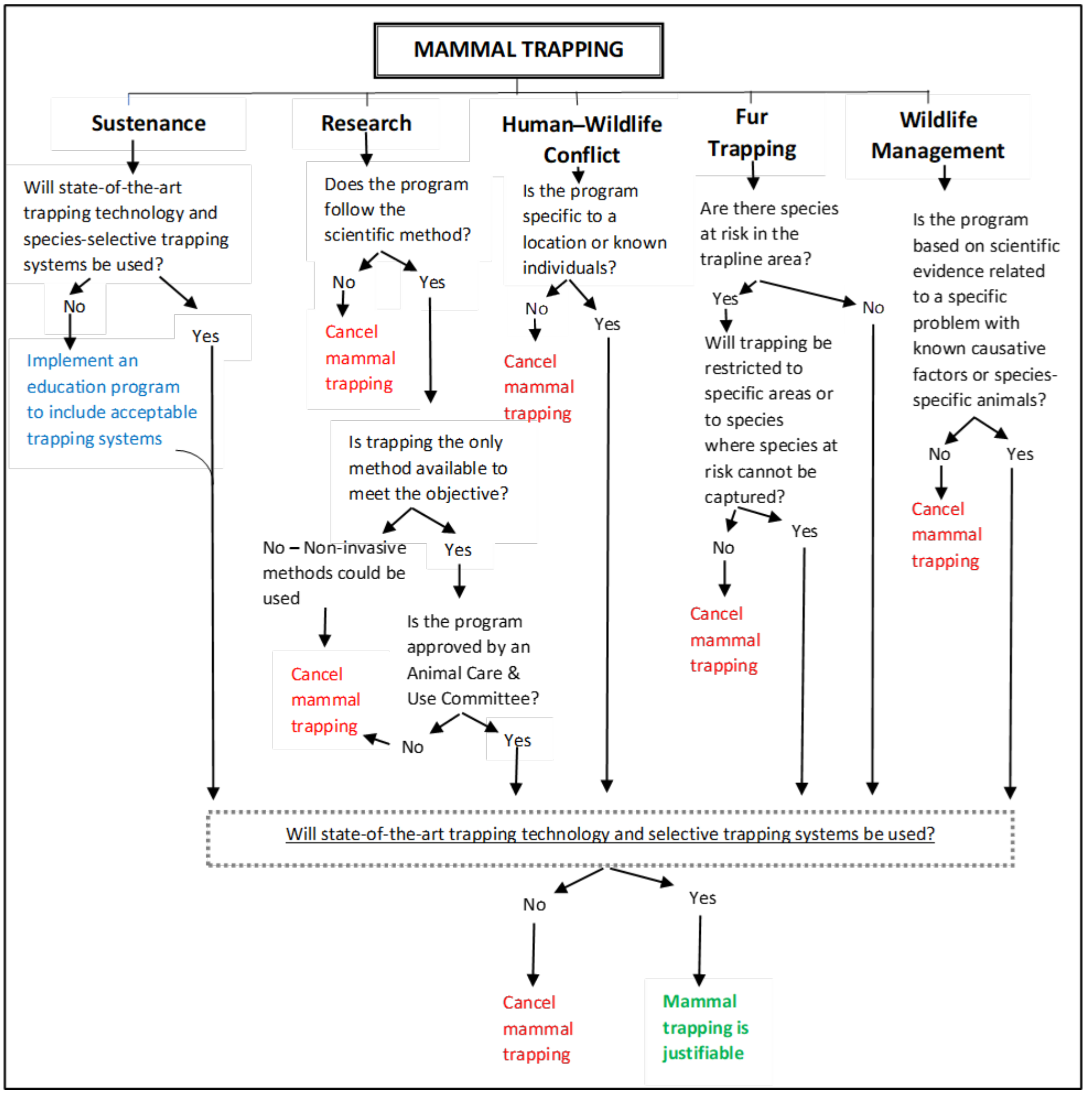

Figure 1. Decision process that may be used to justify the use of mammal trapping.

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Chapter 2

Animal Welfare Issues Pertaining to The Trapping of Northern River Otters: A Review of The Best Management Practice

Thomas L. SERFASS
Department of Biology and Natural Resources, Frostburg State University, Frostburg, Maryland 21532 USA. Email: tserfass@frostburg.edu

Abstract − The Northern river otter (*Lontra canadensis*; hereafter river otter) has been the subject of trapping for various purposes and can serve as a surrogate for discussing animal welfare issues pertaining to both research and conservation, and for evaluating humane and ethical issues pertaining to the wildlife system in the United States (U.S.) and the associated fur industry. In this chapter, I review humane issues relative to traps and trapping systems that are used to restrain river otters for research and conservation purposes, and kill more than 30,000 river otters on an annual basis in the U.S. and Canada, and relate them to the Best Management Practice (BMP) developed for river otters. Although various traps and trapping systems are believed to meet humane standards based on the BMP process and the U.S. furbearing management system, I consider meaningful and objective evaluations to make such conclusions as largely absent and in need of additional review. I explore the existing evidence related to the humaneness of killing and restraining traps and trapping systems used to capture river otters for fur, integrating my experiences with trapping and handling the species for reintroduction projects. I initially review the BMP outcome for river otters and live-trapping studies conducted for river otters and Eurasian otters (*Lutra lutra*) to establish a basis for contrasting various approaches and study designs relevant to the humane trapping of river otters. I integrate these outcomes to critically explore liabilities associated with the BMP developed for river otters. Humane concerns pertaining to the BMP and the trapping of river otters in general focus on: 1) the inadequate variety of traps and trapping systems used to evaluate the humaneness of river otter trapping; 2) the lack of transparency in the process used to evaluate body-grip traps; 3) the extended trap-checking periods often associated with water trapping; 4) the issue of drowning with the use of submersions sets; 5) the trapping of female river otters during periods of cub rearing; and 6) the unintended capture of river otters (lack of selectivity) during American beaver (*Castor canadensis*; hereafter beaver) trapping seasons, and the likely inhumane consequences (for river otters and beavers) of using a recommended trigger modification for 330-size body-grip traps to improve trap selectivity. Based on the limited number of traps and trapping systems tested to date, I conclude that the river otter BMP offers little new or insightful information to enhance humane trapping for this species.

Introduction

This chapter focuses on humane issues pertaining to trapping Northern river otters (*Lontra canadensis*; hereafter river otter) as administered by the state system of wildlife conservation in United States (U.S.). Historically (pre-European colonization), the river otter occupied aquatic habitats throughout the 48 conterminous U.S. and Alaska (and all Canadian provinces and territories) (Hall 1981; Melquist and

Dronkert 1987; Melquist *et al.* 2003). Historical accounts during the mid-1700s and early to mid-1800s indicate river otters were often caught during intense exploitation of the North American beaver (*Castor canadensis*; hereafter beaver) by early Europeans (e.g., Clancey and Clavin 2021, pages 142-143). By the early to mid-1900s, the species had experienced substantial population declines, or complete extirpations, throughout large portions of its historic range, particularly in the interior U.S. and southern Canada (Nilsson 1980; Melquist and Dronkert 1987; Melquist *et al.* 2003; Kruuk, 2006; Bricker *et al.* 2022). These declines were attributable to the interactive effects of ongoing overharvest by trappers, disturbances to riparian habitats (e.g., deforestation), and water pollution.

River otters have recovered substantially from past population declines and now occupy at least portions of all states within their former range, with most populations considered stable or expanding (Bricker *et al.* 2022). The interactions of more progressive furbearer and predator management that evolved through the 1900s, legislation contributing to improved water quality (e.g., "Clean Water Act" in 1972; USEPA 2015), and better protection of riparian areas through federal legislation (e.g., the "Farm Bill"; Johnson and Monke 2019), all undoubtedly contributed to the recovery of river otter populations. In 1977, the river otter was listed as an Appendix II species by CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) (Nilsson 1980; CITES 2013; Akland *et al.* 2017). The Appendix II designation (which mandates tagging of pelts of listed species intended for export) motivated many state wildlife agencies to initiate conservation actions to reverse river otter population declines. These actions included the implementation of successful reintroduction projects among 22 states that involved the combined release of >4,000 river otters, beginning in Colorado in 1976 (Bricker *et al.* 2022).

Recreational fur trapping is a prominent aspect of the system of wildlife management practiced in the U.S., and subsequent expansion of legal trapping should be anticipated to follow the recovery of a furbearing animal such as the river otter. Predictably, the number of states allowing legal trapping of river otters has increased substantially over the last 20 yrs – from 29 states in 1998 to 41 states in 2021 (Bricker *et al.* 2022). The recovery of river otters (and expansion of river otter trapping seasons) has likewise coincided with considerable debates and efforts to address ethical and animal welfare issues pertaining to trapping wild animals in general. In addition to recreational trapping, river otters are also trapped for research and conservation. River otters used for reintroduction projects were almost exclusively caught in foothold traps (Bricker *et al.* 2022).

Humane standards for trapping river otters have been poorly defined in relation to animal welfare concerns (Serfass *et al.* 2017). In 1997, Canada and Russia entered into an "Agreement on International Humane Trapping Standards (AIHTS) and the U.S. entered a comparable arrangement through an agreed "Minute" to better define issues pertaining to what constitutes humane traps and trapping, particularly foothold traps (European Community, Government of Canada, and Government of the Russian Federation [ECGCGRF] 1997; United States Department of Commerce 1997; Iossa *et al.* 2007; Proulx *et al.* 2012, 2020). The U.S. Minute is in the form of "Best Management Practices for Trapping" (BMPs; Association of Fish and Wildlife Agencies [AFWA] 2006). These arrangements represent the first attempt to establish international standards to define what constitutes "humane" for certain categories of traps (Harrop 2000; Princen 2004). Through these arrangements, processes were established for evaluating injuries and associated physical trauma to animals caught in restraining traps (a category including foothold traps, and other traps that can be used in a manner not intending to kill the trapped animal), and the efficiency of traps designed to kill the trapped animal (e.g., body-gripping traps). Mandatory trap testing is essential to the agreements for determining if BMPs meet standards for species being trapped. The focus is on evaluating physical injuries and efficiency associated with various trap types under specific trap setting procedures, i.e., trapping system. I define trapping system as: 1) the trap type, including dimensions, shape, power, and trigger design; 2) the method of attaching (anchoring) the trap, e.g., chain, swivels, and locks; 3) the trap's specific shape and function; 4) specific set location, e.g., dry land or water; 5) use of attractants; and 6) maximum time an animal is permitted to be restrained in a trap. Assessing "trapping systems" provides a more complete review of the various approaches actually used by trappers and more insight to the entirety of factors contributing to injuries sustained by trapped animals.

The river otter serves particularly well for discussing the process of trap testing in relation to the development of BMPs, trapping systems (e.g., variation in anchoring systems and trap checking −not evaluated as part of BMP), and ethical issues pertaining to public relations efforts to promote trapping in the U.S. A BMP for river otters had previously been completed and published through the Association of Fish and Wildlife Agencies (AFWA 2014), and it was followed by a Wildlife Monograph on outcomes of trap testing in the U.S. for 19 species, including the river otter (White *et al.* 2021). These documents enable scrutiny of the virtues and liabilities of current processes associated with the development of BMPs and other humane issues associated with trapping (i.e., those that may not be directly associated with BMPs).

Coinciding with the development of BMPs and expansion of river otter populations has been public messaging presumably designed to gain public acceptance for harvesting river otters and to establish the recovery of river otter populations as a symbol for promoting trapping as a conservation tool − most reintroduced river otters were captured in foothold traps. Of particular concern was messaging prior to initiating trapping in some Midwestern states characterized by strikingly similar negative media portrayals, characteristically beginning with praise for implementation of progressive wildlife conservation policies by state wildlife agencies (i.e., implementing successful river otter reintroduction projects), and ending by proposing that a trapping season may be necessary to alleviate conflict (portrayed as river otters depredating fish in private ponds, and being harmful to gamefish populations) associated with rapidly growing numbers of river otters (see Serfass *et al.* 2014). These negative portrayals appeared to have the intent of lessening public opposition for proposed plans to initiate river otter trapping seasons. Some state wildlife agencies appeared to have aligned with media in the negative messaging. Fostering an acrimonious situation to achieve a wildlife management outcome (i.e., a trapping season on river otters) has potential humane issues pertaining to the way people respond to river otters as well as ethical issues regarding the manner in which a state wildlife agency portrays a native wildlife species to the public (see Serfass *et al.* 2017). Thus, assessing the BMP assessment process is particularly relevant for the trapping of river otters.

In this chapter, I critically review various elements pertaining to the humane trapping of river otters, with particular emphasis on the virtues and liabilities of the BMP process as a basis for establishing trapping standards. The critique goes beyond humane standards for traps recognized for river otters in the current BMP, considering other issues pertinent to humane trapping such as the time an animal spends in a trap, variation in trap setting (e.g., how the trap is anchored at the trap site), and the use of drowning sets. The chapter is comprised of 3 primary sections, each intended to review and critique applied (e.g., testing of traps) and policy processes pertinent to humane considerations and the trapping of river otters: 1) the BMP for river otters, including the process of evaluating traps and the traps recommended; 2) published accounts of river otter live-trapping projects; 3) and an examination of what I perceive as 5 primary liabilities (presented as subsections) of the current BMP for river otters. Each section ends with concerns and recommendations for identifying and addressing what I perceive as inadequacies in the BMP process in addressing humane considerations for trapping river otters.

Best Management Practices and the river otter

Overview

A review of key focal elements of BMPs for trapping in the U.S. are published in "The Best Management Practices for Trapping in the United States" prepared by the Association of Fish and Wildlife Agencies (AFWA 2006). Among various intentions, the document establishes scientific evaluation of traps and trapping systems used to capture furbearers in the U.S. as the primary emphasis of the BMP process, with outcomes of evaluations intended for use in promoting trapping methodologies that enhance the humaneness of trapping, and generating public support and acceptance of trapping through education. Traps considered in BMP evaluations are represented in 2 general categories, 1) "restraining traps" (live-capture devices used on land without the intention of killing the trapped animal, including foothold traps, cage traps, suitcase traps, and cable devices), and 2) "mechanical powered killing traps" (hereafter killing traps, also often referred to as body-grip or rotating-jaw traps), which are designed with the intent of killing when the trap's 2 spring-powered jaws close over opposing sides the trapped animal's neck or chest, i.e., preferred points of impact. Restraining traps, including snares, can also be categorized as killing devices when used in a manner to intentionally drown an animal (i.e., "submersion set").

BMP evaluations for foothold traps focus on: 1) animal welfare (measured on "trauma scales" based exclusively on physical injuries sustained by trapped animals); 2) trap efficiency (*Efficiency = captures/captures + non-captures*) which corresponds to the percentage of the targeted species caught in a trap in relation to the number of times the targeted species sprung the trap; 3) trap selectivity, i.e., the number of non-target species captured−BMPs consider only non-furbearing animals, including domestic animals, as non-target species; 4) trap practicality, i.e., factors that may limit the use of a trap by trappers, such as cost, weight, reliability, and durability; and 5) human safety, i.e., the potential for injury from the trap. Animal welfare and efficiency are quantified based on injury scores established in ISO (1999) guidelines, with a trap considered "suitable" if achieving a threshold score meeting the criteria of 2 injury-assessment scales (see AFWA 2006, page 4). Information on selectivity apparently is recorded but no criteria is provided for acceptable levels of non-target animal captures. A panel of trappers and wildlife biologists subjectively evaluate traps for practicality and human safety.

Animal welfare performance for killing traps is based on a single criterion: time required for an animal to become irreversibly unconscious after being captured. Performance criteria are based on traps set on land, with 70% of trapped animals in the sample needing to be irreversibly unconscious within 300 seconds (AFWA 2006). Kill traps set in the water are not subject to this criterion based on the assumption that the animal will drown after being captured.

Submersion or drowning sets include traps and associated anchoring components that contribute to complete submersion of the trapped animal. A variety of trap categories can be used in submersion sets, including foothold, body-grip, cable devices, and cage traps. To meet animal welfare performance criterion for this type of trapping, the trapped animal must not be able to reach the surface after initially submerging. Evaluations do not consider stress endured or injuries sustained by the trapped animal during drowning (asphyxiating).

Various humane issues are not explicitly part of the BMP process. Issues omitted from BMP consideration having direct or indirect implications for humane trapping are: 1) water-trapping not requiring submersion sets (for both foothold and body-grip traps); 2) drowning animals; 3) overlap of trapping seasons with parturition and periods of rearing young; and 4) trap selectivity pertaining to non-target furbearers.

BMP for the river otter

The recently published "Best Management Practices for Trapping Furbearers in the United States" (White *et al.* 2021) provides details of the BMP assessment process and results of testing various restraining traps for 19 furbearing species from 1997-2018, including river otter. Although river otters are most frequently harvested by trappers using body-grip traps (Responsive Management 2015), assessment of these traps for welfare considerations apparently was not a direct part of the BMP process. Instead, BMP recommendations for body-grip traps are based on studies in Canada (Fur Institute of Canada 2021).

The BMP for river otters is based on the capture of 76 river otters of which 70 were included in the assessment (reasons for omitting 6 river otters from the assessment are not provided) (White *et al.* 2021). Three different foothold traps were used in the study: 1) #11 double long-spring traps with standard jaws (4-inch jaw spread); 2) #11 double long-spring traps with double jaws (4-inch jaw spread); and 3) #2 coil-spring (standard jaw; 5.5-inch jaw spread) (Figure1). Lovallo *et al.* (2021) published the same primary outcomes (derived from the same data) as White *et al.* (2021) but only for river otters. Traps were anchored (presumably staked, but no specifications provided) using 4 segments of 2/0 chain link interspersed with 4 swivels and a shock spring (from the description, I estimate a total length of about 40 cm) and checked daily, prior to 12:00 (Lovallo *et al.* 2021). All traps in the study met criteria for humane standards based on a mean cumulative injury score <49 points (for each trap types), and >70% of trapped river otters (for each trap type) not sustaining injuries considered likely to impact survival or reproduction. Although not mentioned in Lovallo *et al.* (2021), none of the traps met BMP efficiency criteria (scores were <50% for each of the trap types), presumably because the tested traps were small, the anchoring system used a short chain, and traps were set on land (see Shirley *et al.* [1983] and Serfass *et al.* [1996] for using longer chains anchored in the water for trapping river otters). The low capture efficiency is likely the reason trappers seldom select #11 traps to harvest river otters − in a nationwide survey of river otter trappers (*n* = 600), <1% used #11 long-spring traps; Responsive Management 2015). However, despite a capture efficiency not meeting BMP requirements, #2 coil-spring traps were among the more frequently used foothold traps for river otters − about 6% of river otter trappers reported using this trap (Responsive Management 2015). Although only the 3 traps mentioned were tested, the BMP for river otters recommends virtually the use of any size foothold trap (up to #5), if used in a submersion set. The recommendation is based on the assumption that the captured animal will die through drowning soon after being captured, thus negating concern for any trap-caused injuries. There are no standards for quantifying the humaneness of the intended drowning process associated with submersions sets.

There are 13 killing traps recommended in the BMP for river otters, all of which have 2 springs (AFWA 2014). The respective dimensions (height x width of trap window in inches) of 13 traps recommended for river otters range in sizes from 6 7/8 x 7 inches to 10 1/8 x 10 7/16 inches, a size range including body-grip traps commonly designated as Conibear 220, 280, and 330 (AFWA 2014). Two of the body-grip traps specifically approved in the river otter BMP apparently do not meet the 300-second standard of irreversible unconsciousness and are recommended only for use in submersion sets. I was unable to locate (review) results of the trap testing conducted by the Fur Institute of Canada (2021), which served as the basis for recommending the 13 body-grip in the river otter BMP.

Live-trapping river otters and Eurasian otters (*Lutra lutra*) - a review

In this section, I review primary outcomes (e.g., capture rates and injuries) from 10 studies (9 publications and 1 report) that collectively assessed 11 restraining traps for river otters (Table 1). The section is portioned into 2 trap categories (foothold, and suitcase and cage-type traps) between which trap studies pertinent to a particular category are each independently reviewed. In addition to primary outcomes, an important intent of the reviews is to identify factors having implications for identifying limitations in the current process of identifying humane traps and associated trapping systems for capturing river otters. The studies are presented chronologically (within each trap category) to sequentially portray advances or new information about traps, trap-setting, and assessments of trapping (study design) pertinent to humane trapping. Each review ideally (if included in the study) provides information on the following categories: traps used, the overall trapping system (e.g., set location, anchoring system including chain lengths for foothold traps), number of river otters captured, captures per trapping effort, injuries and associated scoring techniques, and any tangential information pertinent to animal welfare. The following approaches pertaining to trapping systems were generally the same among studies and will not be further discussed except when a particular trapping system was developed or refined by a study, or there is deviation from the typical approach, especially when an alternative approach has potential animal welfare implications: 1) traps were checked <24 h; 2) chains used to anchor traps had multiple swivels (where the chain attached to the trap and the anchor, and at various intervals within the chain's length); and 3) trauma scores based on ISO trauma scale, ranging from 0 to 100 (ISO 1999). The scaling systems used to quantify capture rates (captures by capture efforts) differed among studies and were standardized as the number of trap-nights required to capture 1 river otter or Eurasian otter (trap-nights/otter).

Foothold traps

The following review focuses on primary outcomes relevant to humane issues associated with 7 studies that used foothold traps to live-capture otters – 5 of the studies captured river otters, and the other 2 studies captured the comparably sized Eurasian otter (Kruuk 2006) (Table 1). Nine types of foothold traps are represented among the studies, with 3 of the studies comparing >1 foothold trap. Versions of #11 long-spring traps and #1.5 SoftCatch™ coil-spring traps were the most frequent traps used in evaluations; the smallest and largest traps evaluated were #11 long-spring and #3 SoftCatch™, respectively.

Melquist and Hornocker (1979)

This study summarizes the use of foothold traps as part of an extensive field study of river otters in Idaho (Melquist and Hornocker 1983). Foothold traps were used exclusively during the first year of the project but were generally discontinued for what the investigators referred to as "preferred traps" (presumably Hancock livetraps‒see suitcase traps below‒which were used extensively throughout the rest of the project). Injuries to captured river otters and other factors (e.g., time requirements – leghold traps were reportedly kept under constant surveillance, probably to minimize injury to river otters by quickly removing them from traps) undoubtedly led to the discontinued use of foothold traps. The investigation used #2 coil-spring and #3 jump (underspring) traps, combining in the capture of 9 river otters (5 and 4 river otters, respectively). Injuries were more prevalent in river otters captured in jump traps (2 juveniles suffered broken hind legs and subsequently died). River otters captured in the coil-spring traps had fewer injuries but capture efficiency was low (at least 35 escapes were reported). The summary did not provide details of injuries for each captured river, the trapping system, or number of traps deployed over time.

Table1. Summary of 7 live-trapping studies that evaluated various foothold traps to capture Northern river otters (*Lontra canadensis*) and Eurasian otters (*Lutra lutra*).

Author(s)	Location of study	Trap Type(s)	No. Captures - Capture rate[c]	ISO scoring Yes/No	Trap Transmitters Yes/No
Melquist and Hornocker (1979)	Idaho	#2 coil-spring	5 - NA[d]	No	No
		#3 underspring	4 - NA[d]	No	No
Shirley et al. (1983)	Louisiana	#11 long-spring	30 – 85	No	No
Serfass et al. (1996)	Pennsylvania	#1.5 SoftCatch™	29 - 60.3	No[g]	No
		#11 long-spring[b]	NA		
Blundell et al. (1999)	Alaska	#11 long-spring (double-jaw)	29 - 20.8[e]	Yes	Yes
Fernandez-Moran et al. (2002)	Spain[a]	#1.5 SoftCatch™	55 – 159	No[g]	No
O'Neill et al. (2007)	Latvia[a]	#3 SoftCatch™	46 - NA[d]	Yes	Yes
Belfiore (2008)	California	#11 long-spring #1.5 coil-spring #1.5 SoftCatch™ #1.75 coil-spring #1.75 coil-spring (offset jaws)	13 - 64[f]	No[g]	No

[a] Study involved capture of Eurasian otters (*Lutra lutra*)

[b] River otters caught in this trap were trapped in Louisiana for reintroduction in Pennsylvania. These river otters were evaluated for injuries but no information on capture rates were available.

[c] Capture rate was calculated as the number of trap-nights per otter captured.

[d] Information for capture rates not provided.

[e] Only 11 of the 29 captured river otters were used to calculate capture rate.

[f] Represents captures and capture rate among the 5 trap types combined.

[g] Injuries quantified using scoring system different from ISO.

Shirley et al. (1983)
Researchers captured 30 river otters in Louisiana using #11 long-spring foothold traps and a novel trap-setting system. The use of #11 foothold traps and the trap-setting system was pioneered in Louisiana by Lee Roy Sevin for live-trapping river otters (Note: Mr. Sevin used this live-trapping system to capture and sell the majority of river otters (>2000) used in U.S. reintroduction projects; Bricker *et al.* 2022). Traps were modified by adding a swivel under the trap pan to serve as the point of attachment for anchoring the trap, rather the point of attachment on a spring. Traps were attached to chains varying in length from 0.6 to 1 m, with the chain interrupted with a swivel placed 16 cm from the trap. To my knowledge, Shirley *et al.* (1983) is among the first publications to advocate the use of swivels to prevent injuries to trapped animals. The project used pocket sets at the water's edge, with traps set in the water at a depth of 3 to 30 cm. Stakes for anchoring the traps were also in the water with no information provided regarding proximity to the shoreline (adjacent, perpendicular, or otherwise). To avoid entanglement of the captured river otter, traps were set in areas where the radius of the chain did not reach surrounding obstructions (e.g., stumps or vegetation). (Note: Entanglement prohibits or limits the trap from pivoting with the movement of the trapped animal, with the restricted mobility contributing to escapes and injuries to the trapped appendage. The addition of swivels likewise serves to prevent the chain from binding if tangling does occur.) Capture rates differed over the 3-yr trapping data: 85 trap-nights/otter; 215 trap-nights/otter; and 315 trap-nights/otter. Although there was no detailed review of trap-caused injuries, 16% of the captured otters sustained broken toe(s). Among 22 river otters captured over the last 2 yrs of the study, 30% displayed evidence of old trap wounds (such information was not provided for the first year of the study), presumably having been previously captured and pulled free from a foothold trap.

Serfass et al. (1996)
This study reviews the extent of injuries sustained by river otters live-trapped for use in the Pennsylvania River Otter Reintroduction Project (PRORP). Three approaches were used to obtain river otters for use by PRORP through live-trapping: 1) #1.5 SoftCatch^{TM} trap following procedures developed by PRORP (*n* = 38 river otters from Pennsylvania, which were trapped by PRORP personnel, and Maryland, which were trapped by Maryland Department of Natural Resources personnel; 2) #11 long-spring trap following procedures described by Shirley *et al.* (1983) (*n* = 17 river otters from Louisiana); and 3) purchases from trappers and licensed commercial suppliers with permits to trap and sell live river otters using various foothold traps and trap-setting procedures (*n* = 32 river otters from Michigan, New Hampshire, New York, and Pennsylvania). Approaches used by PRORP for trapping river otters with SoftCatch^{TM} traps included: 1) replacing 1 factory installed spring with a #2 spring to increase holding strength; 2) setting traps in shallow water at the base of trails leading to river otter latrines; 3) adding a 0.5 to 1.5 m segment of chain with a swivel added about every 30 cm through the length of the chain, 4) attaching the trap chain to an anchor positioned perpendicular to the shoreline at the trap site (far enough from the shoreline to prevent captured river otters from achieving a solid purchase on land while struggling to pull free from the trap); and 5) clearing all debris within the radius of the trap to prevent tangling and possible drowning of a capture river otter. Metrics pertaining to trap performance in the field (trap-nights/otter captured and capture efficiency) were only available and calculated for river otters captured in Pennsylvania by PRORP personnel.

Trapping for river otters in Pennsylvania resulted in 29 captures over 1,749 trap-nights (60.3 trap-nights/river otter) and 22 escapes (capture efficiency = 0.57). PRORP developed the system used to portray and quantify trap-caused injuries and did not follow the ISO trauma scale. River otters captured by PRORP sustained few serious injuries to the dentition or the trapped appendage. Eleven (38%) of the river otters sustained injuries to canines (most typically the top third of a single canine was broken) and 5 otters (17%) sustained broken incisors (breakage of 3, 2, and 5 incisors for 3, 1, and 1 river otters, respectively). Injuries to the trapped appendages were likewise generally minor with 1 (3%) river otter requiring an amputation (a single toe). Injuries to canines were much more frequent and severe in river otters obtained from trappers/commercial suppliers than those caught following PRORP's techniques and those of Shirley *et al.*

(1983), but injuries to incisors were comparable among all approaches used to obtain river otters through live-trapping. However, injuries to appendages requiring amputations (primarily toes) were much more frequent in river otters obtained from trappers/suppliers and following Shirley *et al.* (1983). Two river otters from trappers/suppliers required amputation of a leg and another the amputation of a foot.

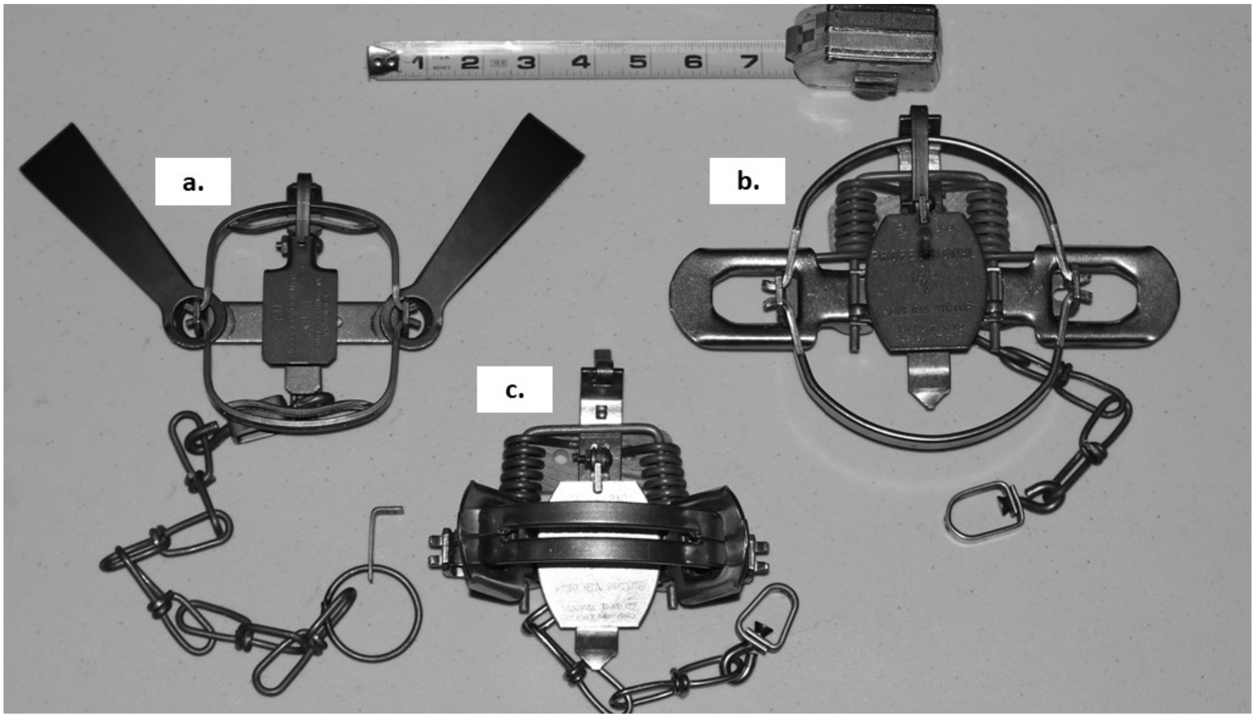

Figure 1. Examples of foothold traps that have been evaluated for live-trapping river otters and for the river otter Best Management Practices (BMP) assessment. The #11 long-spring trap with double jaws (a.), #11 long-spring trap with standard jaws (not pictured, but the same size as #11 long-spring trap with double jaws; and the #2 coil-spring trap (b.) were the 3 traps tested for the river otter BMP. The other trap in the image (c.) is a #2 coil-spring trap with offset jaws, which is among traps recommended in the river otter BMP.

Blundell et al. (1999)

This study examined injuries and other factors related to trapping success among 29 river otters captured in #11 long-spring traps with double jaws (Figure 1) in coastal Alaska. All traps were set on land and anchored to 38-cm angle-iron stakes. Trap chains (<70 cm) were attached to the trap and stake with swivels, and another swivel was inserted in the middle of the chain. Transmitters attached to traps served to alert investigators when a trap had been triggered. Transmitter signals were checked 2 to 3 times daily, which enabled most river otters to be removed from traps within 4 to 5 h of capture (transmitters did not indicate a sprung trap on 6 instances). A capture rate of 20.8 trap-nights/otter was calculated for a sample ($n = 11$) of the 29 captured river otters. Injuries were calculated at 2 levels: 1) on the ISO trauma scale, and 2) the percentage of river otters sustaining an injury to teeth or appendages, with no indication of the severity of injuries. A large portion of trapped river otters sustained some form of injury (70%;), but trauma scores indicated that most injuries were minor (range = 0 to 100; median = 5).

Fernandez-Moran et al. (2002)

Eurasian otters were captured for a reintroduction project in Spain using #1.5 SoftCatch^{TM} traps modified following Serfass *et al.* (1996). Traps were set beneath shallow water adjacent to the shoreline and attached to a 1-m chain typically anchored to rocks using “climbing bolts.” Traps were checked daily. Fifty-five otters were captured (159 trap-nights/otter) and there were 36 escapes resulting in a capture efficiency of 0.60. Injuries were assessed for 43 of the captured otters. Severity of injuries to the trapped appendages were graded on a 4-point scale ranging from no or very minor injury to severe injury characterized as an open luxation with exposed or missing phalanges. Dental injuries were described based on severity and the percent of otters with any injury to one or more teeth. Injuries to the trapped appendages were generally minor, with 34 (79%) of the otters represented in the first injury category (no or minor injury), and 6 (7%) in the 2 highest injury categories. Dental injuries occurred in 8 (19%) of the otters and all were considered minor, but details of the injuries were not provided.

O'Neill et al. (2007)

Researchers captured 46 Eurasian otters in Latvia and Ireland using #3 SoftCatch^{TM} traps. Traps were set on land following Blundell *et al.* (1999) and trapping systems included an alarm system at each trap site activated when a captured otter moved the trap. Investigators responded immediately to check a trap when an alarm activated, and checked traps daily as a precaution in the event of alarm malfunctions. Alarm malfunctions sometimes occurred, enabling comparison of injures to otters restrained in traps for shorter periods (i.e., when alarms signaled a capture) versus longer periods (i.e., when an alarm malfunctioned). Trauma scores for otters caught in traps with functioning alarms (average time in trap was 22 min) were very low, averaging 5.5 points, in comparison to those caught in traps when alarms malfunctioned and were in traps <24 h, which averaged 77.2 points. No injuries to otters were considered severe enough to impact survival. Trap efficiency of the SoftCatch^{TM} traps improved from 77% to 88% by replacing trap pads about every 2 wks and by not having the surface of the trap pads of set traps covered by soil.

Belfiore (2008)

Five types of foothold traps (#11 long-spring, #1.5 coil-spring, #1.5 SoftCatch^{TM} trap, #1.75 coil-spring, and #1.75 coil-spring trap with offset jaws) were used to capture 13 river otters in California. In addition to the large number of traps considered in the trapping effort, there was variation in where traps were set (i.e., set both on land and in the water) and length of trap chains, with most lengths described as short, 25 to 40 cm with swivels, and other unspecified lengths described as long. Two of the trap types were used most frequently (#11 long-spring and #1.5 coil-spring) and resulted in the most captures (7 and 4 river otters, respectively). Traps were checked every 6 h and injuries were few and typically minor – the injuries described as the most severe were represented among 3 river otters: one had 2 canines broken to the "base;" one had a chipped canine and punctures on a footpad; and one lost a toenail and digit pad had a tear. The more serious injuries occurred when traps were set in the water with long chains that allowed captured river otters to access the shoreline. The combination of relatively few trapped river otters, use of several trap types, and multiple trap-setting techniques limit meaningful conclusions by trap type or procedures for setting traps pertaining to capture rates, capture efficiency, and injuries.

Summary – Humane implications for foothold traps

Published information on the use of foothold traps for live-capturing river otters progressed from evaluation of efficiency and capture rates of various traps and trapping systems to addressing humane concerns related to intervals for checking traps and injuries. The progression started with the incorporation of swivels at the point of attachment to the trap, at various intervals within the trap chain, and at the anchor, which is now included as part of all live-trapping systems for river otters involving foothold traps and recommendations for capturing furbearing animals in foothold traps.

The manner of describing and evaluating trapping-induced injuries to river otters varied considerably from initial to investigations that are more recent. The earlier investigations focused mostly on descriptive portrayals of the types and frequencies of injuries, with subsequent evaluations evolving to more detailed and quantifiable depictions of injuries. Each study provides useful insight about injuries sustained in relation to the use of various traps and trapping systems but inconsistencies in the depiction of injury-data limits direct comparisons among all studies. Most of the more recent studies scored injuries based on the ISO trauma scales. Such consistency in the use of a standardized trap-scoring system is especially important for making meaningful comparisons among investigations. The ISO scoring system has evolved since inception, when injuries to the trapped limb were the focus, to include whole body assessments and dental injuries (Proulx *et al.* 1993; Hubert *et al.* 1996). However, the ISO scoring system has limitations by not portraying specific injuries as part of the cumulative scoring system. For example, there is no differentiation in the scoring system for different categories of teeth – i.e., a severely damaged incisor is scored the same as a severely damaged canine. Accompanying descriptive and inferential statistics based on ISO scoring should be information that will provide insight on frequency that trapped animals sustain a specific type of injury, and details of the extent of injuries to dentition and trapped appendages. Such information is fundamental for assessing the suitably of a trap used for research or conservation activities where captured animals are intended to be released and trap-related injuries sustained during capture should not be at levels to impact post-release survival (e.g., for radio-telemetry studies or reintroduction projects). The same considerations apply to the required release and subsequent survivability of protected or out-of-season furbearers incidentally captured in traps intended for legal furbearers. The investigation by Serfass *et al.* (1996) demonstrate both the liabilities of not following the ISO scoring system and virtues of providing a more detailed assessment of the type, degree, and frequencies of injuries. In this case, the portrayal of dental injuries (as an overall percentage) sustained by river otters captured in modified #1.5 SoftCatch^{TM} traps was sometimes interpreted as representing major dental injuries (presumably based on what constitutes a dental injury with ISO scoring and incomplete review of the accompanying information). The dental injuries were generally minor and most would have not received an ISO injury score.

In addition to assessing a variety of foothold traps (various forms of #11 long-spring traps and #1.5 SoftCatch^{TM} traps were most frequently represented), the investigations also represent a diversity of trapping systems and trapping conditions. Protocols for all investigations included checking traps at least once daily and 3 of the studies used either trap-transmitters or multiple-trap checks daily to further minimize time a captured river otter would remain in the trap. The diversity of traps and trap setting systems provides important insight useful for assessing the humaneness of trapping under the variety of circumstances trappers are likely to follow in trapping river otters.

Suitcase and cage traps

Configuration of suitcase and cage traps vary but all require an animal to enter or cross over the trap to activate the triggering mechanism. Suitcase-type and cage traps are respectively represented in 5 and 2 of the following 6 studies (Table 2). The traps are designed to capture and restrain an animal within a cage or cage-like enclosure. Suitcase traps have 1 or 2 spring-loaded movable sides comprised of chain-link fencing overlaying a metal frame to form a cage-like area when the trap frames close. The frames are separated (open) in the set position and close forcefully (1 or both frames are movable depending on trap type) when activated by an animal depressing a trap pan (Figure 2). Cage traps are designed with 1 or 2 open doors for an animal to enter; doors are activated (closure) by the animal depressing a trigger plate. There is a general paucity of studies available for assessing the performance of cage traps for river otters. However, a recent study represented in this review (Rutter *et al.* 2020) adds extensively to the discussion of using cage traps to live-capture river otters.

Northcott and Slade (1976)

This represents the first assessment of suitcase traps (or any live-trapping technique) for capturing river otters. The study evaluated the efficacy of 2 suitcase traps, Bailey beaver traps and Hancock livetraps, both originally designed for capturing beavers, to capture river otters in coastal Newfoundland. Only 2 river otters were captured in Bailey beaver traps during 1,140 trap-nights (570 trap-nights/river otter). The low capture rate apparently was attributable to the 2 movable sides (frames) of the trap not closing synchronously, enabling river otters to escape prior to complete closure of trap frames. There was no information provided on escape rates. In contrast, the use of Hancock livetraps contributed to the capture of 46 river otters with capture rates varying from 77 to 167 trap-nights/river otter depending on trap site preparation. The traps were set on land in pathways or slides used by river otters. The authors described 2 modifications to the trap important for avoiding escapes by captured river otters. There was no information provided about injuries to river otters.

Melquist and Hornocker (1979)
The researchers evaluated the use of 4 cage-type traps: Tomahawk Live Trap −2 sizes, 107 x 41 x 38 cm and 51 x 20 x 20 cm; culvert trap constructed of 1.2-m diameter x 30-cm length aluminum culvert; and barrel trap constructed for the capture of wolverines (*Gulo* gulo) from "barrel drums" (46-cm diameter x 74 and 91-cm lengths). They also used the Hancock livetrap. Apparently, none of the cage-type traps were used extensively and collectively contributed to the capture of 6 river otters (at least 1 river otter was captured in each of cage-type traps, including both sizes of the Tomahawk Live Trap). There was no mention of injuries sustained by captured river otters. The authors describe modifications suggested by Northcott and Slade (1996) and 2 additional modifications to Hancock livetraps also important for minimizing escapes by captured river otters. Overall, 44 river otters were captured in Hancock livetraps over 5,425 trap-nights (126 trap-nights/otter) (Melquist and Hornocker 1983) – there was no information provided on escape rates. There was no mention of injuries sustained by river otters caught in Hancock livetraps. However, the authors warned of potential injuries to a river otter caught between the sides of the trap.

Table 2. Summary of 6 live-trapping studies that evaluated various suitcase and cage traps to capture North American river otters (*Lontra canadensis*).

Author(s)	**Location of study**	**Trap Type(s)**	**No. Captures – Capture rate[b]**	**ISO scoring Yes/No**	**Trap Transmitters Yes/No**
Northcott and Slade (1976)	Newfoundland	Bailey beaver trap	2 – 570	No	No
		Hancock livetrap	46 – 77 to 167	No	No
Melquist and Hornocker (1979)	Idaho	Tomahawk livetrap	3 - NA[c]	No	No
Melquist and Hornocker (1983)		Culvert trap	1 - NA[c]	No	No
		Barrel trap	2 – NA[c]	No	No
		Hancock livetrap	44 – 126	No	No
Penak and Code (1987)[a]	Ontario	Bailey beaver trap	1 – 320	No	No
		Hancock livetrap	9 - 100	No	No
Blundell *et al.* (1999)	Alaska	Hancock livetrap	11 – 26.3	Yes	Yes
Serfass *et al.* (2017)	Pennsylvania	Hancock livetrap	6 – 53.7	No[f]	No
Rutter *et al.* (2020)	Illinois	Comstock (cage) trap	36 - 63	Yes	No

[a] Eighteen river otters were captured in this study, but information was provided for only 10 – for 1 caught in a Bailey beaver trap and for 9 caught in Hancock livetraps.
[b] Capture rate was calculated as the number of trap-nights per otter captured.
[c] Information for capture rates not provided.

Penak and Code (1987)
The researchers described the use of Bailey beaver traps and Hancock live traps to capture river otters in Ontario for translocation to Missouri and Nebraska as part of reintroduction projects. Traps were set in small streams, with Bailey beaver traps completely under water when sent and the stationary side of Hancock livetraps underwater. Overall, 18 river otters were captured. However, capture-related information was only provided for 10 river otters: 1 was captured using Bailey beaver traps (320 trap-nights/otter) and 9 in Hancock livetraps (100 trap-nights/river otter). No information was provided on injuries.

Blundell et al. (1999)
Hancock livetraps were used to capture 11 river otters (26.3 trap-nights/otter) in Alaska. Trap transmitters were used to indicate when traps were sprung, with signals monitored 2 to 3 times daily – the maximum length of time a river otter was in a trap was about 8 h. The traps were set on land at river otter latrines. Six (55%) of the river otters captured sustained injuries. Trauma scores (based on ISO trauma scale) ranged

from 0 to 95 (median = 20 points). Injuries to appendages were limited to edema and abrasions. Dental injuries occurred in 5 (45%) of river otters, attributable to broken canines and molars in 3 and 2 river otters, respectively. The dental injuries were described as serious but no information was provided about number of teeth damaged or extent of tooth breakage.

Serfass et al. (2017)

Authors described additional modifications to Hancock livetraps (Figure 2) and the capture of 6 river otters during limited use of these modified traps during early phases of the Pennsylvania River Otter Reintroduction Project (Serfass *et al.* 1986). In addition to applying modifications suggested by Northcott and Slade (1976) and Melquist and Hornocker (1979), 2 further modifications were described. The first modification enables the trap to lay flat when set, in contrast to the trap frames of a set trap forming an angle of about 130° when not modified; and the second involves covering the 5 x 10-cm wire grid on the fixed side of the trap with vinyl coated 2.5 x 2.5-cm welded wire fencing (Figure 2). Modifying traps to lay flat enabled complete submersion of the entire trap in shallow water when set, and addition of the vinyl-coated, smaller-grid fencing served as a precaution against potential tooth or paw damage by captured river otters described by Blundell *et al.* (1999). Traps were set in water perpendicular to the shoreline (the fixed, non-movable side always adjacent to the shore), with trap sites selected where the entire trap would be relatively level when set. Precaution to prevent debris (e.g., leaves or branches) from covering the moveable side of the trap served to avoid slowing or blocking proper closure of an activated trap. The 6 river otters were captured over 322 trap-nights (53.7 trap-nights/otter) – 2 juveniles were caught simultaneously in the same trap. Injuries to river otters were minor (the tip of a canine broken off was the most severe injury). Diligent monitoring of water levels was recommended to avoid drowning captured river otters in Hancock livetraps modified for setting in shallow water‒the chain-link of the movable side of a closed Hancock livetrap can expand upward to about 30 cm from the bottom of the trap. Hypothermia should likewise be a consideration when using this trap in the water.

Rutter et al. (2020)

This research represents the first live-trapping project for river otters focused on the use of cage-type traps. Two types of Comstock traps (“12 x 12 Double Door trap” and the larger “Double Door beaver trap”) were used to capture 36 river otters (62.5 trap-nights/otter). Traps were mostly set partially submerged in small streams and drainage ditches, and less frequently on overland paths used by river otters. For the water sets, traps were placed parallel to the water channel in narrows (natural or constructed by adding rocks and branches]) to direct river otters through the trap. Twenty of the 36 river otters captured were examined for injuries, with 11 (55%) sustaining some form of injury (mean trauma score = 32.1; range= 0 to 100). Tooth fractures and lacerations represented severe injuries, respectively occurring in 25% and 10% of the sample. There was no information provided on the number of teeth damaged or the extent of tooth breakage. Deaths occurred in 5 (14%) of the captured river otters – 2 from drowning, 2 from hypothermia, and 1 from injuries caused by the trap. Drownings occurred during unanticipated rises in water levels, and deaths by hypothermia was attributed to constant exposure to water while the animals were restrained in traps that were set partially submerged. Among disadvantages of the Comstock trap were large size, frequent capture of non-target furbearers (trap-nights/animal = 7.0), especially beavers (trap-nights/animal = 26.3) and Northern raccoons (*Procyon lotor*; trap-nights/animal= 16.7), and high malfunction rates.

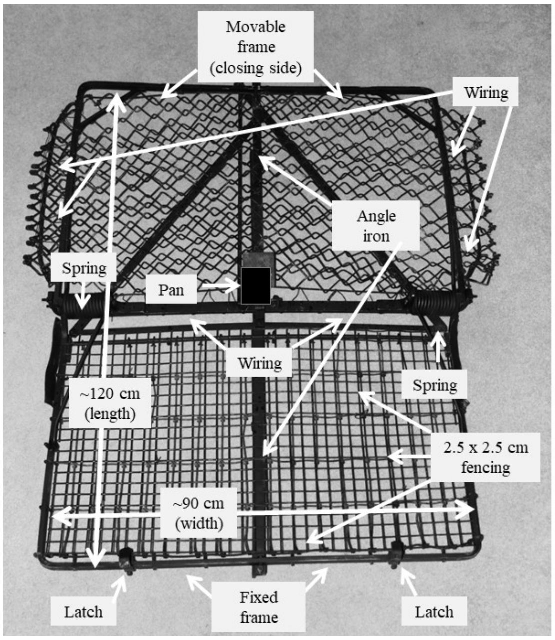

Figure 2. A Hancock livetrap with modifications by Serfass *et al.* (2017) that enable the trap to lay flat when set in the open position. The trap is held flat when set by affixing a section of angle iron to back of the trap. To minimize chances of river otters escaping Melquist and Hornocker (1979) recommended: 1) adding springs on the inner side of "catches," which are intended prevent a captured animal from forcing open the movable side of the opening (the springs better ensure that catches remain over the frame of the movable sides of a closed trap), and 2) using wire to close gaps along the margins of the trap frame. Serfass *et al.* (2017) also recommends covering the 5 x 10-cm wire grid on the fixed side of the trap frame with vinyl coated 2.5 x 2.5-cm welded wire fencing to prevent escape or injury of a captured river otter.

Summary – Humane implications for cage-type trap

The first significant live-trapping studies for river otters focused on the use of suitcase traps. Those studies demonstrated the utility of Hancock live traps and failings of Bailey beaver traps for live-capturing river otters. Hancock livetraps were the primary capture devices in Melquist and Hornocker's (1983) largest and most comprehensive study of native river otter populations. However, this trap has seldom been the focus of live-capture efforts for river otters since Blundell *et al.* (1999). The large size and cost of Hancock livetraps likely have contributed to the preference for foothold traps in capturing river otters for research and conservation. In addition, injuries reported by Blundell *et al.* (1999) to river otters captured in Hancock livetraps may have further diminished interest in these traps. However, I suspect trapping circumstances that exposed the non-movable side of the trap (comprised of a large mesh, fixed, non-flexible wire grid) as the focal area for escape efforts by captured river otters contributed to these injuries. Modifications suggested by Serfass *et al.* (2017) resulted in captured river otters being primarily exposed to the chain-link fencing covering the movable frame of the trap. The chain-link fencing compresses and flexes when bitten or clawed, which may substantially reduce the types and frequency of dental and foot injuries reported by Blundell *et al.* (1999)−these injuries may have been contributed by exposure to the inflexible wire grid covering the non-movable side of the trap. Large size and cost present practical limitations to the use of Hancock livetraps. Nonetheless, there are shoreline conditions and other trapping circumstances (e.g., where the use of foothold traps is not permitted) where these traps may provide a useful and humane option for restraining river otters.

Until Rutter *et al.*'s (2020) project, cage traps had received relatively little attention for use in capturing river otters. Rutter *et al.* (2020) demonstrated that large numbers of river otters can be captured in cage traps, particularly when trapping is done in particular aquatic habitat conditions. Many of the same aquatic conditions that Rutter *et al.* (2020) indicated as preferable for placement of cage traps would likely serve well for use of Hancock livetraps. Rutter *et al.* (2020) also described liabilities of trapping in the water, including exposing captured animals to drownings and hypothermia, and frequent capture of non-target animals. As with Hancock livetraps, traditional cage traps may have application in areas not always best suited to the use of foothold traps. Administration of chemical restraint to remove animals from traps also typically is easier for animals captured in cage-type traps than in foothold traps. The above and other potential virtues warrant additional investigation of practical and humane considerations of cage-type traps for use in capturing river otters.

BMP and river otter – Limitations

River otters are among 22 furbearing species evaluated as part of the BMP process. In this section, I review the adequacy of the BMP developed for river otters in addressing humane trapping of the species − both those defined and evaluated in BMP process and others not considered for evaluation. When applicable, outcomes of the river otter BMP are compared to those from the previous live-trapping studies of river otters (see above section). Because BMPs serve only as recommendations, I also review aspects of trapping regulations pertaining to river otters among the 41 states allowing river otter trapping to determine the extent BMP recommendations are followed. Recommendations and outcomes from the river otter BMP and evaluations of foothold traps tested for river otters presented in White *et al.* (2021) and Lovallo *et al.* (2021) form the basis of this critique. Recommendations for body-grip traps in BMPs apparently are based on testing conducted in Canada and processes followed and outcomes of the testing are not available for review. Body-grip traps of the size used to capture river otters (the sizes commonly designated as 220 to 330) typically are not allowed for dry-land sets in most states and are discussed only in the context of use in water.

Limited, inconsequential, and opaque trap testing

Foothold traps

All of the foothold traps tested for the river otter BMP (#11 unmodified and offset long-spring, and #2 coil-spring), along with body-grip traps generally falling within the range of traps commonly categorized as 220 and 330, are listed as meeting humane criteria for river otters (AFWA 2014). White *et al.* (2021) and Lovallo *et al.* (2021) published trap-testing outcomes for the 3 foothold traps assessed for the river otters BMP. These respective publications are based on the same data and all traps passed BMP humane standards but not trap efficiency standards – Lovallo *et al.* (2021) does not mention failure of the traps to meet efficiency criteria. Outcomes of 2 previous evaluations of #11 long-spring traps for capturing river otters do not align with outcomes of trap testing for the river otter BMP. River otters captured in Louisiana with #11 long-spring traps often sustained serious injuries to toes (loss >1 toe) (Shirley *et al.* 1983, Serfass *et al.* 1996) but different trap setting techniques were used (in comparison to the BMP testing) to enhance capture efficiency and injuries were not portrayed using the ISO trauma scale. Belfiore (2008) and Blundell *et al.* (1999) reported minimal injuries to river otters captured in #11 long-spring with unmodified and offset jaws, respectively. However, meaningful comparison is limited by small sample size in Belfiore (2008) and captured river otters were restrained in traps for much less time (typically no more than 6 to 8 h) in Belfiore (2008) and Blundell *et al.* (1999) compared to BMP testing (<24 h).

Reasons for selecting the #11 long-spring traps tested for the river otter BMP are unclear, as are reasons for evaluating only land sets. These traps have small inside jaw spreads (3 7/8"), a size not typically used by fur trappers trapping river otters. In a national survey of trappers, the percentage of trappers using #11 long-spring traps and #2 coil-spring traps for river otter was 0% and 6%, respectively, whereas the untested #3 coil-spring trap was most frequently used, i.e., about 7%, and most foothold traps used for river otters were set in the water (Responsive Management 2015). Almost 30% of trappers surveyed indicated capturing river otters incidentally while trapping for beavers, and foothold traps most frequently used by beaver trappers were #3 and #4 coil-spring traps (17% of all traps used to trap beavers; Responsive Management 2015). Hence, foothold traps most frequently used to capture river otters were not evaluated for the river otter BMP.

The river otter BMP indicates foothold traps larger than traps tested met humaneness requirements when used in submersion sets, which are commonly used for trapping river otters with foothold traps (Responsive Management 2015). However, the efficacy of submersion sets in drowning river otters is not mentioned in the BMP and apparently has not been tested. Thus, there is no way to determine if river otters typically die quickly in the tested or untested traps recommended only for use in submersion sets.

Body-grip traps

Any body-grip trap with dimensions for height and width of the trap window respectively ranging from 6 7/8 to 10 1/8-inches and 7 to 10 7/16-inches meets BMP requirements for the river otter, as do any body-grip traps with larger dimensions if used in submersion sets. Among the 7 body-grip traps specifically discussed in the river otter BMP, 2 (representing the 220 and 280 size categories) are recommended only for use in submersion sets. The recommendation for use only in submersion sets implies that these traps did not meet humane requirements (irreversible loss of consciousness <5 min after the trap closes over the animal), with drowning apparently serving as a surrogate for being killed by the trap. Information pertaining to study design or outcomes from trap testing of body-grip traps for river otters is not available for review. Apparently, BMP recommendations for body-grip traps (for river otters and other species) are based on evaluations administered through the Fur Institute of Canada. The BMPs for beaver and muskrat (*Ondatra zibethicus*) indicate that most approved body-grip traps for these species were tested through "computer simulation modelling," and presumably the same process was used for river otters. Using computer simulations in lieu of actual testing raises various concerns about the reliability of outcomes indicating a body-grip trap meets existing time standards for a humane death (Proulx *et al.* 2020).

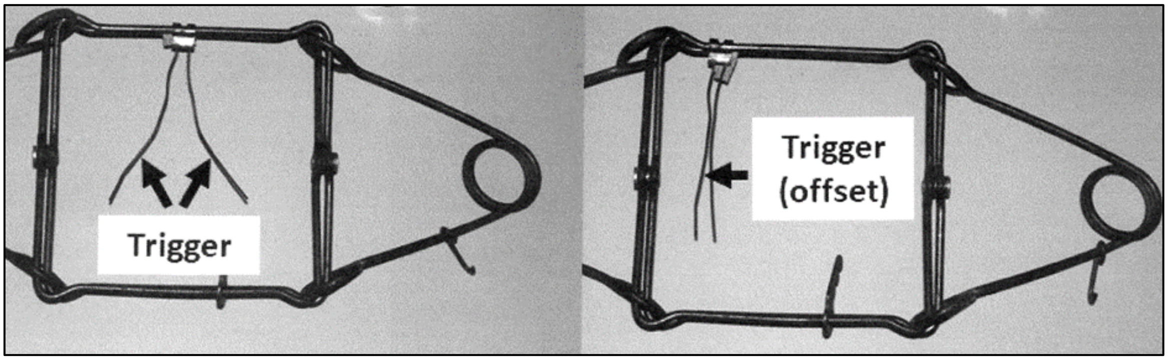

Figure 3. A 330 rotating-jaw trap, (also called body-grip, body-gripping, or Conibear^{TM} traps) in the closed (not set) position. This type of trap is intended to quickly kill a captured animal and is frequently used by trappers to capture river otters (*Lontra canadensis*) for fur (Responsive Management 2015). Typically, the trigger configuration is centred in the trap frame (e.g., on the left side of the picture), but an offset trigger configuration (e.g., on the right) is widely recommended to avoid capturing river otters when the trap is set with the intent of capturing American beavers (*Castor canadensis*).

The river otter swims rapidly and has a narrower overall cross-section diameter, including smaller head and neck circumference, relative to beavers, the furbearer most frequently captured in large body-grip traps and subjected to more trap testing than river otters. These physical characteristics enhance the likelihood of a river otter penetrating far enough into the frame of a 330-size body-grip traps prior to releasing the trigger and being captured with a non-lethal strike to the torso. Also, adult river otters possess a relatively heavy musculature in the cervical region, mitigating prospects for a humane death, even if captured in 330-size body-grip traps with cervical strikes. Hence, in the absence of empirical evidence, there is reason to suspect that a 220-size body-grip trap is particularly incapable of consistently killing an adult river otter within time limits defined as humane, even if the trap strikes a preferred area (i.e., cervical region). This concern for river otters is supported by Proulx and Barrett's (1993) conclusion that fishers (*Pekania pennanti*) captured in "mechanically improved" Conibear 220 traps are unlikely to be killed at rates sufficient to meet time requirements for a humane death. Particularly noteworthy is that fishers are both smaller and possess relatively less musculature in the cervical region than river otters. Extensive efforts to promote a trigger modification to 330-size body-grip traps with the intent of minimizing incidental capture of river otters by beaver trappers furthers the potential for inhumane capture of both species (Figure 3). This modification has been widely advertised by many state wildlife agencies and in BMPs for both river otters and beavers (AFWA 2014, 2016), and may contribute to delayed triggering of body-grip traps (i.e., an animal not initially releasing the trigger when entering the trap) and more non-lethal strikes to the torso (see the following section "Selectivity").

The potential inadequacies of body-grip traps in meeting requirements for causing a humane death to river otters are arguably mitigated if used in submersion sets, where an animal not killed by the trap would drown (see the following section "Drowning" for a separate discussion about humane issues and drowning). As with all aspects of BMPs, use of submersions sets are recommendations, not mandates. Most states require that large body-grip traps (220-size and larger) be set in the water (or apply other precautions, such as a minimum height above the ground requirements to minimize non-target captures if used on land), but the requirement often does not stipulate those traps need to be completely submerged. Thus, a river otter would potentially suffer a long, agonizing death if captured but not killed in a partially submerged body-grip trap, and the same concern applies to foothold traps set in the water but not as submersion sets. Such trapping scenarios are not just speculative, but occur – e.g., at the behest of Wildlife Conservation Officers in Pennsylvania I often removed river otters incidentally caught by fur trappers from traps, typically from foothold traps but in one case a live adult-female river otter caught mid-torso in a partially submerged 330-size body-grip trap. The river otter suffered severe stress, physical trauma, and died during transport to a veterinarian.

The Conibear 330 is inadequate for humanely killing Canada lynx (*Lynx canadensis*; Proulx *et al.* 1995) and fisher (Proulx 1997). The musculature of a river otter exceeds that of both the Canada lynx and fisher. Without evidence to the contrary, there is reason to doubt that a 330-size body-grip trap has the striking force to humanely kill a river otter with any consistency. The striking force (momentum) of a 330-size body-grip trap is further reduced when triggered while submerged, potentially resulting in a captured river otter struggling for up to 5 min underwater if not killed by the trap and for unknown periods if the trap is not submerged.

Concerns

The BMP developed for river otters contributes little new insight for addressing humane issues pertaining to trapping the species. The assessment of foothold traps for the river otter BMP is based on a small sample (n = 70), ranging from 21 to 27 captures among the 3 traps evaluated (White *et al.* 2021, Lovallo *et al.* 2021), and does not consider the variety of traps or the entirety of trapping systems most likely to be used by trappers to capture river otters. Nor can outcomes of foothold traps tested be extrapolated to many of the other larger foothold traps more frequently used to trap river otters, or those set for other species that contribute to the non-selective capture of river otters. Also, the river otter BMP states that "*All traps listed in the BMPs have been tested and meet performance standards for animal welfare, capture efficiency, selectivity, practicality and safety*" (AFWA 2014), but criteria for capture efficiency were not met for any trap tested (range = 34.8−47.6%; ≥60% of the target species captured needs to be retained in the trap to meet BMP criterion), and selectivity evaluations did not consider unintentional capture of any furbearing species (White *et al.* 2021). Also not considered in the river otter or other BMPs is the issue of capture efficiency which has humane implications given the potential for river otters to lose digits when pulling free from a trap (see Shirley *et al.* 1983). Particularly disconcerting is the inaccessibility of information for external critique associated with the research design or outcomes derived from testing body-grip traps – from White *et al.* (2021): "*Nonetheless, killing trap welfare (time-to-death) data collected in Canada (Fur Institute of Canada 2017) were shared with us and traps were included in BMPs if they met our thresholds for welfare and efficiency; …… we are not at liberty to publish the killing-trap welfare data collected by Canada,… .*"

Specific recommendations

1. Focus assessments on the traps and trapping systems most frequently used by trappers to capture river otters. A priority should be to assess the humaneness of capturing river otters in the water using non-submersion sets for foothold traps, submersion sets for foothold traps, and body-grip traps only partially submerged (Proulx *et al.* 2020).
2. Make available information summarizing outcomes and procedures followed for testing body-grip traps. Such transparency is necessary to establish creditably of the BMP process. If computer simulations are the basis for testing body-grip traps, information is needed to justify of the reliability and demonstrate the process of validating outcomes for this type of trap testing.
3. Trap testing representing the range of climatic conditions experienced during trapping seasons throughout the distribution of river otters.

Trap-checking requirements

The duration an animal is alive in a trap has humane implications related to prolonged stress and degree of physical trauma sustained by trapped animals. Variation among states for "general" trap checking (i.e., those typically applied to foothold traps used in dry-land trapping, but not necessarily to body-grip traps and/or water trapping) and "extended" trap-checking periods (i.e., beyond "general" trap-checking requirements−applied in some states specifically to body-grip traps; hereafter, discussion of trap-check requirements for body-grip traps will pertain only to water trapping) confound humane assessments beyond considerations of physical trauma contributed by traps tested under a narrow set of protocols, including minimum time requirements for trap-checking. Protocols followed in testing the 3 foothold traps considered for the river otter BMP included a <24 h trap-check requirement, which represents the most typical time period among the 41 states allowing legal trapping of river otters (see Proulx and Rodtka 2019 for a review of typical and extended trap-checking periods in the U.S. and Canada).

Among the 41 states allowing the legal trapping of river otters, trap-check requirements when using footholds for dry-land trapping was daily or <24 h in the majority of states. However, many of those states have "extended" trap-check requirements that apply only to body-grip traps, only to foothold traps, or to both trap types (Proulx and Rodtka 2019). Extended trap-checking periods are generally applied to 'water trapping', and are justified in part on the presumption that furbearing animals will soon drown when captured in trap sets in the water. Distinctions between 'water trapping' and 'water trapping with submersion sets' has various potentially adverse consequences pertaining to the welfare of the trapped animal in relation to trap checking requirements. Submersion sets indicate an intention for animals caught in foothold traps to drown and that a body-grip trap will be entirely underwater (i.e., the animal will drown if not killed by the trap), whereas drowning is not necessarily the outcome of trapping in the water with non-submersions sets, and the trapped animal may remain alive until the trapper visits the site. Although recommended in many states, only 1 of the states that have extended trap-check periods for water trapping mandate submersion sets.

The relationship between the time a river otter is restrained in a foothold trap to the extent and proportion of injuries sustained has received no specific research attention, particularly where "time in trap" and other, potentially confounding, covariates were controlled. Nonetheless, 3 of the live-trapping studies previously portrayed provide insight on the implications for retaining an otter <24 h in a foothold trap in relation to injuries: Blundell *et al.* (1999), O'Neill *et al.* (2007), and Belfiore (2008). Blundell *et al.* (1999) and O'Neill *et al.* (2007) used 2 different types of transmitting devices that signaled if a trap was triggered, resulting in river otters typically being in traps about 4-5 h and 22 min (when transmitters functioned), respectively, and Belfiore (2008) checked traps at 6-hr intervals. Versions of #11 long-spring traps were used in both Blundell *et al.* (1999) (offset jaws) and Belfiore (2008) (standard vs unmodified jaws) and injuries were minor (see Section 3.1). Occasional malfunction of trap transmitters in the O'Neill *et al.*'s (2007) study uniquely enabled comparison of injuries sustained by otters removed quickly from traps (when transmitters signaled properly) and longer periods (up to 24 h) when transmitters failed to signal a capture. Injury scores based on ISO trauma scores were about 14 times higher for otters that retained up to 24 h in comparison to those restrained for a shorter time (average scores = 77.2 and 5.5, respectively). These outcomes support Proulx and Rodtka's (2019) concerns about time in a trap and the extent of injuries sustained by the captured animal.

Although the river otter BMP recommends use of submersion sets when trapping river otters with foothold traps in the water, few states mandate this trapping system for water trapping. Regardless, trappers frequently incorporate submersion sets when using foothold traps to capture river otters (Responsive Management 2015). Most states require daily trap checks when foothold traps are used in the water, but extend the trap check period when trappers use submersion sets, apparently presuming the captured animal will drown, and many states extend trap checks to >24 h for any water set. Hence, captures in failed submersion sets (i.e., animal does not drown) or in non-drowning water sets could result in trapped river otters being retained in the water alive >24 h. These capture scenarios further welfare concerns for river otters related to interactive effects of being restrained in the water by large, untested traps for periods >24 h, which enhances potential for hypothermia (see Rutter *et al.* 2020; Section 3.2) and capture-induced physical trauma. The American Veterinary Medical Association (AVMA 2020) has determined hypothermia as not meeting humane requirements for euthanasia.

Body-grip traps in the general size of 220 and larger are legal for water trapping in all but 2 states allowing trapping of river otters. The river otter BMP recommends use of submersion sets for body-grip traps, but regulations for using body-grip traps in the water do not mandate submersion of the entire trap in most of states. Trap-check requirements for body-grip traps suitable for capturing river otters are >24 h in most of the 41 states allowing use of this trap type in the water. Thus, river otters captured but not killed in a body-grip trap would also not necessarily die from drowning if the trap is only partially submerged, raising similar, but more severe, humane concerns as with failed submersion sets incorporating foothold traps. The absence of reviewable information pertaining to testing body-grip traps recommended for river otters prevents anticipating frequency that river otters caught in partially submerged body-grip traps will survive >300 s. Nonetheless, river otters captured and not killed in partially submerged body-grip traps would endure extensive pain and suffering, which could potentially extend for >24 h.

Concerns

Outcomes from several of the live-trapping studies of river otters infer or demonstrate that time spent in a trap influences the extent of injuries incurred by the trapped animal. Proulx and Rodtka (2019) established humane concerns pertaining to regulations in the U.S. and Canada allowing trap checking periods >24 h if traps are set in the water. Extended trap-checking requirements for water trapping are of particular relevance to river otters, which are often caught in water sets and may thus suffer alive and in the water for periods >24 h in many states (Proulx and Rodtka 2019).

Specific recommendations

1. Trap-checking requirements should be <24 h for land and water trapping, except where body-grip traps are set completely underwater. The reliability of submersion sets for foothold traps to consistently result in the quick drowning of river otters is not adequately evaluated to allow trap-checking periods >24 h, and is in need of evaluation.
2. The relationship between time in a trap and extent of injuries needs better understanding for river otters. Inclusion of trap transmitters or remote cameras with studies of humane trapping will facilitate such assessments. Remote cameras will also enable assessments of the duration of behaviours likely to contribute injuries or indicating stress to trapped animals (Proulx *et al.* 2022).

3. Assessments of physiological stress are not included in the BMP process. The level of stress a trapped animal endures in relation to time in the trap should be a part of the evaluation process (see Kreeger *et al.* 1990; Proulx *et al.* 2022).
4. Rutter *et al.* (2020) demonstrated the potential for river otters to die from hypothermia when caught in cage traps partially submerged in water when traps were checked at intervals <24 h. The AVMA (2020) considers death of an animal by hypothermia as not representing a humane death. The interaction of time in a restraining trap and non-submersion water trapping in relation to causation of death by hypothermia needs further consideration.

Drowning

Successful use of submersion sets (i.e., the captured animal drowns) contributes its own set of welfare concerns pertaining to intentional drowning of animals. Trappers reportedly prefer submersion sets when using foothold traps for river otters (Responsive Management 2015), and river otters are also undoubtedly caught in submersions sets intended for other semi-aquatic species (e.g., beaver, mink *Neovison vison*, and muskrat). Drowning would also be the primary form of death to a river otter caught in a completely submerged 330 body-grip trap when not killed by the strike of the trap. Advocates of submersion sets for water trapping have argued drowning provides a humane death to semi-aquatic furbearers, often citing a study by Gilbert and Gofton (1982) to support that contention. Gilbert and Gofton (1982) evaluated time until death and physiological responses to mink, muskrat, and beaver subjected to drowning in a controlled environment, concluding that the early onset of CO2-induced narcosis experienced by the drowning animal causes rapid unconsciousness (early in the drowning process) followed by a relatively stress and pain-free death. In their article in the Wildlife Society Bulletin, "Drowning is Not Euthanasia," Ludders *et al.* (1999) effectively refute contentions that drowning animals undergo a humane death, demonstrating that drowning causes stress and pain before dying from hypoxia and anoxia (not CO2-induced narcosis). The authors stated: *"....any technique that requires minutes rather than seconds to produce death [can not] be considered euthanasia.*" River otters reportedly can remain underwater for 8 min (Larivière and Walton 1998), and would thereby endure an extended period of pain and suffering if killed by drowning. The AVMA (2020) does not consider drowning acceptable for euthanasia stating: "*Drowning is not a means of euthanasia and is inhumane.*"

Concerns

The BMP process does not consider the inhumane implications of drowning. The river otter BMP (and others) tacitly implies that drowning represents a humane death through recommending use of submersion sets, conflicting the AVMA's rejection of drowning as a form of euthanasia.

Specific recommendations

1. The disparity between AVMA guidelines for euthanasia and BMP recommendations implying drowning as meeting humane requirements for trapping river otters needs reconciliation.
2. Injuries sustained by animals do not contribute to humane assessments for captures made in restraining traps used in submersion sets (i.e., restraining traps used as killing traps). Such injuries need to be included in assessments, especially given the paucity of information available for predicting the time a river otter may remain undrown in an intented submersion set.
3. Criteria need to be established for what constitutes a timely, humane death for river otters caught in restraining traps used as killing traps in submersion sets. Understanding if an intended submersion set contributes to the death of a river otter and the time required for the death are fundamental to the development of such criteria.

Trapping and cub rearing

Trapping seasons overlapping the period of parturition and newborn rearing of a trapped species poses various humane and ethical concerns. Causing newborns to starve or become vulnerable to predation in the absence of parental care are foremost among concerns. Biologically, the loss of these newborns is of little consequence at the population level – the loss to the next generation is the same if the female is killed prior to or after parturition. Nonetheless, most wildlife agencies try to avoid overlap of hunting and trapping seasons during periods when newborns require parental care. A "Trapping Matters" video ("Regulated Hunting and Trapping in the United States") sponsored by the U.S. Fish and Wildlife Service, AFWA, Wildlife and Sport Fish Restoration Program, and Max McGraw Wildlife Foundation, and uploaded to YouTube by AFWA, affirms the intention of state wildlife agencies to not have hunting or trapping seasons during periods when the target species is likely to be rearing young (AFWA 2015). For example, at 3:10 into that video, a biologist states: *"….to make sure they [seasons and bag limits] are in sync with the seasonal calendar of the animal so, for example, we don't generally allow hunting and trapping seasons when the animals have young or small offspring…*" (AFWA 2015). However, trapping seasons and parturition periods for river otter likely overlap in many states.

Young river otters are typically born between February and April (Hamilton and Eadie 1964; Melquist and Hornocker 1983) but there is considerable variation, with parturition dates tending to be progressively later from south to north latitudes (Melquist and Hornocker 2003). Bailey (2016) examined river otter parturition dates among 46 river otter litters born at zoos. Parturition dates among these litters ranged from 8 November to 2 April, with most litters born in February (n = 14, 30%) and March (n = 24, 52%). Among states with river otter trapping seasons, many have seasons that extend into the middle or end of March (n = 15, 37%) and several extend into April or beyond. Beaver trappers also frequently capture river otters as a non-target species (Responsive Management 2015). Beaver trapping seasons extent beyond river otter trapping seasons in 25 (61%) states and include March, April, and May or beyond in 16 (39%), 9 (22%), and 10 (24%) states, respectively, further increasing opportunities to capture female river otters involved in cub rearing. The overlap between river otter and beaver trapping, and river otter parturition periods, is another humane concern neglected in the river otter BMP.

Concerns

River otter trapping seasons and presumed parturition periods overlap in a large number of states. Concern of capturing female river otters rearing cubs is further exacerbated by the potential for river otters to be caught in traps set for beavers.

Specific recommendations

1. Do not allow river otter trapping during periods of parturition and cub rearing.
2. Conduct evaluations to determine parturition periods of river otters in different regions of North America (based on commonalties such as latitude and habitat conditions) as a basis for determining overlap with existing river otter trapping seasons within the regions. Compilation of published information or information in agency databases relevant to river otter reproduction can serve as an initial basis for the evaluation. Initiate specific studies to determine parturition periods in regions where there is a paucity of river otter reproductive information.
3. Investigate the propensity for capturing female river otters rearing cubs.
4. Develop and implement protocols to avoid trapping female river otters during cub rearing, including during beaver trapping seasons (see next section "Selectivity" for concerns about non-target capture of river otters during beaver trapping seasons).

Selectivity

Selectivity in trapping refers to the likelihood of capturing the intended (target) species instead of other (non-target) species. Traps and associated trap-setting techniques showing propensity for capturing primarily the target species are judged "selective." Many factors other than the trapping system influence trap selectivity, including general location, specific habitat conditions, abundance and behavioral characteristic of target and non-target species, and decisions made by the trapper (Pawlina and Proulx 1999).

The BMP process narrows the concept of selectivity by defining only non-furbearing species, and domestic animals as non-target (incidental or secondary) captures. By this definition, unintended capture of furbearing species in traps set for the target species do not represent a non-target capture and are thereby not included in calculations to derive a selectivity rating. Such an approach for defining and evaluating selectivity ignores various humane implications pertinent to the capture of non-target furbearers in traps not meeting welfare standards. Among concerns are traps set for a target species may not meet welfare standards for non-target captures. The concern of non-target captures is further exaggerated in areas where multiple furbearers are being trapped with an array of trap sizes not all meeting humane standards for each of the various species that could be incidentally captured. Also, selectivity needs to consider unintended capture of protected furbearers, such had been the situation for river otters in many states prior to expansion of trapping seasons; also, in several states, river otters are still protected from legal harvest (Bricker *et al.* 2022).

River otters are active in the land-water interface (i.e., riparian and nearshore areas) for feeding, accessing resting and denning sites, and use of latrines (Swimley *et al.* 1998, Stevens *et al.* 2011, Just *et al.* 2012). These areas attract a variety of upland furbearing species of various sizes (Wagnon and Serfass 2016), representing differing trap and trap-setting requirements. Hence, a species like the river otter is exposed to potential incidental capture in traps and trap sets intended for other semi-aquatic species (e.g., beaver, mink, and muskrat) as well as upland furbearers that frequent riparian areas (e.g., facultative wetland species such as raccoons), and these traps may not universally meet humane requirements for the river otter. Ultimately, river otters are vulnerable to capture by virtually the entire array of foothold trap sizes legal for both land and water trapping in a particular state – including foothold traps only meeting BMP criteria for river otters if used as submersion sets.

River otters often occupy beaver flowages, lodges, and bank dens as resting and denning sties (Swimley *et al.* 2012). This commensal relationship contributes to river otters being frequently captured in traps intended for beavers, most often in 330-size body-grip traps (see Trapping Today 2018; We Are #8Strong 2021). Based on a nationwide survey to determine preferences of trappers (e.g., equipment used, techniques applied, and species sought) in the U.S., river otters were reportedly caught secondarily (i.e., non-target captures) by about 30% of beaver trappers (Responsive Management 2015). The need to mitigate the frequency of these non-target captures is well recognized among furbearer biologists, as evidenced by the development of recommendations (for beaver trappers) intended to reduce the unintended capture of river otters during beaver trapping seasons. The most prominent recommendation involves offsetting the trigger on 330-size body-grip traps (i.e., moving the trigger to the side of the trap; Figure 3) – the trigger modification intends to improve selectivity (i.e., reduce non-target captures of river otters by beaver trappers) and is based on the presumption that river otters would less frequently contact an offset trigger when passing through the trap frame. The recommendation originated from an investigation of various trigger configurations of 330-body-grip traps for capturing river otters and beavers (with a primary intention to determine if specific trigger configurations could minimize secondary captures of river otters) published in the Trapper and Predator Caller (Gotie *et al.* 2000). The trigger modification is widely recommended in state trapping regulations, and BMPs for river otter and beavers– "*Moving the trigger to one side of a body-grip trap increases the chance an otter can get through [a 330-size body-grip trap]*" (AFWA 2014, 2016).

Sundelius *et al.* (2021) demonstrated offset triggers as inconsequential for reducing incidental capture of river otters. Of particular importance, the offset trigger contributed to trap strikes in non-vital regions of captured beavers, i.e., over the abdomen and hip areas at rates higher than traps with triggers centered in the trap frame, which more frequently resulted in strikes to the cervical area. Such an outcome has substantial humane implications in that cervical strikes are more likely to cause quicker deaths than those to the torso (Proulx *et al.* 1990; Proulx and Rodtka 2019). The authors speculate that an offset trigger placement enabled more of the beaver's body to fit into the trap frame prior to activating the trap (i.e., rather than the head making first contact with the trigger). Unfortunately, Sundelius *et al.* (2021) does not mention the locations of strikes to the body of river otters captured in the study. Regardless, considering that river otters generally have a smaller body circumference and are faster swimmers (up to 11 km/hr; Larivière and Walton 1998) than beavers, frequency of strikes to the torso should be considered at least comparable for both species – and likely more so with river otters. Proulx and Rodtka (2019) reported that American martens (*Martes americana*) will circumvent the trigger (2-pronged trigger centered in the trap frame) when initially entering Conibear^{TM} 120 traps, contributing strikes to the abdomen and hind legs. A similar outcome can reasonably be anticipated for river otters given similarities in the general body form of American martens and river otter, particularly so when a body-grip trap is modified by offsetting the trigger.

The capture of river otters in 330-size body-grip traps set for beavers in the U.S. state Vermont serves to highlight humane concerns pertaining to lack of trap selectivity (and well-intended attempts to enhance selectivity). The trapping seasons for beaver and river otters were concurrent until March, when only beavers could be legally trapped. Until recently, trapping beavers in March required offsetting triggers of 330-size body-grip traps with the intention of minimizing non-target capture of river otters. Excerpts from a newspaper article demonstrate unintended consequences of this regulation and associated rationale for extending the river otter season (Ready-Campbell 2017): "*Beaver and otter are caught using the same traps, but otter season ends at the end of February and beaver season ends March 31. This means trappers going after beaver in March are required to modify the trigger mechanisms in their traps to allow otter to pass through unscathed*." Gjessing and Royar [general counsel and furbearer biologist, respectively, for Vermont's Fish and Wildlife Department] identified two primary reasons the department supports P-1704 [proposal to modify trapping regulations], both related to different end dates of the otter and beaver seasons. "*First, they said the department has heard reports from trappers that the modified traps used in March sometimes simply pin beaver until they drown instead of breaking their necks, leading to inhumane kills. Extending otter season would remove the requirement that trappers use the modified trigger mechanism.*" The state wildlife agency in Vermont subsequently addressed the issue by extending the river otter trapping season through March.

Concerns

Trap selectivity evaluations for BMP testing does not consider non-target capture of other furbearing species, thus limiting understanding of the full array of traps a species may encounter and negating the value of trap testing.

Specific recommendations

1. A review is necessary to determine how best to address the issue of selectivity in relation to secondary capture of a species in traps not meeting BMP requirements (or not undergoing testing for that species). Such a review by Responsive Management (2015) serves as a basis for such an evaluation. However, the frequency of secondary capture of river otters in traps set for other furbearers needs to be stratified in a manner that ensures representation of the narrow set environmental covariates likely to include the presence of river otters, which is not the case in the current assessment. For example, rates of incidental river otter captures should only be considered for areas where river otters occur and have the potential to access a trap (i.e., riparian areas, the land-water interface, and in the water).
2. The widely disseminated recommendation to modify the trigger of 330-size body-grip traps to avoid capture of river otters represents a substantial failure of the furbearer management system. Failure to properly evaluate such a recommendation has potentially substantial humane concerns for captured river otters and beavers. The suggested trigger modification needs to undergo additional evaluations before being recommended further as a method for minimizing incidental take for river otters during beaver trapping seasons.

Concluding thoughts

River otter populations in the U.S. have recovered substantially over that last 40 yrs through advent of reintroduction projects in 22 states and natural expansion of remnant populations (Bricker *et al.* 2022). Expansion of river otter trapping seasons followed the reestablishment of river otter populations (Bricker *et al.* 2022). From the late 1990s through present, the number of states allowing legal trapping of river otters expanded from 28 to 42. Coinciding with the recovery and expansion of trapping for river otters was the development of the ongoing BMP initiative intending to address humane concerns pertaining to trapping.

In addition to BMPs, 11 primary research projects evaluated various aspects of different restraining traps pertinent to both practical and humane issues pertinent to capturing river otters. These projects serve as a basis for evaluating the completeness and shortcomings in the BMP developed for river otters. Primary shortcomings of the BMP process relevant to the humane trapping of river otters are represented in these 6 primary areas: 1) approaches followed for selecting traps and trapping systems to be evaluated and the unavailability of details (processes followed and outcomes) for the testing of body-grip traps; 2) variation in trap-check requirements among states, particularly for water trapping; 3) drowning as meeting requirements for a humane death; 4) not addressing humane concerns associated with trapping seasons overlapping periods of parturition and cub rearing; 5) not considering capture of non-target furbearers in evaluations of trap selectivity; and 6) negative messaging that has preceded the initiation of trapping seasons in some states and questionable facts sometimes accompanying messaging to promote trapping (see Serfass *et al.* 2017).

Some of the above limitations relate to the underlying focus of the BMPs process, which is to provide recommendations for humane trapping and not having regulatory capacity. Regardless, many of the limitations highlighted in this chapter should have been addressed in the river otter BMP. The limited number of traps and trapping systems tested result in the river otter BMP offering little new and insightful information pertinent to enhancing the humane trapping of river otters.

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Chapter 3

Approval of Restraining and Killing Trap Models in Sweden, and Suggested Improvements Through Behavioural and Physiological Evaluation

Erik O. ÅGREN[1], Johan LINDSJÖ[2], Ulrika Alm BERGVALL[3], Åsa FAHLMAN[4], Odd HÖGLUND[5], Therese Arvén NORLING[6], and Petter KJELLANDER[3]

[1]Department of Pathology and Wildlife Diseases, National Veterinary Institute, SE-751 89 Uppsala, Sweden. Email: erik.agren@sva.se

[2]Department of Animal Environment and Health, Swedish University of Agricultural Sciences (SLU), SE-750 07 Uppsala, Sweden.

[3]Grimsö Wildlife Research Station, Department of Ecology, Swedish University of Agricultural Sciences (SLU), SE-739 93, Riddarhyttan, Sweden.

[4]Swedish Biodiversity Centre, Department of Urban and Rural Development, Swedish University of Agricultural Sciences (SLU), SE-750 07 Uppsala, Sweden.

[5]Department of Clinical Sciences, SLU, SE-750 07 Uppsala, Sweden.

[6]Department of Organismal Biology, Genome Engineering Zebrafish, SciLifeLab, Uppsala University, SE-752 36 Uppsala, Sweden.

Abstract – Trapping wildlife in Sweden is considered as hunting and is regulated by legislation from the Swedish Environmental Protection Agency. Any trap model used to trap wildlife in Sweden must be approved according to Regulation NFS 2013:13. The basis of the evaluation is to ensure that both killing and restraining traps do not cause unnecessary suffering. Animal welfare, as well as handler safety, are considered. The test protocol also evaluates selectivity, and bycatch is one criterion that can lead to non-approval. Over 30 trap models have been evaluated since the Regulation was implemented in 2013. Over 150 models had been approved previously, without a protocol guided by legislation. Here we summarize our experience from some trap evaluations in the context of future improvements of the animal welfare aspects when testing traps with the present Regulation. We are concerned about the inability of killing traps to cause immediate unconsciousness so that approved trap types cause unnecessary suffering. The present assessment of restraining traps is based on evaluation of lesions noted at necropsy of trapped test animals. Also, the trapping event is to be video-recorded. We suggest that inclusion of requirements such as behavioural studies, measurements of physiological parameters, and more species-specific trapping protocols in the Regulations could improve the animal welfare assessment of traps. The 3Rs need more consideration. Re-evaluation of trap models approved prior to the present Regulation is required as the current standards are higher.

Introduction

Wild mammals are trapped in Sweden as a hunting method and for other management purposes or research. Trapping is regulated by the Swedish Environmental Protection Agency (EPA), in the Regulations on the use of traps, NFS 2018:3, and Regulations on trap model approval, NFS 2013:13. New trap models have to be approved according to a test procedure described in NFS 2013:13. The aim of the evaluation and trap model approval is to ensure that killing traps and restraining trap captures do not cause unnecessary suffering, an important issue mentioned in §27 of the Swedish Hunting Act (1987:259): "*The hunt shall be conducted so that the game is not inflicted unnecessary suffering and that people and property are not exposed to danger*".

Trap capture can impact wild animal welfare in different ways. Killing traps that lead to injuries and fail to cause irreversible instant unconsciousness or death at capture cause prolonged suffering. Restraining trap capture may cause pain, fear, and stress through injuries, restraint, escape attempts and poor environmental conditions, with negative short- and long-term effects on physical health, fitness, and welfare (Powell and Proulx 2003; Iossa *et al.* 2007; Gregory 2004; Cattet *et al.* 2008; Soulsbury *et al.* 2020). In Sweden, to avoid unnecessary suffering, trap approval has to be done according to Swedish legislation (NFS 2013:13), which was created by adapting various parts of the ISO standards (ISO 1999a, 1999b) and the Agreement on International Humane Trapping Standards (AIHTS) (ECGCGRF 1997). According to these standards, approval of trap models is based on time to unconsciousness (killing traps) and physical injuries documented at necropsy (restraining traps). These standards provide minimum criteria aiming at improving animal welfare for trapped animals. However, these standards do not fully reflect the welfare aspects of trapped animals (Iossa *et al.* 2007; Proulx *et al.* 2020). In fact, Proulx *et al.* (2020) found that the AIHTS "*have relatively low animal welfare performance thresholds of killing trap acceptance and do not reflect state-of-the-art trapping technology*" and "*the AIHTS animal welfare indicators and injuries for restraining traps are insufficient*". If an animal is not killed instantly in a killing trap or is captured in a restraining trap, the capture event is a stressor which the animal is unable to control (handle or avoid) (Iossa *et al.* 2007). An inability to cope with the situation results in stress and poor animal welfare (Gregory 2004; Broom and Johnson 2019).

Studies have assessed time to unconsciousness in killing traps (Proulx and Barrett 1993; Proulx and Drescher 1994; Warburton *et al.* 2000), but studies evaluating pain, fear, stress, and suffering during induction of unconsciousness in animals captured in killing traps seem to be rare. Proulx (2018) recorded behavioural changes, such as escape attempts and vocalizations, in predators killed by neck snares, consistent with stress and suffering. Similar evaluations have been made during commercial seal hunting (Butterworth and Richardson 2013) and, more commonly, during the slaughter of domestic animals (Nielsen *et al.* 2020). For example, domestic animals that are exposed to long induction times, incomplete stunning or slaughtered without prior stunning express pain, anxiety, and stress before unconsciousness through behavioural (e.g., vocalizations, escape attempts and other movements, facial expressions), and physiological (hormonal and blood metabolite changes, autonomic responses, brain activity) responses (Authie *et al.* 2013; Nielsen *et al.* 2020).

During capture in restraining traps, exposure to fear, pain, physical exertion, and poor thermal comfort will result in a stress response, such as changes in behaviour (escape attempts, etc.) and physiological parameters (heart rate, body temperature, hematology, stress biomarkers, etc.) (White *et al.* 1991; Proulx *et al.* 1993; Schütz *et al.* 2006; Barasona *et al.* 2013). The AIHTS concluded that there is a need to include behavioural and physiological parameters when evaluating the welfare impacts of restraining traps (ECGCGRF 1997). Several studies confirm that behaviour and physiology provide essential information about the welfare of animals captured in restraining traps (e.g., Schütz *et al.* 2006; Huber *et al.* 2017; Fahlman *et al.* 2020).

The Swedish trap tests includes legal minimum requirements regarding animal welfare concerns. In this chapter, we discuss the present Swedish trap model approval procedure, benefits and pitfalls. We suggest possibilities to provide a more complete picture of trap-captured animals' welfare by introducing behavioural and physiological assessments in the test protocol, as well as some other suggestions to improve animal welfare in both restraining and killing traps.

The Swedish system for testing restraining and killing trap models

Background history

The Swedish system for testing trap models was implemented in the early 1980s, after a new Regulation (SFS 1981:678) stated that restraining traps had to be approved (revision of the hunting Regulation SFS 1938:279). Breaking new ground, an approval system was established in collaboration between the Environmental Protection Agency (EPA), the National Veterinary Institute (SVA), the Board of Agriculture, and animal welfare associations. There were no formal or regulated requirements for the approval of traps at that time. Most trap models were then home-made and built by trappers, so it was usually a blueprint with details on how a trap was to be constructed that was evaluated, and when approved, the blueprint was made available to the public. The killing trap models were usually evaluated by necropsy of field captured animals from experienced trappers, and in some cases, of more controlled trapping in a laboratory animal house setting. The researchers involved were active in discussing the development of proposed ISO standards (Torsten Mörner, personal communication, 2019, 2021).

After rotation of involved staff, the work with trap testing and approval was dormant for several years. In the 2010s, a backlog of over 30 new applications for approval of new trap models needed evaluation by the EPA. A need to formalize the evaluation process and ensure that the system was transparent to all applicants, was also recognized.

The Swedish trap approval Regulation process

Specific EPA Regulations for trap approval were drafted, based on contents of the AIHTS and the ISO-standards (ECGCGRF 1997; ISO 1999a, 1999b) and with input from competent authorities such as SVA, and the current criteria were finally made official in 2013 (NFS 2013:13). In addition to evaluation by necropsy of trapped animals, video recordings of the test capture events were now also required. The present trap test organisation (see below) found the video material useful in assessing or confirming if lesions found at necropsy originated from the capture event. Using the video material to study the behaviour of trapped animals has been used in some, but not all, evaluations, as this requires scientific knowledge on the behaviour of the target species involved in the trap test. However, assessment of behaviour is not a compulsory component of the approval protocol.

That new trap models must be approved according to the Regulation NFS 2013:13 provides a transparent and detailed trap testing procedure, including how and what is evaluated in the assessment of new trap models, and cut-off criteria for the approval process (Table 1). Applications for approval now mainly involve commercially manufactured traps sold over the counter, and the trap producer needs the EPA approval to make the trap legal to use for trapping. Therefore, approval or decline of an application may result in an appeal and possibly litigation if the process is in doubt. Selling or building a trap is not regulated but actively using it to trap animals is defined as a hunting method and is thus regulated. It is also regulated for trapping purposes other than culling, such as wildlife management activities or research, although research also falls under the Swedish Animal Welfare Act (2018:1192). An ethical permit is needed for all test trapping, also for field captures in a natural setting, according to the same Act. So, regardless of the reason for trapping, all traps must be approved under the same standards and the EPA lists all approved traps on their website (EPA 2021). Regulation NFS 2013:13 has been used to evaluate and approve over 30 new trap models, both killing and restraining systems, since 2013. Also, a similar number of traps were not approved after assessment by the test organisation, since 2013.

The present trap testing process also assesses trap selectivity and safety for humans and property. The test protocol does not evaluate how effective the model is at capturing the target species, but bycatch (trapping of non-target species indicating non-selective capture) and failure to capture target animals within the test period may prevent approval. Trap models that have been approved in an EU member state, Turkey or an EFTA country, do not necessarily need to be tested and approved before use in Sweden. For this to apply, such traps must, however, still be registered with EPA and must meet Swedish animal welfare and safety standards. Traps tested according to the AIHTS and approved in Canada and Russia, are approved for use in Sweden by the EPA without further testing (NFS 2013:13). Applications are reviewed and approved based on the AIHTS criteria. However, the AIHTS only covers certain species (ECGCGRF 1997).

The backlog of trap approval applications at the EPA arose as there has not been any commercial or permanent test facility in Sweden where the traps can be tested. A temporary solution was to contract researchers from SVA to test killing trap systems, and later restraining systems have been tested by the University of Agricultural Sciences (SLU) and SVA in collaboration, which constitutes the present test organisation, albeit an ad hoc solution. The practical trap tests and evaluations that have been conducted based on the NFS 2013:13, have highlighted a number of shortcomings of the test procedure and Regulation, with either missing or flawed issues being noticed.

Another issue of concern is that trap models approved before 2013 remain legal to use. It is our opinion that several of these traps would not pass the requirements of the Regulation NFS 2013:13, based on the experience of the present test organisation with multiple practical tests performed and in view of the consequent approval or declined approval of various new traps. We have put forward to the EPA the need to re-evaluate older approved traps to ensure that at least minimum requirements of animal welfare performance are maintained for all approved trap models when trapping wildlife. This action is possible according to responses from EPA, but still needs to be realised. In addition, as there is no requirement for trappers to report poor performance of a trap model, there is no data available to use as guidance for which traps should be re-evaluated. Thus, reporting of poor performance of a trap model is crucial, and we suggest reporting should be mandatory, or be conducted by contracted trappers who are willing to collaborate with the responsible authorities.

Table 1. Limiting criteria for tests of killing and restraining traps in Sweden according to Regulation NFS 2013:13.

KILLING TRAP TEST

12 animals of target species to be captured

Approved if: 9 of the 12 captured animals are irreversibly unconscious within the maximum time limit (see below). Selectivity: not more than one individual of other species than target species.

Not approved or test aborted if:

- 3 animals not unconscious within maximum time limit
- 3 animals are obviously struck in non-target body area
- The trap obviously does not fulfil the described functionality or breaks down during normal handling according to included instructions.

Maximum time limits in seconds, to reach unconsciousness in at least 80% of captured animals:

• Squirrel, ermine, lemming, mole, mouse, shrew, vole, rat, weasel	45
• Muskrat, polecat, mink, marten, ptarmigan, rabbit	120
• Beaver	180

RESTRAINING TRAP TEST

20 animals of target species to be captured

Approved if: The lesion points do not exceed the maximum allowed. Selectivity: not more than one individual of other species than target species.

Not approved or test aborted if:

- The lesion points exceed the maximum allowed (see below).
- The trap obviously does not fulfil the described functionality or breaks down during normal handling according to included instructions.

Maximum allowed lesion points:

- Maximum 3 individuals that each have lesions adding up to 10-19 points, or
- Maximum 2 individuals that each have lesions adding up to 10-59 points, or
- Maximum 1 individual that has lesions adding up to 60 points or more

Experiences from the current trap testing system – benefits and challenges

Here we present some examples of performed trap tests and discuss some of the benefits and challenges we have experienced while working with the current trap testing system in Sweden, evaluating both killing and restraining traps. Although the work on improving animal welfare during trapping has been ongoing for decades, and Regulations regarding trap model approval in Sweden are in place, further improvement is needed. Existing data and experience from trap tests should be used to improve the Regulations and thus achieve a more complete and better animal welfare evaluation of trap models.

Killing traps – Rodents

Several killing trap models for small rodents such as mice and rats have been tested based on Regulation NFS 2013:13 (Figure 1). Interestingly, the results showed that most models of the common snap trap, with a spring-loaded wire bar that is supposed to hit the rodent over the neck, do not kill the animals instantly (with immediate and irreversible unconsciousness), even if they often are advertised with the claim to do so. The outcome will be determined by both impact momentum and clamping force (Parrott *et al.* 2009; Baker *et al.* 2012). The clamping force for most models is only effective when the strike of the wire bar hits directly on the dome of the skull, causing immediate unconsciousness followed by death due to brain trauma (Morriss and Warburton 2014). When the wire bar strikes the neck, behind the head, the animal is suffocated to death as the momentum and clamping force do not severely damage or crush the neck vertebrae, which are protected and cushioned by furred skin, muscle, and other soft tissues.

The time from capture to unconsciousness varied from 0 to >60 sec in the tests, and after 60 sec, a caught animal was euthanized as per the ethical permit for the trapping test. The NFS 2013:13 presently allows for a delay of up to 45 sec from capture to irreversible unconsciousness for at least 80% of captured animals when testing killing traps for mice and rats. Notably, this conflicts with the same Regulation if this delay is caused by strangulation, which is not a permitted method for euthanasia of domestic animals or pets (SJVFS 2019:8) and suffocation of wild animals in traps (NFS 2013:13). Prolonged time to unconsciousness in killing traps is consistent with pain and fear (Proulx *et al.* 2020). Research suggests that breathlessness itself can cause psychological stress as air hunger has been recognized as the most unpleasant sensation (Beausoleil and Mellor 2015).

With present knowledge, we foresee that several killing traps for rodents approved prior to 2013 would not pass the test criteria or be approved if re-evaluated based on NFS 2013:13. The testing organisation has raised this issue with the EPA and hopes that re-evaluation of the older approved traps will be required in the future. Presently, the approval of a trap model is not time limited, and action from the EPA would be needed to revoke an approval.

Implications for rodent welfare due to mechanical performance (Baker *et al.* 2012) and adaptions of killing traps have been published (Morriss and Warburton 2014). For rodents, killing traps should cause immediate and irreversible unconsciousness, as this is possible to achieve. There is presently one model used in a couple of commercial mouse trap models that guides the animals' head into the trap towards the bait, so the clamping bar should always strike the head and not the neck when the trap mechanism is triggered, enabling instant unconsciousness.

We believe it is important for trap manufacturers to consider the results of performed trap tests. Then they could avoid production of variants of the mainstream and suboptimal models, and instead improve the design to ensure optimal animal welfare when developing new trap models.

Restraining traps – Mice and rats

Two small (about 14 x 3 x 3 cm) models of enclosed box traps for restraining capture of one mouse or small rodent at a time, have been tested by the test trapping organisation (Figure 2). No live-capture traps of this type of restraining trap model have been approved, as testing was stopped when trapped wild house mice (*Mus musculus*) were found dead in the trap about 5 h after capture. The necropsy showed signs of empty stomachs and acute gastric hemorrhage, indicating severe, acute stress (Hall *et al.* 1988), maybe in association with lack of food, as the main cause of death. In the light of these results, the EPA shortened the time limit of trap checking to maximum 5 h for restraining traps for mice.

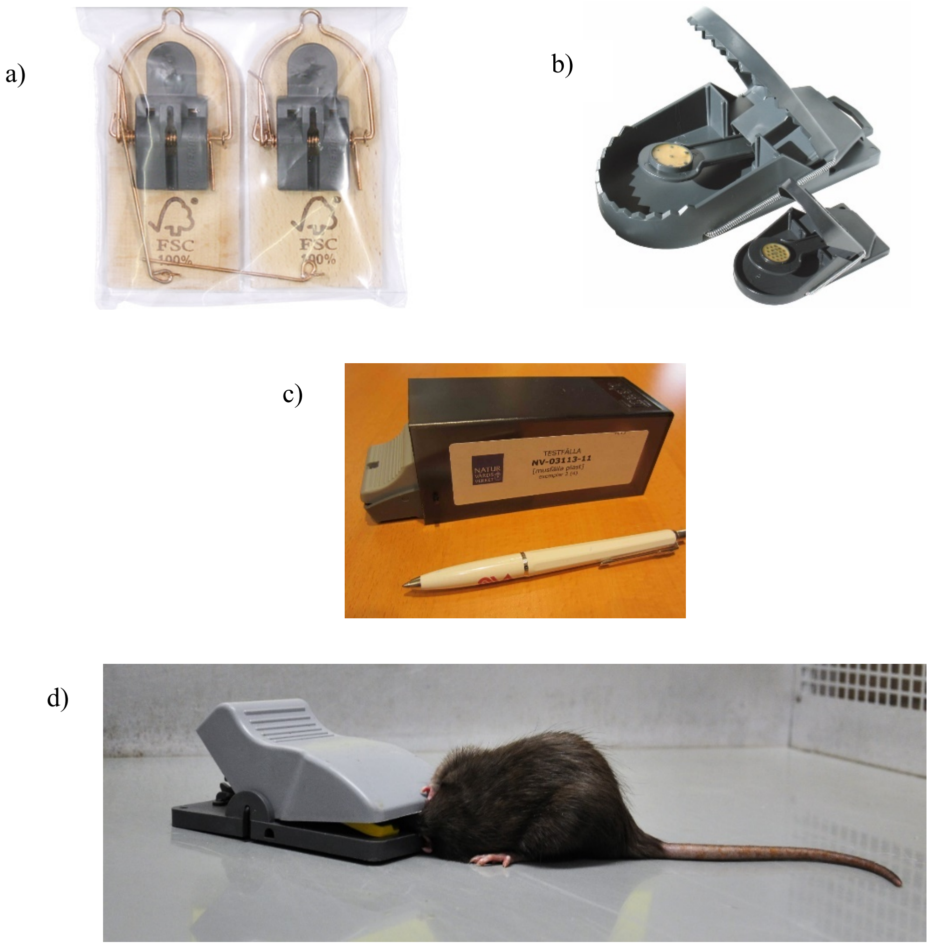

Figure 1(a-d): Examples of killing rodent traps for rodents that were tested, but did not pass the criteria of the Swedish Regulation NFS 2013:13, and were not approved for use in Sweden. The bottom photo (d) shows a still living trapped rat that is trying to free itself from the trap, which struck correctly at the target site over the neck, but did not become unconscious and had to be euthanized after the maximum time had passed. Photos from the application documents, Swedish EPA, and SVA.

The test organisation considered that capture of small rodents in this type of restraining trap need to be regulated by strict and short capture-to-release times, if they are to be used at all, or sold to the public. To improve animal welfare when capturing mice in restraining traps, an electronic alarm system informing the trapper when the trap is sprung, would be a necessary component to minimise suffering by keeping capture time as short as possible. But at present, without legislative requirements or consumer driven demands, this seems unlikely to be realised as rodent traps in general are very cheap and adding an alarm system would increase costs considerably.

Video recordings of mice captured in the trap provided minimum time of death by showing when the mice stopped moving altogether. In total, 5 out of 16 captured mice died in these types of small restraining traps. The shortest time from the moment of capture until a mouse was presumed dead was 5 h and 38 min. The average time to death for 5 animals was 6 h and 38 min, presumably from capture stress.

Footage of the trapping event also gave us an idea of when a lesion occurred. We could also note if other animals approached the trap. The videos of some restraining traps for mice showed that tail injuries noted at necropsy occurred at the moment of capture, as the mouse tail was still outside the trap when the trap door was sprung and closed. In 2 cases, the mouse was stuck with its tail for several hours before it managed to pull it loose, with apparent skin lesions as a result. In 3 cases, the mouse was trapped with its tail clamped by the trap door for the entire time it was in the trap. These tail injuries occur when the distance between the bait and the trap door is too short. These test traps were less than 110 mm or 140 mm in length; an adult house mouse is between 125 and 200 mm long including the tail, which can vary between 50 and 100 mm in length.

Another observation was that one mouse gnawed on the trap wire mesh, which was confirmed by finding paint flakes in the stomach of the mouse at necropsy, which is a sign of non-lethal but potentially significant stress, further emphasising the importance of using video footage for behavioural assessments (Proulx *et al.* 1993; Fahlman *et al.* 2020). The level of stress response would likely have been confirmed with physiological biomarkers of stress validated for mice.

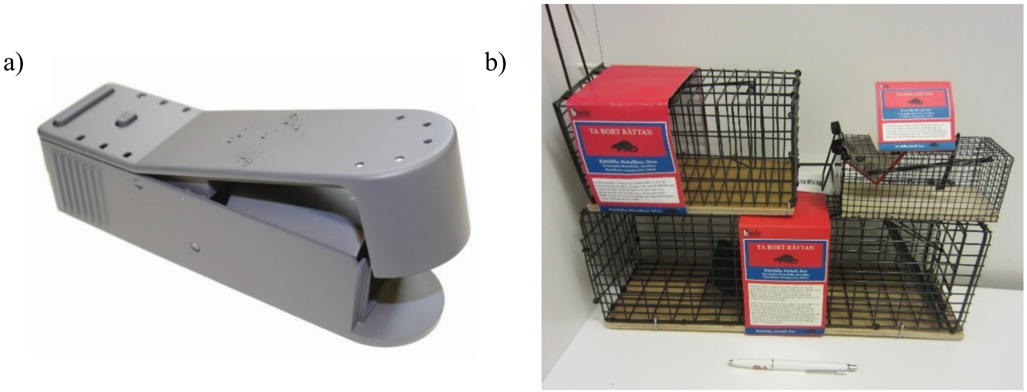

Figure 2 a-b. Example of restraining traps for mice and rats that were tested, but did not pass the criteria of the Swedish Regulation NFS 2013:13, and were not approved for use in Sweden. Photos from the application documents, Swedish EPA and SVA.

Restraining traps – Wild rabbits (*Oryctolagus cuniculus*)

Restraining traps for wild rabbits are generally wire mesh cage traps (Figure 3 a-b) baited with attractive feed in form of carrots. According to the legal requirements, these traps only need to be visited at least once every 24 h, but always once at dawn (NFS 2018:3). For the practical test, following NFS 2013:13, of a wire mesh rabbit trap for single captures, 20 rabbits were caught and killed, 16 of which were documented on film. The traps were placed directly on the ground, on a flat surface, protected from strong winds and with about 5 carrots placed at the far end from the entrance. Trapped animals were killed upon arrival with a .22 caliber handgun or rifle.

For this trap test evaluation, we added a study of the rabbit behaviour on video footage from the captures, to help evaluate the trapping events. More than 12 h of film from when rabbits were inside that trap were analyzed, and behaviour was recorded using continuous focal individual observations (Altmann 1974). To describe the rabbits' behaviour, an ethogram by Andersson *et al.* (2014) was used as a starting point. The behaviours that could be discerned were: lying down, fleeing (moving quickly to the other side of the trap from obvious threat heard, smelled or seen through the mesh), foraging (eating and handling food), grooming, sitting still (sitting with the chest close to the front legs), being vigilant (sitting with straight front legs or standing on hind legs and having pointed and moving ears), gnawing on the bars, and a behaviour noted as 'movement', where the rabbit moves around the cage, sniffing the walls and ceiling of the cage, the carrots, or twigs and, in rare cases, digging with its front paws into the bottom of the cage.

In addition to the behavioural observations on focal individuals, a simple snapshot observation was performed to assess the extent to which rabbits were present outside the cage. For this observation, the videos were used where the camera record the cage at an angle where 2 areas of about 40 cm each beside the trap are visible on the film. This study material consisted of the initial sequence of 154 film recordings where the area was visible and were randomly selected among these films.

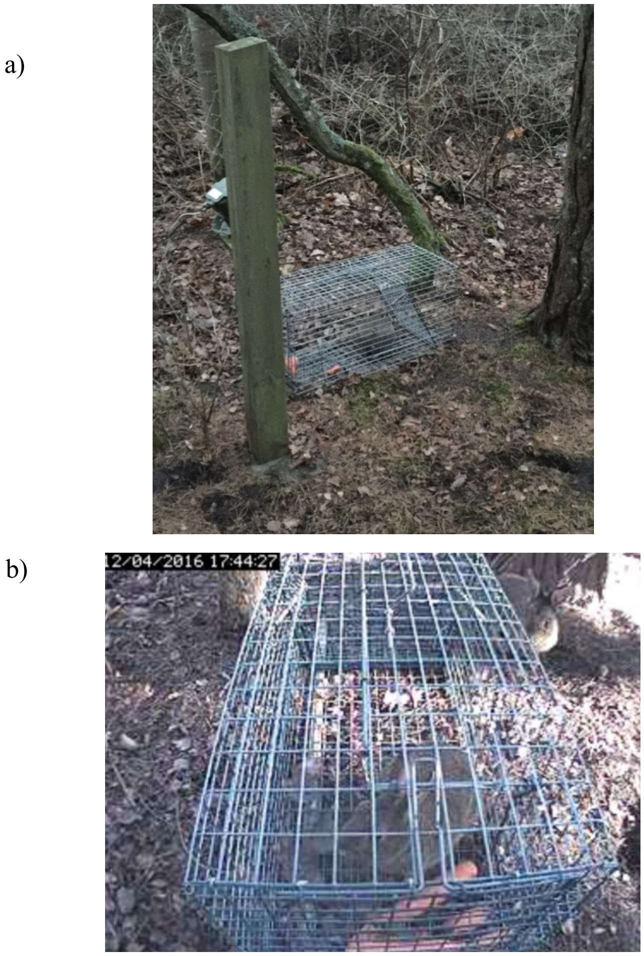

Figure 3 a-b. Rabbit mesh cage restraining trap with caught rabbit. Image (b) from video film. Photos: SLU and SVA.

From the 13 rabbits which were filmed with satisfactory quality, the most frequent behaviours inside the cage were moving (57.3%) or foraging (16.6%), followed by being still (14.2%) and grooming (4.5%). Rabbits gnawed on the bars 2.7% of the time, and made nose to nose contact with another rabbit outside the cage 2.1% of the time. They were visibly vigilant 2.6% of the time. The behaviours of fleeing and lying down were performed less than 0.1% of the time. Rabbits that were outside sometimes tried to get into cages and access the carrots. Cage were also frequently visited by small rodents that fed on the carrots but moved freely in and out through the mesh.

Behaviour at the moment of capture varied from being startled and jumping away to continued foraging, which is what triggered the trap. When a rabbit was caught, other rabbits outside the cage often continued their behaviour. On one occasion, the rabbit in the trap was chased from side to side, and probably attacked, by a red fox (*Vulpes vulpes*) that was outside the trap for 1.5 min. Since the trap was made of mesh, the fox tried to capture the rabbit that ran over to the other side of the trap and so on until the fox disappeared. The rabbit then sat still for 12 min before moving and eating carrots after 15 min.

From our behavioural observations, we draw the conclusion that rabbits did not display neophobia towards the trap itself, but the captured rabbits tried to follow the outside individuals if they moved away from the trap. Rabbits live in social groups (Ekesbo and Gunnarsson 2018), and it is therefore desirable that when using traps for single captures, there are other rabbits present outside the trap and that the rabbit inside the trap can see and smell other rabbits. For group-living species such as rabbits, it may be more beneficial from an animal welfare perspective to use traps that allow multiple animals to be captured.

While a rabbit was in the trap, another rabbit was visible in the vicinity of the trap for 27% of the total time. Rabbits were actively sniffing each other 2% of the time. Also, rabbits outside the trap could be visually separated from the captured rabbit by branches, tall grass, or other items. The rabbits may have been more affected by not being able to follow other rabbits and less by the fact that they were trapped.

In conclusion, the trap design allowed captured rabbits to perform some of their natural behaviours such as foraging and grooming (Ekesbo and Gunnarsson 2018). Trapped rabbits could see other rabbits outside and could have nose contact through the wire mesh when rabbits were outside. However, this requires that the trap be placed in an area that allows other rabbits to be outside the trap most of the time, which depends on how long and when the trap is set. The rabbits in our test were trapped on average 4 h and 13 min (minimum of 2 h, maximum of 11 h) before they were killed.

Under these conditions, with abundant food and contact with other rabbits, the trapped rabbit continued eating even after many hours in the trap. In all trap events, carrots were still available at the time of killing. It is well known that severe stress can cause rabbits to stop eating. This was not seen in the study of this trap model. However, animals may show different displacement behaviours associated with frustration and stress (Appleby *et al.* 2018), and eating as a potential displacement behaviour in trap-captured animals needs further investigation.

In addition to the actual trap design, it is important that the trap is used under conditions that minimise stress, such as protection from weather and predators (NFS 2018:3), and written instructions be provided on how to use the trap for optimal animal welfare. Such instructions were at a later stage included in the approval document of the trap from EPA, but ensuring that all instructions are followed by the users is difficult to control. Sometimes rabbits are to be captured in populated areas, and under such circumstances it is of great importance to inspect traps early in the morning, before humans start to pass by in the vicinity, to reduce stress to the animals. But predators can also harass rabbits captured in more rural areas.

The main findings at necropsy of euthanized rabbits captured in restraining trap were minimal microscopic chipping of the front teeth (incisor) cutting edge due to gnawing on the trap cage. This is not expected to induce any physical pain, as the incisor teeth grow continuously, and the tips are not innervated (Crossley 1995). Minor claw lesions were seen after digging and escape behaviour on the wire mesh floor in some of the examined animals. The captured rabbit chased by a fox outside the trap had a skin bite wound and a tooth lesion, but the accumulated lesions points for the 20 captured rabbits were within the acceptable range and the trap model was approved. However, based on behavioural observations and injuries, we can conclude that rabbits showed signs of stress at some point during capture. Physiological measurements would provide additional information about the stress response (or lack thereof) in animals that seem calm, undisturbed or with no obvious or minor trap-related injuries, which could identify stress in seemingly undisturbed and unharmed animals. For example, rabbits are very good at hiding signs of pain. (Ekesbo and Gunnarsson 2018).

Restraining traps - Wild boar (*Sus scrofa*)

Free-ranging wild boar were captured as part of the approval process for 8 restraining trap models in 2010, before the NFS 2013:13 Regulation was in place, but the evaluation was based on the, at the time, not yet implemented ISO standards for restraining traps (ISO 1999b). Most models were portable box traps for 1 large adult or several smaller juvenile wild boars, but also a couple of larger pen traps for multiple animal captures (Figure 4). The ethical permit for these tests limited the time from capture to euthanasia of test trapped animals to 3 h, although the hunting Regulations for trapping wildlife in general allowed a maximum time of 24 h from capture to trap inspection for release or euthanasia. Since we were only able to assess the effects of trapping for up to 3 h, this limited the evaluation of longer capture times for the animals. The field staff euthanized the test animals in the traps with a caliber .22 rifle, with head shots as soon as practically possible after arriving to the trap, followed by bleeding the animals.

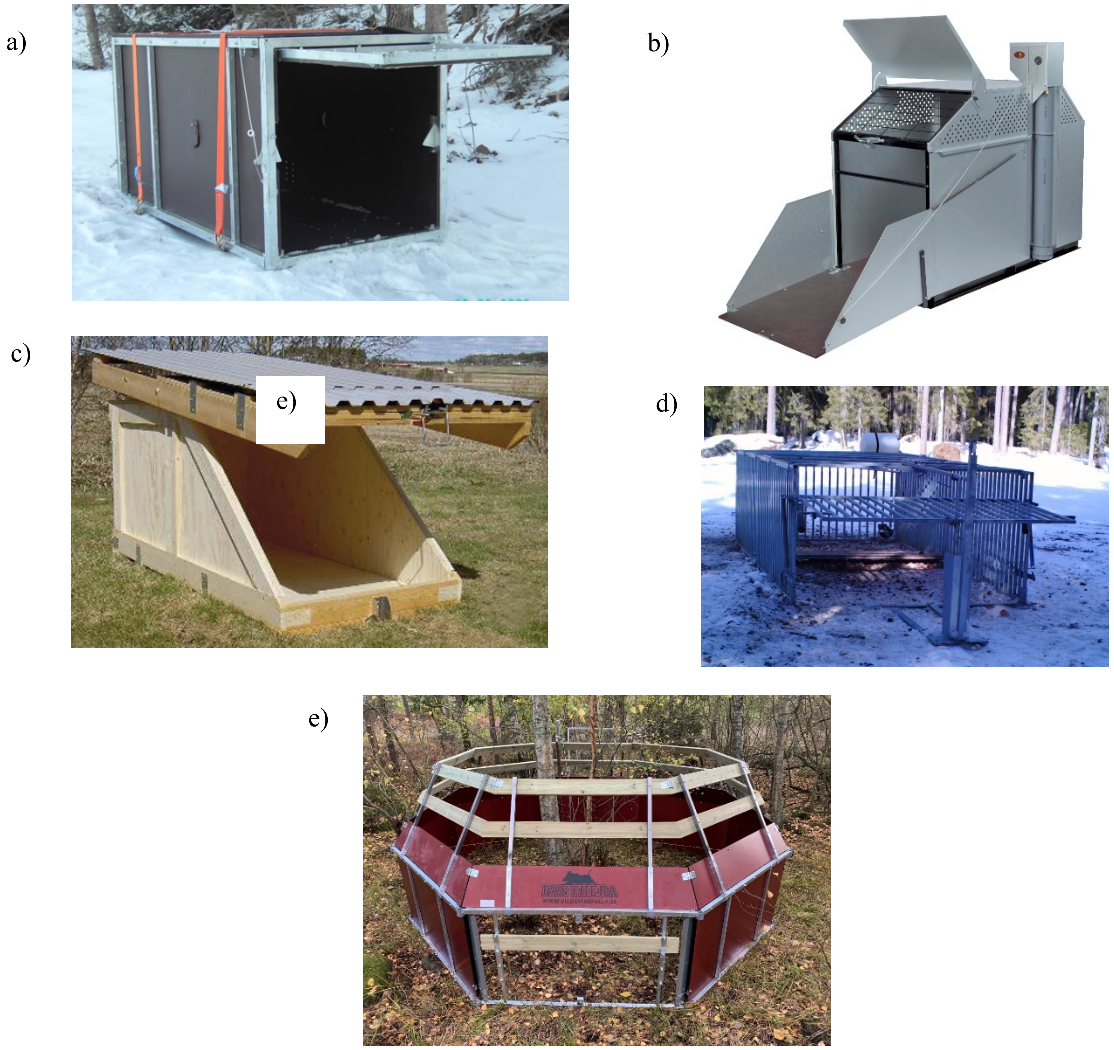

Figure 4 a-e. Various models of restraining traps for wild boar that have been assessed for approval by the Swedish EPA. The 2 bottom figures (d-e) are multitrap models. The wooden bar across the entrance in the bottom figure trap is a height limit to avoid capture of adult wild boar. Photos from the application documents and from SVA. The bottom photo is from the website www.vildsvinsfalla.se.

Notes were taken on the observed behaviour of the captured wild boar (Table 2). Both single animal and multiple animal capture events occurred, both in smaller, enclosed box traps, and in larger open multi-trap systems. The euthanized animals were transported to SVA for necropsy, which was usually done on the same or following day during office hours. Visible external lesions were noted, and lesions assessed as acute were attributed to the capture event. Especially, skin, teeth, and claws were inspected for any acute lesions. Internal organs inspected were especially the gastric mucosa, for signs of possible stress in the captured animals with changes such as gastric mucosa hyperemia or hemorrhage, and hyperemia, as well as lungs for signs of circulatory changes.

The injuries were, with one exception, minor with superficial skin lesions dominating. Also, wild boar that displayed high activity at the time of euthanasia, running around and charging into the trap walls, did not necessarily have obvious skin lesions. The skin of wild boar is thick and resilient to trauma, therefore, assessing visible lesions is not a fine-tuned method to evaluate stress in this species. Various trap-related injuries in wild boar have been reported elsewhere (Sweitzer *et al.* 1997; Fenati *et al.* 2008; Fahlman *et al.* 2020).

In addition to pathology, film sequences showed behaviour indicating signs of stress in several captured wild boars. The most apparent stressor resulting in escape behaviour was when the field staff approached the trap for euthanasia. This implies that protocols for euthanizing from a hidden and distant position where the trapped animals cannot see or sense the human presence would improve animal welfare. However, possible passive stress responses could not be properly evaluated.

An additional side-study that attempted to evaluate stress in captured wild boar, was done by analyzing muscle tissue for PSE (pale, soft, exudative) changes, as seen in domestic pigs affected by stress (Hestvik *et al.* 2011; Trevisan and Brum 2020). The results did show presence of PSE changes in trap-captured wild boars. There was a weak correlation of more PSE changes in captured wild boars in which also acute traumatic lesions were found at necropsy, compared to animals without visible lesions (Hestvik *et al.* 2011).

This assessment was subjective and there is limited knowledge on PSE muscle tissue change in wild boar. Therefore, the results could not be used for the official evaluation of the trap system, and this criterion is presently not required or included as an indicator of stress in NFS 2013:13.

Table 2. Ethogram with behaviour categories and descriptions used in a study on restraining trap captured wild boar in a corral-style trap (Fahlman *et al.* 2020).

Behaviour categories	**Behaviour of focal individual**	**Behaviour description**
Rest	Rest	Lying down, usually together with others. The behaviour is preceded by a bedding behaviour in a calm way.
Still	Still	Stands without any foraging attempts and takes maximum two steps.
Foraging	Foraging	Foraging behaviour including searching, rooting, eating, and scraping with front legs.
Active	Walk	Walks with short pauses, exploring the environment within the trap, or interacts with other individuals in an exploring or neutral way.
	Moves fast	Moves fast and pauses between the fast movements are less than five seconds.
	Chase	Chases or is chased by another individual.
	Bite	Bites or is bitten by another individual.
Escape	Biting mesh	Bites the mesh wall.
	Rearing	Rise up on its hind legs and puts the front legs on the wall or the door.
	Charging	Running/charging into the mesh wall or trap door, colliding, with usually snout first, or with other body parts.

After the implementation of the Regulation NFS 2013:13, several other restraining traps for wild boar have been tested for approval, with similar necropsy findings and scoring of trap-related injuries. However, behaviour, muscle tissue changes, or other physiological measures have still not been part of the final decision of approval. To decrease the risk of suffering, it is now mandatory to equip restraining traps for wild boar with an alarm system, and to respond as soon as possible after an alarm is set off to minimise capture time periods (NFS 2018:3).

Conclusion – Experiences from the current Swedish trap testing

In conclusion, after testing multiple trap models according to the new Regulation NFS2013:13, we have gained a lot of experience on how the regulatory details can be applied in the assessment of a test trapping result, and what is lacking and could be improved to refine the evaluation. Time to unconsciousness in killing traps is a serious welfare concern. For capture in restraining traps, we find observations of species-specific behaviour helpful to assess welfare and suggest that further improvements can be made with validated physiological assessments.

Because an application for approval is valid only for a trap model in the design version submitted to the EPA, there is presently no possibility to modify the trap during the approval process. We propose that the approval protocol could be revised so that trap designers could be suggested to alter any obvious flaws in the design that the experienced testing organisation finds when scrutinising the application for trap model approval. In that way, fewer animals would be sacrificed in trapping tests, and newer trap models with improved animal welfare aspects could become available. In addition, we propose that reporting of poor trap performance (animal welfare, selectivity, and safety) should be mandatory since this can result in withdrawal of the approval of previously approved traps (available for sale) (NFS 2013:13).

Ways forward to a test system for improved evaluation of animal welfare

Based on our experiences from the Swedish trap testing system and with support from peer-reviewed literature, we suggest that today's trap testing in Sweden, and elsewhere, is insufficient from an animal welfare perspective, with approval of unacceptable killing trap models and incomplete indicators for restraining traps.

Injuries from killing traps may cause unnecessary pain and fear if death is not immediate (Gregory 2004). Accepted maximum time to unconsciousness is far too long (for some species, a maximum of 180 sec in the Swedish legislation [NFS 2013:13], and 300 sec in AIHTS [ECGCGRF 1997]). The induction time to unconsciousness needs to be considerably shortened (Warburton *et al.* 2000; Proulx *et al.* 2020). Still, immediate and irreversible unconsciousness followed by death is the only killing trap performance that would ensure that a captured animal does not suffer at all, and should be aimed for.

This would be achievable with innovative design and construction of new trap models. Thus, mechanical evaluation is crucial for improved animal welfare performance in killing traps, as well as detailed instructions for handling and increasing selectivity, such as placement, choice of bait to avoid bycatch as well as avoiding non-killing captures that cause injuries and pain. The impact on animals that escape from a triggered trap also needs to be considered in the welfare assessment of killing traps (Proulx *et al.* 2020).

When assessing capture welfare performance of restraining traps, the present injury score system based only on necropsy findings does not necessarily mirror inflicted pain (e.g., seemingly minor injuries with low injury scores may actually cause significant pain), fear and stress, which is manifested by behavioural and physiological alterations (Iossa *et al.* 2007).

Behavioural observations and physiological measures may also provide information about potentially less stressful situations for trapped animals (e.g., group-living herbivorous animals captured together in large, enclosure-like traps), and reactions to capture duration, thermal comfort, separation from conspecifics, and threats from predators and approaching humans. For a more complete picture of animal welfare of animals trapped in restraining traps, we emphasise the need to develop, validate and include behavioural and physiological indicators when testing welfare performance (Iossa *et al.* 2007, Proulx *et al.* 2022).

Assessment should take both short- and long-term effects into consideration (Iossa *et al.* 2007; Proulx *et al.* 2020). For example, cameras can provide film sequences of behaviour during and following capture (Proulx *et al.* 1993; Fahlman *et al.* 2020), and GPS-fitted collars can show behaviour and survival after release (Cattet *et al.* 2008; Brogi *et al.* 2019). Biomarkers in blood, saliva, urine and feces, and changes in hematology and serum chemistry associated with stress, strenuous physical activity, muscle injuries, and dehydration, provide physiological data during and after capture (Monterroso *et al.* 2022; Nájera 2022). Body temperature and heart rate can be logged in microchip and tags (Cattet *et al.* 2003; Schütz *et al.* 2006). In fact, AIHTS stated that for "good experimental practices", physiological and behavioural indicators can be included in a trap testing protocol after scientific studies to validate such indicators (ECGCGRF 1997).

Ways forward to integrate behaviour and physiology in trap testing – Evaluating restraining trap capture of wild boar as an example

Trap-related physical injuries and increasingly, but not mandatory, behavioural observations are used in testing restraining traps (see previous examples of testing restraining trap for rabbit and rodents). To further advance our understanding of behaviour and physiology as indicators of animal welfare, we conducted parallel studies when the EPA was evaluating a wild boar trap, including scoring of trap-related injuries (Fahlman *et al.* 2020, 2021).

Behavioural observations

Wild boars were studied during 13 trapping events in a corral style trap during March−April 2015. In 12 of the trapping events, the trap was set and on one occasion the trap was un-set for the entire duration of the recording. In total, the animals were filmed for 105 h. The total recording time was 371 h of filming of individuals. The cameras (EYE-02 Jablootools) were equipped with infrared light for night vision filming and were adapted for surveillance. The cameras were motion sensitive, and recorded video or still images only when activity was detected. When animals had been inactive for about 10 min, recordings stopped. The behavioural study was also part of a bachelor thesis resulting in a research study (Fahlman *et al.* 2020). Therefore, we were able to watch more hours of recordings and also analyze wild boar behaviour, in addition to conduct the EPA trap test assignment.

A pilot study was conducted in which selected behaviours were recorded, and the resulting ethogram was evaluated (Table 2). Thereafter, behavioural observations were conducted on 3 separate time periods of each capture event (up to 5 h of recording per capture); evening (from capture and 2 h ahead, before 23:00), night (1 hour between 23:00–05:00), and morning (2 hours after 05:00, until euthanasia). The total number of charges (wild boar running as an escape behaviour) into the trap mesh walls or door was counted for all individuals during the 3 different periods of each capture event, and divided by the number of individuals per capture. The time from arrival of the wildlife manager until all trapped animals were euthanized was recorded. In recordings shorter than 5 h, observations were performed on the entire footage. When recordings had more than 1 individual, a focal animal was selected using convenience sampling; where one animal left the trap by jumping out, a new focal animal was selected. In the case where sows with accompanying piglets were recorded, only the sow was observed while the behaviour of the litter was noted more sketchily. In addition to the behaviour of the focal animal, the presence of other boars outside the trap was also recorded.

In total, we observed 43.5 h of film from 12 different captures. Wild boar in an open unset trap spent a significantly greater part of their time foraging in the trap compared to captured animals in closed traps (Arvén Norling 2015). Animals in closed traps spent more time foraging in the evening than in the morning. In some cases (4 out of 11 captures), trapped animals charged against the mesh wall at the moment of capture; in other cases, wild boars continued to eat and no reaction could be observed from the films. However, upon the approach of a hunter, wild boar jumped to the mesh wall 6 times out of 7 occasions. Similar escape attempts in wild boar traps have been described by Sweitzer *et al.* (1997).

Nine out of 20 animals were noted with trap-related physical injuries at necropsy. The risk for injuries on the snout was greater upon arrival of humans at the time of killing or release than at the moment of capture (Fahlman *et al.* 2020). The results also show that a single animal reared up against the wall with its front legs for longer times than animals that were captured as a group.

In general, filming animals in traps can provide information on any details of a trap that can cause injuries and when injuries occur. Importantly, observed behaviour indicated stress in animals, irrespective of whether injuries were minor (low injury scores) or absent. Thus, stress and suffering may be present without or with only minor injuries, and a low injury score does not necessarily represent the animal welfare of trapped animals. In our wild boar example, the animals behaved in such a way that injuries could occur during capture or when the hunter arrived in the morning, but clearly stressful behaviour, such as escape attempts, occurred without lesions, or with minor injuries.

However, we believe that injuries during capture may be reduced when bait is applied correctly and in sufficient amounts. The approach of the hunter may also be adapted to reduce the fear and stress of captured animals. The timing of escape behaviour (observed at different occasions from capture until killing) and when injuries are sustained is important in assessing the length of time an animal is subjected to stress and suffering. Whether a boar receives an injury immediately before being killed or whether the injury occurs 12 h before makes a big difference in time of suffering, although the aim should be to avoid all injuries. A problem to assess behaviour and possible injury events arises when the video quality is too low (poor resolution and short sequences due to idle camera when there is no movement in the trap) and the followed focal individual cannot be continuously observed. This makes our type of filmed behaviour study suitable for evaluating test traps but hardly for getting an idea of individual differences in behaviour.

Another concern is when a sow is caught with her piglets. In one case, piglets from a sow were observed outside the trap when the sow was trapped inside the trap with the rest of the litter. In one occasion, a piglet was trampled and severely injured, and had to be euthanized. It would be desirable to have small holes to allow small piglets to enter and exit the trap to assure necessary nursing and heat from the sow. However, the Regulation does not allow for the constructor to make design changes during the test. This particular case highlights the problem of this rule, which is an obstacle for improved animal welfare performance. It may be added that sows with piglets must be released but this category of wild boar may still be trapped for several hours.

Foraging and resting are indirect measures of lack of stress; stressed individuals perform fewer of these behaviours (Hulsen and Scheepens 2006). Our findings suggest that the ability to rest in the trap is important for welfare. Other studies have found that shade and mud are preferred for sleeping and resting (Blasetti *et al.* 1988), and soil is a good substrate for rooting, especially if there is food to find. In Sweden, some traps approved for wild boar capture have a metal or wooden floor, which limits the possibility to perform natural foraging and resting behaviours.

In our study, single-captured animals expressed more behaviours reflecting stress than group-captured animals. Traps for single animal capture will lead to social isolation. Isolation itself can elicit stress, especially in animals that live in groups, such as wild boar and pigs (Ruis *et al.* 2001). However, comparisons between traps for a single wild boar capture and multitrap systems are lacking.

Physiological biomarkers of stress

Wildlife captured in restraining traps may handle stress passively (Broom and Johnson 2019), but stress alters several physiological blood variables. It has been shown that different types of traps may affect physiological variables differently (White *et al.*1991; Cattet *et al.* 2003, 2008). For example, lactate and glucose were higher in wild boars captured and immobilized in corral traps than in cage traps (Barasona *et al.* 2013). Torres-Blas *et al.* (2020) identified different levels of stress in wild boars exposed to teleanaesthesia, drop-net, corral trap, and cage trap through assessment of hematology and serum biochemistry.

In combination with the behavioural study described above, Fahlman *et al.* (2021) identified a potential novel biomarker of stress in serum in 12 wild boars; the CgA-derived peptides catestatin (median 0.91, range 0.54–2.86 nmol/L) and vasostatin (median 0.65, range 0.35–2.62 nmol/L). Adrenalin and noradrenalin are quickly released at acute stress, but these hormones have a very short half-life in blood and are difficult to measure in situ. Chromogranin A (CgA) is a glycoprotein which is co-released with noradrenalin and adrenalin at a stressful event and is relatively stable in circulation. The CgA-derived peptides catestatin and vasostatin can be measured in serum, plasma, or saliva and have been used for evaluation of stress responses to different stressors in several domestic species, including domestic pigs (Escribano *et al.* 2015; Jitpean *et al.* 2015; Martínez-Miró *et al.* 2016). For example, salivary CgA increased in pigs immobilized with nose snare for 3 min (Escribano *et al.* 2015). We suggest that assessing physiological indicators and using them as surrogate measurement of stress allows the comparison and evaluation of different restraining trap-capture techniques for wild boar.

As proposed by AIHTS (ECGCGRF 1997), Iossa *et al.* (2007), Fahlman *et al.* (2020), and Proulx *et al.* (2020, 2022), welfare assessment of wild animals captured in restraining traps need to include pathology, behaviour, and physiology. We propose that, after species-specific validation, an array of physiological measures be compared with reference intervals, and selected behaviours be quantified according to an ethogram. These findings would be combined with pathological findings to get a more complete picture of the welfare impacts of captures with restraining traps (Proulx *et al.* 2022). Findings may be rated in a scoring system with thresholds for acceptable animal welfare performance.

However, alternative assessment models are possible. For example, Sharp and Saunders (2011) developed a model for assessing the relative animal welfare impacts of wildlife control methods, based on the five domains model (Mellor and Reid 1994) which were developed from the five freedoms (Farm Animal Welfare Council 1993): 1) water/food deprivation/malnutrition, 2) environmental challenge, 3) disease/injury/functional impairment, 4) behavioural or interactive restriction, and 5) anxiety/fear/pain/distress, and also an evaluation of killing method. Welfare impact under each domain and overall, and duration of impact (seconds to weeks) were rated and then combined in a final relative humaneness score; this model has been used when assessing for instance trap captures of feral cats and dogs (Sharp and Saunders 2011). In fact, Proulx *et al.* (2020) suggested that the five domains could be integrated into the AIHTS to improve welfare assessments. Although this assessment approach is not easily adapted to current Swedish legislation and testing standards, we believe it deserves further consideration.

Further improvements

So far, some possible improvements for revising the Regulations and thus improving the evaluation of trap models, especially the animal welfare aspects, have been suggested for further discussion with the EPA. Issues for improvement include, in particular with regard to restraining traps, specifying how and when the video recording of the captures should be done, and how this data is to be used in the evaluation. A list of scored lesions, adapted from the ISO standards (ISO 1999b) and AIHTS (ECGCGRF 1997), is the basis of evaluation of the practical test of restraining trap models, but, similar to Iossa *et al.* (2007) and Proulx *et al.* (2020), we find that it needs refining.

Filming captures in killing traps is to be done (NFS 2013:13), which facilitates the documentation of a test and animal reactions, and importantly, enables verification of time to irreversible unconsciousness. A problematic issue involves killing traps for rodents that use electricity to kill the animal. For these trap types, there is presently no easily used method to safely check time to unconsciousness and death when the electric current is activated, but could hopefully be developed.

Trap selectivity in Sweden is important, as each trap model is approved for specific species of wildlife. The design of the trap, but also the placement of the trap as well as type of lures and baits used are important to only trap targeted species and avoiding bycatch (non-target species). In Sweden, specific courses in trapping are compulsory for trapper to snare rock ptarmigan (*Lagopus muta*), use foothold snares for red fox, or killing traps for European beaver (*Castor fiber*) (NFS 2018:3). We suggest a requirement to attend a general trapping course before using traps for other wildlife species to improve animal welfare during trapping.

Testing restraining trap models should also assess risk for exposure to weather, predators, and approaching humans (Huber *et al.* 2017; Fahlman *et al.* 2020). Trap models should include a trap alarm system, preferably connected to a smartphone, to shorten trapped time for the animal and thereby shorten time of stress and lower the risk of animal suffering (Larkin *et al.* 2003).

The 3Rs (*Replacement, Reduction, Refinement*) (Russell and Burch 1959) are applicable in the testing of traps (Proulx *et al.* 2020). Computer simulations are used instead of live animals in some trap testing (Hiltz and Roy 2000). However, *Replacement* of live animals in trap testing is debated. According to Proulx *et al.* (2020) and Serfass (2022), there is a lack of scientific publications on the accuracy of computer simulations, and live animals are necessary to accurately assess welfare effects since the animals' approach to traps differ between species and trap models.

Prior mechanical evaluation of a trap's potential can, if deemed unsatisfactory, reduce the number of animals used (Proulx *et al.* 2012). Employing the normal approximation to the binomial distribution in a test may also allow for reduced number of animals used in testing (see Proulx *et al.* 2020 for details). According to the requirements of NFS 2013:13, 20 animals need to be tested for approval of restraining traps and 12 animals for killing traps. Thus, reducing the number of animals used in the Swedish testing system, for example with the help of statistical analyses, is currently not permitted due to this Regulation. Data from current tests may provide information on number of animals needed in the future. Moreover, the Regulation NFS 2013:13 states detailed cut-off points that are used to abort the practical test (Table 1). If a test trapping for any reason cannot be completed with the complete number of animals, then approval of the application is by default declined, and no more animals are used, in line with *Reduction*. Also, as some new trap models in the applications to EPA are very similar to already tested and approved traps, there is the possibility to approve a new trap without a practical test with test animals, if it can be considered similar enough after assessing mechanical function, etc. This spares animals that otherwise would have been tested for every single new trap model. Enabling changes in flawed trap models before and during a series of tests with live animals would reduce the number of animals used in vain. Testing killing traps on anaesthetised animals can reveal traps that do not function on conscious animals, and no more animals have to be used for further testing (Proulx *et al.* 2020).

The environment, which often is under field conditions, as well as trap design, and not least, the handling of animals, are essential for *Refinement*. In addition, the ethical committees will issue ethical permits for restraining trap tests that for the first 5 captures in a trap test only allow a shorter capture-to-euthanasia time span (3 h). This is to discover possible severe animal welfare issues and thus avoid prolonged suffering before allowing the usual 24-h testing span.

As part of the 3Rs, test results should be published and made available for scrutiny and sharing (Proulx *et al.* 2020). In Sweden, all documents received and registered by an authority must be made publicly available on demand, unless found to be classified after legal assessment. This applies also to trap test results sent from the test organisation to EPA, and formally, this enables anyone who wants, to study them.

Conclusions

Many conclusions can be drawn on the basis of this chapter.

- Ambitions from responsible authorities to improve animal welfare in trapping has over several decades resulted in developing national Regulations regarding trapping.
- Practical experience from trap model testing, as in the examples above, have shown that further improvements and revision of these Regulations are warranted, to improve animal welfare during trapping. Examples are requirements of trap alarm systems, to shorten captivity times at restraining capture of all species, and the aim of designing killing traps to achieve immediate unconsciousness in trapped animals.
- There is a need to include behavioural and physiological data as additional test criteria together with rating of physical injuries at necropsy when assessing animal welfare effects of capture in restraining traps, and to validate these methods for various wildlife species.

- There is need of a permanent and competent test organisation in Sweden, to fulfill the practical parts of the compulsory approval protocol.
- Trap designers need to consult trapping and animal welfare expertise to minimise the animal welfare effects of a new trap design, and to ensure that a trap model can be approved when tested, which also minimises the number of animals needed for evaluation tests.
- Mandatory reporting systems for poor trap performance is crucial to reduce unnecessary suffering.
- The concept of the 3Rs needs to be considered further for the trap test assessments.
- There is a need to re-test previously approved trap types, those with approvals from before the implementation of NFS 2013:13.

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Chapter 4

Testing Animal Welfare of House Mouse (*Mus musculus*) Snap and Electrocution Traps

Anke GEDUHN, Annika SCHLÖTELBURG, Agnes KALLE, Samantha FLEISCHER, Deborah DYMKE, and Erik SCHMOLZ
German Environment Agency, Corrensplatz 1, 14195 Berlin, Germany. Email: Anke.geduhn@uba.de

Abstract − The use of killing traps for rodent pest control is currently gaining relevance again but there is no approval or authorization process for rodent traps in most countries. Hence, a guidance for testing and evaluating animal welfare impact was recently published by the expert group on "Non-Chemical alternatives for Rodent control" (NoCheRo). Using the NoCheRo-Guidance, we investigated the animal welfare impact of 10 different house mouse (*Mus musculus*) killing trap products in a semi-natural setting. All 10 trap products were attractive to the target mice because ≥90% of them visited the traps at least once within a few days; in 5 tests, ≥90% approached traps on the 1st day. Two electrocution trap products and 3 of 8 (37.5%) snap trap products met the animal welfare criteria. Most (95%) of the test animals caught with criteria-compliant traps were irreversibly unconscious within 50 sec; 90% within 30 sec. The majority (97 %) of house mice were rapidly unconscious when hit in the head/neck region by a snap trap. Five trap products were not in compliance with the animal welfare criteria. The results show that the NoCheRo-Guidance enables a distinction between rodent traps that meet the criteria for animal welfare and those that are deficient in this respect. Certification of such tested traps based on a sound scientific basis allows for a selection of suitable traps, and thus improve animal welfare in pest rodent control.

Introduction

House mice (*Mus musculus*) are controlled if they damage crops, products and infrastructure (Capizzi *et al.* 2014), threaten native species (Cory *et al.* 2011; Harris 2009), or pose a risk to humans and companion animals by the transmission of rodent-borne pathogens (Battersby 2015; Meerburg *et al.* 2009). Baits containing anticoagulant rodenticides (AR) are the most frequently used method to control house mice infestations resulting in prolonged suffering of poisoned animals as they bleed to death over several days (Mason and Littin 2003). Thus, slow acting ARs "*are generally not considered as a humane method to control rodents*" by the Biocidal Products Committee (ECHA 2016), and are rated as one of the killing methods with the worst animal welfare impact (Sharp and Saunders 2011). Driven by the global technological progress in the area of digitalization and automatization as well by the increasing regulation restrictions on the use of environmentally hazardous rodenticides, the use and development of rodent traps has experienced a renaissance in recent years. Technical innovations include multi-capture traps, self-resetting traps, and automated and remotely operated trap systems, which enable real-time permanent monitoring of rodent as well as trap activity, thereby improving efficacy and minimizing the control effort of traps.

However, the animal welfare impact of killing mouse traps is not assessed in most countries worldwide (Littin *et al.* 2014), except for UK and Sweden, which have a trap approval. For many people, animal welfare plays only a subordinate role when it comes to pest rodents (Buckland and Nattrass 2020; Meerburg *et al.* 2008). This attitude, in combination with missing regulation, can lead to the development of products that are unsuitable from an animal welfare point of view, such as disposable traps that cannot be opened to release animals that are still alive due to hits in non-vital regions (Baker and Sharp 2015).

Most small rodent traps are snap traps killing with a striking bar/striker/bolt mechanism that ideally hits the target animal's head or neck, or acting otherwise with physical force on the target rodent; other trap types kill by suffocation (e.g., killing snares), drowning, automatic shooting, or electrocution (Broom 1999). Within and between each group of trap types, traps have different impacts on animal welfare ranging from long-lasting suffering (e.g., glue traps) to immediate death of the trapped animal (Broom 1999; Mason and Littin 2003; Meerburg *et al.* 2008). Snap traps crushing the skull are considered to kill most efficiently (Proulx and Barrett 1991; Mason and Littin 2003). However, systematically and uniformly collected data to assess welfare issues are generally lacking for such traps.

In order to separate traps that repeatedly kill fast from those that do not, experts from science, industry and political authorities started an initiative based on the results of the EU workshop on "Non-Chemical alternatives for Rodent Control" (NoCheRo) in 2018 (Fischer *et al.* 2019). The aim of this initiative was to develop a tiered trap testing approach (Friesen *et al.* 2020). The NoCheRo expert group published the criteria and methods used to evaluate snap traps on the basis of their impact on animal welfare, besides their mechanical properties and efficacy in the laboratory and the field (Schlötelburg *et al.* 2021).

We tested the animal welfare impact of 8 snap trap products and 2 electrocution trap products with house mice according to the NoCheRo-Guidance (Schlötelburg *et al.* 2021). The testing was part of the listing process according to § 18 German Infection Protection Act where manufacturers or distributors applied for listing their product as effective control measures. The test results are discussed on the basis of the following questions:

- Do trap products vary in their attractiveness and animal welfare impact?
    - Does the time of the 1st trap visit, and the number of visits per day during the conditioning period, vary among trap products and trap types? Or does it depend on the use of a safety station that could direct the target organism head-on into the trap?
    - Where should animals be struck by snap traps to quickly lose consciousness?
- Is the method proposed in the NoCheRo-Guidance suitable for assessing the impact of house mouse traps on animal welfare?

Although more data are needed to completely answer these questions, the first test results can indicate if the protocol is suitable to identify traps with an acceptable/inacceptable animal welfare impact.

Material and Methods

Tested traps and animals

From August 2019 to March 2021, 8 snap trap and 2 electrocution trap products were tested in a semi-field trials for their attractiveness and impact on animal welfare with house mice. According to the NoCheRo-Guidance, a semi-field test is defined as a test which simulates field conditions in a controlled laboratory environment.

Seven snap trap products had a pan trigger and 1 trap product had a trigger that had to be lifted (Table 1). Three snap trap products were tested without, and 5 snap trap products with, a safety station that were plastic boxes in which the animals were directed to the snap traps.

The electrocution traps were triggered when 2 metal plates on the trap base were bridged. As the manufacturer or distributor applied voluntarily for the assessment of traps according to § 18 German Infection Protection Act, names of trap products that failed the tests and applicants must remain confidential.

During the conditioning period, a total of 172 animals were accommodated to the 10 tested trap products; 86 animals were tested in an animal welfare test (Table 1). Tests were aborted if the required criteria based on 12 test animals (Table 2) could no longer be achieved. This resulted in different numbers of test animals for each trap product (Table 1).

All test animals were adult house mice bred from wild strain animals. The rodents were held in groups of mixed sexes. The offsprings were separated by sexes at the age of about 2 months. Sex-separated groups of a maximum of 40 animals were kept in 2-chamber cages (H 450 x W 800 x D 400 mm) until the start of the tests. Adult animals with an initial body weight of 16.3 to 30.7 g were used for testing. The sex ratio (Table 1) depended on the availability of males and females in the breeding colony.

Table 1. Characteristics of tested traps and number of tested house mice during the conditioning period and animal welfare tests. All animals used in the animal welfare tests were previously accustomed in the conditioning period.

Trap ID	**Type**	**Trap characteristics**		**Number of test animals**				
		Step-on trigger	**Safety station**	**Conditioning period**		**Animal welfare**		
				Male	**Female**	**Total**	**Male**	**Female**
A[a]	Snap	No	No	9	9	12[b]	5	6
B	Snap	Yes	No	8	10	3	0	3
C	Snap	Yes	No	6	8	2	2	0
D	Snap	Yes	Yes	8	7	10	7	3
E[a]	Snap	Yes	Yes	7	9	12	4	8
F	Snap	Yes	Yes	16	0	8	8	0
G[a]	Snap	Yes	Yes	19	0	12	12	0
H	Snap	Yes	Yes	18	0	3	3	0
Total	**Snap**	**7 Y / 1 N**	**5 Y / 3 N**	**91**	**43**	**62[b]**	**41**	**20**
I[a]	Electric	No	Yes	5	13	12	4	8
J[a]	Electric	No	Yes	7	5	12[a]	7	4
Total	**Electric**	**0 Y / 2 N**	**2 Y / 0 N**	**12**	**18**	**24[b]**	**11**	**12**

[a] Trap A: SuperCat® Mausefalle Pro; Trap E: Anticimex® Smart Snap; Trap G: NoSeeNoTouch Mausefalle; Trap I: Victor® Electronic Mouse Trap; Trap J: Victor® Multi-Kill Electronic Mouse Trap

[b] 1 animal escaped from the trap before its sex could be determined.

Table 2. Times to irreversible unconsciousness (sec) of at least 80% and 90% of trapped animals in Categories A and B. Tests included 12 animals, but they were stopped if 2 animals were not irreversibly unconscious in 120 seconds or 3 animals in 60 seconds.

Category of animal welfare	**Time to irreversible unconsciousness**	
	≥ 80% of 12 test animals	≥ 90% of 12 test animals
Category A	≤ 30 sec	≤ 60 sec
Category B	≤ 60 sec	≤ 120 sec

Test chambers and materials

Three test chambers (H 2.3 x W 1.4 x L 2.6 m per chamber) were connected by closable passage tunnels, which had a diameter of 70 mm and a length of 300 mm. The chambers were fully tiled, and daylight through 2 windows was the only illumination, except when artificial light was switched on during control visits.

The 1st chamber provided 2 to 4 wooden nesting boxes (H 160 x W 190 x D 250 mm; board thickness: 20 mm; 2 square entrance openings: 40 x 40 mm; cellulose paper inside the boxes) and a plastic tray (H 35 x W 230 x D 350 mm) in each corner of the chamber with sawdust for the mice to urinate.

In the 2nd chamber, food consisting of a 3-grain mixture (70 % wheat, 25 % oats, 5 % sunflower seeds) in enamelled clay trays (diameter: 200 mm; H 35 mm) as well as water in a drinking trough were offered ad libitum. Furthermore, 4 trap (if applicable, in a safety station) were positioned on flat platforms (H [bottom] 850 x H [top] 350 x W 850 x D 400 mm) against the wall of the 2nd chamber (Figure 1). Below the platforms, the antenna and logger system (TML133 air-core coil antenna with a 40-mm diameter; TCL122 reading device, PTS Technology & Systems GmbH, Erbach, Germany) were inaccessible to the test animals. The antennas were positioned directly under the trap triggers. The antenna cables were protected by metal pipes that were also used by the test animals to climb. Pipes were covered with a plastic collar at a height of 140 cm as climbing barrier. Only during the conditioning period, the traps were fixed by positioning them between the wall and a heavy object (brick). This ensured that no animal could move the trap or was registered right beside the trap by the antenna and logger system.

Figure 1. Test chamber with 4 traps (in this case without a safety station) on platforms covering the antenna logger system as well as a food tray and a drinking trough (during the conditioning period) and connected to the nesting chamber (not shown)

Test procedure

The tiered test design ensured that only trap products proven to be attractive to mice during the conditioning period were tested in subsequent animal welfare tests. The test procedures were in accordance with the NoCheRo-Guidance on the evaluation of rodent snap traps (Schlötelburg *et al.* 2021) except that test animals were not selected by their weight and assigned to 2 different weight classes.

Conditioning period

Prior to the release of the test animals in the test chambers, house mice were tagged for individual identification. A passive-integrated transponder (1.4 x 8 mm; Mini ISO-Transponder with injector, Tierchip Dasmann, Tecklenburg, Germany) was injected in the scruff of the neck. If an animal entered the trap, the antennas registered the individual transponder.

The traps were not activated but baited with peanut butter that was renewed daily if necessary. The daily number of visits to the trigger of the trap was determined for each animal. The conditioning period lasted until 90 % of animals had visited at least 1 trap within at least 3 d, up to a maximum of 7 d. If less than 90% of animals visited a trap within 7 d, the trap product was excluded from further tests.

Animal welfare tests

If the trap product was generally accepted by the animals, the impact of the trap on animal welfare was tested with the previously conditioned animals, using the same lure in the traps. Traps were not baited the day before the beginning of the test. When the test started, the animals were located in the 1st chamber, and the food tray and drinking trough had been removed from the 2nd chamber to the 1st chamber. Then, 1 to 3 animals were released in the 2nd chamber where the traps were baited and activated. Animals that did not trigger the trap within 1 h were excluded from further testing and transferred to a 3rd chamber with food, water and nesting material.

After an animal had triggered the trap (the snap or start of the electrical current flow could be well heard outside the chamber), the researchers immediately entered the chamber and measured with a stopwatch the time until the onset of irreversible unconsciousness and cessation of body movements. The onset of unconsciousness was determined by repeatedly blowing air at the animal's eyes with an air-filled rubber ball (HADEO Puster for drying BTE earpieces, Hansaton GmbH, Hamburg, Germany) to observe whether the corneal reflex was absent. In case a safety station was used, the lid was opened immediately after the trap had been triggered. If this affected the function of the trap, the station was opened 25 sec after triggering (snap traps) or after stopping of the electrical current flow (electrocution traps). If the animal was not unconscious after 120 sec or was struck in a peripheral region (e.g., tail or legs‒inadequate hits), it was immediately euthanized by cervical dislocation. Cardiac arrest was verified with a stethoscope (3M™ Littmann® Classic II Pediatric Stethoscope, Neuss, Germany). The test animals were weighted after the experiment (Mettler PM4800 DeltaRange, Mettler-Toledo GmbH, Gießen, Germany).

The test procedure was repeated until 12 test animals had triggered the trap or the criteria for animal welfare (Table 2) could no longer be met testing. Testing was aborted if the time to irreversible unconsciousness lasted longer than 120 sec for 2 animals or longer than 60 sec for 3 animals.

Statistical analyses

All statistical analyses were conducted using R (version 4.1.0; R Core Team 2021) and RStudio (version 1.4.1717). We used the R packages "ggplot2" (Wickham 2016) and "tidyr" (Wickham 2021) for creating graphics, "lme4" (Bates *et al.* 2014) for fitting models with maximum likelihood (Laplace approximation), "multcomp" (Hothorn *et al.* 2008) for multiple comparisons of means (Tukey contrasts), and "RVAideMemoire" (Herve 2021) for multiple comparisons following a Fishers exact test.

The time until the 1st trap visit and the number of visits per day were modelled with generalized linear models (GLM) following a negative binomial distribution with log link because models with Poisson distribution resulted in overdispersion. Both variables could be explained by trap type (snap or electrocution trap), trap ID (A-J), and use of the safety station (yes or no). By backward selection, we found the minimal models with the lowest Akaike Information Criterion (AIC; Akaike 1974). We calculated the dispersion parameters and checked model fit by visually evaluating residual graphs. In 1 test, the logger system did not work from the 2nd to the 4th test day. Therefore, this trap product was excluded from the analysis.

For snap traps, data were analyzed with Fishers exact test and multi comparisons if the strike location influenced the numbers of sufficient or insufficient strikes (defined as mice that were or were not irreversible unconscious within 120 seconds). Mice that were struck on limbs/tail (*n*=3) were excluded from this analysis because those animals were immediately euthanized.

Results

Attractiveness of traps

All 10 tested house mouse trap products were attractive to the test animals, i.e., ≥90 % of test animals were registered at least once at a trap during the conditioning period. For 5 trap products, ≥90 % of test animals were recorded on the 1st day; for 2 trap products, on the 2nd day; and for 2 other trap products, on the 4th day. In a test where the logger system did not work from the 2nd to the 4th test day, the day on which ≥90% of animals visited the traps could not be defined. GLMs showed that the time until the 1st trap visit and the mean number of visits per day for the first 90 % of test mice varied among trap products. However, there was no significant difference in both measured parameters among electrocution and snap trap products or among trap products with or without a safety station (Figure 2).

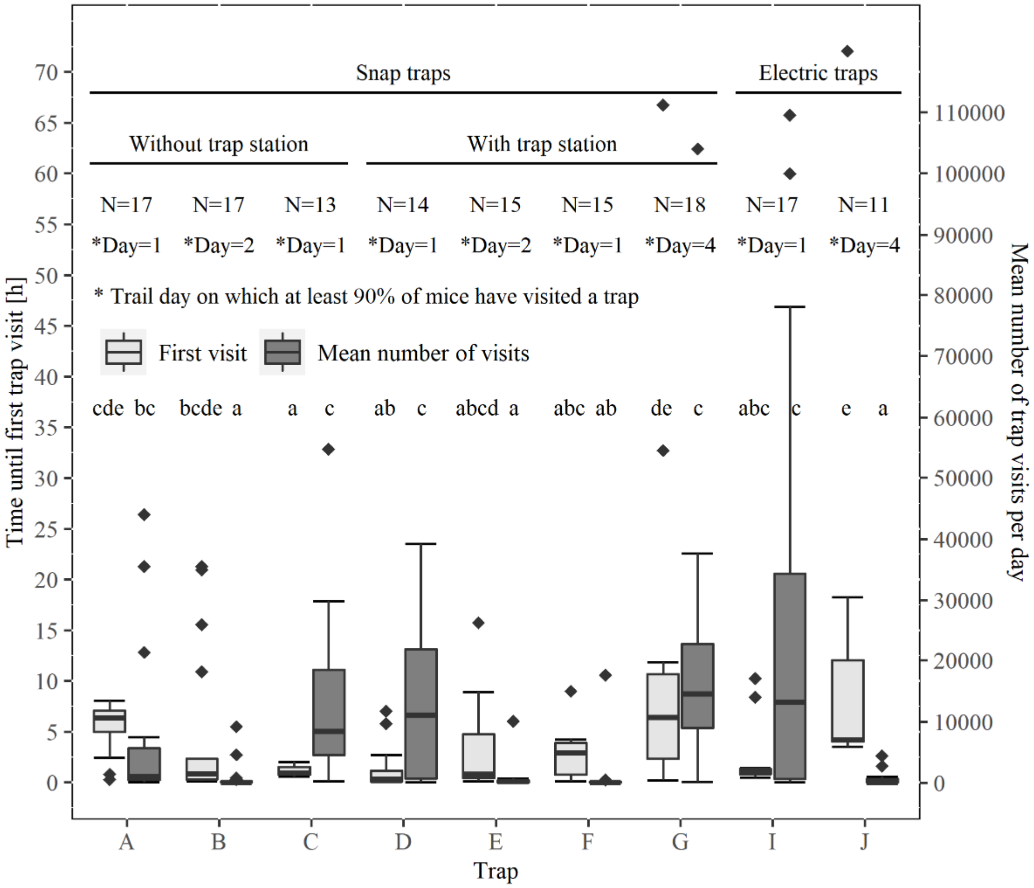

Figure 2. Attractiveness of traps measured as hours until the 1st visit (light boxplots) and the mean number of trap visits per day (dark boxplots) for 9 different traps during the conditioning period. Both variables were calculated for the first 90% of the test animals because animal welfare tests were initiated when ≥90 % of mice had visited ≥1 trap (at the earliest after an acclimatization period of 3 d). One trap (H) was excluded from the analysis because the logger system did not work on 2 test days. The trial day when ≥90% of mice had visited at least 1 trap is stated. N is the number of tested animals. Different letters indicate significant differences between traps separately for time until 1st trap visit and mean number of trap visits (GLM results).

Animal welfare impact of traps

Both electrocution trap products (Victor® Electronic Mouse Trap, Victor® Multi-Kill Electronic Mouse Trap) and 3 out of 8 snap trap products (Anticimex® Smart Snap, NoSeeNoTouch Mausefalle, SuperCat® Mausefalle Pro) passed the animal welfare criteria, and were classified as category A traps (Fig. 3; Tab. 2). On average (mean ± SE), 95 % (± 2 %) of the house mice tested with these traps were irreversibly unconscious within 50 sec , and 88 % (± 3 %) within 30 sec. These trap products met the criteria of §18 German Infection Protection Act (https://www.umweltbundesamt.de/dokument/liste-ss-18-infektionsschutzgesetz), and they were included in the list of methods that must be used when animal control is ordered by the German local health departments to prevent or control disease outbreaks.

Electrocution traps

On average (mean ± SE), 96 % (± 4 %) of 24 test animals trapped in 2 electrocution trap products (Figure 3) were unconscious within the defined time periods (Table 2). Mean times until onset of unconsciousness were 23 (± 3) sec (Trap I) and 22 (± 2) sec (Trap J). However, these are maximum values because unconsciousness could only be determined after the electric current flow was terminated (lasting a maximum of 33 sec). All animals that were unconscious within 120 sec were already dead when the traps were opened but 1 mouse (4 %) was still conscious when the current flow stopped after 30 s and could escape (Trap J).

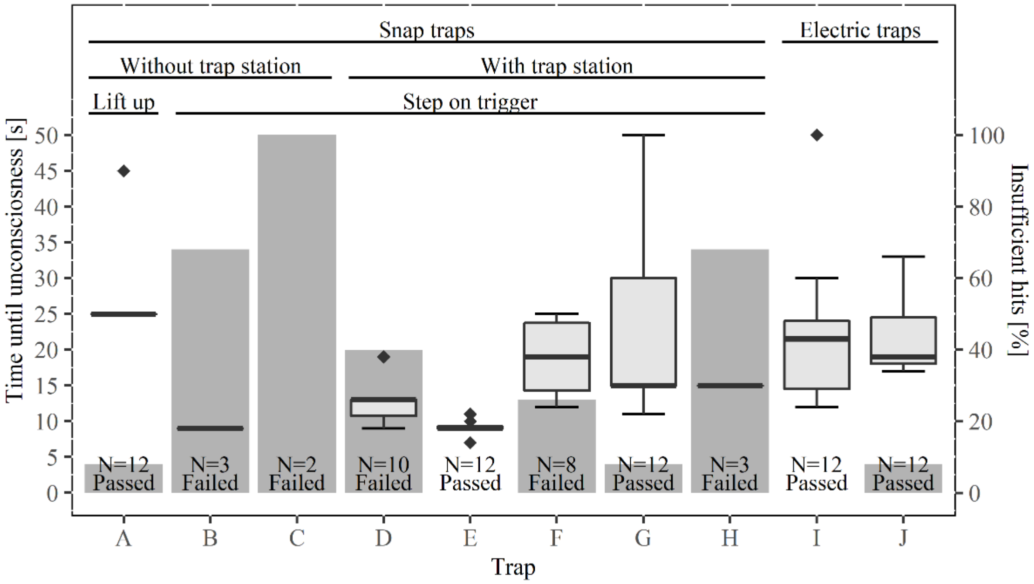

Figure 3. Time to unconsciousness for all mice that were irreversibly unconscious within 60 sec (for acceptable strikes; boxplots) and percentage of inadequate strikes (bars) for each of the 10 tested trap products. N is the number of tested animals (test were stopped if the animal welfare criteria could no longer be met). It is indicated if a trap product met (passed) or did not meet (failed) the animal welfare criteria.

Snap traps

The snap trap product with a lift-up trigger and without a safety station (Trap A) and 2 out of 7 trap products with a step-on trigger in combination with a safety station (Trap E and G) met the animal welfare criteria (Table 2). On average (mean ± SE), 94 % (± 3 %) of test mice trapped with the 3 trap products that positively passed the test were irreversibly unconscious within a maximum time period to unconsciousness of 50 sec, and 89 % (± 6 %) within 30 sec (mean ± SE of mice being unconscious within 120 sec: 19 ± 4 sec; Figure 3). However, in 15 cases, the eyes of the trapped animals were inaccessible; after about 25 sec, the traps were opened (in all cases, the animals were unconscious but not dead). Therefore, these are maximum values. Two mice (6%) were not unconscious within 120 sec, 1 mouse could escape from the trap (Trap A), and another was struck on the nose and was euthanized after 120 sec (Trap G).

Both tests with trap products with a step-on trigger but without safety station, and 3 tests with trap products with a step-on trigger and safety station, were aborted when 2 animals did not lose consciousness after 120 sec in each test. In total, 2 (Trap C), 3 (Traps B and H), 8 (Trap F) and 10 (Trap D) mice were tested until the criteria could no longer be met (Table 2).

A strike on the head/neck (*P*<0.001) or thorax (*P*<0.001) was more likely to cause unconsciousness within 120 sec than a strike in the abdomen, whereas the effect of strikes on either region did not differ (*P*=0.097). When struck in the head/neck region (*n*=35; Figure 4), 97 % of the mice were irreversibly unconscious within 45 sec, and 94 % within 30 sec; 1 mouse (3 %) struck on the nose was euthanized 120 sec after the trap was triggered. When struck in the thoracic region (*n*=17), 82 % of the mice were unconscious within 30 sec, whereas 18 % were still conscious after 120 sec. All 7 mice that were struck in the abdomen did not lose consciousness within 120 sec, and 3 mice caught by a limb or tail were euthanized immediately.

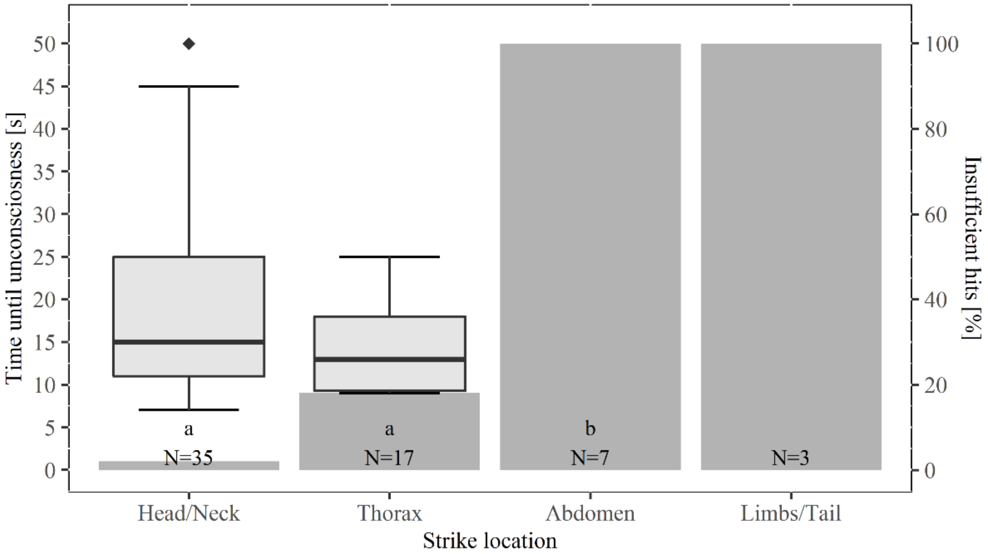

Figure 4. Mean time to irreversible unconsciousness for mice (acceptable hits; boxplots) and percentages of inadequate strikes (bars), depending on the strike locations (head/neck, thorax, abdomen, limbs/tail) for 8 tested snap traps. Different letters indicate significant differences in the frequency of inadequate strikes (Fishers exact test– head/neck – thorax: *P*= 0.097; head/neck – abdomen: *P* < 0.001; thorax – abdomen: *P* < 0.001).

Discussion

Attractiveness and animal welfare impact of snap and electrocution traps

All tested trap products were attractive to house mice because a visit rate of 90 % during the conditioning phase was reached in all cases, often on the 1st day (5 out of 9 trap products). This suggests that, if used correctly, killing traps are attractive to mice and can be an effective control method (i.e., a population reduction of ≥90 %). Neither time to first trap visit nor mean number of visits per day depended on the presence or absence of a safety station. However, data from field tests are needed to prove the efficacy of animal welfare-compliant traps under practical conditions.

Furthermore, our results show that both electrocution and snap traps can fulfill the criteria of the NoCheRo-Guidance, and represent an animal welfare friendly alternative to rodenticide use. Half of the tested trap products passed the tests, and all successful trap products corresponded to category A. However, small sample sizes in the lab could overestimate the impact of traps on animal welfare (Proulx *et al.* 2020). The majority (95%) of the animals captured in criteria-compliant trap products were irreversibly unconscious within 50 sec, and 88 % within 30 sec; however, irreversible loss of consciousness was similar among all criteria-compliant trap products (Figure 3). Nevertheless, it is difficult to compare time periods to unconsciousness among trap products because in both electrocution trap products and in 2 snap trap products, the eyes of the test animals were not visible until the trap was opened after about 30 sec. Although these trap products rapidly killed animals, other trap products did not meet animal welfare criteria, and their testing was aborted quickly.

Since both tested electrocution trap products killed in accordance with the animal welfare criteria, compared to only 3 of the 8 tested snap trap products, electrocution traps seem to kill more reliably. Hence, electrocution traps should be further investigated for their electric properties. Additionally, further tests should be conducted to examine the animal welfare impact of other electrocution trap models, and the functionality of traps under field conditions, which could be altered by weather, soiled electric contacts, or battery discharge.

Our study is in agreement with previous studies (e.g., Proulx *et al.* 1989) which showed that a rapid loss of consciousness resulted from striking animals in vital regions. Our results showed that animals were consistently unconscious within a short time span if they were hit in the head/neck region. A hit on the head can be more likely if the trap has a trigger that must be lifted by the animal (92% of hits) than a trap with a trigger that must be stepped on (48% of hits). However, traps with step-on triggers can also kill fast, although 5 of 7 snap trap products did not pass the animal welfare criteria. The differences in mechanical forces greatly differed among snap trap products and could lead to the differences in animal welfare performance (Baker *et al.* 2012). For example, clamping force values varied 4−5.5-fold, and impact momentum 6−8-fold, among killing trap products for mice, rats and moles (Baker *et al.* 2021). Although we did not test mechanical forces, the clamping force of all tested trap products seems to be sufficient for a rapid kill because 97 % of the test animals (including animals that were killed in traps that failed the tests) struck in the head/neck region were unconscious within 50 sec. Other mechanical forces (e.g., trigger force) or parameters (e.g., trigger type) might have more influence on strike efficacy than the clamping force. We suggest a high clamping force could even have a negative effect on animal welfare if it is mechanically coupled with the trigger force, which then becomes too high and makes it more difficult for light animals like mice to trigger the trap. As a consequence, animals may trigger the trap only until they sit with their entire body on the trigger, which means that they can be hit in non-vital regions. However, data are missing to determine the mechanical forces that are necessary for an animal welfare-compliant kill. Besides the mechanical forces, the combination of trap and safety station could influence the animal welfare impact because both traps tested without safety station failed the animal welfare criteria. It is likely that the velocity and direction from which mice approach traps influence which body region will be hit.

In summary, traps that passed the animal welfare criteria killed by electrocution or, in case of snap traps, hit the target animals in the head/neck region in most cases. A strike in this region could be connected to the following features of the traps: *i*) a trigger that the animal must lift with its head, *ii*) a safety station design which decelerates the running speed of the animal (e.g., guiding the animal around a corner) and leading the mouse frontally into the trap, or *iii*) several bars that ideally hit several body regions of the target animal.

NoCheRo test protocol

The NoCheRo test protocol is suitable to enable a differentiated assessment of snap and electrocution traps for mice into animal welfare-compliant and non-animal welfare-compliant traps for the AIHTS standards. The proposed tiered approach ensures that as few test animals as possible are used in animal welfare tests, which are stopped if *i*) the trap is not attractive, or *ii*) 2/3 animals are not unconscious in 120/60 sec (the latter did not occur in our tests).

Compared to the Agreement on International Humane Trapping Standards (AIHTS) between the European Community, Canada and the Russian Federation (Harrop 1998; Proulx *et al.* 2020), the NoCheRo-Guidance (Schlötelburg *et al.* 2021) sets stricter time periods to unconsciousness, and therefore improves animal welfare criteria, while trap performance criteria (percentage of animals that have to meet criteria) are the same. According to AIHTS, time to irreversible unconsciousness may not exceed 300 sec for 80 % of 12 animals, whereas 80 % of house mice must be unconscious within 120 sec and 90 % within 60 sec in the less stringent animal welfare category of NoCheRo.

The National Animal Welfare Advisory Committee guidelines (NAWAC, 2019) call for different criteria for time to unconsciousness depending on sample size. Because the relation of criteria to number of test animals is non-linear, it is difficult to compare the requirements of the NoCheRo and NAWAC guidelines. For example, NAWAC's requirements for a category A trap are stricter than the NoCheRo criteria if 15 test animals are used; however, if 50 animals are tested according to NAWAC, a longer time maximum time span is accepted compared to NoCheRo. Therefore, in addition to providing detailed test protocols, the NoCheRo-Guidance can also be considered an improvement of existing selection criteria. Regardless, the time periods for the onset of unconsciousness set in AIHTS, NAWAC and NoCheRo could be even shorter for mouse traps because our testing showed that 90 % of mice were irreversibly unconsciousness within 30 sec for traps that passed the criteria (Figure 3). Furthermore, all 15 test animals that were not unconscious after 60 sec had to be euthanized after 120 sec showing that either a mouse is unconscious relatively fast (often much faster than the upper limits) or the animal remains conscious for a period that would likely be longer than 120 sec.

Although the test design is well suited to evaluate snap traps according to NoCheRo and AIHTS criteria, tests with house mice could still be improved by:

- aiming for broken skulls/necks because they are indicators of fast and efficient kills;
- using the pain withdrawal reflex (by pinching the foot sole/the skin between the toes) if the eyes are not accessible to determine the state of unconsciousness of the trapped animals;
- using 3 connected test chambers instead of 2 to better simulate a pest control situation where the traps should be set on paths used by mice;
- improving selection criteria for mouse traps: 90 % of mice should be irreversibly unconscious within 30 sec because mice quickly lose consciousness when struck in vital regions. When mice did not lose consciousness within this time period, they did not become unconscious between 60 and 120 sec; and

Further possible improvements are discussed in Proulx *et al.* (2020).

While animal welfare plays an important role in animal experiments, it has been given secondary consideration in commensal rodent management programs in most countries (Paparella 2006; Meerburg *et al.* 2008). Using NoCheRo-compliant rodent traps can therefore improve efficacy and animal welfare of rodent control campaigns. By certifying NoCheRo-compliant traps, it is possible to make animal-welfare friendly traps available on the market, even without a legally based approval or authorization scheme which can only be established in the long term. Then, consumers, pest controllers and veterinarians would have a scientific basis to select traps. The next step in the NoCheRo protocol is to test animal welfare-compliant traps under real pest control conditions for their efficacy. In addition to testing the practical suitability (e.g., soiling of electrocution traps, effects of weathering, usability and effort of trap setting), the efficacy of the traps and their impact on non-target organisms should be further investigated.

Acknowledgements

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Chapter 5

Foothold Trapping: Australia's History, Present and A Future Pathway for More Humane Use

Paul D. MEEK[1,2], Guy A. BALLARD[2,3], Greg MIFSUD[4,] and Peter J. S. FLEMING[2,5]
[1]Vertebrate Pest Research Unit, NSW Department of Primary Industries, PO Box 530, Coffs Harbour, NSW 2450, Australia. Email: paul.meek@dpi.nsw.gov.au
[2] School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia.
[3]Vertebrate Pest Research Unit, NSW Department of Primary Industries, c/-University of New England, Armidale, NSW 2351, Australia.
[4] Centre for Invasive Species Solutions, PO Box 5005, University of Canberra LPO, Bruce ACT 2617.
[5] Vertebrate Pest Research Unit, NSW Department of Primary Industries, 1447 Forest Road, Orange, NSW 2800, Australia.

Abstract – Little has been written in the scientific or grey literature on the Australian trapping culture. Newspaper articles report that soon after their arrival in the Sydney region of Australia, European colonists adopted trapping as a means of reducing pest impacts on introduced livestock and agricultural production. Two centuries later, trapping in Australia primarily focuses on predator impact mitigation rather than being used for fur or food purposes as is common in other countries. Trapping the introduced European rabbit (*Oryctolagus cuniculus)* was once common practice for food and fur across the continent but waned since the 1960s and has now all but ceased. The main species currently targeted by Australian foothold trappers are wild living dogs (wild dogs and dingoes; *Canis familiaris*), foxes (*Vulpes vulpes*) and feral cats (*Felis catus*) for pest management in accordance with jurisdictional laws. Since the 1980s, legislative changes have shifted away from unpadded and toothed steel-jawed traps to off-set, laminated and padded alternatives, primarily to improve welfare outcomes for introduced pests. A range of further legislative and technological advances, all aimed at improving the culture and practices of trappers in Australia, have occurred in recent years. Here we present an overview of the history of Australia's use of foothold traps, to provide insight into the nation's unique trapping culture and outline a pathway for continued and more humane use of foothold trapping in pest control programs.

Introduction

In Australia, native wildlife has not been the target of foothold trapping practices. Just after colonisation (1880s) until the 1930s, native possums (mostly *Trichosurus vulpecula*) and koalas (*Phascolarctos cinereus*) were poisoned, shot and trapped for the European and American fur markets (Hrdina and Gordon 2004; Downes 2018). However, introduced pest animals have been the main quarry of Australian trappers following colonisation., in contrast to northern hemisphere countries, where native animal trapping for fur, food and income has a long history (Bateman 1976). The introduced European rabbits (*Oryctolagus cuniculus*) were historically trapped with foothold traps for food, fur and to control their detrimental effects on agricultural production (Rolls 1984; Coman 1999; Downes 2018). During World War 1 & 2 and the depression years of the 1890s and 1930–39, rabbit became an Australian food staple, colloquially called "underground mutton" (Coman 1999). From those times, trapping rabbits became a profession (Coman 1999) as did the effort to capture dingoes and other wild dogs (*Canis familiaris*), and European red foxes (*Vulpes vulpes*), primarily to reduce their effects on livestock (Ward 1986), and sometimes for pelts for the fashion industry (Saunders 1995). In contemporary Australia, trapping is aimed at removing wild-living dogs, foxes and feral cats (*Felis catus*) from agricultural and biodiversity landscapes (Meek *et al.* 2019a). Wild canids and felids were introduced to Australia by humans, foxes being introduced for sport hunting in the 1860s, and feral cats introduced between 1824 and 1886 (Rolls 1984; Abbott *et al.* 2014). The dog probably arrived with Asian traders in Australia some 2500 years ago and have continued to interbreed with modern breeds (Jackson *et al.* 2019). These wild-living dogs (hereafter referred to as dogs), are also classified as native dingoes and are ignored, protected and controlled depending on the managed landscape (Fleming *et al.* 2014). Foxes and feral cats are classed as introduced pests throughout Australia.

A brief history of Australian trapping

Steel-jawed toothed foothold traps were introduced into Australia in the early 1800s to trap dogs and in later years rabbits and foxes; the specific details are poorly documented (Walsgott 2001; Meek *et al.* 2019a). Newspaper articles relating to trapping in Australia give some insight into how long trapping has been used as a tool since European arrival. Records from 1817 refer to "native dog" trappers working the forests on the outskirts of Sydney in an area later named Dog Trap Road (Anonymous 2008). By 1883, "gin traps" supposedly a derivative of "engine" (Anonymous 2003), an inappropriate colloquial term for steel jawed foothold traps, were being used to trap rabbits because that year the *New South Wales Rabbit Act* enabled a bounty to be proclaimed. During this period of colonisations, rabbits were in plague proportions and trapping was one of the preferred methods of capture (Coman 1999). It was not until 1899 that trapping to control the introduced European red fox was discussed in newspapers (Anonymous 1899) which follows their successful release (Rolls 1969). However, the exact time when serrated or toothed steel jawed traps were first used in Australia is unconfirmed.

Early newspaper clippings state that traps (dog and rabbit) were brought to Australia in casks from London prior to the 1860s (Anonymous1860, 1884) and sold by ironmongers. Records from 1857 provide double-spring dog trap sales records from Sydney (Anonymous 1857). However, given trapping was occurring in 1817, just 47 yrs after European colonisation, they may have been shipped over with other agricultural supplies. In the 1850s there were 30 English trap manufactures selling traps in Australia (A. Macdonald, personal communication, 2012). It was not until towards the end of the 1800s that Australian trap manufacturers such as Downee and Davies both of Sydney, Coombs of Adelaide, and Emu Traps in Wellington area, began to enter the market. Around 1913, Henry Lane, of Lanes' trap manufacturing in England sent his son out to Australia to set up a company in Newcastle New South Wales (NSW) to make the first Australian made Lane's traps (Figure 1a). Lane's traps would later become the largest manufacturer in Australia, although throughout the early 1900s, hundreds of patent applications were made for trap and trap mechanisms in Australia (Walsgott 2001). There were also attempts to develop alternative traps. Mr C. R. J Tilling of Brighton, Victoria, was reported on the 6 October 1948 in the Daily News, published in Perth, Western Australia, to have developed a dozen or so novel traps, with one using a system to knock rabbits out as they took a bait of apple or carrot (Anonymous 1948).

Australia's early trapping culture and systems were no doubt influenced by pest species, demand, use, and possibly the introduction of bounties for wild dogs in the 1830s (Breckwoldt 1988) with some 286,398 bounties paid between 1883–1930 in NSW alone (Glen and Short 2014). These country specific needs have and continue to influence trapping in Australia.

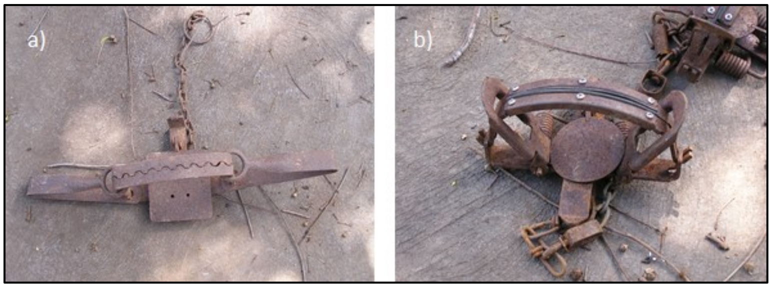

Figure 1. a) A Lanes toothed, steel-jawed leg-hold trap, which is banned from use in Australia, and b) the Victor® Soft Catch® Trap #3 showing the padded jaws, and swivels and spring on the anchor chains. It was designed for trapping coyotes (*Canis latrans*) in North America but is commonly used in Australia for dogs, foxes and feral cats.

Historical changes in trap design, application and management to reduce animal welfare impacts?

Evolution of more humane trapping and laws

Social expectations for the humane treatment of all animals have increased since the 1900s (Proulx and Barrett 1989; Singer 1990; Warburton and Norton 2007; Wallach *et al.* 2015). More recently in Australia, this concern has extended to animals considered to be pests (Wallach *et al.* 2018). For example, extreme but once such common practices, such as checking traps infrequently, or the use of tethered animals as lures and baited shark hooks hung in trees, would no longer pass public scrutiny, let alone comply with Australian animal welfare related legislation today.

The gazettal of animal welfare laws and policies since colonisation has also changed significantly. The earliest animal protection legislation was gazetted for the colony in 1837, despite issues of animal cruelty being publicly discussed in 1804 (White 2016). It was not until 1850 and 1859 in New South Wales that prevention of animal cruelty legislation was enacted (White 2016). The focus of these acts was more about domestic animal cruelty until the State of Victoria produced legislation to include the control of wild animals (White 2016). Over the intervening years, the influence of society and the support for animal protection laws by the RSPCA throughout the colony led to great change. While these changes to various State and Territory Acts led to vast improvements and the way domestic animals were treated, it was not until the 1970s that the same principles started to be applied to pest animal control (including trapping) through legislation. During the 1980s, the use of toothed, steel-jawed foot-hold traps, such as the Lanes trap (Figure 1a), was slowly phased out throughout much of Australia, leading to the development of alternative trap types (Table 1) that were considered to be more humane (Meek *et al.* 1995). One such trap, the treadle snare (Stevens and Brown 1987) or "banjo-trap" (Meek 1995) (Figure 2.) was a cross between a snare and jaw trap and was widely used in the 1990s in Victoria. In the mid-1990s, Victor® Soft Catch® traps (Figure 1b) from Woodstream Pty Ltd were imported into Australia and distributed throughout the country by one of these authors (PM) in an attempt to replace steel-jawed Lane's traps. Modifications using rubber tubing to toothed Lane's traps to improve animal welfare outcomes were also adopted after a review of trapping protocols used in dingo research showed that injury to trapped limbs and feet could be substantially reduced by filing off the steel teeth, padding the jaws, and installing shock-absorbing spring and swivels to the anchor chain (Fleming *et al.* 1998; York *et al.* 1999). In contemporary Australia, there are now many brands, types of soft-jawed traps and sizes being used, although all traps used are targeting the foot not the leg (Table 1).

Table 1. List of foothold traps used in Australia and the need for humaneness assessment. * The terms foothold and leghold traps are interchangeable in Australia, there are no criteria to differentiate because all traps are intended to capture the foot not the leg (for clarity a leghold trap below is defined by a large trap that could close above the ankle). Foothold trap (FH), leghold (LH), foot snare (FS), snare (S). ● denotes the species targeted with the trap type.

Trap Name/Model	**Type***	**Common Use**	**Dog**	**Fox/Feral Cat**	**Rabbit**	**Assessment Required**
raun	FH		●			Y
Bridger #2 offset laminated	FH		●	●		Y
Bridger #3 offset laminated	FH		●			Y
Bridger #3 padded	FH	●	●			Y
Bridger #5 offset laminated	FH/LH		●			Y
Bridger #5 padded	FH/LH	●	●			Y
CDR 7.5	FH		●	●		Y
Collarum	S		●	●		Y
Conibear	FH		●	●		Y
Duke #1.5	FH			●	●	Y
Duke #1.5 padded	FH			●	●	Y
Duke #3	FH		●			Y
Duke #3 padded	FH		●			Y
Jake	FH		●			Y
Bridger #2 offset laminated trap	FH			●		Y
Bridger #3 offset laminated	FH	●	●			Y
KB 5.5	FH		●	●		Y
Lane Padded Jaw (Old Lane)	FH/LH		●			N
Lane Soft Jaw Trap (New)	FH		●			Y
MB450 offset laminated	FH		●	●		Y
MB550 padded 4 coiled	FH		●			Y
MB650 Wolfer offset laminated	FH		●			Y
MB650 Wolfer padded	FH		●			Y
MB750 Wolfer laminated	FH		●			Y
Treadle Snare	FS		●	●		N
Victor Soft Catch #1	FH				●	Y
Victor Soft Catch #1.5	FH	●		●	●	N
Victor Soft Catch #1.75	FH			●		N
Victor Soft Catch #3	FH	●	●	●		N
Victor Soft Catch #3 4x4	FH	●	●	●		Y
WTS #3 Dogless	FH		●	●		Y
WTS #3 Offset	FH		●	●		Y
WTS #5 Dogless	FH		●	●		Y
WTS #5 Offset	FH		●	●		Y

Historically, the preference of Australian trappers has been to select the biggest trap with the fastest closing speed and largest plate to catch their target (Meek *et al.* 2018). In the last 20 yrs, the availability of larger sized, rubber-lined foothold traps has seen a dominance of Bridgers and Jake traps as the traps of choice for many wild dog trappers. Selection is based on plate size and the perception that smaller traps are slower, despite evidence to the contrary (Meek *et al.* 2018; Meek *et al.* 2019a). Victor® Soft Catch® traps are also preferred in some areas for dogs, foxes and feral cats (Meek *et al.* 2019a). However, the welfare impacts and humaneness evaluations of many of these traps have not been systematically evaluated in Australia (see Table 1).

Trap choices (size and specifications) are also influenced by State legislation in each jurisdiction as there are no Australian standards regulating trap use. Trap mechanical evaluations are needed to assess the effects of the number and size of springs on traps, clamp force and jaw size related to target species welfare, like those recommended by Baker *et al.* (2012). Moreover, assessments of other types of traps such as Collarums® need to be systematically tested for humanness. Sharp and Saunders (2008, 2011) recommend consideration of factors in addition to injuries, which influence the relative humaneness of traps including: duration of restraint; effects of exposure or dehydration; levels of anxiety, fear and distress; pain; method of killing and long-term impacts of injuries in escapees or those captured and later released. Proulx *et al.* (2022a,b) have provided quantitative recommendations for international standards for assessing trapping systems, including trap mechanical testing and physiological evaluations of captured animals that recognises the nuances of Australian trapping systems.

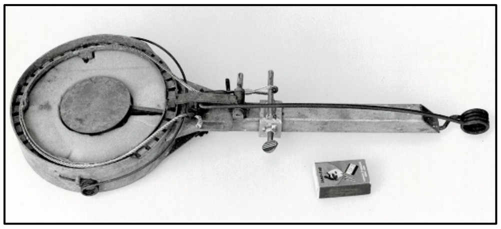

Figure 2. The treadle snare or banjo-trap, a combination of a sprung trap mechanism and a leg snare cable tightening system.

Use of toxins on trap jaws for euthanasia

In some Australian jurisdictions (see section below), provisions have been made to put toxins on the jaws because of the inability of trappers to check traps within 24 h. This inability can be due to the vast distances required to check traps daily, inaccessibility due to sudden extreme weather, and sometimes the perceived need to visit traps infrequently to improve chances of capture success. In some of these circumstances, registered toxins can be placed on the trap jaws to kill trapped predators. This practice involves attaching a strychnine-soaked cloth around a trap jaw (Fleming *et al.* 2001), and relies on the trapped animal biting at the jaw while trying to free their foot from capture and consequently receiving a lethal dose. Strychnine must be used in accordance with the relevant legislation, permits and policies of the respective jurisdictions. There is not broadscale acceptance of this toxin. An alternative, para-aminopropiophenone (PAPP), which is more humane than strychnine, was tested as a replacement in 2019-20 (Meek *et al.* 2019b). PAPP can be presented in either of 2 ways: a silicon device (similar to a TTD, see Balser 1965) that can be fitted to a trap jaw or PAPP Putty that can be used like strychnine on cloths (Meek *et al.* 2019b). This new toxin shows great promise as an alternative to strychnine especially as it is considered more humane (Allen 2019). While the use of toxins on jaws is not mandatory in every jurisdiction and is not utilised broadly by Australian trappers (Meek *et al.* 2019a), it does provide a more humane option to reduce the time animals are restrained in traps.

Trap alerts and devices

The use of devices to alert and notify trappers when traps have closed is another way to limit the time animals are in traps and to save costs on trap checking (Larkin *et al.* 2003; Darrow and Shivik 2008; Jones *et al.* 2015; Warburton. *et al.* 2015; Croft *et al.* 2016; Notz *et al.* 2017). There were 2 historic projects aimed at developing trap alerts in Australia, both constrained by the limitations of technology at the time. Marks (1996) and Woodford and Robley (2011) made pioneering attempts to develop systems that would notify a trapper remotely when a trap was set-off. However, at that time, communicating a trap closure alert was limited to the telecommunications network and components that have since been superseded. Modern day systems are now available (Meek *et al.* 2020) using both the telecommunication network (which has significantly expanded in coverage) and the satellite infrastructure. As a result, trap alert devices can now be fitted to jaw traps in remote parts of Australia and can transmit alerts that are delivered to a trapper in real-time (Meek *et al.* 2020).

The advancement of other technology such as camera traps with SMS capability are also providing trappers with forms of alert systems, so that, where there is coverage, an SMS photo can be sent to a mobile phone. The use of camera traps as an alert system has yet to be formalised into a reliable system. The nuances and unreliability of camera traps (Meek *et al.* 2015) pose a risk of animals being trapped and undetected in an image if the camera is not placed properly. Image quality of SMS transmitted photos, especially at night with low quality cameras can fail to give the observer an accurate description of the trap site (P. Meek, personal observations). Using the time lapse function each morning, where the camera trap is carefully placed to show the integrity of the area in the immediate vicinity of the trap, needs to be tested. Deploying camera traps that are triggered by passive infrared (PIR) settings near a foothold trap may cause the animal to avoid the area if the flash disturbs their approach to the trap (Séquin *et al.* 2003; Meek *et al.* 2016).

Evolution of predator trapping training and culture

Historically, the trapping culture in Australia was focussed around a relatively small fraternity of professional "old-timers" whose skill had developed over decades and who "earned their stripes through the school of hard knocks" (e.g., Ward 1986). With the exception of Victoria, which still employed trappers (also known as 'Doggers'), a career as a trapper looked dire at the end of the 1980s, with many "old-timers" retiring or dying, a general disinterest from young people, and the demand for professional "doggers" to trap predators waning.

However, with the advent of the internet and a strong underlying support base by landowners from some parts of South-eastern Australia, new opportunities for trapping arose (Jenkins *et al.* 2000). The transfer of trapping knowledge from old trappers, was partly superseded by internet access to northern hemisphere trapping sites (Meek *et al.* 2019a). Since there was little to no governance in Australia around who could trap or learn trapping prior to the 1980s, North American trapping practices, albeit out of context, were embraced by Australians interested in learning how to trap.

This interest together with increasing demands during the 1990-2000s for trapping as part of an integrated wild dog management and more formal control efforts, highlighted the need for more advanced training and nationally recognised training programs for pest animal controllers. Additionally, the ongoing and, in some areas, escalating impacts of dingoes and other wild dogs on the sheep and wool industry (Allen and West 2013) generated a need to educate and train landholders in the use of a wide range of control techniques including the use of traps. Formal training programs for existing and new pest control officers were initiated through Australian Government-registered training institutions (Jenkins *et al.* 2000) and expanded by the Invasive Animals Cooperative Research Centre (IACRC) (Crawford and Fleming 2008). The courses included theory and practice of trapping, including animal welfare requirements and procedures, and 12 months service with a mentor professional trapper. This course was offered as part of the nationally recognised Conservation and Land Management package for certification at Australian Qualification Framework (AQF) levels II to Diploma (Level V), and later delivered through the then annual NSW Vertebrate Pest Management Course (Crawford and Fleming 2008). During 2008, 47 trainees from

New South Wales had been certified for the Apply Animal Trapping Techniques Unit (Crawford and Fleming 2008). However, the trapper training program stalled after 2012 when the national AQF training program was reviewed and led to the exclusion of the course.

In 2012, the IACRC recognised the lack of contemporary extension material on pest animal trapping and funded a series of educational videos on Australian trapping practices. In subsequent years, additional extension material was produced under the National Wild Dog Action Plan 2014. As a result of these education and extension activities, tighter regulations around trap use, and recognition by landholders of the importance of wild dog management, trapping practices have improved (Meek *et al.* 2019a). The adoption of best practice trapping has further been enhanced by the production of Standard Operating Procedures, Codes of Practice and guidelines (Sharp and Saunders 2008, 2011).

A modern trapping era has now evolved, and the career of a trapper has re-established with a greater animal welfare emphasis than historically. Training for trappers has expanded into broader pest animal management and monitoring, and while their role is evolving to meet modern societal expectations of accountability and transparency, predator trapping remains the priority. This poses a new set of challenges in managing trapper activities and animal welfare related matters because there are more trappers than ever in our history.

Since the 1990s, Australia has made significant progress in improving welfare outcomes for pest animals in trapping programs. The development of best practice guides for more humane trapping of pest animals has been achieved through a combination of more humane trap choices and injury assessments (Meek *et al.* 1995; Fleming *et al.* 1998), humaneness assessments (Sharp and Saunders 2008), the development of trap alerts and lethal trap devices (Meek *et al.* 2019b; Meek *et al.* 2020), and the development of Codes of Practice and Standard Operating Procedures and better training. Now, a contemporary and progressive framework is required to ensure Australia continues its trajectory towards internationally accepted trapping best practice by improving policies and the regulatory framework.

Current Australian animal welfare legislation

The Australian legal system operates under federalism. As such the Commonwealth of Australia is administered under a version of the Westminster system and national legislature, and consists of eight State and Territories, each with separate law systems. Each jurisdiction is responsible for administering their own legislature and independent of the Commonwealth. The system of governance in Australia is peculiar to each the States and Territories, and the Commonwealth Government has little influence over jurisdictional affairs. To this end, animal welfare legislation, and in particular laws pertaining to predator trapping varies between the 6 States and 2 Territories of Australia, and in recent years there have been several reviews of legislation. In Australia, kill traps are only allowed to be used for rodents. In the following section, a general summary of the relevant legislation is presented for live capture only, providing an overview of the nuances between jurisdictions and emphasising the difficulties of implementing consistent legislative improvements to trapping practices in Australia.

In New South Wales, pest animal trapping is permitted under the *Prevention of Cruelty to Animals Act 1994*, although permissible traps are well defined; rubber jawed traps, and short anchor chains with swivels at the trap and anchor peg end and a shock-absorbing spring being mandatory (York *et al.* 1999). Traps must be checked daily, and trapped animals quickly and "humanely" killed. The NSW government has also invested considerable effort in improving the humane treatment of pest animals through research and policy (e.g., Fleming *et al.* 1998; Sharp and Saunders 2008, 2011).

Trapping in Victoria is highly regulated with *The Prevention of Cruelty to Animals Act 1986, Regulation 2019* stating that only rabbits, foxes and wild dogs can be trapped, with specific approval required to trap feral cats. Specific trap requirements including specified jaw spread size, padded, off-set jaws, and fitted with an anchor chain and swivels must be met. Traps must be checked every 24 h, although Ministerial approval for up to 72 h can be granted. The use of trap alerts has also been approved for use to facilitate a quick response to capture, and non-kill snares are permitted although under strict guidelines.

Regulations under the *Animal Welfare Act 1985* in South Australia (amended in 2012) enable the use of "jawed leg-hold traps" only for wild or feral dogs, feral cats, foxes and rabbits. In the case of dogs, an approved agricultural product that ensures "rapid" death must be applied to the trap (currently strychnine, although PAPP has been recently approved as a replacement toxin). Traps set for foxes, cats and rabbits must be checked every day. Non-kill body gripping traps are not permitted for dogs, foxes and feral cats, only for rabbits and rodents.

The use of jawed traps in Western Australia is administered under the *Biosecurity and Agriculture Management Act 2007* (BAM Act 2007) and it is specified that all foothold traps for dogs must be deployed with strychnine, which was regulated under the *Animal Welfare Act 2002* and associated regulations. The application is required to ensure that captured animals die "quickly". The use of strychnine is controlled under the *Medicines and Poisons Act 2014*. A Code of Practice for Strychnine Use and other toxins has been prepared to provide guidance on safe practices (Anonymous 2018). A permit must be acquired to use strychnine on traps. Foothold traps are only allowed to be used for wild dogs and foxes, and a permit is required under the BAM Act 2007 for foxes; snares are prohibited. Trappers who work for statutory bodies in Western Australia are required to be registered, trained and licensed under the *Health (Pesticides) Regulation 2011*.

Queensland legislation has the most liberal practices in relation to trapping, resulting in a vast array of traps and methods being deployed within this state. In 2021, the *Animal Care and Protection Act 2001* was reviewed to improve welfare outcomes. The focus of the amendments was to ensure that "unjustifiable, unnecessary or unreasonable pain" caused by trapping and control efforts does not occur. Guidelines on trap use have been prepared to accompany the legislation. Queensland is one of 2 Australian States where the neck-restraint trap the Collarum®, which was designed for a more humane capture of coyotes (*Canis latrans*), dogs, wolves (*Canis lupus*) and foxes (Shivik *et al.* 2000), can be used. When triggered, the Collarum® device throws a non-choking loop of cable over a canid's head that restrains them until a trapper returns to kill them.

The Australian Capital Territory (ACT) was one of the first Australian statutory jurisdictions to ban (in 1992) the use of steel-jawed traps (Meek 1995; Meek *et al.* 1995) replacing them with treadle snares (Stevens and Brown 1987) and later with padded alternatives like the Victor® Soft Catch® trap. In the ACT, a trapping permit is required to carry out commercial or private trapping under the *Animal Welfare Act 1992*.

Trapping of predators using jawed traps is not commonplace in Tasmania or the Northern Territory (NT), and this practice has not been widely recognised or addressed in the legislation. In Tasmania, the *Animal Welfare Act 1993* prohibits the use of jawed traps unless approved by the Minister. In the NT, the *NT Animal Protection Act 2018* allows the use of padded jawed traps although very little trapping is reported.

Given the nuances of each jurisdiction and legislation, it is difficult for trappers to understand their legal boundaries. As such, the Codes of Practice and Standard Operating Procedures are used to guide best practice. However, these documents are not legally binding and trapping data is not collected broadly across the jurisdictions to gain insight into capture efficacy, injuries and non-target captures.

Future directions for trapping in Australia

Trapping practices in Australia have evolved out of necessity and innovation. It is important that as new devices, tools and technologies develop that we continue to refine and improve trapping practices towards achieving more humane outcomes for animals. In parallel, we need to move towards better governance consistent with international models while maintaining our unique requirements to ensure trapping remains a management option.

Data recording and management

Data recording and management of trapping practices is inconsistent throughout Australia with only a few agencies developing geo-referenced data bases. However, there are few consistencies across the jurisdictions. Applications like FeralScan (https://www.feralscan.org.au) provide useful tools for the public and trappers to record their observations and general activities, although specific data on captures, injuries and non-target captures are not collated by a central authority. The Victorian Government has developed a detailed recording system for dog and fox trappers (MAX Forms), and Forest Corporation NSW have their own data recording system (MappApp). The data capture methods have great application, but they are not widely available at a national level. While it is unlikely that a national trapping data system would be embraced by the jurisdictions, a State and Territory trapper recording system with some consistent data fields would ensure better management of trapping practices and systems.

Importation of traps into Australia

The importation of traps and trapping paraphernalia (lures, setters, etc.) into Australia are governed by the *Customs (Prohibited Imports) Regulations 1956*. The importation of any product such as lures containing cat or dog fur is subject to an approvals process by the Australian Border Force. There are no constraints on the importation of predator trapping devices under the Regulations. Similarly, the Commonwealth Department of Agriculture, Water and the Environment have no role in assessing traps and lures from an animal welfare or biological products perspective. At present there are no constraints on the importation of traps, although as outlined, their sale and use are restricted in some jurisdictions. The adoption of internationally agreed standards on trapping practices designed around improving animal welfare outcomes (Proulx *et al.* 2020) did not include Australia until recently (Proulx *et al.* 2022a,b). These standards provide a scientific, technical and quantifiable benchmark for improving animal welfare in Australian trapping systems. Embracing international standards on trap types and equipment is a fundamental progression towards improving the regulatory framework for trapping equipment.

A national agreement ratified by the Environment and Invasives Committee on importation of traps and associated paraphernalia is required to ensure inappropriate trapping related equipment does not enter Australia. The framework for a licensing system for importation of traps would need to be submitted to Australia Border Force in relation to jurisdictional legislation that governs the use of predator traps. This process could not be advanced in the absence of Australian Government legislation governing the use of traps for pest control. If there was State and Territory support for a licensing and permit system aimed at regulating traps and trap paraphernalia, new legislation would need to be ratified.

Evaluation of new traps and equipment

In Australia, improving animal welfare during capture has largely focussed on trap types, training, policy and devices. Evaluations have been driven mostly towards improving animal welfare impacts of foothold traps, while other types of traps like Collarum® snares have avoided evaluation. There has not been an Australian framework driving trapping research evaluations. Almost all new innovations have been initiated by researchers seeking to improve welfare outcomes for trapped animals, few are industry derived and trapping based industry funding for innovations is non-existent. In the Northern Hemisphere where private enterprise together with the hunting industry and trapping culture has a long history, resources have been more forthcoming. As a result, trapping and innovation has been fostered for decades by organisations like the Fur Institute of Canada, Federation of Trapper Managers of Quebec, Ministry of Forests, Wildlife and Parks Quebec, Alpha Wildlife Research & Management. Trapping practices would improve by formalising the legal framework and affiliations with professional groups around the evaluation of traps and equipment, trapping practices and training/certification throughout Australia.

Governance: training, certification and licensing

Traditionally, the skills required to trap rabbits, foxes and dogs in Australia were handed down through kinship and on-the-job training by experienced trappers. In recent decades, the importance of trapper training has been recognised and there is a growing number of trapping training courses available throughout Australia.

To manage inconsistencies and update earlier training units (described in the historical training section above), the industry and government stakeholders of the National Wild Dog Action Plan 2014-19 developed the Apply Predator Trapping Techniques Apply Predator Trapping Techniques (https://training.gov.au/Training/Details/AHCPMG403) training competency under the Australian Vocational and Educational Training Sector. The trapping competency was developed through in-depth consultation with experienced vertebrate pest controllers that specialise in trapping and vertebrate pest control experts already undertaking trapping courses for the IACRC (now Centre for Invasive Animal Solutions).

This competency provides some of the skills and knowledge necessary to carry out legal and more humane trapping programs. However, it is crucial that contemporary guidelines and support is available to training providers. Importantly, training courses must continue to include experienced trappers and accredited trainers, especially where toxin use is required. All trapping courses need to extend over sufficient time to train trappers how to prepare, deploy, check and retrieve traps and trapped animals, at least 4-5 d. Training must teach the animal welfare requirements of trapping operations, contemporary understanding of animal welfare, the general principles of biology of the target animals, trap types, preparation and maintenance of equipment, the use of lures, trap placement and animal handling including euthanasia techniques. Exposing trappers to the range of responsibilities necessary to be a competent and capable trapper will ensure that Australian best practice continues to be promoted and provides an avenue for adoption of new skills.

The "art" of trapping is not a skill that can be acquired on a short trapping course. Efficacy requires practice and persistence. It is recommended that prior to any certification, trappers spend time in the field with mentors to oversee their trapping prowess and to receive instruction and guidance. This ensures trappers are not catching animals without certified training and that animal welfare standards are adopted. Certification as a competent trapper could include theoretical and practical training by a Registered Training Organisation (RTO), and endorsement from an authorised trapper mentor confirming they are capable of humanely, safely and effectively trapping animals. The establishment of recognised training programs provides for the development of "trapping" as a professional career. Given the public scrutiny on lethal control and animal welfare (van Eeden *et al.* 2021), the adoption of nationally consistent training and development of more informed practitioners is warranted. Further safeguards could be put in place through the creation of a vertebrate pest control licence and registration with an association such as the Vertebrate Pest Managers Association of Australia (VPMAA). A licence of this description managed by the vertebrate pest control industry would provide the opportunity for the "industry" to regulate its own profession and practitioners and stamp out poor trapping practices and improve animal welfare.

There are inconsistencies in the licensing of trappers throughout Australia with some statutory bodies requiring certified training, certification and licenses before any trapping can be contracted. This licensing can relate to the use of vertebrate pesticides where contractors must have permission to obtain and use these substances as part of an integrated control program or where chemicals are required for use as lethal trap devices. A broader licensing system, as suggested above, that advances the adoption of best practice trapping should be mandatory throughout all jurisdictions. This poses legal and governance difficulties in a Federation because the Commonwealth defers management at this level to the jurisdiction; however, there are examples of jurisdictional licenses that span the borders, such as driving licenses.

Licensing is especially important where trappers are working under contract to government agencies to ensure best practice is adopted. Moreover, a periodic assessment of training providers must be instigated to ensure the information and skills being taught reflect contemporary best practice.

Discussion

The Australian trapping culture and regulatory framework continues to evolve albeit in ways complicated by the jurisdictional differences between each State and Territory. Today, the primary objective of foothold trapping in Australia is the live capture of pest animals. In pest management, these animals are killed, and in research, they are often released for tracking studies to further improve our ability to control pest populations in the future (e.g., Meek *et al.* 2018; 2019a). Foothold traps cannot be used for capturing native wildlife, with the exception of dingoes, which are considered both a native predator and an introduced pest (Ballard *et al.* 2018). The continuation of trapping in Australia over the next few decades will most likely develop around the professional trapping industry. We have proposed mechanisms necessary to develop a framework fostering humane practices and professional standards that align with international directions (Allen *et al.* 2022*;* Proulx *et al.* 2022a,b).

It is crucial that trapping as a tool for pest management and research in Australia continues to be available to land managers and professionals. As such, developing a culture of best practice trapping with animal welfare at its core is fundamental for all practitioners and a continued social acceptance of trapping. Adoption of humane methods in Australia has led to considerable advances over the last 20 yrs. Although there are still many challenges ahead. It is important to find mechanisms for "imposing ethical rigor" (Warburton and Norton 2007) into pest management programs, especially trapping. In 2008, a number of recommendations were made by Nocturnal Wildlife Research (2008) to help improve Australian trapping practices. A stock-take of some of the relevant recommendations highlights the progress made over the last 13 yrs.

A partnership between trappers and researchers should be fostered, when possible, to encourage future assessment of potential improvements to be appropriately rigorous.

Historically, the relationship between on-ground trappers and researchers was disconnected because there were no opportunities for engagement. However, the chasm that existed between trappers and researchers has improved significantly because of training courses, practitioner conferences, internet forums, trapping guides, training video, and internet websites. The role of researchers in advancing the methods and technology of traps, trapping equipment and methods is key to improving and expanding on the way we trap animals. The relationship between researchers and industry, researchers and farmers, researchers and landowners and managers, all contribute to achieving best practice. Information dissemination on new innovations and methods from scientific papers to the non-research audience continues to be a challenge. Innovative ways of communicating this information through podcasts and other extension tools require ongoing resources. Using professional organisations such as the VPMAA could provide a new avenue for disseminating new knowledge in a collaborative forum.

A schedule of appropriate actions concerning post-capture treatment and release or obligatory euthanasia should be prepared in order to guide the action of trappers

The humane treatment of trapped animals is a fundamental part of best practice, and Australia has made many advances in improving the treatment of target and non-target animals in traps. Injury recording methods adopted from North America have been proposed since the 1990s (Meek *et al.* 1995; Fleming *et al.* 1998) but adopted in an ad hoc way. Formal systems for recording trap injuries during programs only exists in some organisations and are not yet mandatory. Humane practices in pest management have been discussed in detail by Sharp and Saunders (2008, 2011) and detailed guidelines for humane treatment and euthanasia of animals are freely available. Presently, non-target capture and release statistics are not recorded comprehensively, consistently or centrally. The formation of a national system of administration and governance would ensure that trapping statistics are provided as a requirement of the licencing system.

Research should seek to test if more durable smaller trap devices can be produced to offer increased target-specificity without a reduction in capture rates.

Testing traps and the development of new devices is a valuable recommendation although very challenging. Most trap designs have evolved from the USA and Canada where the trapping culture is well-established and well-funded by the fur industry. The existing range of traps available on the market (not just Australia) is enormous and developing new models specifically for Australia is probably not possible on cost-benefit grounds. However, research on the existing types of traps is desirable and valuable.

The argument by many trappers that bigger traps are better is not founded on evidence. The important question is "what is a suitable size trap for my target species?". There is growing evidence that Victor®

Soft Catch® #3 traps are very versatile and effective at trapping wild dogs (G. Ballard, unpublished data; P. Meek, unpublished data). Trapper folklore can be misleading and perpetuate mythology about trap size and speed (sensu Meek *et al.* 2018).

An argument often used in support of using larger traps is that the pan size is larger, and as such the probability of capture is higher than for traps with smaller pans. These concepts could be tested by investigating trap speeds and efficacy of different sized pans on current trap models. However, claims about smaller pan size on traps compared to the large pans may be addressed through better engagement and education programs reporting on research findings. Training provided to existing and new trappers relating to trap position, lure placement and pan tension, has improved catch rates in many instances where trappers were hesitant to adopt the use of these smaller, more-effective devices (P. Meek personal observations, 1993). Proving it is possible to "teach an old dog new tricks", although breaking folklore myths alone will not result in broadscale uptake of new information by trappers. A structured, integrated and systematic strategy with appropriate governance across the jurisdictions is necessary to implement the recommendations outlined.

Conclusions

Our recommendations are intended to provide strategic direction for advancing humane trapping practices in Australia. We assert that the underlying philosophy of a trapper must always be to consider the welfare of the animal being targeted, irrespective of it being a predator of livestock and biodiversity. Poor trapping practices and inhumane trapping and behaviour need to be resolved through better training, governance and certification. The recommendations discussed are not intended to be restrictive or an impediment to "getting the job done", but more so, setting a standard across all aspects of trapping that trappers should all aspire to achieve.

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Chapter 6

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

Benjamin L. ALLEN[1,2], Guy BALLARD.[3,4], Peter J.S. FLEMING[1,3,5], Paul D. MEEK[3,6], and Deane SMITH[4]
[1]Institute for Life Sciences and the Environment, University of Southern Queensland, Toowoomba, Queensland, Australia. Email: benjamin.allen@usq.edu.au.
[2]Centre for African Conservation Ecology, Nelson Mandela University, Port Elizabeth, South Africa.
[3]Ecosystem Management, School of Environmental and Rural Science, University of New England, Armidale, New South Wales 2351, Australia.
[4]Vertebrate Pest Research Unit, NSW Department of Primary Industries, Armidale, New South Wales 2350, Australia.
[5]Vertebrate Pest Research Unit, NSW Department of Primary Industries, Orange, New South Wales 2800, Australia.
[6]Vertebrate Pest Research Unit, NSW Department of Primary Industries, Coffs Harbour, New South Wales 2800, Australia.

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.

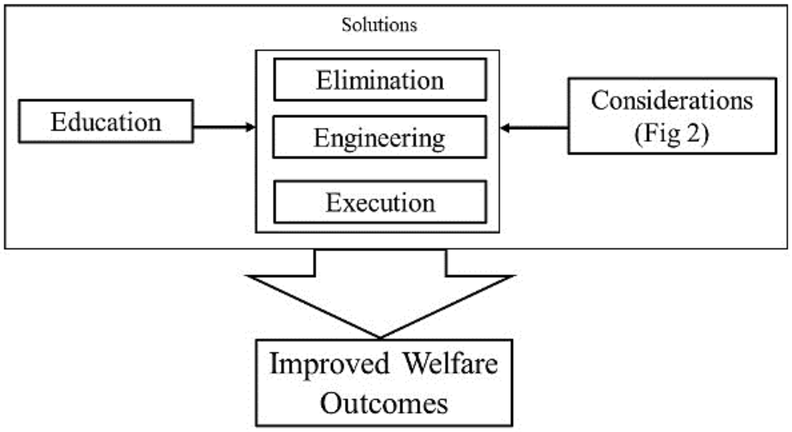

Figure 1. A conceptual model using the four Es and associated considerations for improving the welfare of trapped animals.

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).

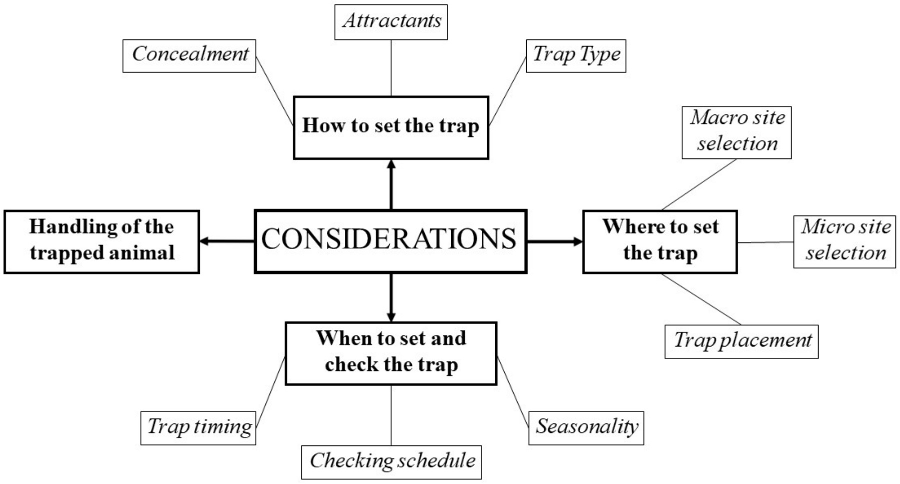

Figure 2. Factors that must be considered for practical improvements to the welfare of trapped animals.

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 ($\overline{x}$ = 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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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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Chapter 7

Some Thoughts on The Impact of Trapping on Mammal Welfare with Emphasis on Snares

Donald M. BROOM
Department of Veterinary Medicine and St Catharine's College, University of Cambridge, Madingley Road, Cambridge CB3 0ES, U.K. Email: dmb16@cam.ac.uk

Abstract − All vertebrate animals, including wild mammals considered to be pests or food and fur resources, have the capacity to feel pain, fear, and to suffer in other ways. If they are to be trapped, the impact on their welfare should be assessed scientifically and traps should be evaluated using criteria comparable with those used for all other animal treatment. The term humane has been used for many years in science and law in relation to the management and killing of domestic animals, and should be used in the same way in relation to capturing and killing wild animals. Snares do not operate humanely, either as restraining or as killing traps as the pain, fear, mortality and morbidity of animals caught in snares is high. Animals left in snares are susceptible to thirst, hunger, further injury and attack by predators, especially if in the trap for many hours or days. The magnitude of poor welfare when animals are caught in snares varies but is always high in comparison with all other regulated killing. Snares are inherently indiscriminate and commonly catch non-target animals, including protected species, so can have negative effects on conservation efforts. The regulation and monitoring of the use of snares, including the methods used to kill animals that are alive after snaring, is probably impossible. Some methods of pest control and other capture and killing of animals have such extreme effects on the welfare of the animals that, regardless of the potential benefits, their use is never justified. The use of snares is in this category.

The concepts of welfare and humane trapping

Welfare, like all other biological terms, has the same meaning for human and non-human animals. The welfare of an individual is its state as regards its attempts to cope with its environment (Broom 1986, 1991), and this includes feelings and health. Welfare is a characteristic of an individual animal at a certain time. The state of the individual can be assessed so welfare will vary on a range from very good to very poor. Welfare concerns how well the individual fares, or goes through life, and quality of life means welfare, although normally referring to a period of more than a few days (Broom 2007, 2022).

Non-human animals are sometimes killed to: 1) provide a human resource such as food, 2) prevent destruction of a resource by an animal that we might call a pest, 3) prevent spread of disease, 4) provide human entertainment, or 5) benefit the animal itself by preventing suffering. Where the killing is under human control, every person has an obligation to avoid causing pain, suffering or other poor welfare to the animal during the processes leading to death. We use the word humane for such killing and it has been used in science and legislation for many years. While much of this usage refers to treatment of companion and farmed animals, it is also used for humans, laboratory animals and wild animals. There is only one biology, and biologically-relevant words, especially those that are used scientifically, should mean the same whether referring to humans or to any particular group of animals (Tarazona *et al.* 2020; Broom 2022). Humane is an absolute term, so the action is either humane or not, and cannot be somewhat humane. Humane means treatment of animals in such a way that poor welfare is avoided. This has been written as:

"*welfare is good to a certain high degree*" to emphasise that humane is not a relative term but should be used when welfare is above a defined threshold level, explained in the detailed wording as avoidance of pain and suffering (Broom 1999, 2022; Broom and Fraser 2007). According to generally accepted principles, for example EU legislation and American Veterinary Medical Association guidelines (commercial slaughter, disease control, veterinarian procedures), humane killing implies that: (i) the treatment of the animals in the course of the killing procedure does not cause poor welfare; and (ii) if there is stunning, the stunning procedure itself results in instantaneous insensibility or, if the agent causing insensibility or death is a gas or injectable substance, no poor welfare occurs before insensibility and then death. This may be achieved because the stunning or killing agent is not detectable by the animal. Shooting that causes instantaneous unconsciousness and then death would therefore be humane. If there are several minutes of extreme pain or fear, for example in a killing trap, a snare or a restraining trap, neither the action of capturing nor the trap or snare could be called humane. In order to assess whether or not a trap is humane, scientific assessment of welfare and whether or not an individual is unconscious is needed. This evidence may indicate that one trap results in better welfare than another, and shows how much better the welfare is.

Assessing the welfare of trapped animals

Animal welfare science has developed rapidly in recent years, and a wide range of measures are available to evaluate the welfare of animals such as those caught or otherwise affected by snares or other traps (Broom and Johnson 2019; Broom 2022). Many of these measures indicate anxiety, distress, fear, pain and other negative feelings. All of the animals considered in this paper are sentient so capable of feeling pain and it is now appreciated in studies of the welfare of humans and other sentient animals (Broom 2014) that fear is often worse than pain. Information about the needs of wild animal species can be used in identifying factors that cause problems to trapped species and, in the absence of detailed information about needs, a general guide such as the five domains approach may be helpful (Sherwen *et al.* 2018). Some of the welfare indicators listed below have been used in assessing the welfare of trapped animals but others are more difficult to use or less valid for wild animals. Measures of behaviour include: activity levels, immobility, postural changes, vocalization, digging, pacing, chewing, lunging, self-mutilation and other escape behaviours. Physiological measures include: levels of cortisol and other hormones in the blood, levels of muscle enzymes in the blood, levels of blood cells as markers of the stress response (e.g., neutrophils), markers of the inflammatory response (e.g., acute phase proteins), markers of exposure or food and water deprivation (e.g., changes in haematocrit or blood proteins), heart rate, and body temperature. Health measures include: extent of body damage (physical injuries), indicators of exertional or capture myopathy and effects of exposure (e.g., freezing of extremities).

When assessing welfare during a procedure likely to have negative effects, such as handling by a human, abattoir slaughter, or capture in a trap, the magnitude of poor welfare is a function of the duration of the effects and the severity of the effects. This is shown in Figure 1 which can also be used for the magnitude of good welfare as a function of duration and intensity.

The scoring of how much pain is caused by injuries received by trapped animals has, in the past, underrated the severity as compared with scoring by laboratory and domestic animal scientists (Baumans *et al.* 1994; Broom 1999; Broom and Johnson 2019; Proulx *et al.* 2020). The extent of injuries and distress experienced by a trapped animal is strongly influenced by the length of time it is restrained in the trap. Long restraint time can lead to the development of dehydration (Powell 2005; Marks 2010), starvation, effects of exposure (e.g., hypothermia), and capture myopathy. It can also cause stress by disrupting natural behaviour and motivational systems (Schütz *et al.* 2006; Sharp and Saunders 2008). Females may be prevented from returning to their offspring, who will subsequently die of starvation. The rate at which welfare becomes poorer in a trapped animal varies with species, climatic conditions and condition of the trapped animal. Many guidelines about checking restraining traps are much too long (Proulx and Rodtka 2019), for example once every 24 h will lead to considerable worsening of welfare for most animals. Powell and Proulx (2003) recommended that restraining traps should be checked at least twice daily, and more often if weather conditions are poor.

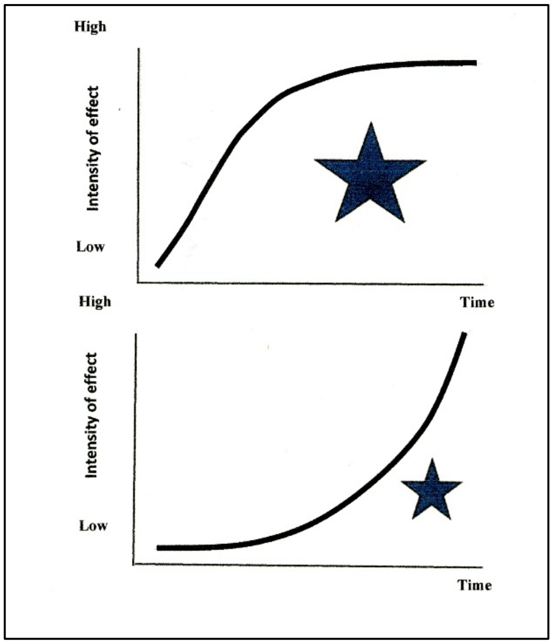

Figure 1. When the severity of poor welfare is plotted against time, the upper plot shows an animal that is killed by a method involving prolonged pain and other poor welfare while the lower plot shows an animal that is killed by a method that has a much more rapid effect. The magnitude of poor welfare is the area under the curve (modified after Broom 2001, 2014).

Snares

The basic principle of a snare is to put a loop, now usually made of wire, in a place where a target animal is likely to put its head or foot. The remainder of the snare mechanism is intended to either hold the animal until the snare can be revisited or to kill it. The target animals for most snares are mammals, for example canids, felids or rabbits, but birds and non-target mammals may also be caught. The snare may be set in a baited area or on a trail. An anchor mechanism is used to minimise the chances that the trapped animal moves away taking the snare with it. Killing snares are less likely to be set if pet animals, farm animals, conserved species or humans may be caught. The size of the loop is designed for a target species but a neck snare for one species may catch the same or a different species by the leg. As explained by Proulx *et al.* (2015), manual killing neck snares have a self-locking tab so that when the animal's head moves forward, the loop can tighten but not loosen. In power killing neck snares, 1 or 2 springs provide the energy necessary to tighten the noose. Self-locking snares can have an ever-tightening action leading to severe injuries or death due to crushing, ischaemia, necrosis of tissues, or asphyxia. Guthery and Beasom (1978) found that 65 coyotes (*Canis latrans*) and 60 non-target animals were caught in killing snares that had a swivel but no stop. Snares were checked daily. Fifty nine percent of coyotes were caught by the neck, and the remainder by other parts of the body (flank, leg, neck, foot). Of the catch, 52% of animals were dead and 48% were alive when the snare was checked. Although some animals caught in a killing snare could become unconscious and die within a few minutes, as Proulx *et al.* (2015) explain, many live for several hours or days after being caught, sometimes because they were caught by the body or leg. Neither manual nor power killing neck snares reliably rendered the majority of snared target animals unconscious within 5 min. A long list of non-target mammals and birds were caught and most would have taken longer to die than the target species.

The animal welfare indicators used in studies of animals caught in snares have mainly been measures of injuries, mortality rate and delay before death. A few studies have measured emergency behavioural and physiological responses at the time of capture (e.g., Marks 2010; Proulx 2018) and, in animals that were released, behaviour after release as an indicator of degree of aversion and disturbance (e.g., Gese *et al.* 2019). It is sometimes said that the extent of poor welfare caused by a killing trap or snare is less than by some attacks by a predator or by starvation. However, most predators kill faster than a trap or snare and humans interacting with individuals of other species have an obligation not to cause them to have poor welfare (Broom 2022).

Foot snares, which are used less commonly in many countries, are placed horizontally and are designed to close upon the animal's leg or legs in order to restrain it (Powell and Proulx 2003). Some neck and foot snares are not designed to kill but are free-running and have a stop. A free-running snare is supposed to loosen when the animal stops pulling against it. The free-running mechanism is easily disrupted and prone to failure since any kink, twist, rusting, fraying, or entanglement of the wire in vegetation or branches may prevent the snare from being free-running (Frey *et al.* 2007; McNew *et al.* 2007; Murphy *et al.* 2009). A swivel may prevent this, but in practice a swivel placed near the anchor point of the snare can become jammed with vegetation and fail to work. Murphy *et al.* (2009) studied European badgers (*Meles meles*) trapped in stopped restraints and found that 62% of restraints after use had some degree of twisting, unravelling or fraying. Damaged restraints were associated with an increased risk of injury. Free-running snares may become self-locking and contribute to the death of the animal. A stop on the snare is set to prevent the wire loop from tightening to less than a certain diameter. However, there is variation in size of target animals and in non-target animals that are caught, sometimes by other parts of their bodies (Frey *et al.* 2007). Injuries can be particularly severe when the snare catches diagonally across from the shoulder to the axilla (Murphy *et al.* 2009). A stop may prevent injury in the target species, caught as intended, but not if caught around other parts of the body or in non-target species that differ in size, amount of subcutaneous fat, or behavioural response to restraint.

Muñoz-Igualada *et al.* (2010) tested 2 cable restraining trap systems to capture red foxes (*Vulpes vulpes*) in Spain. The Spanish Snare is made from multi-strand steel cables that end in a simple loop, and includes a stop that prevents the snare from closing smaller than 8 cm in diameter. Another restraining snare, the Wisconsin Restraint, is built with a 180° bend relaxing-type lock on aircraft cable, and incorporates 2 swivels, a break-way S-hook, and a stop that prevents the loop from closing to less than 6.5 cm in diameter. The snares were anchored to a branch or to the ground, and were either set in gaps in a 1-km-long pile of brush and branches or in fauna trails. All were checked daily in the morning and captured foxes were necropsied by a pathologist and scored for injury according to ISO (1999). Of fox captures, 35% were around the body rather than the neck, and 9.4% had a "severe injury" score. In another study, Marks (2010) found that foxes trapped in leg-hold snares had similar haematological and biochemical responses to those found by Kreeger *et al.* (1990) for foxes caught in leg-hold traps. In a comparative study of wolves (*Canis lupus*) in Minnesota (Gese *et al.* 2019), some individuals were caught, in order to attach a radio-collar, using padded leg-hold traps while others were caught in cable-restraint stopped neck snares. After release, the wolves caught in the neck snares travelled faster initially but a shorter distance before resuming more normal behaviour than wolves caught in a padded leg-hold trap. Although both trapping methods were aversive, the padded leg-hold trap had greater impacts. Using a different minimum loop size for the capture of coyotes, Wegan *et al.* (2014) found that there were few injuries and no mortalities in coyotes caught with cable neck restraint neck snares so this study also suggests that such snares are not the worst for welfare of the methods of trapping. All of these studies follow Etter and Belant (2011) in comparing the cable neck restraint snares with leghold traps. However, leghold traps would not be permitted in many countries of the world because they have such negative effects on welfare, even if padded to some extent.

There is less evidence concerning leporids but in a Scottish Government study of rabbits (*Oryctolagus cuniculus*) caught in snares without a stop, 14% were dead the day after capture (Science and Advice for Scottish Agriculture 2008). Rabbits in traps, which are likely to be similarly affected to those in snares, had 4 times higher cortisol than shot rabbits (Hamilton and Weeks 1985). The proportion of non-target species caught in snares set for foxes ranged from 21% to 69% (Chadwick *et al.* 1997; Harris *et al.* 2006; Muñoz-Igualada *et al.* 2010). The species included cats (*Felis catus*), dogs (*Canis lupus familiaris*), sheep (*Ovis aries*) and protected wildlife such as capercaillie (*Tetrao urogallus*), other birds, badgers, Eurasian otters (*Lutra lutra*), deer (Cervidae) and hares (*Lepus europaeus*).

If an animal is caught in a snare, the plot of intensity of poor welfare against time, calculated as shown in Figure 1, will vary according to the design and the way in which the animal is caught. If an individual caught around the neck in a killing neck snare struggles immediately and tightens the snare loop so that breathing is not possible, time to unconsciousness will be a few minutes. There will be a high level of fear and pain but, if the individual becomes unconscious and dies, the period of very poor welfare may last for 3-5 min and the magnitude of poor welfare calculated as the area under the curve would be approximately 3-5 times the severity of effect. If the period before unconsciousness is much longer before unconsciousness and death, for example for one of the reasons explained by Proulx *et al.* (2015), the magnitude of poor welfare would be much greater. If the snare is not a killing snare, the fear will be just as great but the pain may be less. However, the duration is very likely to be much greater than the mean for a killing snare, as explained in the studies quoted above, so the magnitude of poor welfare would be greater. None of these magnitudes of poor welfare would be permitted for any other regulated killing procedure.

Discussion and Conclusions

Mammals considered to be pests, or trapped for food or fur, have the capacity to feel pain and fear and to suffer just like humans or any other vertebrate animal. Their welfare should be scientifically assessed. However undesirable the impact of these animals on humans, whenever control methods are considered, their effects on the welfare of affected animals should be carefully considered. Where there are adverse effects of a species considered to be a pest, a cost-benefit analysis comparing these with the extent of poor welfare of the pest and non-target animals caused by the control method may be reasonable. However, some control, capture and killing methods have such extreme effects on an animal's welfare that, regardless of the potential benefits, their use is never justified (Sandøe *et al.* 1997; Broom 1999).

In Iossa *et al.*'s (2007) review of animal welfare standards of killing and restraining traps, it was reported that few studies had evaluated the impact of snares on welfare in the same way as has been done for some other types of restraining traps. Injuries from snares, such as pressure necrosis of tissues, can be difficult to detect because they may not be obvious until after release. Also reports of misuse are frequent and even when set and used correctly, neck snares commonly catch non-target species and these can have high morbidity and mortality. Subsequent work summarised by Proulx *et al.* (2015) found, firstly, that the best killing neck snares generally caused poor welfare for less time than the widely used snares without self-locking mechanisms but, secondly, that even these snares seldom killed target animals within 5 min and were unselective as they killed or injured large numbers of non-target mammals and birds. Proulx *et al.* (2015) commented on the illogicality of international agreements that did not include snares when snares are being used in some countries in ways that cause more long-delayed deaths and hence worse welfare than leg-hold traps or cage traps. They recommended that, unless neck snares killed all trapped animals quickly, the use of snares should be phased out. A review by Harris *et al.* (2006) recommended that the use of all neck snares should be banned. The difficulty of enforcing the frequency of checking even the best snares and traps so that any suffering that is still occurring does not continue for more than 12 h (Proulx and Rodka 2019) means that sales of snares and use of snares will always result in a very large amount of poor welfare in the animals trapped.

Based on the scientific literature summarised above and by Rochlitz *et al.* (2010), the following conclusions are reached.

- Killing and restraining snares are easy to use but are often not checked for 12 or more hours and do not then operate humanely.
- Killing and restraining snares are inherently indiscriminate and commonly catch non-target, including protected species.
- When left without checking for 12 or more hours, the best killing traps cause a smaller magnitude of poor welfare than restraining traps but neither manual nor power killing neck snares reliably kill the majority of snared target animals within 5 min.
- Restraining snares can cause severe injuries, pain, suffering, and death in trapped target and non-target species, and mortality and morbidity is higher than with some other restraining traps, such as box traps.
- Animals left in snares are susceptible to adverse weather conditions, thirst, hunger, further injury and attack by predators, especially if in the trap for many hours or days.
- It is difficult to assess the severity of injury in an animal when it is caught in a snare without careful veterinary pathology study, and if the animal escapes or is released, it may subsequently die from injuries or from exertional myopathy over a period of days or weeks.
- Methods used to kill animals caught in snares, but still alive when the snare is checked, are not regulated, and may not be humane.
- The monitoring of correct snare use is probably impossible.
- It is the opinion of the author that the negative effects of killing and restraining snares on target and non-target animals are so great that the use of snares should not be permitted.

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Chapter 8

Inadequate Implementation of AIHTS Mammal Trapping Standards in Canada

Pauline FELDSTEIN and Gilbert PROULX
Alpha Wildlife Research & Management Ltd., 229 Lilac Terrace, Sherwood Park, Alberta, T8H 1W3, Canada. Email: pfeldstein@alphawildlife.ca

Abstract − The Agreement on International Humane Trapping Standards (AIHTS) is a binding agreement that governs the use of trapping devices in Canada. The standards set out in the Agreement to improve animal welfare can be effective only if they are implemented by trappers. In this paper, we review the implementation of AIHTS trapping standards in Canada. We assess: 1) the trapping supplies market, 2) the components of traps sold on the market, 3) measures undertaken by government wildlife agencies to ascertain the use of certified traps on traplines, and 4) the contents of humane trapping courses relative to the use of certified traps. We conclude that the AIHTS is not properly implemented in Canada because non-certified traps and banned steel-jawed leghold traps are still in use, traps are sold with inadequate trigger systems, there are virtually no trapline checks by government agencies, and humane trapping courses promote the use of inhumane and unselective trapping devices that are not certified according to, or have been exempted from, acceptation criteria set forth in the AIHTS. We conclude that conformity in applying trapping standards cannot be taken for granted, and there is a pressing need for the implementation of a trap standard enforcement system.

Introduction

In 1991, because no international humane trapping standards were yet available, the Council of the European Union adopted the "Leghold Trap" Regulation 3254/91. This regulation prohibited: 1) the use of steel-jawed leghold traps in the European community, and 2) the introduction into the European Community (EU) of pelts and manufactured goods from countries that capture animals by using leghold traps or trapping methods that do not meet international humane trapping standards, which, at the time, still needed to be developed and approved (Proulx *et al.* 2020). In 1995, under pressure from the EU, negotiations began toward an Agreement on International Humane Trapping Standards (AIHTS) that would result in the banning of steel-jawed leghold traps in the territories of signatory countries (Proulx 2018). This agreement was signed by the EU, Canada, and Russia in 1997 (ECGCGRF 1997). The United States of America implemented humane trapping standards through an Agreed Minute with the EU in 1997 (https://iea.uoregon.edu/treaty-text/3276), which virtually replicated the AIHTS text (Anonymous 1998; Harrop 1998), and should be the only trapping methods used on traplines.

The Agreement's implementation schedule is as follows:

> Section 4.2.1: *"…trapping methods must be tested to demonstrate their conformity with these Standards, and certified as such by the competent authorities of the Parties, within:*
> *a) for restraining trapping methods, three to five years after the entry in force of the Agreement depending on the testing priorities; and*
> *b) for killing trapping methods, five years after the entry into force of the Agreement.*

That is to say that, starting in 2005, restraining and killing traps used for the capture of members of certain mammalian species, traded among the parties for their fur, should be certified in accordance with a set of standards (ECGCGRF 1997; Anonymous 1998). However, according to Section 4.2.3, a competent authority may continue to permit the use of traps on an interim basis while research continues to identify replacement traps.

The AIHTS is a binding agreement that has a direct impact on fur trading between the signatory parties (ECGCGRF 1997). In these countries, the AIHTS identifies certified traps to address animal welfare concerns associated with trapping. Although the standards are not, and never were, representative of state-of-the-art trapping technology and inadequately addressed animal welfare in trapping (Proulx *et al.* 2020), they are recognized in signatory countries as the standards to follow to trap furbearers. In other words, the implementation of these standards should signify that only AIHTS-certified traps should be allowed on traplines, steel-jawed leghold traps should not be used in the field independently of the convictions of or claims from organizations that are involved in the testing of trapping devices (e.g., the Fur Institute of Canada [FIC], the USA Wildlife Agencies), untested traps that are structurally similar to certified traps should not be allowed on traplines, and to be legally relevant, courses on humane trapping should be focused on trapping devices that have been certified according to the AIHTS. Also, AIHTS-certified traps should be used in the manner as they were tested during their assessment, i.e., traps should be checked daily, and assessed trapping systems (i.e., traps, triggers and sets) should be used in the field (ECGCGRF 1997).

In their critical review of the AIHTS, Proulx *et al.* (2020) stated that undue delays in the implementation of mammal trapping standards need to be eliminated, and standards must be enforced at all levels, e.g., trapping supply markets including e-commerce businesses, as well as traplines. They further recommended that trappers and researchers be trained in certified trapping methods by individuals who understand trapping standards and animal welfare.

The implementation of binding standards, no matter how inadequate they may be, should be a major step undertaken by signatory countries toward improving mammal trapping on their territory. If standards are not implemented properly, people will continue to use trapping devices that have been banned as per the signed agreement, and are known to cause pain and suffering, and long and distressful deaths in animals.

In this paper, we review the implementation of AIHTS trapping standards in Canada. We focus on the trapping supplies market by comparing a series of AIHTS-certified traps (FIC 2021) to trap models that can be purchased and used by trappers. We assess measures undertaken by government wildlife agencies to ascertain the use of certified traps in the field. Because the AIHTS refers to trapping systems, and therefore implies that traps and all their components must be used on traplines, we assess the components of rotating-jaw traps sold on the market. Finally, we review the contents of humane trapping courses relative to the use of certified traps and daily checks on traplines. Our objectives are to assess if 1) the AIHTS mammal trapping standards are effectively implemented across Canada, and 2) there are non-certified or banned traps that continue to be sold and used on the Canadian market.

Study area and Methods

Our investigation was conducted across Canada. We contacted all main provincial and territorial government offices, and trappers in western Canada, to discuss how the implementation of standards on traplines was carried out. The majority of government employees and trappers who agreed to talk with us requested that their name be withheld from publication. Our online search of Canadian trapper supply stores was also done at provincial and territorial levels.

Trapping supplies market

We reviewed traps being sold in Canada using a sample of 11 online trapping supply stores: 4 in Alberta, 1 in New Brunswick, 3 in Ontario, 1 in Quebec, and 2 in Saskatchewan (see links in Appendix I). We also reviewed large corporations such as Peavey Mart, Walmart and Cabela's. We compared the list of traps offered by these companies for sale within or shipment to Canada to that of traps certified by FIC (2021) for fisher (*Pekania pennanti*), American marten (*Martes americana*), weasels (*Mustela* spp.), northern raccoon (*Procyon lotor*), and muskrat (*Ondatra zibethicus*) (Appendix II). It is noteworthy to mention that the AIHTS encompasses a limited number of furbearer species (Proulx *et al.* 2020), and species that are important in the Canadian fur trade because of the number of pelts sold every year, e.g., the American mink (*Neovison vison*) and the red squirrel (*Tamiasciurus hudsonicus*) (Proulx 2000; Statistics Canada 2010), are not included in FIC's list of species for which traps have been certified. We also identified steel-jawed leghold traps that are sold unmodified (i.e., no offset, laminated, or rubber-padded jaws), which are banned in Canada as per the AIHTS ruling (Government of Canada 2020).

The AIHTS is a binding agreement between signatory countries (Proulx *et al.* 2020). The Agreement states that Parties should enforce legislation on humane trapping methods (Article 8), which include traps and their setting conditions (e.g., target species, positioning, lure, bait and natural environmental conditions; ECGCGRF 1997). Therefore, we compared the trigger systems of rotating-jaw traps sold for American marten, mink, Canada lynx (*Lynx canadensis*), and northern raccoon to those tested by a Canadian research team from 1985 to 1993 (Proulx 1999). On the basis of these studies, we determined if traps and trigger systems sold on the market could consistently strike target furbearers in vital regions (e.g., single strikes in the head-neck region, preferably above C3, or double-strikes in the head-neck and thorax regions; Proulx *et al.* 1989a; Proulx *et al.* 1990; Proulx 1991; Proulx *et al.* 1995), and ensure that the use of certified traps meets the AIHTS's implementation requirements.

Trapline inspections

We contacted the main offices of conservation officers of Provinces and Territories to determine how often conservation officers visited traplines to enforce AIHTS standards. Also, from 1997 to 2009, we personally visited 4 traplines in Saskatchewan, 2 in Alberta, and 1 in British Columbia that we encountered during mammal ecological studies. We checked traps and sets and recorded photographic evidence of trapping methods in violation with the AIHTS.

Humane trapping courses and online education material

Whereas FIC uses computer-based assessments to certify traps (Proulx *et al.* 2020), no data or results are disclosed regarding field assessments and findings relative to certified traps (D. Rodtka, trapper and retired Alberta predator control specialist, personal communication based on inquiries forwarded to FIC, 2019; Proulx *et al.* 2020; H. Barron, Wolf Awareness, based on Freedom of Information and Protection of Privacy Act applications, personal communication, 2021; Serfass 2022). However, a series of Best Trapping Practices was developed by the Quebec government and the Fédération des Trappeurs Gestionnaires du Québec, based on the results of trap testing by FIC (Fournier and Marquis 2014). As these Best Trapping Practices are being shared across Canada to further the education of professional trappers (e.g., Manitoba Agriculture and Resource Development 2020), we compared them to findings published in scientific journals since 1985 by researchers who were not involved in the AIHTS certification program (e.g., Proulx 1999; Proulx *et al.* 2012).

Results

Trapping supplies markets

Non-certified traps for on land trapping

We found that all online trapping supplies stores offered AIHTS-certified traps. However, we identified many non-certified trap models sold for the capture of American mink, fisher, American marten, weasels (*Mustela* spp.) and muskrat on land (Appendix I). All these correspond to small rotating-jaw traps, and based on Cook and Proulx's (1989) and Proulx's (1997) work, they likely have relatively low impact momentum and clamping forces, and therefore are unlikely to meet the requirements set out in the AIHTS for restraining and killing trapping methods.

Steel-jawed leghold traps

We identified a minimum of 10 uncertified steel-jawed leghold trap models in online supply stores that we reviewed (Figure 1). These trapping devices are of different sizes and can be used for the capture of most furbearers in Canada.

Snares

Manual and power killing snares are not certified trapping devices, and they are not considered in ISO (1999) and AIHTS (ECGCGRF 1997) standards. However, they are sold by all trapping supplies stores, on the basis that they are exempted from AIHTS standards (Section 4.2.3).

Duke Coil Spring

Duke Long Spring

Minnesota MB750 Coil Spring

Bridger ##1-1/2 Coilspring

Bridger #4 Long Spring

Sleepy Creek 1 1/2 Long Spring

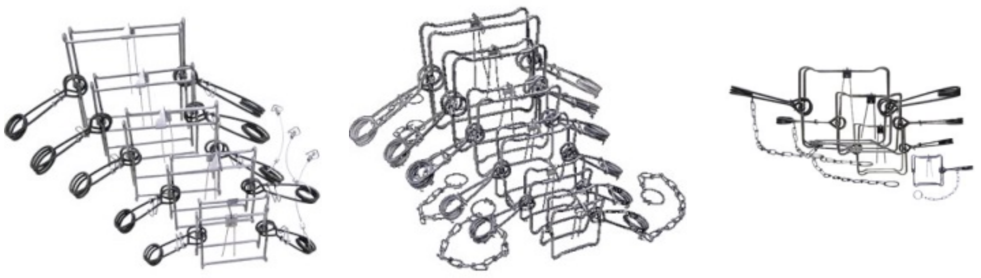
Figure 1. Examples of steel-jawed leghold traps sold in online trapping supplies stores.

Triggers

The great majority of rotating-jaw traps, certified or not, are sold with a 2-prong trigger (Figure 2). However, scientific studies have shown that 2-prong triggers did not allow for consistent strikes in vital regions for American marten, American mink, Canada lynx, and northern raccoon (Table 1). With the 2-prong trigger, animals try to bypass the prongs and they get captured in the corner of the trap where the striking and clamping forces are lower, and the animals stay alive for long periods of time (Suter 2013; Proulx, personal observations; Figure 3), or they go further into the trap opening and they get captured by the shoulders and lower abdomen (see video by Larkham 2012) or lower body (Figure 3). Animals may also use their paws to activate the trap and be captured by the neck and the legs (Proulx, G., personal observations), which interferes with the closing and clamping of the jaws, as has been video-recorded for northern raccoon (Wright 2011) and Canada lynx (Proulx 2012).

Based on approach tests where traps are wired in set position but can be fired without hurting the animals (Proulx 1999), a series of pitchfork triggers and a pan trigger have been successfully developed to consistently strike American marten (Proulx *et al.* 1989b), American mink (Proulx *et al.* 1990), Canada lynx (Proulx *et al.* 1995), and northern raccoon (Proulx 1991) in vital regions (Table 1; Figure 4).

Surprisingly, the pitchfork trigger developed for American marten is the only pitchfork available on the market, and it is sold with Sauvageau traps. However, variations of the pan trigger system developed for American mink are sold separately on the market.



Belisle Body Grip Traps Victor Conibear Traps Bridger Body Grip Traps

Figure 2. Examples of rotating-jaw traps with 2-prong triggers sold in online trapping supplies stores for the capture of American marten, American mink, Canada lynx, and northern raccoon.

Figure 3. Examples of American martens captured by the neck in the corner of the trap, or by the lower body, in Conibear traps equipped with 2-prong triggers (Photos: G. Proulx©).

Table 1. Scientific assessments of the ability of 2-prong triggers to properly position American martens, American mink, Canada lynx, and northern raccoons in rotating-jaw traps.

Species	**Assessments of 2-prong triggers**	**Assessments of alternative trigger systems**
American marten	Lunn (1973) considered the trigger of the Conibear 120 trap was unreliable and performed erratically. Barrett *et al.* (1989) reported a high proportion of undesirable strike locations.	A pitch-fork configuration with short centre prongs kept 30 mm apart provided consistent strikes in vital regions (Proulx *et al.* 1989b).
American mink	Cook *et al*. (1973) concluded that it was difficult to properly position mink in the Conibear 120 trap. Voigt (1974) found that mink could easily pass through the trap without touching the 2-prong trigger.	A pan trigger system that ensured that mink would be consistently struck in both head-neck and thorax regions (Proulx *et al.* 1990)
Canada lynx	The Conibear 330 was set with its 2-prong trigger in a baited cubby but it failed to position lynx for a proper strike in the head-neck region (Proulx *et al.* 1995).	A one-way 4-prong trigger (the center prongs are 75 mm apart; the outside prongs are kept equidistant from the center ones and the trap frame) consistently positioned lynx for a head-neck strike (Proulx *et al.* 1995).
Northern raccoon	Either the animals used their paws to fire the trap or they walked into the trap and their legs interfered with the closing of the jaws (Proulx 1991).	A one-way 4-prong trigger (the center prongs are 75 mm apart; the outside prongs are kept equidistant from the center ones and the trap frame) consistently positioned raccoons for a head-neck strike.

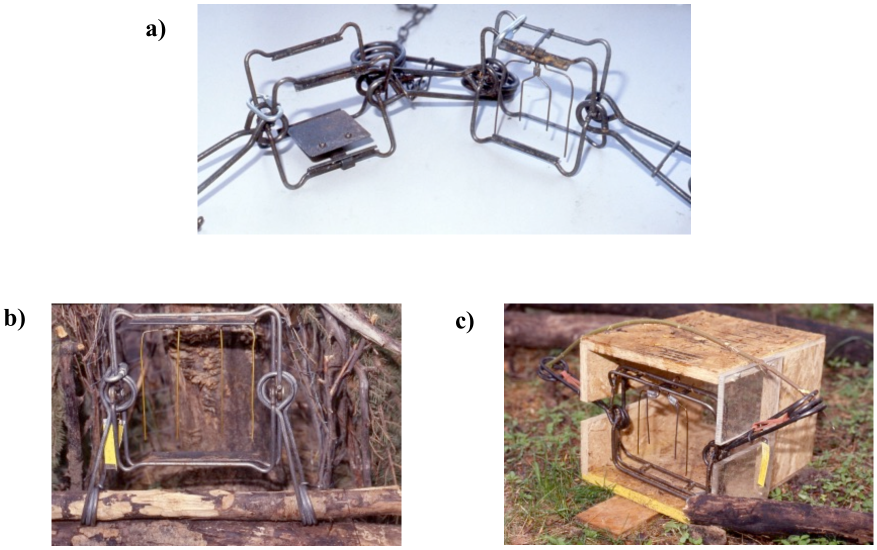


Figure 4. Trigger system alternatives to 2-prong triggers to ensure strike locations in vital regions: a) 4-prong pitchfork for American marten, and pan trigger for American mink; b) modified Conibear 330 with 4-prong pitchfork trigger for Canada lynx; and c) Sauvageau trap with 4-prong pitchfork trigger for northern raccoon (Photos: G. Proulx©).

Trapline inspections

Representatives of the Government of Alberta refused to discuss trapline inspections with us. Other jurisdictions suggested that Conservation Officers inspected traplines every now and then and verified the conformity of traps used. However, it is our experience that such inspections are relatively rare. A Conservation Officer from British Columbia indicated that, due to a lack of staff to enforce fishing, hunting and trapping regulations over a large territory, they do not conduct trapline inspections. A Conservation Officer from Saskatchewan indicated that they focus their inspections on human conflicts and campgrounds.

We found non-certified traps that were usually improperly set for an adequate capture of target furbearers on all traplines that we visited (Figures 3 and 5).

Humane trapping courses

Fournier and Canac-Marquis (2014) properly reported strike locations in vital regions and the pitchfork trigger for the capture of the American marten. However, all other triggers proposed for the capture of northern raccoons and Canada lynx in Conibear traps are 2-prong triggers that were found unreliable in the past (Table 1). Interestingly, although manual and killing neck snares are not included in the AIHTS, their use is included in Best Management Practices. However, past studies have repeatedly shown that these trapping devices were inhumane and unselective (Proulx *et al.* 2015; Proulx and Rodtka 2017; Proulx 2018). Humane trapping courses based on these Best Management Practices are incomplete, misleading, inadequate, and in violation of the AIHTS.

Discussion

Certified traps are accessible on the trapping supplies market. However, non-certified traps, including steel-jawed leghold traps, can be easily purchased and used in Canada. Our review of online stores is only a sample of the stores that are involved in the sale of improper trapping devices. In fact, non-certified and banned traps can easily be found in flea markets or website platforms that allow Canadians to sell or exchange goods such as Kijiji, Etsy, and others (Figure 6). Furthermore, Canadians have access to the

American market where all types of traps are sold online. Since traplines are virtually not inspected, we suspect many old devices and non-certified traps are being used by trappers.

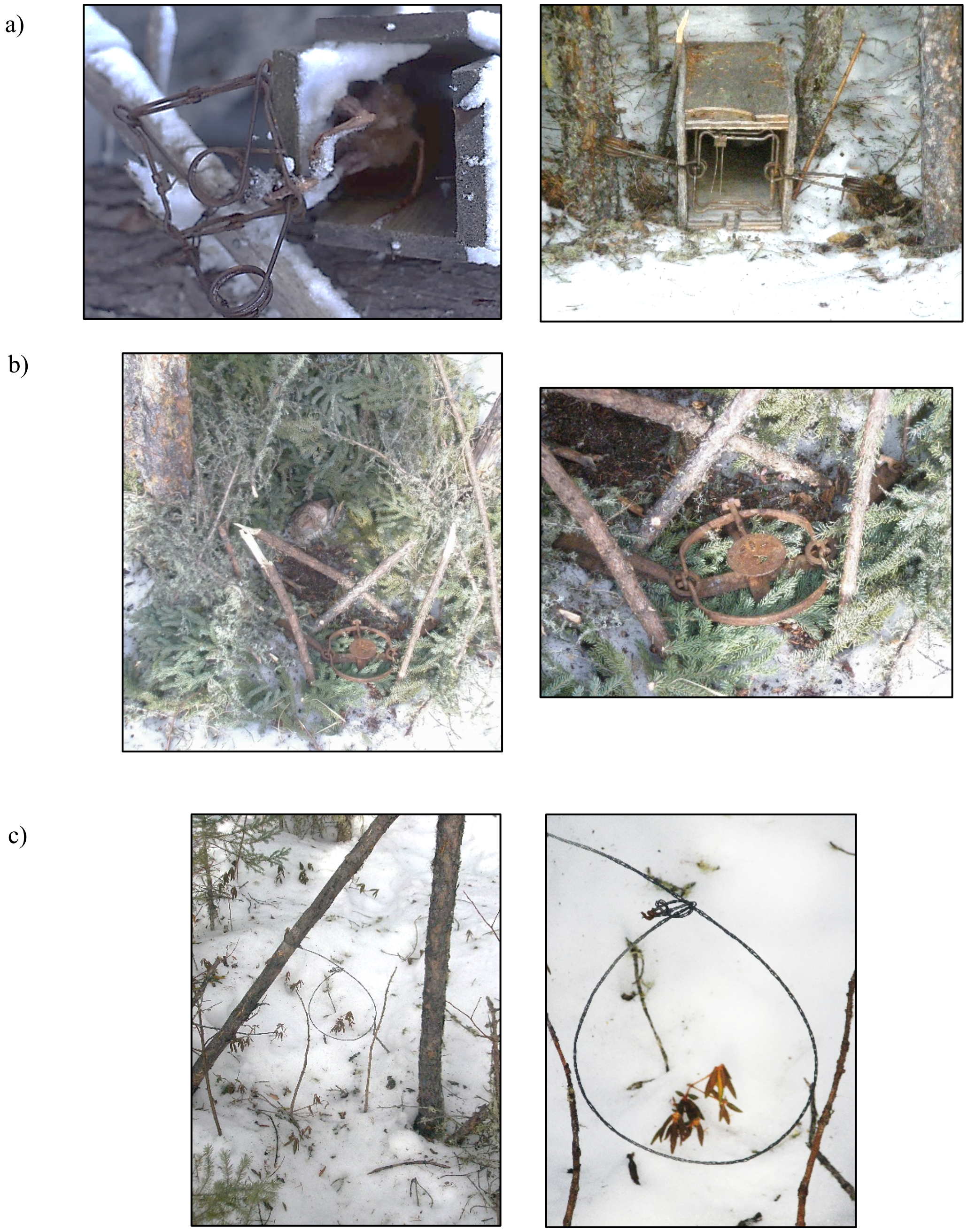


Figure 5. Non-certified traps and snares encountered on traplines that we visited in Saskatchewan, Alberta and British Columbia from 1997 to 2009: a) traps with 2-prong triggers set for American marten – on the left, the trapper did not remove the marten that was captured by the back foot; b) unselective steel-jawed leghold trap set; and c) manual killing neck set for canids – note the absence of a locking device on the snare noose (Photos: G. Proulx©).

One loophole in the AIHTS certification and implementation process is that any jaw type trap (body gripping or leghold) set as a submersion set that exerts clamping force on a muskrat and that maintains this animal underwater is considered acceptable (FIC 2021). This means that all traps, certified or not, banned or not, can be considered for trapping muskrats underwater. In practice, it is impossible to enforce the AIHTS at the market level.

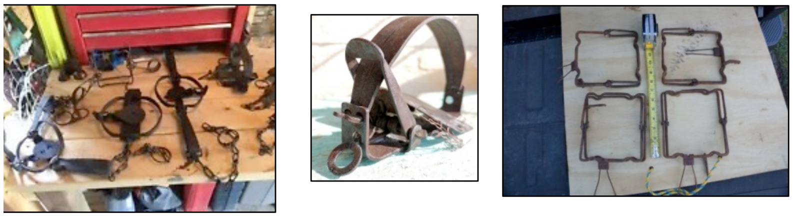


Figure 6. Examples of non-certified and banned traps sold in flea markets or public platforms on the internet.

Although killing neck snares are known to be inhumane, and as injurious as steel-jawed leghold traps (Proulx and Rodtka 2017), they can be used in Canada because they are exempt from the AIHTS by a "competent" authority, and they are considered homemade devices. However, according to Section 4.2.3, permission may be given on an interim basis only while research continues to identify replacement traps. To our knowledge, no such replacement traps have ever been developed since the enforcement of the standards. Trappers using snares have apparently benefited from an interim permission that already lasted more than a decade. When implementing trapping standards to improve animal welfare and selectivity, there should not be any exemption for devices that are inhumane and unselective, no matter how popular the devices are, even if they are homemade (Proulx *et al.* 2022). Section 4.2.3 of the AIHTS actually ensures that inhumane but popular trapping devices will continue to be used in Canada. A trap that has not met standards should not be allowed on traplines. Likewise, one should not be allowed to trap a species for which no humane trap has been certified. This is particularly true for American mink and red squirrel because hundreds of thousands of animals are trapped every year (Proulx 2000; Statistics Canada 2010).

Teaching the use of killing snares in trapper courses is basically attesting that AIHTS standards are just an artifice to allow trappers to continue to use antiquated technology, despite their inhumaneness and non-selectivity. Teaching people about the use of trigger systems that cannot properly and consistently position an animal for an effective strike in rotating-jaw traps is also puzzling. Again, this shows that there is no conviction in the implementation of trapping systems that are truly humane. Trapping standards cannot be effectively implemented unless high standards of education are in place.

Conclusion

Conformity in applying trapping standards cannot be taken for granted. Enforcement efforts are required to eliminate access to traps that have been banned or are not officially certified. There is a need to ensure that proper trapping devices are being used on traplines, and significant consequences must be put in place for those who sell or use traps that do not meet the standards. There should be no exemptions for trapping devices that are known to be inhumane and unselective, and fail to meet the standards (Proulx *et al.* 2022). Finally, trapping courses must represent the values and criteria held by the standards. Any exception to these enforcement efforts can only result in the use of unacceptable trapping devices at the expense of animal welfare, the proper management of natural resources, and Canada's economic reputation with the EU, a major pelt trading partner.

Acknowledgements

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Wright, B. J. 2011. Raccoon bucket set Conibear 220. Available at: https://www.youtube.com/watch?v=NhNh6Tz9G-o. Accessed January 2022.

Appendix I. Links of online trap supply companies consulted for this paper

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Alberta

https://www.halfordsmailorder.com/traps-and-accessories

https://trappergord.com/trappingsnaring.html

https://canadiancoyotecompany.com/collections/traps

https://www.goldengunsandtackle.com/trapping-supplies/

New Brunswick

https://www.longcreektrappingsupplies.com/

Ontario

https://furharvesters.com/trapscatalogue.html

https://thepalaceoutdoors.com/

http://sapsfur.com/TRAPS.html

Quebec

https://distributionpleinair.com/en/shop/traps/traps-and-snares

Saskatchewan

https://macdonaldsportinggoods.com/collections/trapping-supplies

https://www.dambeaver.ca/

http://www.findglocal.com/CA/Nipawin/791671794335505/KD-Ventures

Large corporations

https://www.peaveymart.com/search?query=leghold+traps

https://www.walmart.com/c/kp/animal-traps

https://www.cabelas.ca/category/trapping-supplies/1219

Appendix II. Fur Institute of Canada's (FIC; 2021) list of AIHTS-certified traps for a specific group of species, and list of uncertified killing traps and steel-jawed leghold traps sold on the Canadian market, October 2021. Note that the American mink (*Neovison vison*) and the red squirrel (*Tamiasciurus hudsonicus*) are not included in FIC's list. The listing of these FIC-certified traps is for descriptive purposes only and does not imply endorsement by the authors.

American mink	**Fisher**	**American marten**	**Weasels**	**Raccoon**	**Muskrat**	**Red squirrel**
FIC's Certified traps						
None	Belisle Super X 120/ X160/ X220 – Koro no. 2– LDL C160 Magnum/C220 Magnum – Ruby 120 Magnum/160Plus/220 Plus–Sauvageau 2001-5/2001-6/2001-7/2001-8	Belisle Super X 120/X160 –B.M.I. 126 Body Gripper Magnum – Koro nos. 1/no. 2– LDL B120 Magnum/ C160 Magnum – Northwoods 155 – Oneida Victor Conibear 120-3 Magnum Stainless Steel–Rudy 120 Magnum/160 Plus Sauvageau C120 Magnum–/2001-5/ 2001-6– KP120	Belisle Super X 110/X 120 – B.M.I. 60/120 Body Gripper – Bridger 120/120/155 Mag Body Gripper – Koro Muskrat Trap/Rodent trap/ Large Rodent Double Spring – KT-140 (Russia)–LDL B120 Magnum–Ouell 411-180/3-10/RM– Rudy 120 Magnum – Sauvageau C120 Magnum/ C120 Reverse Bend/ 2011-5 – Triple M – Victor Rat Trap – WCS Tube Trap Int'l/ Shorty Tube Trap– Woodstream Oneida Victor Con 110/120	Belisle Classique 220/Super X 160/ X 220/ X 280– B.M.I. Body Gripper160/220/280 – Bridger 160/220/280 Mag Body Gripper – Duke 160/ 220 – Koro no. 2– LDL C160/ C160 Magnum/ C220/ C220 Magnum/ C280 Magnum – Duke 220–Oneida Victor C-220 Stainless Steel – Northwoods 155– Rudy 160/160 Plus/220/220 Plus – Sauvageau 2001-6/2001-7/2001-8– Species-Specific 220 Dislocator Half Mag – Woodstream Oneida Victor Conibear 160/220	Belisle Super X110/X120 – B.M.I. Body Gripper 120/120 Magnum /126 Magnum– Bridger 120/120 Mag/155 Mag.–CONV 110 SS Can (Holland) –Duke 120–FMB 110 SS/150 SS –FS-110 SS – HZ-110 Stainless Steel – Koro Muskrat/ Large Rodent Double Spring –KT-140 – LDL B120/ B120 Magnum– Oneida Victor Stainless Steel 120/ 110-3 /110-3 Mag/ Oneida Victor 120-3 / 120-3 Mag – Ouell 411-180/RM – Rudy 100/120/120 Magnum– Sauvageau 2001-5/C120 Magnum/C120 Reverse Bend – Triple M – WCS Tube Trap Int'l/ Tube Trap Int'l/ Shorty Tube trap – Woodstream Oneida Victor Con110/120	None
Uncertified traps available on the Canadian market						
Victor 50 Conibear – Bridger # 110 Body Grip – Northwoods 155– Duke 0400 110 Body Grip	Northwoods # 155 Body Grip	Conibear 120	Victor 50 Conibear trap – Bridger # 110 Body Grip		Victor no. 50 Conibear trap – Bridger # 110 Body Grip	Bridger # 110 Body Grip

Species unspecified = Minnesota MB - 1216 - JC trap – Duke # 110 Body Grip

Steel-jawed leghold traps sold on the Canadian Market

Duke # 1 coil Spring/# 1 Long Spring – Minnesota MB 750 – Bridger # # 1. and # 4 Long Spring – Bridger nos. 1.75, 3 and 5 Regular Jaw Predator Trap – Sleepy Creek # 1-1/2 Long Spring – Minnesota Trapline Spring Trap

Chapter 9

Impact of Wild Mammal Trapping on Dogs and Cats: A Search into An Unmindful and Undisclosed World

Kimberly A. VILLENEUVE and Gilbert PROULX
Alpha Wildlife Research & Management Ltd., 229 Lilac Terrace, Sherwood Park, Alberta, T8H 1W3, Canada. Email: kimvilleneuve09@gmail.com

Abstract – Although it is claimed by many that dogs (*Canis familiaris*) and cats (*Felis sylvestris catus*) are constantly captured in traps set for furbearers, trappers and government agencies claim that there are few such incidents. In this paper, we aim to assess the frequency of pet captures in traps set for furbearers, and the reasons for such captures. We hypothesized that 1) a constant number of pets are captured in traps set for furbearers on an annual basis; 2) the capture of pets in furbearer traps commonly happens in urban and suburban areas; 3) most captures occur during the fur-trapping season; and 4) most captures are lethal due to the type of traps used by trappers. Despite a lack of cooperation from government and professional groups, we succeeded in gathering enough information to test our hypotheses. Our data showed that a minimum of 162 dogs and cats were captured in traps set for furbearers from 2010 to 2020. On average, the annual number of captures of pets in Canada was 14.7 (± Standard deviation: 6.2). In Manitoba, Alberta and British Columbia, provinces for which we had more data, the average capture of reported dogs and cats was 9.5. (± 4.4) /yr. The average number of captures/yr was significantly higher in 2016–2020 ($\bar{x}$= 12.2 ± 3.1) than in 2010–2015 ($\bar{x}$ = 7.3 ± 4.2) ($P<0.005$). We found that the majority of captures of pets occurred in urban settings and on multi-purpose trails. Most captures occurred in winter, in killing traps and neck snares. These findings supported our hypotheses. This study showed that the capture of pets in traps set for furbearers is generalized across the country and poorly monitored by unmindful government wildlife agencies which apparently prefer to keep pertinent datasets undisclosed. We recommend a series of actions to avoid capturing pets in urban, suburban and agricultural areas.

Introduction

According to The Fur-Bearers (2013), a Canadian advocacy group, dogs (*Canis familiaris*) and cats (*Felis sylvestris catus*) being captured in traps set for furbearers steadily increased over the years but because governments do not collect data on this aspect of trapping, the exact figures are unknown. In Ontario, a '*No traps on trails*' petition received over 40,000 signatures to protect pets from fur trapping (Porter 2015). Another one was initiated by a landowner in Manitoba to ban snares that killed her dog and other pets (Karina 2021). In the United States, Animal Welfare Institute (2016) claims that traps set for furbearers in populated areas capture, and kill or maim, dogs and cats.

On the other hand, according to the Alberta Trappers' Association, *"…there are very, very few incidents with dogs getting into traps and lethal snares…*" (CBC News 2019). Also, according to the Fur Institute of Canada (FIC; 2019), it is rare to capture pets in traps but it can happen. FIC argues that, in Canada, far more pets are hit by cars than caught in traps. Interestingly, while it is claimed that few pets are captured in traps set for furbearers, governments from across Canada have released information packages and warnings about the capture of pets in traps, (e.g., Nova Scotia Natural Resources 2007; Ontario Ministry of Natural Resources and Forestry 2021), thereby suggesting that accidental captures occur often enough to justify such publications.

When searching literature about the capture of dogs in traps set for furbearers, one can often read that "*If you allow your dog to run 'at large' in wildlife habitat at any time of year, you are breaking the law*" (e.g., Nova Scotia Natural Resources 2007). When pets are captured on traplines, it is portrayed as the fault of the owners (e.g., CBC News 2015). However, are all dogs and cats captured on remote traplines or in areas inhabited by people and their pets? Has the number of pets captured in traps set for wildlife decreased over the years? In which type of traps do dogs and cats get captured?

In this paper, we aim to assess the frequency of pet captures in traps set for furbearers, and the reasons for such captures. We hypothesized that 1) a constant number of pets are captured in traps set for furbearers on an annual basis; 2) the capture of pets in furbearer traps commonly happens in urban and suburban areas; 3) most captures occur during the fur-trapping season; and 4) most captures are lethal due to the type of traps used by trappers.

Methods

From April to August 2021, we contacted (emails followed by telephone calls) veterinarians (including an advertisement in the Canadian Veterinary Medical Association newsletter) and rescue groups from rural communities who may have dealt with pets captured in traps, and provincial and municipal offices − the number of contacts varied among jurisdictions depending on the responses and contacts received from central government agencies (Appendix 1). We spoke with designated government employees who deal with furbearer trapping inquiries, and we asked for records of statistics relative to the capture of pets in traps set for furbearers, copies of case files (police and conservation reports), and recommendations for contacts who could help us further our research. A few informants provided some information and most requested to remain anonymous.

We reviewed newspapers and television broadcaster companies from 2010 to 2021. We also communicated with various wildlife conservation and user groups (some of which included individual trappers and representatives of trapping organizations) and animal welfare organizations (Appendix I).

We reviewed all cases identified through our search and eliminated duplicates resulting from different contacts. For each capture of a pet, we recorded the type of trap, the time of year, and the location, i.e., trapline, town/city, agricultural region, or multi-use trails (used by people for hiking through various forested areas in urban, and sub-urban areas usually found in parks and natural areas). Using local maps, we approximated how far the captures of dogs and cats occurred from multi-use trails, ditches, roadways and dwellings. In some instances, we communicated with pet owners to complete our data. Because of the scarcity of data, we mainly used descriptive statistics to report our findings. Because most captures occurred in winter (see Results), data for 2021 were incomplete at time of writing and we did not include this year in our data analysis. We used a Student t-test (Dixon and Massey 1969) to compare the number of captures/year for some provinces. Probability values $P< 0.05$ were considered statistically significant.

Results

Sources of information

Government offices

In general, provincial government offices were not helpful. In Alberta, government employees refused to talk with us, although a few conservation officers indicated that they did not record captures of pets and we should look elsewhere.

In Saskatchewan, a representative of the Ministry of Environment indicated that he was unable to provide statistics on captured pets because they do not keep records. He suggested that there would be captures of dogs and cats in southern Saskatchewan where 71,000 coyotes (*Canis latrans*) were killed in 2009−2010 through a bounty program (see Proulx and Rodtka 2015), and since the end of this program, the province introduced a "pelt incentive" program for licensed trappers.

In Québec, Ontario, and the Maritimes, we were told that there is little or no monitoring of captures of pets. The Ontario Ministry of Natural Resources and Forestry Enforcement Branch sent an email indicating that the number of captures of pets was low, and captured animals were running at large. The Ministers of Environment offices of Yukon and Northwest Territories responded that non-target captures were not an issue since trapping is a remote activity done outside the city limits.

Only Manitoba provided data on captures of pets collected since 2010. The data did not identify the trap types and the locations of the captures, although most of them are likely from urban and suburban areas (communication with Manitoba Environment). British Columbia did not share any data with us. However, they referred us to The Fur-Bearers who collected extensive datasets on captured dogs and cats in the province through FOIPPA (Freedom of Information and Protection of Privacy Act) applications.

Veterinarians and Rescue Groups

With a few exceptions, veterinarians refused to provide information because of confidentiality concerns. Rescue groups provided a few cases of dogs which had been saved from trapping incidents and eventually adopted. However, in most cases, respondents indicated that rescue groups were primarily charitable organizations with little to no funding and they had no intention of "rocking the boat" on this subject.

Captures of pets, 2010 −2020

A minimum of 162 dogs and cats were captured in traps set for furbearers from 2010 to 2020. On average, the annual number of captures of pets in Canada was 14.7 (± Standard deviation: 6.2). The number of captures per province fluctuated considerably from year to year (Figures 1 and 2). In many provinces, no captures were reported in most years. Also, the average was influenced by the more complete datasets gathered in western Canada.

In Alberta, we contacted more resource people and reviewed more newspapers than in any other jurisdiction. On average, from 2010 to 2020, a minimum of 1.5 (±1.9) pets/yr were captured (Figure 1). The government-generated numbers in Manitoba ($\overline{x}$ = 4 ± 3.4 captures/yr), and the detailed information provided to us by The Fur-Bearers for British Columbia ($\overline{x}$ = 4.1 ± 2.4 captures/yr), were the most complete datasets. When pooling together the data gathered for these 3 provinces, an average of at least 9.5. (± 4.4) pets/yr were captured in 2010–2020. The average number of captures/yr was significantly higher in 2016–2020 ($\overline{x}$ = 12.2 ± 3.1) than in 2010–2015 ($\overline{x}$ = 7.3 ± 4.2) (t=3.6, P<0.005). In all other jurisdictions, average number of captures was 1.4 (± 1.4) captures/yr (Figure 2).

Locations of captures

We identified the capture locations for 122 cases. There were few captures of pets on traplines (10%). The majority (50%) of captures occurred in urban settings and on multi-purpose trails (Figure 3). We were able to determine distances of captures from locations in 67 cases. Nearly 45% of them were within 200 m of private property and/or multi-use trails. Interestingly, 16% of captures occurred ≤50m of rural roads (Figure 4).

Captures by season

We determined the period of the year when pets were captured for 115 cases. A total of 70 (60.9%) captures occurred in winter (Figure 5).

Trap types

We identified trap types for 122 captures. Killing traps were involved in 93 (76%) of 122 captures (Figure 6). The majority of captures (47%) occurred in killing neck snares (Figure 6).

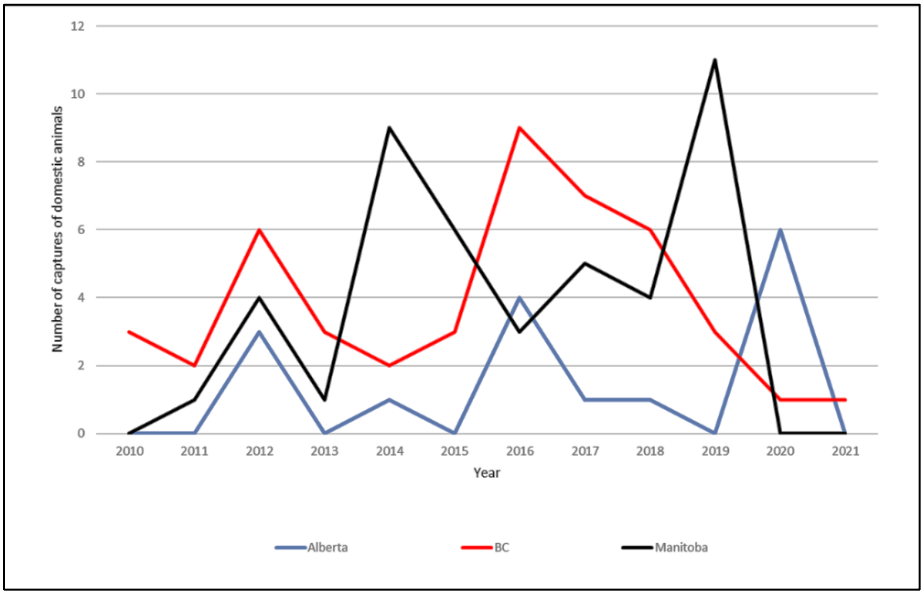

Figure 1. Yearly captures of dogs and cats in traps set for furbearers in Alberta, British Columbia and Manitoba, 2010–2021.

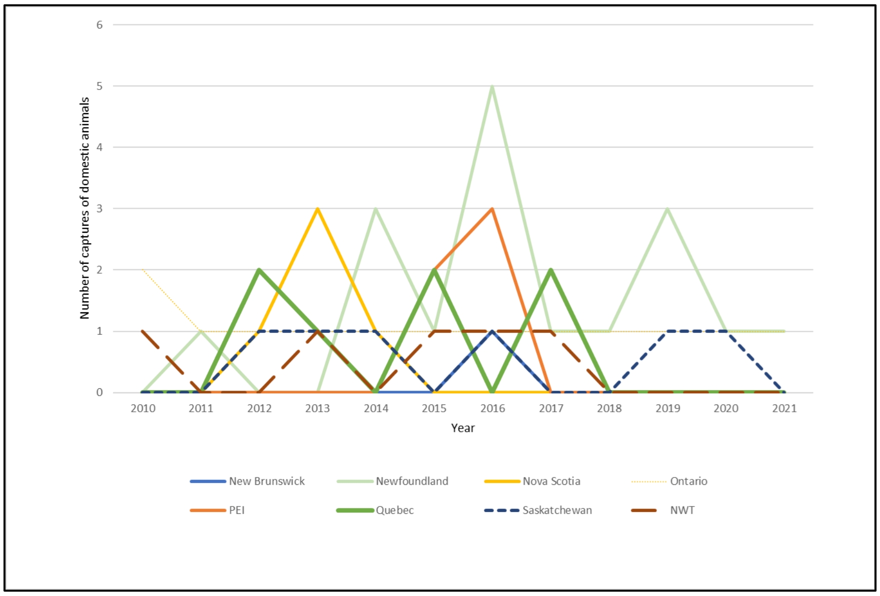

Figure 2. Yearly captures of dogs and cats in traps set for furbearers in New Brunswick, Newfoundland, Nova Scotia, Prince Edward Island, Québec, Saskatchewan, and Northwest Territories, 2010 –2021.

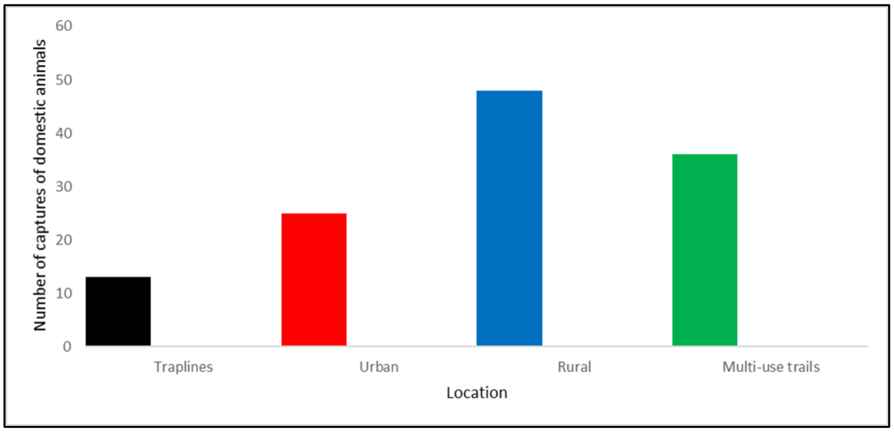

Figure 3. Locations of 122 captures of dogs and cats in Canada, 2010 –2020.

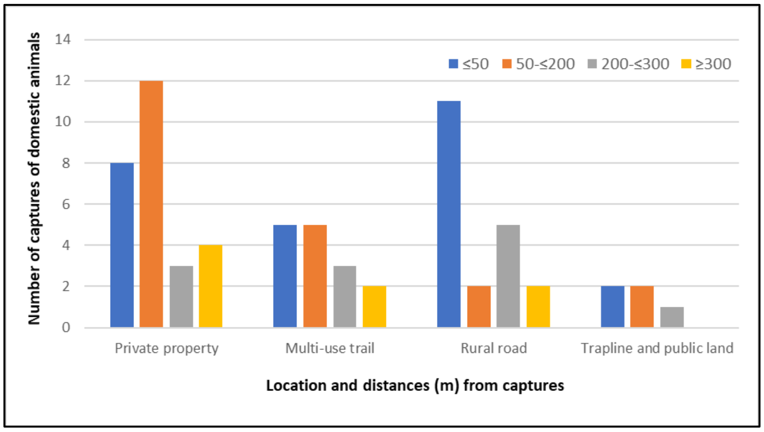

Figure 4. Distances of captures (*n*=67) of dogs and cats from locations recorded in 2010–2020 in Canada.

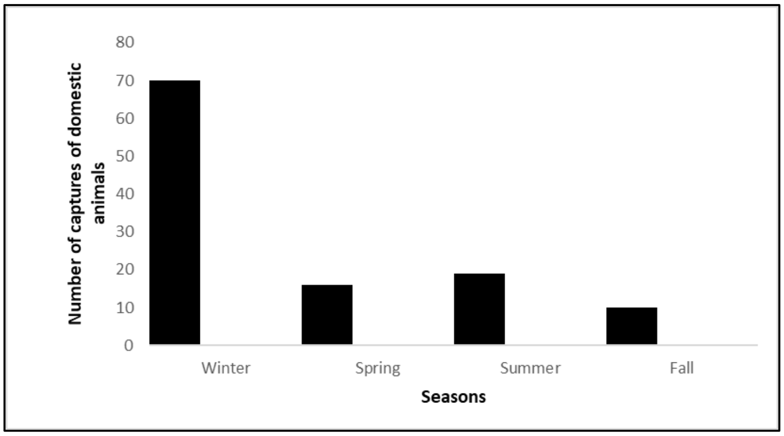

Figure 5. Number of captures (*n*=115) of dogs and cats per season in Canada, 2010–2020.

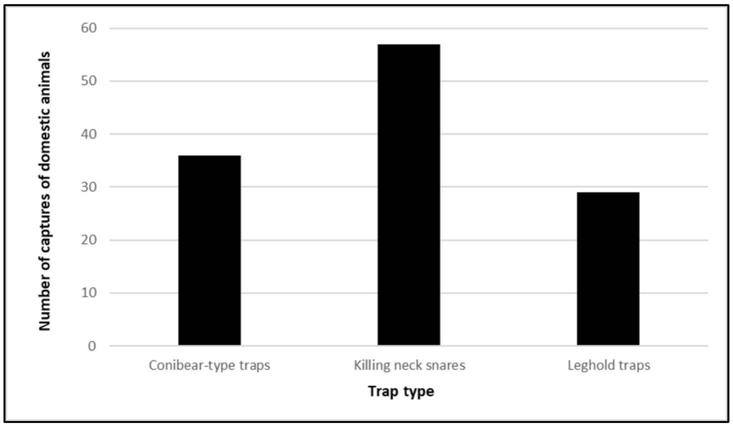

Figure 6. Number of captures (*n*=122) of dogs and cats per trap type, Canada, 2010 −2020.

Discussion

This study made us realize that the capture of dogs and cats in traps set for furbearers is a taboo subject for the majority of provincial and territorial government agencies across Canada, which do not want to discuss the subject at all and do not want to disclose any information. This was particularly obvious in Alberta where, during a 4-d span, we were redirected from office to office, and our inquiry was repeatedly received with disapproving remarks, distrust and contempt. The indifference of government agencies toward the capture of pets is not surprising. Indeed, the federal and provincial government agencies do not implement the Agreement on International Humane Trapping Standards (AIHTS) in trap supply markets and on traplines (Feldstein and Proulx 2022).

More disconcerting is the mutism of some veterinarians who should be concerned with the welfare of pets, and prevent and relieve animal suffering as per the Canadian Veterinary Oath (Canadian Veterinary Medical Association 2021). Concerns expressed by many of them regarding the confidentiality of their treated animals is inappropriate. Veterinarians should be able to disclose the number of dogs and cats they treated due to injuries inflicted by traps without releasing ownership and residency. Obviously, much more work is required to incite animal welfare specialists to get involved in the implementation of practices that would protect wild and domestic animals from undue suffering (Proulx 2021).

Animal rescue groups were very reluctant to discuss any information about pets injured by traps. This is in large part because they believe that their charitable organization status may be revoked if providing information to us was perceived by Canada Revenue Agency as an activity aimed at attempting to influence public opinion, legislation or government policy in relation to trapping and the protection of pets (see Bridge 2002). The first author of this paper adopted a dog from a rescue group in Alberta, which, however, refused to provide data on dogs who had been saved from trapping incidents. The rescue organization indicated that it had no intention of “rocking the boat” and risk losing their charitable status. Rules impacting the activities of charitable organizations across the country have changed (Government of Canada 2020). However, there is still confusion regarding what activities might or might not be permitted. We believe that it is unlikely that a charitable organization would be aware of these changes, would want to risk doing something that could be judged to be against the government policy, or would want to be the first to test the new rules. However, despite all the lack of cooperation from governments and professional groups, we succeeded in gathering enough information to test our hypotheses.

Hypothesis 1 − A constant number of pets are captured in traps set for furbearers on an annual basis

Although our datasets were incomplete due to a lack of participation from provincial and territorial wildlife agencies, they suffice to demonstrate that the claims made by governments and trapping organizations about the lack of captures of pets are false. The average capture of pets/yr in Manitoba, Alberta and British Columbia in 2010 −2020 was 9.5. (± 4.4), and it was slightly higher in 2016 −2020 than in 2010−2015.

This average was slightly greater than 8 animals/yr in British Columbia reported by Rankin (2016). However, this is a minimum estimate. Although trappers are asked to report any non-target furbearer capture to government offices, they are not required to report the capture of dogs and cats. Dogs and cats killed in traps may never be recovered and if they are, owners may not be notified and losses may not be reported to media. In agricultural areas, trappers may not report the capture of a neighbour's dog to avoid being admonished by the owner or banned from trapping in the area (Animal Welfare Institute 2016). Our study showed that the capture of pets in traps set for furbearers is a constant occurrence year after year. However, the exact annual number of captures remains unknown, and this data is not being collected by government agencies responsible for trapping regulations.

Hypothesis 2 − The capture of pets in furbearer traps commonly happens in urban and suburban areas

Our study showed that the majority of captures of pets occur in urban and suburban settings and on multi-purpose trails. Contrary to claims made by wildlife agencies and trappers that many of these animals were running at large in the wilderness, they were captured near people's dwellings and recreational areas (e.g., Rankin 2016; Figure 7). A dog may easily be attracted outside a backyard when baited traps are set in proximity, e.g., within a few hundred metres of a property (e.g., Snowdon 2015; Figure 8). Studies have shown that coyotes travelled from as far as 10−15 km to access carrion (Danner and Smith 1980; Kamler *et al.* 2004). The sense of smell in dogs is keen enough to detect a bait set in the neighborhood of their property. Dogs that are captured in traps set for furbearers are not roaming at large when they are lured into baited traps set near their property. While trapping regulations of most jurisdictions indicate that trappers can set traps on private land if they receive permission from the owner, in agricultural regions, dogs from adjacent properties will travel to baited areas and get captured.

The capture of pets on multi-purpose trails is worrisome. These trails have been developed to incite people to stay fit and to discover natural environments (e.g., Hike Ontario 2021). Even when owners keep their pet on a leash, there are many situations where a dog can escape the owner's attention and stray away. A baited trap or snare set near a trail would certainly attract and capture the dog, as has been reported in many cases in the past.

Figure 7. Almoe, a Rottweiler-Lab cross died within minutes of being caught in a wire snare trap baited with meat, just 3 m off the road that leads to his owner's property (Photo: Randy McNolty) (Rankin 2016).

Figure 8. Marley, a Great Pyrenees-Lab cross, was caught in a baited snare a few hundred metres from her own property in Parkland County, Alberta. Two more neighbourhood dogs were found ensnared and injured at the same small stand of trees where the remains of a moose (*Alces americanus*) and deer (*Odocoileus* spp.) were used as bait (Snowdon 2016).

Hypothesis 3 −Most captures occur during the fur-trapping season

Fur-trapping across the country usually lasts from October to May, but most of it occurs between November and March when furbearers reach the peak of primeness (Stains 1979). Trappers are then more active during this time, thus explaining why a greater number of pets are captured during winter.

Hypothesis 4 − Most captures are lethal due to the type of traps used by trappers

We found that pets were captured mostly in killing traps and neck snares. This means that they are killed or, if they survive the capture, they suffer from major injuries (Figure 9). Among killing devices, killing neck snares were dominant, even though they are known to be highly unselective and inhumane (Proulx *et al.* 2015). Trappers like to use killing neck snares because they are inexpensive, lightweight, easy to set and camouflage, and effective at capturing a diversity of furbearers (Proulx 2018). Not surprisingly, they are abundant near rural and urban property lines where they can be camouflaged at the base of fences, in ditches, and in culverts. Although leghold traps can cause serious injuries to captured mammals, particularly if they are not frequently visited by trappers (Proulx and Rodtka 2019), dogs captured in such traps may be released and will survive if their injuries are properly taken care of.

Figure 9. Yukon, a Husky owned by K. Villeneuve, has a shorter front right leg because, as a puppy, he was captured in a Conibear trap. He cannot properly bend his leg that was broken in 2 locations (Photos: K. Villeneuve$^{©}$).

Management considerations

This study supported all our hypotheses. It showed that the capture of dogs and cats in traps set for furbearers is generalized across the country, and is poorly monitored by unmindful government wildlife agencies which apparently prefer to keep pertinent datasets undisclosed.

The frequency of capture of pets in urban and suburban areas, along multi-use trails, and in agricultural areas will decrease only if the traps are set away from areas used by the public, which needs to know where it is safe for their recreational activities and their pets. We therefore recommend the following:

1. Traps should be kept away from public areas, i.e., urban and suburban areas, multi-use trails, and all roads and paths used by people and their pets. Knowing that dogs have an acute sense of smell and may be attracted to baits, a 1-km buffer zone should be established between urban and sub-urban dwellings and trapping sites. No fur trapping should occur within this buffer zone, and if some animals must be removed for a specific reason, trappers/pest controllers should seek a special permit from local authorities.
2. If traps must be set near areas used by the public, highly visible signs alerting the public that traps and baits will be placed in the area should be posted 7 d in advance of the commencement of trapping activities (Stevens and Proulx 2022). For accountability and transparency purposes, signs should provide the name and telephone number of the trapper, and the name and telephone number of the landowner who provided the permission to trap.
3. Trappers are required to obtain permission from landowners to trap on private land. In agricultural areas or in counties where neighbours live within 2 km from each other, permission should be obtained from the landowners and their adjacent neighbours, and all of them should be provided with a map showing the location and the types of traps used.
4. Only restraining traps known to be humane, i.e., that can capture and hold animals with little or no injury (Proulx *et al.* 2022), should be set. Traps should be monitored frequently by trappers, at least within ≤12-h visits to release pets and non-target animals (Proulx and Rodtka 2019). In suburban areas, if traps cannot be checked easily, trappers should equip them with a motion-sensitive radio alarm that notifies them when the trap has been activated and has possibly captured an animal (Powell and Proulx 2003). Importantly, the use of radio-alarms is not a substitute for an appropriate schedule of trap visits.
5. Government agencies must be informed of any trapping activity being conducted near urban and suburban areas, and they must verify the types of traps and the measures taken by trappers to avoid the capture of pets.
6. Trappers should report all non-target captures, not only furbearers, to government agencies.
7. Government agencies should keep records of all non-target captures by location and time of year. Such records should be posted on the internet and made available to the public.
8. Trappers who capture pets and are in fault should be prosecuted by the authorities, and they should be held responsible for injuring or killing pets.
9. There is a pressing need to educate wildlife agencies and professionals, rescue groups, and veterinarians about mammal trapping methods and standards.
10. An education program should be developed by local authorities or citizen groups, and promoted among communities, to inform the public about trapping methods and rules (Stevens and Proulx 2022).

All these recommendations may be judged excessive by trappers and government agencies. However, dead pets reflect poorly on trappers and governments who allow trapping to occur in urban and sub-urban areas. The injuries and the loss of dogs and cats to fur trapping is costly to owners from an emotional and financial point of view, and it should be prevented regardless of the financial cost or the effort needed. If authorities cannot guarantee that companion animals are safe near urban and suburban areas, they should not allow fur trapping.

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Appendix I. List of organizations and media contacted for this project.

Canadian Province/Territory	**Number of Independent Contacts**				
	Veterinarians	**Animal Rescue Groups**	**Provincial Government Offices**	**Municipal Government Offices**	**Newspapers**
Alberta	9	29	4	17	46
British Columbia	9	26	4	11	35
Manitoba	5	17	2	8	16
New Brunswick	2	3	1	-	8
Newfoundland & Labrador		3	1		5
Northwest Territories	2	3	1	-	6
Nova Scotia	2	3	1	-	6
Ontario	5	24	2	-	30
Prince Edward Island	2	4	1	-	3
Québec	4	7	2	-	15
Saskatchewan	9	16	1	9	15
Yukon	3	5	1	-	5

Other Organizations

Alberta Conservation Association, Alberta Institute for Wildlife Conservation, Animal Alliance of Canada, Animal Defence League of Canada, Canadian Association for Humane Trapping, CBC News (website), Coyote Watch Canada, CTV News (website), The Fur-Bearers, Humane Canada (Canadian Federation of Humane Societies), National Wildlife Rehabilitation Foundation, Northern Lights Wolf Sanctuary, Parks Canada, Toronto Animal Rights Society, Wildlife Conservation Society of Canada.

Chapter 10

Empowering The Public to Be Critical Consumers of Mammal Trapping (Mis)Information: The Case of the Northern Raccoon Captured in A Conibear 220 Trap in A Kansas Suburb

Elizabeth STEVENS[1] and Gilbert PROULX[2]

[1]Department of Learning Sciences, Georgia State University, Atlanta, Georgia, USA. Email: estevens11@gsu.edu

[2]Alpha Wildlife Research & Management Ltd., 229 Lilac Terrace, Sherwood Park, Alberta, T8H 1W3, Canada.

Abstract − In this paper, we: 1) review the case of a northern raccoon (*Procyon lotor*) that suffered for approximately 4 h in a Conibear 220 killing trap set in a suburban area; 2) show how the citizens involved took action to learn about mammal trapping methods, critically evaluate opposing arguments provided, and ultimately bring about change at the municipal level; and 3) propose recommendations for members of the public concerned about animal trapping in their municipalities, means to educate the public about animal welfare and mammal trapping, and ways to avoid the recurrence of events reported in this paper. Our paper stresses the importance of making decisions based on critical evidence and scientific findings; and it warns people against false claims that can be made by pest control companies and state furbearer biologists. As a result of proactive and persistent communication of scientific evidence to decision makers after this incident, the City Council issued a new ordinance specifying the Conibear 220 may be used to capture raccoons *only* as a last resort and with a special permit. This paper highlights the need to educate the public and elected officials on the basics of trapping nuisance animals in residential areas. We propose a series of actions citizens may take if they encounter an animal suffering and an infographic to educate citizens on mammal trapping in urban and suburban areas.

Introduction

Many trappers and pest/predator controllers have long protected and perpetuated traditional methods of trapping, using inhumane mammal trapping devices that result in animal suffering (Proulx 2022). The continued use of trapping devices that cause pain and suffering has led to polarizing debates among trappers, the public, and animal welfare organizations (Proulx 2022). Furthermore, mammal trapping standards are not representative of state-of-the-art trapping technology and do not properly address the welfare of trapped animals (Proulx *et al.* 2020). Concerns about inhumane mammal trapping have led many people to adopt anti-trapping attitudes, and request changes in wildlife management programs and the control of wild animals (Nichol 2011; Anonymous 2018; Proulx 2022).

Claims about the humaneness of trapping devices often lack supporting scientific evidence. This was the case in the 1980s when trappers, some biologists, and wildlife agencies insisted on defending the use of the "steel-jawed" leghold trap despite evidence that captured animals had serious injuries including broken bones, lacerations, and amputations (Proulx and Barrett 1989). Proponents of these traps claimed banning steel-jawed leghold traps would result in potential increases in costs of animal damage control programs and losses to livestock and timber industries; actual and potential loss of information useful for managing wildlife species; and loss of a limited number of jobs and income generated by the fur-trapping industry (deCalesta 1980). The fact is that none of this happened (Proulx 2022). Nevertheless, debates about the use of some traps and the welfare of animals continue (Proulx 2018), and the public, lacking general awareness about trapping and humane killing methods, has difficulty discriminating evidence-based statements from pretense in declarations made by the fur industry, pest control companies, and animal welfare and anti-trapping organizations.

Amidst the perpetual controversy surrounding mammal trapping, critical thinking can be used to analyse and evaluate arguments (Barry 1992), and differentiate between a factual statement (which can be demonstrated or verified empirically) and an opinion (belief or attitude that is not supported by scientific evidence) (Proulx 2004). The public needs to discern mammal trapping facts from stories, unsubstantiated claims, and false inferences. Educating the public and politicians/decision makers on humane mammal trapping, based on scientific evidence – not opinion or anecdote – is an important step in empowering urban and suburban citizens to be critical consumers of mammal trapping information and methods proposed by pest control companies. Critical thinking is a stepwise process consisting of elements very similar to those of the scientific method. The scientific method is based on facts; critical thinking is based on evidence (Proulx 2004). Some of the skills of critical thinking include: 1) identifying the argument's main idea; 2) evaluating sources of information; 3) evaluating the evidence; and 4) evaluating the claim (Proulx 2004).

In 2020, a Kansas suburban family witnessed the inhumane capture of a northern raccoon (*Procyon lotor*) in a killing trap. Their experience and the subsequent events (detailed below) highlight the need to increase public awareness and education on mammal trapping methods. Ensuring the humane trapping of nuisance animals in residential neighborhoods depends on decision makers' and the public's skills in evaluating information, such as recommended trapping methods from pest control companies. We define "humaneness" as not causing undue pain and suffering. We recognize the "humaneness" of a trap is relative and is based on comparisons with other traps. Also, there is always room for improvement. In scientific assessments, the humaneness of killing traps is assessed according to the time period to irreversible loss of consciousness in struck animals (Proulx *et al.* 2020). Previous scientific assessments considered that traps used for the capture of raccoons should render animals irreversibly unconscious within 180 s (Proulx *et al.* 2012). Other less stringent standards, such as those of the Agreement on International Humane Trapping Standards (AIHTS), extended the period to irreversible loss of consciousness to 300 s (see review by Proulx *et al.* 2020).

In this paper, we: 1) review the case of a northern raccoon captured in a Conibear 220 killing trap set in a suburban area; 2) show how the citizens involved took action to learn about mammal trapping methods, critically evaluate opposing arguments, and ultimately bring about change at the municipal level; and 3) propose means to educate the public about animal welfare and mammal trapping and avoid the recurrence of events such as those reported here. In the following, the identity of the family who observed the capture of the raccoon, and the pest control company and owner, are not being disclosed for confidentiality reasons.

Case study: the Conibear-captured raccoon

On July 5, 2020, at 05:00 h, a Kansas suburban family awoke to the vocalizations of a northern raccoon captured in a Conibear 220 trap. The trap struck the animal just in front of the eyes. A female raccoon had established her den in the attic of the neighbouring house to raise 2 kits. A pest control company set a Conibear 220 trap over a hole in the soffit that was used by the raccoon family to come in and out of the attic (Figure 1). The raccoon continued to vocalize loudly for 1 h and struggled to escape until 08:30 h, when an employee of the company finally arrived to remove the animal from the side of the house. The employee placed the raccoon in the back of his truck without euthanizing it and left the house at 08:44 h. The animal suffered nearly 4 h before being removed from the side of the home; it is unknown if, or how, the raccoon was euthanized.

Figure 1. Photographs of the raccoon captured on the side of a house July 5, 2020 in a Kansas suburb area: a) at capture time; b) nearly 4 h later when the pest control company employee came to remove the raccoon.

On July 8, 2020, the family made a formal complaint to City Council, requesting 1) the neighbour immediately repairs any and all entry points into the walls and roof of the home to proof it against invading wild animals; and 2) the City ban the use of Conibear traps on the grounds that they are inhumane, result in the unnecessary painful and excruciating death of animals, and pose a threat to human and domestic animals. Furthermore, they identified alternative, humane ways to trap and remove the animals. The complaint included video and photographic evidence of the trapping incident.

The complaint resulted in 4 subsequent meetings with the City Council subcommittee (i.e., a committee that reviews all relevant information and makes a recommendation to the full council). The 1st meeting consisted of reviewing the complaint. The 2nd and 3rd meetings focused on documents presented by the pest control company, the furbearer biologist for the state Department of Wildlife, Parks and Tourism, and evidence submitted by the complainants that included a summary of raccoon trap research & development (i.e., the work carried out by the second author GP). The following sections relate to the 2nd and 3rd meetings, where claims were made about the humaneness of the Conibear 220 trap to capture raccoons.

The premise of the complaint

The family's request that the neighbor repairs the wall and roof of the house was not an issue since the City already had an ordinance requiring citizens to maintain their houses "rodent-free". All correspondences between City Council, the complainants, the pest control company, and the state Department of Wildlife, Parks and Tourism related to the second aspect of the complaint: the request to ban the use of Conibear traps.

The complainants argued that the Conibear 220 trap should be banned in the suburban area because it is inhumane and could harm humans, domestic pets, and wild animals other than raccoons. The main premise of the complaint related to the "humaneness" of the trapping device.

Response of the pest control company and the state government agency to the complaint

In response to the complaint, the pest control company and the state Department of Wildlife, Parks and Tourism submitted letters justifying the use of the Conibear 220 trap to capture raccoons in a suburban area. Over half of the statements were irrelevant to the main argument relative to the humaneness of the Conibear 220 trap. The proponents failed to provide any evidence that the use of the Conibear 220 trap was humane, either in general or in this particular removal instance. Their response noted that raccoon-human conflicts were frequent and animals had to be removed. However, independent of the frequency of raccoon-human conflicts and the extent of the damages, one cannot justify using an inhumane trap. When removing an animal, it should be done as humanely as possible (Proulx and Barrett 1989).

Response of the complainants to the statements made by the pest control company and state government agency

The complainants sought scientific evidence to show that the claims made by the pest control agency and the state government agency were misleading, without scientific evidence to back them up. The complainants also identified alternative humane ways to remove nuisance animals in residential areas.

Animal-based scientific assessments have shown that the Conibear 220 trap had neither the power nor the potential to humanely kill raccoons, i.e., to render the great majority of the animals irreversibly unconscious in ≤ 3 min (Proulx and Drescher 1994), or even ≤ 5 min (Proulx *et al.* 2020). Contrary to the claims made by the pest control company, raccoons captured in Conibear 220 traps do not expire in less than 2 min.

Interestingly, the pest controllers and the state furbearer biologist had a poor understanding of alternative live-traps (e.g., the EGG trap that can be set in confined areas and will capture raccoons by a forepaw without serious injuries) (Proulx *et al.* 1993). When the EGG trap was tested in the City of Vancouver, British Columbia. (Proulx 1991), all captured raccoons were humanely captured without serious injuries, and properly euthanized in situ or painlessly transferred to cage traps for release or euthanasia.

A new ordinance

Members of the City's subcommittee reviewed and subsequently debated all information submitted by the complainants and the pest control company. The subcommittee acknowledged the potential damage posed by raccoons but also expressed concerns with animal welfare, particularly after reviewing the video of the captured raccoon and the scientific evidence presented by the complainants (i.e., that box and EGG traps are more humane than the Conibear 220 trap).

Following these deliberations, the City Council issued a new ordinance specifying the Conibear 220 may be used to capture raccoons *only* as a last resort and with a special permit; to acquire said permit, the pest controller must demonstrate they have exhausted other more humane methods (i.e., that alternative live-traps have failed to capture the animals). The proposed disposition of the trapped animals must be specified, including the method of euthanasia, when applying for the special permit. The trapper must have a valid Nuisance Wildlife Control Permit. Traps must be installed at a minimum height of 2.4 m; if set on the ground, special precautions must be taken to protect the public and non-target animals. A notice of trapping activity must be posted 7 d in advance of the commencement of the operation and shall contain the name and telephone number of the trapper, and the name of the company if applicable. All traps shall be clearly marked with the owner's name, address and telephone number or the trap shall be confiscated by the Animal Control Officer and destroyed if not claimed within 12 h.

How can the public initiate changes to city bylaws related to mammal trapping?

We believe the complainants were successful in changing the local ordinance due to:

- the documentation of the event (video and photographic evidence of the animal suffering);
- the scientific evidence – acquired via contact with the second author – presented to the subcommittee on the ineffectiveness of the Conibear trap, and alternative, more humane methods of trapping; and
- consistent and persistent communication with authorities.

Their experience demonstrates citizens can enact change at the local level to improve the humane trapping of nuisance animals in residential areas. Citizens encountering situations such as this should not remain passive vis-à-vis animal suffering (Figure 2). If one observes an animal suffering, immediately contact the Animal Control Office of the municipality and report the observation. Next, file a complaint with the responsible authorities (municipal or state governments, Parks administrations, etc.), and include the following information:

- Date and time of occurrence.
- Photos and/or videos of the animal in the trap.
- Identification of the species and the trap.
- Notes on the animal behaviour, apparent injuries, vocalizations, and duration of the observations. Whenever possible, stay at the location to determine how long it takes for the authorities to intervene. Do not approach or touch the animal or the trap.
- Seek out scientific information on the trap, which may be gathered using Google Scholar. Create a file of what is known about the utilization of this type of trap, with copies of scientific papers which assessed the humaneness, selectivity and acceptability of this trap in urban areas. If possible, contact the researchers directly to know more about the attributes of the trap. Also, seek information on the trapping regulations in the area, and the legality of the trap used.
- Send a summary of the information to local media and consider meeting reporters. Consider writing a “letter to the editor” in local newspapers.
- If needed, start a petition and seek the support of a local elected officer.
- Attend local government meetings to request changes to current bylaws.
- Don’t give up! Persevere even if the process may take several months.

Discussion

Every year, raccoons are found suffering in traps set in urban settings, and inhumane captures may be reported in local newspapers (Froese 2016; Yuen 2017; Campbell 2018; Proctor 2018; Morton 2019 a,b; Claxton 2020, and many more). Leghold and Conibear traps are often used in urban and suburban areas. In agricultural areas, near city limits, killing neck snares also cause pain and suffering to domestic and wild animals (Villeneuve and Proulx 2022).

The case of the raccoon captured in a Conibear 220 trap in a Kansas suburban area demonstrates it is possible to bring about change in mammal trapping laws. This occurred, in no small part, due to the complainant’s efforts to learn more about trapping methods in order to educate the committee and advocate for humane trapping. This highlights the need to educate the public and elected officials on the basics of trapping nuisance animals in residential areas. When individuals are better informed, they can better evaluate information presented by pest controllers and advocate for humane trapping methods. When other citizens became aware of the complainants’ effort to ban the Conibear 220 trap, they initiated a petition to support the complaint. People were not against the trapping of raccoons and the protection of their property from wild animals; they were against animal cruelty. We developed an infographic (Figure 2) for distribution to the public; we hope the information presented in the figure will inform urban and suburban citizens on human trapping methods and encourage them to be proactive in advocating for the human capture and removal of nuisance animals.

WHAT SHOULD YOU KNOW ABOUT TRAPPING ANIMALS IN A HOME OR BUILDING?

Trapping and removing nuisance animals can be done humanely

A True Story

In 2020, **a mother raccoon** started to raise her babies in the **attic of a suburban home** in a midwestern city. The homeowner contacted a **pest control company** to remove the racoons.

The pest control company **set a Conibear 220 trap** at the raccoons entrance to the attic. This trap is supposed to kill the animal instantly when it snaps the animal's neck. **Tragically, the trap failed, and the animal suffered for over 4 hours**.

A family living next door witnessed the event and took action to change the city's trapping regulations to **promote humane and safe removal of nuisance animals.**

What can you do?

1. Know possible trapping methods
- **Box & cage trap**
- **EGG trap**
- **Conibear / rotating jaw trap**
- **Leghold trap**

2. Know your city's trapping laws

3. Ask the pest control company:
- What are all the **possible trapping methods** for this animal?
- What are the **advantages/disadvantages** of each method?
- What is the **most humane method**?

4. Take action!
- **Contact** local experts to get more information (spca.org, animal control officers, biology department of local college/university).
- **Meet with city officials** and **advocate** for the use of humane trapping methods in your community.

What is a humane trapping method?

A tool for capturing and removing a nuisance animal (e.g. raccoons, opossums, squirrels) from homes, buildings, or property **with the least amount of pain and suffering.** Humane trapping doesn't ensure the animal lives, but that it is removed with the least amount of pain and suffering.

BOX OR CAGE TRAP

Definition: A wooden or metal cage that closes when the animal enters.

Humane trapping method? YES

EGG TRAP

Definition: An encapsulated leghold trap, restraining the animal without harming or self-mutilation.

Humane trapping method? YES

LEGHOLD TRAP

Definition: Metal jaws that clamp the animal's paw or leg upon contact.

Humane trapping method? NO

CONIBEAR 220 OR ROTATING JAW TRAP

Definition: Two metal frames that snap closed on any part of the animal - also called body grip trap.

Humane trapping method? - NO

Remember: Trapping and removing nuisance animals can be done humanely

Figure 2. Infographic that can be distributed to citizens and elected officials inhabiting urban and suburban areas.

This case also demonstrates that pest controllers and state furbearer biologists may be poorly informed about the true performance of the Conibear 220 trap. Although the Fur Institute of Canada (2021) claims that the Conibear 220 can humanely kill 80% of raccoons, Proulx *et al.* (2020) showed that the trap humanely killed only 50% of the animals. Based on tests carried out with rotating-jaw traps much more powerful than the Conibear 220, Proulx and Drescher (1994) concluded that the Conibear 220 did not have the potential to consistently and humanely kill raccoons. Using a one-tailed test of the normal approximation to the binomial distribution, their findings suggest that the trap could render only 42% of the raccoons irreversibly unconscious within 300 s. Therefore, the Conibear 220 does not have the power to humanely kill 80% of raccoons. This finding has been published and repeated several times in the past (Proulx and Drescher 1994; Powell and Proulx 2003; Proulx *et al.* 2020) but, surprisingly, the pest controller and fur biologist were not aware of the poor performance level of this trap which has been included in Best Management Practices in the USA (AFWA 2019).

The case presented by the complainants was long and challenging but resulted in positive actions to improve the welfare of locally trapped animals. Informed citizens can and should take action to improve the humane, proper management of urban wildlife.

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Chapter 11

Trapping Success of Black-backed Jackals (*Canis mesomelas*) in South Africa Relative to Land Use Type

Alexander E. BOTHA[1,2], Marine DROUILLY [3,4], Katja KOEPPEL[5,6], and Aliza LE ROUX [1,2]

[1]Department of Zoology and Entomology, University of the Free State, Qwaqwa campus, Kestell Road, Phuthaditjhaba, 9866, Free State, South Africa. Email: alexbotha555@gmail.com
[2]Afromontane Research Unit, University of the Free State, Qwaqwa campus, Kestell Road, Phuthaditjhaba, 9866, Free State, South Africa.
[3]Institute for Communities and Wildlife in Africa (iCWild), University of Cape Town, Cape Town, Private Bag X3, Rondebosch, 7701, South Africa.
[4]Panthera, New York, USA.
[5]Department of Production Animal Studies, Faculty of Veterinary Science, University of Pretoria, Onderstepoort, South Africa.
[6]Centre for Veterinary Wildlife Studies, Faculty of Veterinary Sciences, University of Pretoria, Onderstepoort, South Africa

Abstract − Mesopredators are often adaptable species presenting flexible behavioural traits allowing them to live alongside humans. Among them, members of the Canid family are renowned for their ability to persist in human-dominated landscapes, despite persistent lethal control measures. In South Africa, black-backed jackals (*Canis mesomelas*) are the main predators of goats (*Capra hircus*) and sheep (*Ovis aries*), and conflict with farmers is rife and widespread. We live-trapped jackals between 2014 and 2019 in 4 regions of South Africa to investigate whether jackals respond differently to the presence of non-lethal traps between land use types (farmlands vs. protected areas) and review the spectrum of environmental factors that can contribute to variation in the capture of mesopredators. We conducted 639 nights of trapping that resulted in 30 successful jackal captures. We showed that capture rates of jackals were impacted by land use type with significantly more captures in protected areas (14.55 jackals/100 nights) of adult jackals mostly. Farmlands were characterized by less captures (1.27 jackals/100 nights) of mostly young individuals. Our results suggest elevated wariness by jackals as a behavioural adaptation, particularly by older residents, against the long-term lethal control practices on farmlands. Our findings could inform wildlife researchers and managers by highlighting the importance of land use type on the capture success of jackals and probably other medium-sized canids. In particular, the potential impacts of continued lethal control on the behaviour of jackals need to be acknowledged and managed to avoid selecting for compensatory life history traits that may intensify conflicts with small-livestock farmers.

Introduction

Mesopredators (also referred to as mesocarnivores) play an important role in the functioning of ecosystems, acting as a link between upper and lower trophic levels (Ritchie and Johnson 2009). Despite their ecological importance, their broad diets coupled with the expansion of human activities often leads to negative interactions with people (Murray *et al.* 2015). Lethal and non-lethal captures of mesopredators are considered methods to mitigate negative interactions and serve as important tools for wildlife management (Andelt *et al.* 1985; Boggess *et al.* 1990) and research (Powell and Proulx 2003). Trapping as a lethal control tool (trapped animals are then killed) is implemented to limit the abundance of damage-causing animals and to reduce their negative impacts on human activities (McManus *et al.* 2014). In comparison, non-lethal trapping provides unique opportunities for researchers and conservationists to gather biological information on the species, from tissue samples to spatial and behavioural data when the species is equipped with a GPS or VHF device (Mathews *et al.* 2013). In addition, the marking of captured individuals that are not individually identifiable, using ear tags for example, can be used to estimate population size for monitoring population trends and for conducting management actions (Tapply 2018). Regardless of lethality, capture rates partly rely on the technical expertise and personal experience of the trapper (Ruette *et al.* 2003; Mierzejewska *et al.* 2020). Capture rates are also influenced by several other factors (Pawlina and Proulx 1999) including trap location (Saunders *et al.* 1993), habitat type (Ruette *et al.* 2003), trap setup and micro-placement (Naylor and Novak 1994; Kay *et al.* 2000), trapping method (Pawlina and Proulx 1999; Tuyttens *et al.* 1999), weather and season (Way 2012; Martin *et al.* 2017; Mierzejewska *et al.* 2020), substrate (Linhart *et al.* 1986), the use of visual, auditory, and olfactory attractants/baits (Fleming *et al.* 1998), and characteristics of the species and the individual that is being trapped. For example, in wild canids, social structure can have a large impact on capture rates due to behavioural variation across individuals (e.g., Brand *et al.* 1995; Sacks *et al.* 1999; Harris and Knowlton 2001), which can result in sexually and ontogenetically biased trapping figures (Kay *et al.* 2000) and influence the overall success of wildlife management actions or scientific research.

Capture rates can also be influenced by land use type. In farmlands, mesopredators can be extremely wary of any human activity and will explore smaller areas (smaller home ranges) to avoid lethal control (Coman *et al.* 1991 on red foxes *Vulpes vulpes*; Grinder and Kraussman 2001 on coyotes *Canis latrans*). Exposure to lethal and non-lethal traps over extended periods can alter canid behaviour through individual learning, social influence, and social learning (Brand 1993; Brand *et al.* 1995), and eventually result in difficulty in observing and capturing canids. An increase in avoidance (also referred to as trap shyness) has been documented for both lethal and non-lethal control devices for different canid species (Brand and Nel 1997). The behavioural flexibility and cognitive abilities of canids suggest that responses to traps would differ between land use types due to differences in their exposure to human lethal control and infrastructure (Barrett *et al.* 2019).

In South Africa, black-backed jackals (*Canis mesomelas*) are reported to be responsible for an annual loss of over one billion ZAR (approximately USD 61 million) to the livestock industry (van Niekerk 2010), and a recent economics study in the Central Karoo showed that predation rate on small-livestock is estimated to be around 5% of total livestock per year (Nattrass *et al.* 2017). Various control methods have been implemented throughout the country but are proven to be ineffective at halting livestock losses in the long term (Minnie *et al.* 2016). This inability to control jackals has often been attributed to a poor understanding of the species (Du Plessis *et al.* 2015; Minnie *et al.* 2018). However, recent research (Nattrass *et al.* 2020a) has discussed the behavioural plasticity of jackals and the variations in the political and socio-economic contexts of South Africa as reasons for this inability to control the species and reduce livestock losses.

As part of 3 different research projects on the spatial ecology of jackals, we live-trapped jackals between 2014 and 2019 in 4 different regions of South Africa to equip them with GPS radio-collars. We explored jackals' response to non-lethal traps between 2 different land- use types while providing insights into the broad spectrum of biotic and abiotic factors that could influence the trapping success of canids. Our hypotheses were that land use type would affect the trapping success of jackals and influence the age- ratio of captures between areas. We predicted that trapping success would be higher in protected areas than in farmlands where lethal control measures are commonly used (Avenant and Du Plessis 2008), and that capture rates would be higher for 1) older individuals in protected areas due to their reduced wariness in protected areas where interactions with humans are seldom and non-lethal in nature; 2) younger individuals in farmlands due to increased wariness of older individuals occupying farmlands where lethal control is a common practice and the rapid turnover, immigration and exploration of larger areas by younger individuals from bordering protected areas (Minnie *et al.* 2018).

Study Areas

Jackals were captured between January 2014 and March 2019 during 639 trapping nights, using Oneida Victor Soft-Catch® traps (padded foothold traps) and cage/box traps (38 x 38 x 107 cm) in 4 separate regions within South Africa (Figure 1): Golden Gate Highland National Park (GGHNP; 22 trapping sites), Anysberg Nature Reserve (10 trapping sites), the Cradle of Humankind (28 trapping sites), and the Central Karoo farmland (46 trapping sites) (Figure 1). The first 3 protected areas do not lethally control jackals, although they do border on farmlands where lethal control takes place. The Central Karoo farmlands are characterized by regular lethal control measures throughout the year, occurring on a daily basis at the regional scale, using mainly night calling and shooting, trapping, and poisoning (Drouilly 2019). The trapping sites at each study region were defined as areas greater than 100 m apart where a single or multiple traps of the same type (cage vs. padded foothold) were set to trap jackals (Ruette *et al.* 2003). In the reserve, we used padded foothold traps ($\bar{x}$ = 7.96 ± SD 3.29 traps per site; 60 sites,165 trapping nights in total), and on the farmlands either padded-foothold traps ($\bar{x}$ = 2.86 ± 0.96 traps per site; 43 sites; 430 trapping nights in total) or cage traps ($\bar{x}$ = 3 ± 1 traps per site; 3 sites, 44 trapping nights in total) (Table 1). Although the number of traps used at the reserve sites were more than on the farmlands, each trap in the reserve was only active on average for 0.65 ± 1.14 nights while on the farmlands each trap was active for 4.30 ± 2.85 nights (Table 1). At each site, bait was interspersed around the site (when bait was used) to attract jackals and promote movement around the site. At sites within GGHNP, we additionally placed multiple pieces of bait in a hole towards the centre of the trapping site to increase activity around the trapping site. Each site location was chosen for their high jackal activity (i.e., presence of numerous tracks, scats, scent markings) and their accessibility (close to roads for the veterinarians' access). Furthermore, site locations within protected areas were chosen to ensure that they were not near borders and covered a large area to increase our likelihood of trapping different individuals. At each site, traps were carefully placed, covered with vegetation and sediment found within the area. We also took extra precautions in limiting human scent on traps, and to restore the area to its original state once the traps had been set. All staff in the field were trained in humane trapping of animals, and we set up capture sites following the advice of experienced canid trappers/researchers who are familiar with the challenges associated with capturing jackals. We opened and monitored traps from dusk until dawn and used different baits and scent lures due to varying conditions (i.e., proclivity for certain baits in an area, terrain, exposure to humans and availability of bait) in each region (Table 2).

Table 1: Information on the types of traps, their number and trapping success at each of the study area.

Area (land use type)	Number of trapping sites	Trap type used	Average traps per trapping site (mean ± SD)	Number of traps in total	# of jackals trapped	Total nights of trapping	Average # of nights each trap was active (mean ± SD)
GGHNP (reserve)	22	padded foothold	8.1 ± 2.89	194	11	62	0.35 ± 0.26
COHK (reserve)	28	padded foothold	9.7 ± 1.18	254	9	39	0.14 ± 0.06
Anysberg (reserve)	10	padded foothold	2.4 ± 0.52	24	4	64	2.72 ± 1.63
Karoo (farmland)	43	padded foothold	2.64 ± 0.86	103	3	430	4.25 ± 2.96
Karoo (farmland)	3	cage	3 ± 1	9	3	44	4.92 ± 0.14

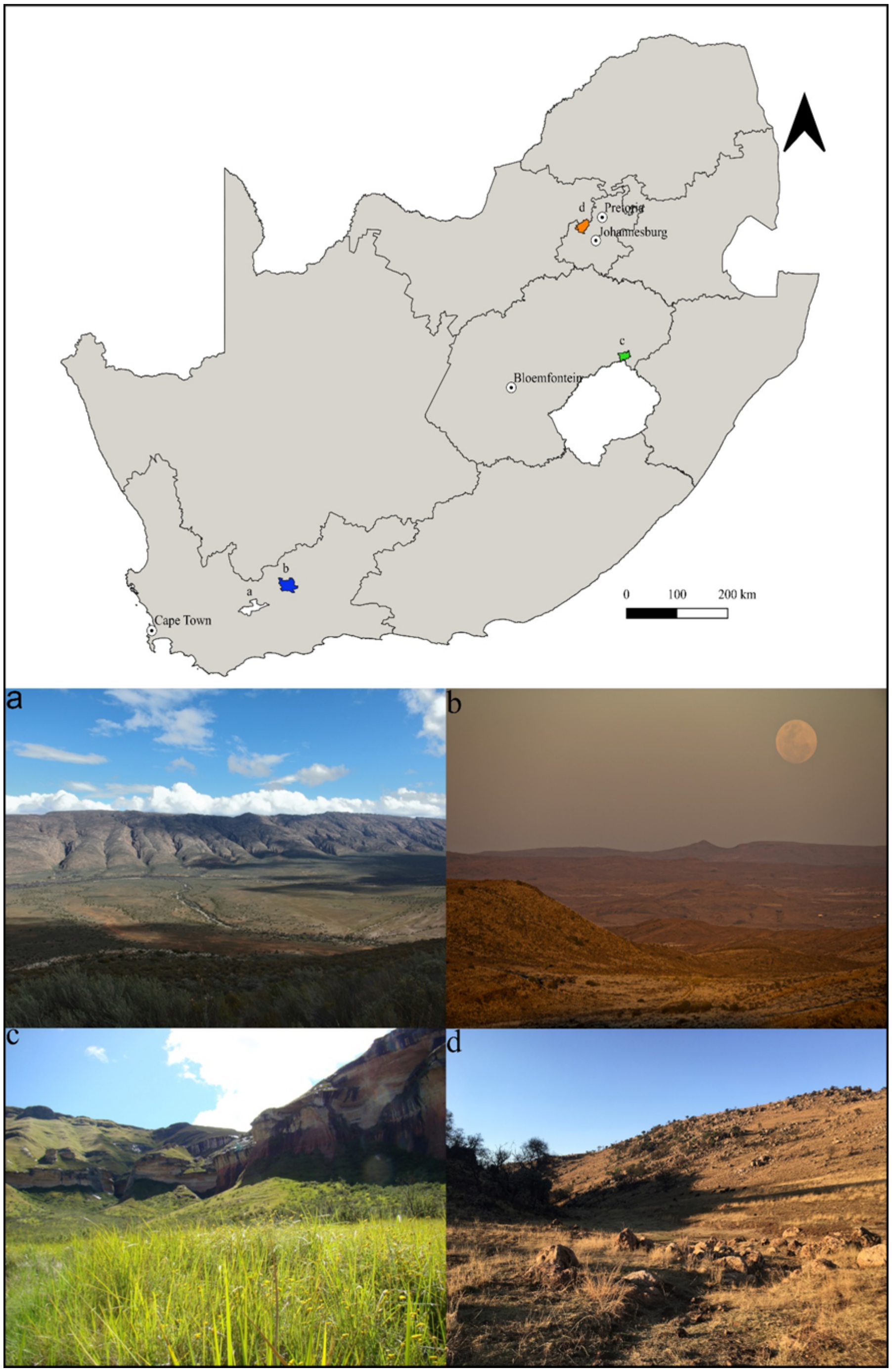

Figure 1: Map and photographs of the typical landscapes of the 4 study regions where we conducted our research within South Africa: a): Anysberg Nature Reserve (white polygon on the map) – Houdin & Palanque©(Karoo Predator Project); b) Karoo farmland (blue polygon on the map) – M. Drouilly©(Karoo Predator Project); c) Golden Gate Highlands National Park (green polygon on the map) – A. le Roux©; and d) Cradle of Humankind (orange polygon on the map) – K. Koeppel©.

Table 2: The trapping and biological information pertaining to each individual jackal captured in this study.

Area	Land use type	Date of capture	Bait	Sex	Age	Trap type	# of traps at trapping site
GGHNP	protected area	2018/01/18	chicken pieces and SeaGro™	M	sub-adult	foothold	4
GGHNP	protected area	2018//01/19	chicken pieces and SeaGro™	F	sub-adult	foothold	4
GGHNP	protected area	2018/07/03	chicken pieces and SeaGro™	F	sub-adult	foothold	10
GGHNP	protected area	2018/07/03	chicken pieces and SeaGro™	M	adult	foothold	10
GGHNP	protected area	2018/10/29	chicken pieces and SeaGro™	F	adult	foothold	13
GGHNP	protected area	2018/10/29	chicken pieces and SeaGro™	M	sub-adult	foothold	7
GGHNP	protected area	2018/10/29	chicken pieces and SeaGro™	F	juvenile	foothold	13
GGHNP	protected area	2018/10/29	chicken pieces and SeaGro™	F	adult	foothold	13
GGHNP	protected area	2020/01/10	whole chicken and chicken heads	F	juvenile	foothold	10
GGHNP	protected area	2020/01/10	whole chicken and chicken heads	F	juvenile	foothold	10
GGHNP	protected area	2020/01/12	whole chicken and chicken heads	F	juvenile	foothold	10
Karoo	farmland	2014/02/04	old sheep blood	F	sub-adult	cage	3
Karoo	farmland	2014/05/08	none	M	sub-adult	cage	2
Karoo	farmland	2014/10/16	none	M	sub-adult	foothold	2
Karoo	farmland	2014/10/17	none	M	sub-adult	foothold	4
Karoo	farmland	2014/11/22	none	F	adult	cage	4
Karoo	farmland	2014/11/30	scented lure	M	sub-adult	foothold	2
Karoo	protected area	2015/04/20	barbecued meat	F	adult	foothold	2
Karoo	protected area	2015/04/21	scented lure	M	adult	foothold	3
Karoo	protected area	2015/04/30	scented lure	M	adult	foothold	3
Karoo	protected area	2015/05/25	horse carcass (natural)	F	adult	foothold	2
COHK	protected area	2018/09/11	whole chicken and chicken heads	F	sub-adult	foothold	10
COHK	protected area	2018/09/11	whole chicken and chicken heads	F	adult	foothold	10
COHK	protected area	2018/09/12	whole chicken and chicken heads	F	adult	foothold	10
COHK	protected area	2018/10/03	whole chicken and chicken heads	F	adult	foothold	10
COHK	protected area	2019/07/07	whole chicken and chicken heads	M	adult	foothold	10
COHK	protected area	2019/08/04	whole chicken and chicken heads	F	adult	foothold	10
COHK	protected area	2019/08/05	whole chicken and chicken heads	F	adult	foothold	10
COHK	protected area	2019/08/05	whole chicken and chicken heads	F	adult	foothold	10
COHK	protected area	2019/09/09	whole chicken and chicken heads	M	sub-adult	foothold	4

Materials and Methods

Each trapping night (i.e., a night when at least 1 of the traps was open and functional) at a particular site was considered an individual observation making up our sample size for the analysis of capture rates (n = 639 individual trapping nights). Capture rate (also referred to as trapping success or capture success in the literature) was defined as the likelihood of capturing jackals at a specific site within a specified land use type and summarized as the number of individual jackals caught/100 trap nights. When a jackal was captured, we recorded its sex and approximate age, following Lombaard (1971). Individuals were considered juveniles if their approximate age was estimated to be between 6 and 10 mos; sub-adults, above 10 mos and up to 18 mos; and full-grown adults, ≥18 mos.

We calculated and reported individual capture rates to summarize our data for different land use types. Using R (R Core Team 2020, v 4.0.5 for Windows), we ran generalized linear models (glm) using the "stats" package to assess the relationship between trapping success and land use type. We used a binomial error distribution with a logit link (successful capture at the site (1) or not (0)) that was suitable for our data with 0 or 1 capture/night at each site and no repeat captures of the same individual. We fitted the model with the binary output as the dependent variable and land use type (protected area vs. farmland) as the predictor variable. We checked model fit by conducting a likelihood ratio test to compare the null and fitted models as inspection of residuals and correlation are not permitted for binary data (Dunn and Smyth 2018). We expressed our results as estimates, degrees of freedom and 2.5% to 97.5% confidence intervals (CI) calculated using the R package "confint", which indicated statistical significance if there was no overlap with zero.

Results

We trapped a total of 30 jackals over 639 trap nights in our 4 study areas (Table 1 and 2). We successfully trapped juveniles (4 females), sub-adults (7 males, 4 females) and full-grown adults (4 males, 11 females). Despite the greater duration of each trap being active on farmland trapping sites (4.30 ± 2.85 nights per trap), we caught less jackals compared to reserves trapping sites (0.65 ± 1.14 nights per trap). Using Oneida Victor Soft-Catch® traps, we captured 3 jackals on farmland over 430 trapping nights (0.7 jackals/100 nights) and 24 jackals in protected areas over 165 trapping nights (14.6 jackals/100 nights). Using cage/box traps, we captured 3 jackals over 44 trapping nights on farmland (6.8 jackals/100 nights). In the protected areas, we caught more adults compared to other age groups, and on the farmlands, our captures were mainly comprised of younger sub-adults (Table 3). Our model indicated that land use type influenced trapping success with a statistically relevant difference between the null and fitted models (χ^2= 40.87, $P < 0.0001$). Our model indicated an increased trapping success in protected areas compared to farmlands (estimate = 2.59, df = 2, CI: 1.73–3.60).

Table 3: Capture rates for the 3 different age groups of jackals in relation to land use type in this study.

Age group	**Land use type**	**Number of jackals trapped**	**Capture rate (number of jackals/100 nights)**
Juvenile	protected area	4	2.42
Sub-adult	protected area	6	3.63
Adult	protected area	14	8.48
Juvenile	farmland	0	0
Sub-adult	farmland	5	1.05
Adult	farmland	1	0.21

Discussion

Our results confirmed our hypothesis and indicated a lower capture rate on farmlands than in protected areas. That might be due to the lethal control of livestock predators on farmlands which can limit their abundance. Although not accounting for detection probabilities, Drouilly and O'Riain (2019) found a higher relative abundance of jackals in Anysberg Nature Reserve than on farmlands (the same farmlands in this study). Furthermore, the human pressure associated with prolonged and sometimes disorganized lethal control on farmlands has in many cases amplified the wariness of canids (Ginsberg and Macdonald 1990; Brand *et al.* 1995; Brand and Nel 1997), which can lead to the avoidance of human objects, including traps. Alphas/older canids are known to display increased awareness and wariness within their territories compared to younger individuals (Sequin *et al.* 2003; Avenant and Du Plessis 2008), which is further intensified when human pressure is high (Brand and Nel 1997; Kaunda 2001). Younger transients on the other hand, are more likely to wander over larger areas (Gese *et al.* 1988; Sacks *et al.* 1999; Sequin *et al.* 2003) which might result in higher capture rates of exploring transients. These studies align with our hypothesis and our results confirmed our predictions: 1) an increased capture rate of older individuals in the protected areas where human interactions are rare and non-lethal in nature; and 2) an increased capture rate of sub-adults in farmlands where individuals are more prone to a rapid turnover and immigration from bordering areas due to lethal control (Minnie *et al.* 2018). Despite various technical means to counteract this increased wariness on farmlands (such as disguising traps, getting advice from trapping experts and farmers, rotating sites, varying trap types and increasing trapping time), trap avoidance was frequent (Sacks *et al.* 1999).

We recorded a capture rate of 14.6 jackals/100 trap-nights in protected areas, which is slightly lower than what was recorded by Loveridge and Macdonald (2001: 16.7 jackals/100 trap-nights in Hwange National Park, Zimbabwe), but much higher than reports by Kaunda (2001: 1.5 jackals/100 trap nights in Mokolodi National Park, Botswana) and Rowe-Rowe and Green (1981: 1.5 jackals/100 nights in Drakensberg, South Africa). The reduced capture rates in the protected areas of this study and those of Kaunda (2001) and Rowe-Rowe and Green (1981), compared to that of Loveridge and Macdonald (2001), might be an indication of lower jackal density, which in turn might be linked to different prey density (Gese 2005 on coyotes), different habitat types, and to lethal control on nearby farms. Jackals, as do other mesopredators, adapt extremely quickly to control measures, including trapping (Nattrass *et al.* 2020b), which can influence the results of long-term scientific studies and further hinder the management of damage-causing animals (Treves and Naughton-Treves 2005).

Although we used a different strategy for setting traps on farmlands (low trap density at trapping sites with traps set for a very long time) compared to the protected areas (high trap density at trapping sites with traps set for a short amount of time), we do not think that has played an important role in our study because the number of trapping nights was still almost 3 times higher on farmlands than in the reserves.

We have provided preliminary evidence for the impact that land use type and the associated long-term lethal control on farmland may have on the trapping success of jackals. However, due to project limitations (budget, time, accessibility, and resources), and a small sample size (30 successful captures), there were multiple sources of variation that we could not account for. Previous studies on canid trapping have highlighted the impact of other factors on trapping success. For example, the social structure and the seasonal reproductive cycle of the target species can influence trapping outcomes as demonstrated by Brand *et al.* (1995) and Brand and Nel (1997) who noted difficulties in capturing alphas (jackal) compared to transient individuals. Way *et al.* (2001) and Way (2012) also documented an increased capture rate of lactating females during spring, which overlaps with their breeding period and lead to a sex-biased capture success during certain periods. Furthermore, factors such as social learning can play a role by teaching younger individuals to avoid human objects (Brand 1993; Brand *et al.* 1995). Weather changes have been shown to alter prey availability as well and influence trap functioning (Pawlina and Proulx 1999). Trapper experience can further influence trapping efficiency over extended periods of time (Kay *et al.* 2000). Trap sampling design in the field can influence trap site visitation by mesopredators (Naylor and Novak 1994), and trap and bait type have been shown to influence the approach by the target species (Michalski *et al.* 2007), thus impacting on the outcome of trapping activities. The intensity and type of human pressure are also likely to influence the trapping success of canids. For example, familiarity with safe and accessible food sources might reduce wariness towards human-made object (neophilic behaviour) whereas canids exposed to prolonged lethal control are likely to avoid human activities and exhibit wariness towards any human-made objects (neophobic behaviour), including non-lethal traps (Brand and Nel 1997; Ginsberg and Macdonald 1990). Furthermore, the large areas often utilized by canids and the inconsistent lethal control effort across a landscape might result in further variation in capture success as canids associate certain areas with lethal control, increasing wariness and limiting the efficiency of trapping in those areas.

Our study presents preliminary findings and reviews multiple environmental factors that affect trapping success; it should be considered when conducting further research on black-backed jackals and other medium-sized canids worldwide. It raises the question of the impacts of unorganized blanket lethal control and continued trap exposure on canid behaviour. These actions can worsen the predation problem (Treves and Naughton-Treves 2005) by creating what farmers call "super-jackals", individuals that are impossible to catch and thus to manage or study (Nattrass *et al.* 2020a). The behavioural plasticity seen in jackals and other mesopredators allows them to adapt to and even thrive in most environments including those characterized by intense lethal control practices (Drouilly *et al.* 2018; Nattrass *et al.* 2020b). As a result, long-term negative interactions between jackals and farmers risk intensifying the avoidance of control measures, altering jackal behaviour, and increasing the prevalence of associated social conflicts (Nattrass *et al.* 2020b). We thus advocate for more research into the factors influencing the behaviour of jackals on farmlands. We also recommend halting unorganized blanket lethal control on farmlands, which can alter the behavioural patterns of canids and increase conflicts with farming activities.

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Chapter 12

Modifications to Improve The Performance of Mammal Trapping Systems

Gilbert PROULX
Alpha Wildlife Research & Management Ltd., 229 Lilac Terrace, Sherwood Park, Alberta, T8H 1W3, Canada. Email: gproulx@alphawildlife.ca

Abstract − The assessment of trapping systems according to stringent mammal trapping standards usually requires design improvements. Modifications that have been found effective in improving killing and restraining trapping systems should be used by progressive trap manufacturers and inventors. The objectives of this chapter were to identify changes to trapping systems that resulted in: 1) a quicker loss of consciousness in animals captured in killing traps; and 2) a reduction of injuries and distress in animals captured in restraining traps. On the basis of a review of scientific literature, I identify suitable modifications for killing trap systems that relate to striking jaws, springs, triggers, and trap sets. I also identify successful modifications for restraining traps, namely for jaws, springs, chains, cable lengths, swivels, and components of cage/box traps. Finally, I review the importance of using innovative approaches such as tranquiliser-trap devices (TTDs) and lethal-trap devices (LTDs). Innovation is required for further developing commonly used killing and restraining trap systems, and this will certainly be hastened if stringent trapping standards are implemented.

Introduction

The assessment and development of mammal trapping systems is a complex stepwise approach aiming at 1) assessing the mechanical properties of traps, 2) the ability of killing traps to strike animals in vital locations (e.g., single strikes in the head-neck region, preferably above C3, or double-strikes in the head-neck and thorax regions; Proulx *et al.* 1989a; Proulx *et al.* 1990; Proulx 1991; Proulx *et al.* 1995) and quickly render them irreversibly unconscious, and 3) the ability of restraining trap systems to hold animals for long periods of time without causing serious injuries and impacting on the behavioural and physiological state of the animals (Proulx *et al.* 2022). In most cases, modifications to the striking jaws are necessary to kill animals quickly or restrain them without pain and suffering. Triggers or sets may be modified to properly position the animals in the traps. Cage and box traps may also be modified to protect live-captured animals from cold or heat, and predators (Powell and Proulx 2003). Overall, small modifications to trappings systems may be repeatedly used with different trap models and sets for different species to improve animal welfare.

In an effort to improve mammal trapping and develop effective mammal trapping standards, Proulx *et al.* (2022) suggested that trapping systems rather than traps be certified and used on traplines. The components of a trapping system are: 1) a trap with specific dimensions, shape, power, and attachments (e.g., chain, swivels, locks); 2) a trigger with a specific shape and operation; and 3) a set with a specific placement of the trap, and bait or lure. In the last 35 yrs, I have been involved in the assessment and modifications of trapping systems for carnivores and herbivores (Proulx 1999a,b; Proulx *et al.* 2012). With the implementation of new trapping standards, the production of new traps, and the refurbishing of old traps, modifications that have been found effective in improving killing and restraining trapping systems should be used by progressive manufacturers and inventors to enhance animal welfare.

The objectives of this chapter are to identify changes to trapping systems that result in: 1) a quicker loss of consciousness in animals captured in killing traps; and 2) a reduction of injuries and distress in animals captured in restraining traps.

Methods

I reviewed scientific literature on mammal trapping to identify structural changes and components that improve the performance of killing and restraining trapping systems. I used Google Scholar with the following key words (and variants): mammal trapping humaneness, mammal trapping injuries, animal welfare in trapping, and mammal trapping standards. I consulted all mammal trapping publications in the library of Alpha Wildlife Research & Management, which includes over 50 yrs of publications related to "humane" trapping, trap research & development, and standards.

Structural changes to killing trap systems were judged significant if they produced reduced time to irreversible loss of consciousness. Structural changes to restraining trap systems were judged significant if they reduced serious injuries or distress that impact on the release and survival of captured animals. In all cases, trap modifications were found valuable when they allowed traps to meet state-of-the-art trapping standards (e.g., Proulx *et al.* 2020, 2022). The efficacy of the identified changes must have been demonstrated in sound assessments based on scientific datasets collected with wild animals in real trapping situations, and published in peer-reviewed journals or reports.

Modifications to killing trap systems

Traps are defined by their mechanical properties, namely their momentum (striking force) and clamping force (Proulx *et al.* 2020). The momentum is the product of the velocity of a striking bar and its equivalent mass. That is to say that increasing the speed of the striking bar, or its mass, will result in a greater impact and increase the possibility of rendering animal irreversibly unconscious faster. The clamping force is the steady-state force exerted on an animal by the jaw(s) of the trap after the striking force has been delivered.

Striking bars

Welding a plate to striking jaws

Although the Conibear 120 is popular among trappers to capture American martens (*Martes americana*), Proulx and Barrett (1989a) found that it did not have the potential to quicky render martens irreversibly unconscious. Proulx *et al.* (1989b) welded 2 metal bars or plates to the striking jaws − a modification adopted by the Federal Provincial Committee for Humane Trapping (1981) upon recommendation by trapper Ron Lancour and the British Columbia Trappers 'Association −to improve both momentum and clamping forces (Cook and Proulx 1989). Such a modification, in conjunction with the replacement of the original springs with stronger ones (see below), resulted in the development of the C120 Magnum trap (Figure 1), which quickly render martens irreversibly unconscious (Proulx *et al.* 1989b). The C120 Magnum trap was also found acceptable to kill American mink (*Neovision vison*; Proulx *et al.* 1990). Proulx *et al.* (1995) also welded 2 metal plates to the Conibear 330 to quickly render Canada lynx (*Lynx canadensis*) irreversibly unconscious.

Welding 2 metal plates transformed killing traps that were ineffective to kill American marten, American mink and Canada lynx into traps that met the highest standards in mammal trapping (Proulx 1999a). Such a modification successfully improved the mechanical characteristics of traps. However, there is a limit to which the effective mass of the striking jaw can be increased without seriously compromising its velocity (Cook and Proulx 1989). The impact of modifications to the mass of the striking components on the momentum of traps must therefore be assessed in a laboratory before testing traps with animals (Proulx *et al.* 2022).

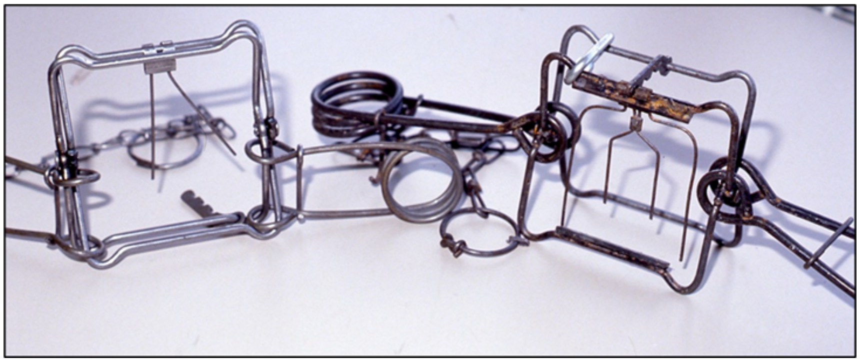

Figure 1. The Conibear 120 (left) and the C120 Magnum trap (right) with metal bars welded to the striking jaws and larger springs (Photograph: G. Proulx©).

Double jaws

Les Pièges du Québec (http://pages.citenet.net/users/ctmx1010/web-content/PAGE1englishINTRO.html) developed a structural modification that consisted in doubling the frame of rotating-jaw traps (Figure 2), thereby increasing the mass of the striking bar and improving its momentum. This modification, which was similar to the welding of a bar or plate to the striking jaw, played an important role in the acceptation of the Sauvageau 2001-8 killing trap to capture Arctic foxes (*Vulpes lagopus*) (Proulx *et al.* 1993a).

Proulx (1997) showed that the killing box ConVerT (L. B. Bachelder, Calgary, Alberta, Canada) with a single striking bar that struck animals ventrally, could efficiently capture northern pocket gophers (*Thomomys talpoides*). However, Proulx (1997, unpublished data) conducted a series of tests in semi-natural environments and found that the trap did not quickly render pocket gophers irreversibly unconscious. Individuals that had moved too far into the killing box, and smaller animals, were often struck in the abdomen or hip regions, and stayed alive in the traps. Also, on traplines, many captured animals were found alive. Proulx (1999b) modified the ConVerT trap by adding a second killing bar (Figure 3) that struck animals simultaneously in 2 regions: head-neck and thorax-abdomen, or thorax and abdomen. Independently of the location of the animal in the killing box, or the size of the animal, strike locations consistently struck pocket gophers in vital regions and quickly rendered them unconscious.

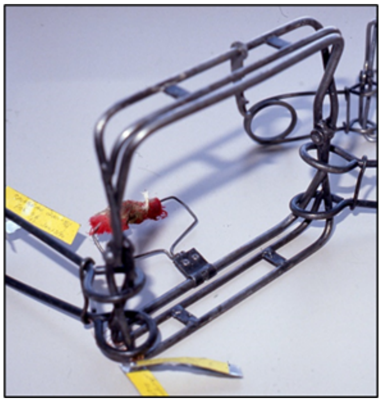

Figure 2. The Sauvageau 2001-8 for Arctic fox. Note the double jaws (Photograph: G. Proulx©).

Jaw shape

Warburton and Hall (1995) found that the clamping force and impact momentum of the Timms trap (K. B. L. Rotational Moulders, Palmerston North, New Zealand) designed for the capture of possums (*Trichosurus* *vulpecula*) were theoretically too low to achieve a rapid death. Warburton *et al.* (2000) showed that the killing ability of the trap could be improved by offsetting the jaws without the need of increasing the striking and clamping forces of the trap.

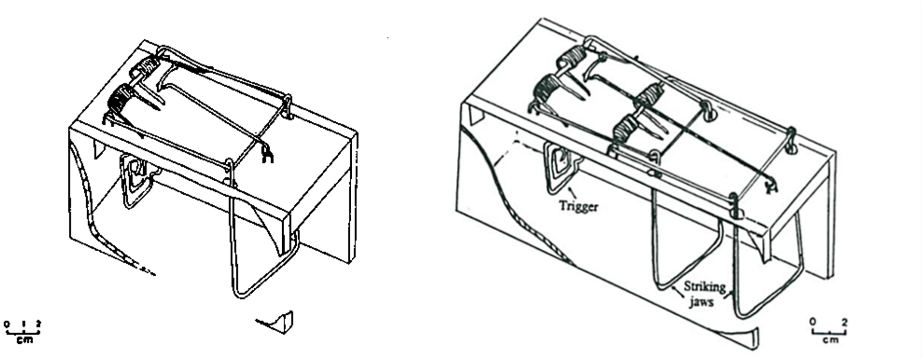

Figure 3. The ConVerT trap (left) with one striking bar, and the PG trap (right) with two striking bars (Drawings: G. Proulx©).

Spring size

During the development of the Conibear 120 into more powerful trap models, Cook and Proulx (1989) and Proulx *et al.* (1989a) assessed the impact of different spring sizes on the momentum and clamping forces of traps. After several tests, Proulx and Barrett (1989b) significantly increased the momentum of the Conibear 120 trap by replacing its original springs (4.1 mm diameter wire) with those of the Conibear 220 trap (6.4 mm wire) (Figure 1). This modification, in conjunction with the welding of plates to the striking jaws (see above), resulted in the production of the stronger C120 Magnum for American marten (Proulx *et al.* 1989b).

Triggers

While it is important to increase the momentum and clamping force of a trap, researchers must also focus on the location of strikes. For rapid loss of consciousness, animals must receive a single strike in the head-neck region (preferably above C3), which causes maceration of the brain or severe haemorrhage, cervical spinal cord maceration or severance (Proulx *et al.* 1989b; Onderka 1999); or a double-strike in the head-neck and thorax regions (Proulx *et al.* 1989b), which results in tracheal occlusion or severance, and cardiac or aortic rupture (Onderka 1999).

Pitchfork triggers for rotating-jaw traps

In an effort to determine if animals will be struck in vital regions, it is necessary to monitor the approach and position of the animals when traps are activated. Proulx *et al.* (2022) recommended the use of approach tests where traps are wired in a set position, cannot close completely, and cannot hurt the animals at firing time. With these tests, Proulx *et al.* (1989a) were able to demonstrate that 2-prong triggers sold with the Conibear 120 trap to capture American martens did not properly position animals for a strike in vital regions. Through a series of trigger modifications and experimental designs, a one-way pitchfork trigger (Figure 1) was eventually developed and used with the C120 Magnum (Proulx *et al.* 1989a,b). With a more powerful trap such as the C120 Magnum, and a trigger system that properly positioned the animals in the traps, martens quickly and consistently lost consciousness.

Pitchfork triggers were also used for the capture of northern raccoons (*Procyon lotor*; Proulx 1991) and Canada lynx (Proulx *et al.* 1995; Figure 4). Most of today's rotating-jaw traps are sold with 2-prong triggers that fail to properly strike mammals in vital regions, usually because the animals are able to bypass the prongs. Pitchfork triggers incite animals to move toward the centre of the trap and focus on the bait located at some distance behind the striking jaws. Without the pitchfork trigger, mechanically-improved traps may have failed because the animals would have been struck in the shoulders or the abdomen.

Figure 4. A modified Conibear 300 trap with pitchfork trigger for Canada lynx (Photograph: G. Proulx©).

Pan triggers

With American mink, although the use of the pitchfork trigger resulted in proper single strikes in the head-neck region, the C120 Magnum could not quickly render the animals irreversibly unconscious, possibly because of the greater cervical musculature and stronger bones of the mink (Proulx *et al.* 1990). The trap could, however, render mink quickly unconscious when it double-struck the animals in the head-neck region and the thorax. It was therefore necessary to develop a pan trigger which operated on a cam-lever principle that allowed mink to travel further into the trap frame (Proulx *et al.* 1990; Figure 5). This pan trigger could also be successfully used for the capture of American martens and muskrats (*Ondatra zibethicus*) (Proulx, unpublished data).

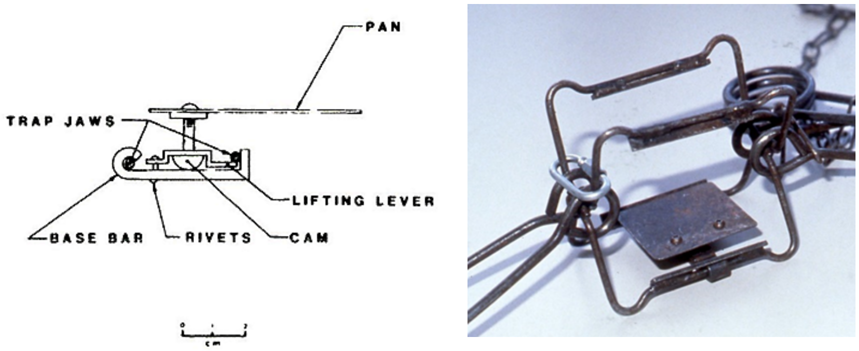

Figure 5. The C120 Magnum trap with a 66 x 69 mm pan trigger double-struck American mink in the head-neck region and the thorax to render them quickly unconscious (after Proulx *et al.* 1990).

Trap set

There are probably as many ways to set traps as there are trappers. However, not all sets ensure that animals will properly approach killing trap systems, get struck in vital regions, and lose consciousness within a specific time period. The locations of the bait and the trap in a set are as important as the mechanical properties of the trap itself. In the following, I compare sets that have been developed to ensure that animals will be struck in vital regions and rapidly lose consciousness to sets commonly used on traplines where animals are struck in non-vital regions.

Cubby set for American marten

Proulx *et al.* (1989a) developed a 35 x 17 x 17-cm cubby box with slotted sides and one end closed by a 2.5-cm wire mesh (Figure 6a) for the capture of American martens. Animals can enter the trap from only one side (compare the cubby set– Figure 6b – to naked pole set – Figure 6c). The cocked springs must be kept 10 cm away from the back of the slide slots so the trap cannot jump forward when fired (compare with Figure 6c). Otherwise, when the springs hit the end of the slots, the trap is thrusted forward and the animals may be struck across the shoulders rather than in the head-upper neck region. The trap should be secured in the box by joining spring loops with a flexible branch. The bait should be secured on the floor of the box, 10 cm behind the centre of the trap. The cubby box should be placed on a horizontal pole affixed between trees, approximately 1.5 m above ground level. The trap should be wired to the crosspole. Finally, a running pole should be leaned on the horizontal pole to incite martens to go up on the crosspole and investigate the trap and bait (Figure 6b). Such a set passed kill tests on traplines, i.e., traps consistently struck martens in vital regions, and as many martens were captured in the C120 Magnum as in control traps (Conibear 120 and leghold traps) used by trappers (Barrett *et al.* 1989).

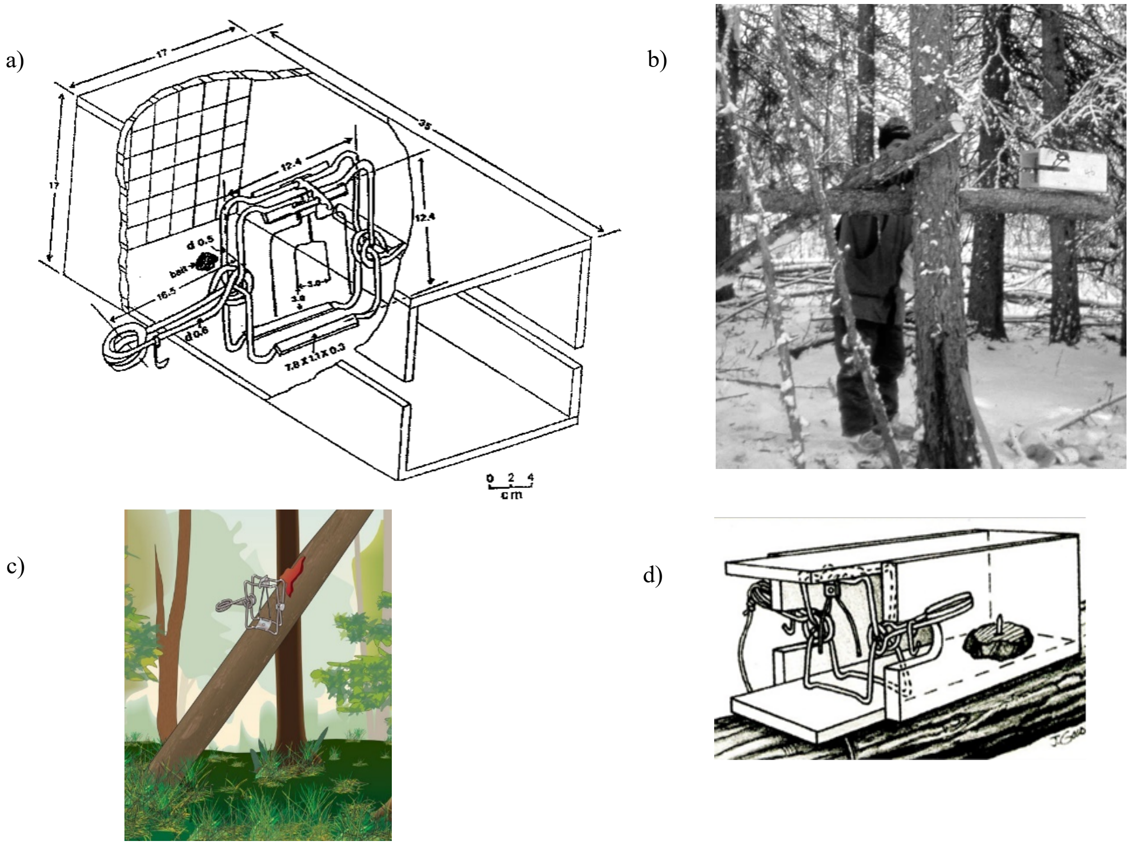

Figure 6. Cubby set developed by Proulx *et al.* (1989b) to capture American martens with the C120Magnum trap: a) details of the cubby set; b) set on a trapline; c) a naked pole set with a body gripping trap (Hunter-ed 2021); and d) an improper cubby with short slots on the side and body gripping trap with a two-prong trigger (Association of Fish & Wildlife Agencies 2014).

Bait cones

Proulx and Barrett (1991, 1993) developed the Bionic trap with a 6-cm-high bait cone for the capture of American mink, and a 10-cm-high bait cone for the capture of fisher (*Pekania pennanti*) (Figure 7). In both cases, the cone properly positioned the animals for an effective strike on the head or C1−C2 vertebrae for a rapid loss of consciousness. Thomas *et al.* (2011) and Morriss and Warburton (2014) also modified snap traps by adding a bait cone to achieve more consistent approaches and strike locations.

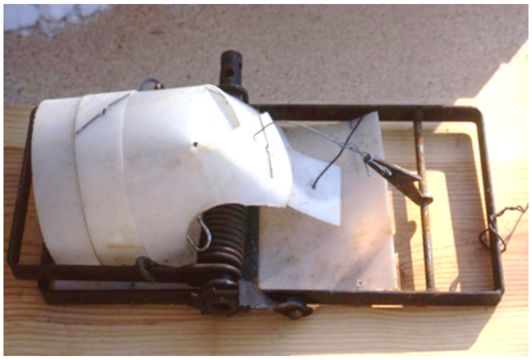

Figure 7. The bionic trap and its bait cone (Photograph: G. Proulx©).

Modifications to restraining trap systems

Since the beginning of the 20th century, a growing number of animal welfare organizations joined forces to try to ban the steel-jawed leghold traps that were known to cause serious injures to mammals (Proulx and Barrett 1989b). Under such pressure, wildlife agencies tried to find alternatives to these traps. Although restraining trap systems include a variety of trap designs, the following focuses mainly on legholds and their sets.

Jaw modifications

Rubber-padded leghold trap

Tullar (1984), Olsen (1986, 1988), and Linhart *et al.* (1988) developed rubber-padded jaw leghold traps (Figure 8) for the capture of foxes (*Vulpes* spp.) and other mesocarnivores. Their findings indicated that this modification substantially reduced the frequency of serious injuries. Since then, rubber-padded jaw traps have been repeatedly tested in different regions and with different species, and proved to be acceptable by causing only minor injuries to captured animals (Onderka *et al.* 1990; Mowat *et al.* 1994; Fleming *et al.* 1998; McKenzie 1989; Meek *et al.* 1995; Kamler *et al.* 2000, 2008; Jolley *et al.* 2012; and many others).

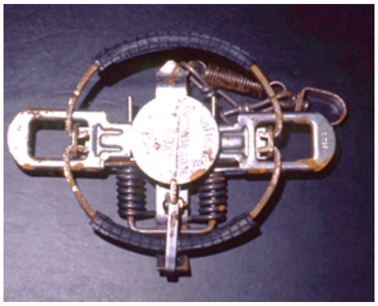

Figure 8. Rubber-padded leghold trap (Photograph: G. Proulx©).

Laminated and offset trap jaws

Two popular modifications to leghold traps consist of 1) offsetting the jaws, i.e., when a trap has fired, there is a gap between the closed jaws and less pressure is exerted on the captured limb; and 2) laminating the jaws, i.e., welding a plate to the jaws to increase the surface area over the jaw face (Figure 9). Offsetting the jaws was not sufficient to minimize injuries caused by steel-jawed leghold traps in coyotes (*Canis* *latrans)* (Phillips *et al.* 1996; Hubert *et al.* 1997). Also, steel foothold traps with varying degree of offset for wolves (*Canis lupus*) did not typically result in lower injury scores than non-offset, smooth jaw traps (Turnbull *et al.* 2011). According to Huot and Bergman (2007), coyotes captured in the laminated KB Compound 5.5™ leghold trap have substantially less cuts to the foot than those captured in the standards steel-jawed leghold model. Houben *et al.* (1993) reported that coil-spring traps with both offset and laminated jaws significantly reduced injuries to coyotes.

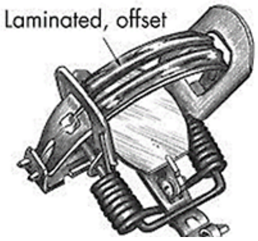

Figure 9. An offset laminated leghold trap (Association of Fish & Wildlife Agencies 2018).

One striking bar

Proulx *et al.* (1993b) tested the EGG trap™ (Egg Trap Co., Ackley, Iowa, USA), which consists of a plastic housing and a pull trigger mechanism which releases a 5.7-cm-long striking bar (diameter: 0.38 cm), moving laterally across the opening to block the animal's paw (Figure 10). They found that both the striking and clamping forces of the EGG trap were significantly lower than those of the popular rubber-padded leghold trap, and the EGG trap could capture raccoons without serious injuries. This was due to the fact that the striking bar blocked the paw of the animal in the plastic casing, and the animal was not subject to the much higher clamping of the jaws of leghold traps. Also, because of the plastic casing that encompassed the captured limb, raccoons could not self-mutilate themselves at the capture point as some do in leghold traps (Hubert *et al.* 1996).

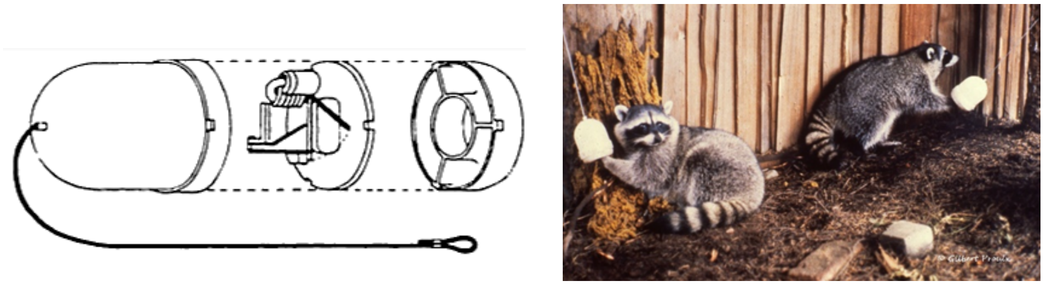

Figure 10. The EGG trap, and capture of northern raccoons (Photograph: G. Proulx©).

Stronger springs

Studies have shown that firmly restraining limbs in leghold traps by replacing the original springs of a leghold trap with stronger springs or with supplemental springs, and thus increasing striking and clamping forces, significantly reduced injuries in coyotes (Linhart *et al.* 1988; Gruver *et al.* 1996; Phillips *et al.* 1996) and bobcats (*Lynx rufus*) (Earle *et al.* 2003). Undoubtedly, there are upper limits to impact and clamping forces where the severity of trap injuries will increase. Also, the impact of stronger or supplemental springs on injuries will likely vary among species, and with the sex and the age of the animals.

Chain and cable length, swivels and shock-absorbing coil springs

Linhart *et al.* (1988) found that padded long-spring traps with a long (90 cm) center-mounted chain resulted in less injury to coyotes than padded long-spring traps with a shorter (15 cm) center-mounted chain with shock spring. On the other hand, unpadded Victor no. 3 NM traps with a 15-cm center-mounted chain caused less injury (more than 50%) than the same trap with the 90-cm long-spring-mounted chain. These data contradicted earlier information that suggested shortened chains on unpadded traps had no effect on injury rates (Linhart *et al.* 1981). Injuries caused by the edge of steel jaws cannot be significantly reduced in severity just by changing the length of chains. Also, while the addition of chain-springs had a significant effect on reducing the severity of injuries to possums captured in steel-jawed Lanes-Ace and Victor No 1½ traps, these reductions were not sufficient to render traps acceptable from an animal welfare point of view (Warburton 2004). Although shorter chains, swivels and shock-absorbing springs may contribute to reducing the severity of injuries, they must still be used with traps that have been found less harmful such as the rubber-padded leghold traps.

Hanson *et al.* (2010) successfully captured red foxes (*Vulpes vulpes*) and feral cats (*Felis silvestris catus*) with Oneida Victor® #1 Soft Catch® padded-jaw traps that had been modified by shortening and changing the type of anchor chain, including and positioning 2 large barrel swivels (1 more than the standard), and adding a more flexible shock absorbing spring (Figure 11). Similarly, a shorter cable with swivels, and a trap site cleared of bush and logs, can reduce cable entanglement and minimize injuries in captured Canada lynx (Mowat *et al.* 1994).

Figure 11. A short chain with shock-absorbing spring and swivel (Hanson *et al.* 2010).

Cage/box traps

Cage/box traps are usually considered to be humane for the capture of mammals (Proulx *et al.* 2012), but they have not been adequately evaluated in the past (Proulx 1999a). White *et al.* (1991) found that foxes caught in box traps undergo less trauma than foxes restrained in padded- or unpadded-jaw leghold traps.

Wire mesh

Mammals captured in wire mesh traps may sustain serious injuries (Powell and Proulx 2003). Jung and O'Donovan (2005) found small mammals with their snouts caught in the wire mesh of the traps. Because their upper incisors went through to the other side of the mesh, they were unable to free themselves and their snouts were lacerated on both sides; a few animals died. I observed the same incidents when live-trapping red squirrel (*Tamisciurus hudsonicus*) and muskrat. Fishers may damage or lose their teeth by chewing on traps (Arthur 1988). A smaller mesh size prevents such injuries and death (Arthur 1988; Jung and O'Donovan 2005) and can be added to the outside walls of a cage trap.

Box traps and covers

Using box traps eliminates many of the injuries observed with wire mesh traps. Proulx *et al.* (1992) showed that northern raccoons could be held for up to 24 h in the Freed'Em trap, an aluminium box trap with polyethylene lining. They suggested that unibody plastic box traps would likely reduce oral injuries in raccoons and other mammals. On the basis of these findings, wire mesh traps can be modified into box traps by adding wooden or aluminum covers over cage traps (Brown and Batzli 1985). Using a canvas cover (Mantor *et al.* 2014) or plastic sheeting (Barr 1974) for wire mesh traps also minimized stress and injuries in several species of squirrels. However, animals caught in plastic-walled traps during summer conditions may show signs of heat stress (Vantassel 2020).

Adjoined nest boxes

Death in cage and box traps has been attributed to cold temperatures in winter, overheating in summer, and multiple captures of individuals (Lemckert *et al.* 2006; Vantassel (2020). In summer, traps should be concealed and covered with vegetation to protect animals from sunlight (Kantola and Humphrey 1962; Powell and Proulx 2003). Fourie and Perrin (1986) recommended the addition of a wooden box trap at the back of a wire mesh cage to capture rock hyrax (*Procavia capensis*). The box had an entrance with a hinged trapdoor that opened inwards only, allowing hyrax to enter but prevented departure. When caught in the wire cage, hyrax took refuge in the box where they were trapped in the dark. The researchers found that the trap box minimized injuries and provided ample protection during hot summer days and cold winter nights. Cage/box traps without insulated attached nest boxes with bedding are not recommended for small mammals in winter when temperatures are -20°C, or if researchers cannot frequently check traps (Powell and Proulx 2003). The use of an insulated nest box attached to a cage or box trap is recommended for the live-trapping of small mammals in winter (Powell and Proulx 2003).

Enclosures and off-the-ground sets

Disturbance of traps and molestation of captured animals by predators can be an issue on small mammal traplines. Dennett and Kidd (1960) described the problem of raccoon predation on fox ((*Sciurus niger*) and gray (*Sciurus carolinensis*) squirrels. Layne (1987) recommended building an enclosure to encompass small mammal traps. Trap sets off the ground (Huggins and Gee 1995) have the potential advantage of being out of the reach of livestock (Barr 1974), dogs (*Canis familiaris*) (Copeland 1976), feral hogs (*Sus scrofa*) (Kidd and Soileau 1962), and other non-arboreal wildlife. Godbout and Ouellet (2008) also placed wire mesh traps in boxes affixed to trees to protect American martens from the elements.

Add-ons

Tranquiliser-trap devices (TTDs)

To date, most efforts to improve trapping systems have focused on changes to trap structural components. This resulted in significant improvements such as the rubber-padded leghold traps, but there are still cases where animals of some species, possibly because of their age or sex, or the inadequacy of some sets, get injured. Furthermore, padded traps do not prevent all injuries. Animals still suffer from oral injuries, tooth damage, exertional myopathy, distress and anxiety. On the other hand, more than 50 yrs ago, Balser (1965) introduced the concept of adding tranquiliser tabs to trap jaws. The use of such tabs has been delayed by the development and availability of stable tranquilisers (e.g., Primus *et al.* 2005), and the persistent reluctance of trapping groups to use such tabs (Proulx, unpublished data). Nonetheless, in the last decades, the development of tranquiliser-trap devices attached to traps to deliver sedative and anxiolytic drugs to trapped animals has markedly evolved (Marks *et al.* 2004).

Modern TTDs consist of a moulded rubber tube or polyethylene bulb reservoir containing a tranquiliser. After capture, animals bite at the tube and ingest a portion of the drug. Less struggling and reduced injuries to feet, legs, and teeth and gums, has been observed (Sahr and Knowlton 2000; Marks *et al.* 2004; Savarie *et al.* 2004). Pruss *et al.* (2002) used diazepam tabs on a modified restraining neck snare to decrease injuries and stress to captured coyotes. Coyotes that were held in snares where the diazepam tab was removed or ingested by the coyote had a lower incidence of facial and oral lacerations, and were less aggressive.

Lethal-trap devices (LTDs)

To minimise stress and trauma to trapped animals, Meek *et al.* (2019) tested the efficacy of 2 types of LTDs containing para-aminopropiophenone (PAPP), a toxin used to induce euthanasia. They recorded a mean time from trap-to-death of 66 min in feral dogs. Whereas more work needs to be done on the LTDs and the selection of drugs, these new devices may be valuable in the future. Holding an animal in a restraining trap only to kill it later may be less humane than using a trap equipped with LTDs.

Discussion

In this paper, I identified a series of modifications to improve killing and restraining trap systems. In the case of killing trap systems, improving momentum and clamping force through modifications of the jaws or the springs resulted in more acceptable trapping devices. Successful modifications to the leghold traps consisted in minimizing or softening the contact between the steel and an animal's limb, and using short chains, shock absorbing springs, and swivels to minimize injuries resulting from yanking movements associated with escape attempts. These modifications were successful because of an understanding of the physical and physiological limitations of the captured animals, and most importantly, their behaviour when approaching traps or trying to free themselves.

There are certainly valuable modifications to trapping systems that I did not discuss in this paper. However, there is a lack of scientific, peer-reviewed publications on the mechanical characteristics of traps that have been assessed by organizations such as the Fur Institute of Canada (2021). For example, several certified rotating-jaw trap models have an inward bend of the striking jaws. Such a modification may have an impact on the striking and clamping forces of traps, and they may be able to quickly render some animals unconscious, but nothing is published about their mechanical characteristics and tests with animals. Since the scientific testing of the EGG trap, similar devices such as the DP Coon Trap (Duke Traps, West Point, Missouri, USA) have been produced but, to my knowledge, thorough assessments of these traps have not been carried out.

All the modifications that I identified in this paper will improve the welfare of trapped animals if, and only if, they are used as they are intended. The C120 Magnum, or similar trap models, will quickly render American martens unconscious if they strike animals in vital regions. Previous studies (Proulx *et al.* 1989a, 1990) have shown that consistent kills can be obtained with the pitchfork trigger, not with the two-prong trigger sold with the traps (Feldstein and Proulx 2022). Likewise, animals captured in cage/box traps will not suffer serious injuries or long and painful deaths if nest boxes are used to protect them from inclement weather. Finally, no matter how humane modified leghold traps may be, they need to be visited frequently, at least ≤ 12 h (Proulx and Rodtka 2019), or equipped with alert systems that inform trappers that a trap has been activated and needs to be checked (Powell and Proulx 2003). Unless trappers and researchers change their habits, the betterment of animal welfare in trapping will not happen.

Researchers and trappers must also use common sense when trapping mammals and they should employ trapping protocols that minimize pain and discomfort. When using cages, they should attach nest boxes, and supplement the animals with water or snow, and food. For example, because shrews (*Sorex* spp., *Blarina* spp.) are small and have very high metabolic rates, trap-check intervals of 6 −12 h are too long and the animals will die of starvation (Younger *et al.* 1992). Trap visits should happen ≤4 h and traps should be replenished with food each time.

Finally, it is time to include new, innovative ways when developing trapping techniques. The use of TTDs and LTDs is an example of how one can improve animal welfare when trapping with leghold traps. Innovation is required for further developing commonly used killing and restraining trap systems, and this will certainly be hastened if stringent trapping standards (e.g., Proulx *et al.* 2022) are implemented.

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Chapter 13

Trapping Carnivores: The Role of Physiological Parameters as Capture Stress Response Biomarkers

Fernando NÁJERA[1,2,3]
[1]The Bornean Wild Cats Veterinary Project, Department of Animal Physiology, Veterinary College, Complutense University of Madrid 28040, Madrid, Spain.
[2]Current address: Saint Louis Zoo Institute for Conservation Medicine / Saint Louis Zoo WildCare Institute. One Government Drive, Saint Louis, MO, 63110, USA
[3]Living Earth Collaborative, Washington University, St. Louis, 1 Brookings Drive, St. Louis, MO 63130, USA. Email: fernanaj@ucm.es

Abstract – Trapping carnivore species for research is essential to answer ecological questions that are otherwise difficult to answer with the use of non-invasive methodology. However, the safety of capture devices and capture protocols should be evaluated to avoid potentially harmful impacts to the target species. External injuries in trapped carnivores have historically been considered as trap safety and welfare indicators, although capture stress response may be also measured by the sum of selected physiological and behavioural parameters that have already received the attention of free-living carnivore researchers. The responses that may reflect capture stress include changes in 4 major types of physiological mediators: vital signs (respiratory and cardiac rates and body temperature); endocrine mediators (e.g., total serum cortisol, free serum cortisol); hematological and immunological mediators (e.g., red blood cell count, hematocrit, hemoglobin, leukograms, neutrophil/lymphocyte ratio, leukocyte coping capacity); and serum biochemistry (e.g., serum enzymes, total proteins, metabolites, electrolytes). The stress response after capture events may also be investigated by monitoring for behavioural mediators of the captured carnivore by camera-traps and computing the distance travelled/activity budgets after the capture event. It is recommended to include the above mediators during live trapping operations to assess and further decrease the negative impact of capture on physiological responses of the target carnivores.

Introduction

Carnivore research, management and conservation often involves the capture and handling of individuals, which is probably the most stressful situation that these animals may experience in their lifetime (Nielsen 1999). Stress is undoubtedly one of the most challenging concepts to define in biology and medicine, and theories from this century define it simply as "a state in which homeostasis is lost" (Reeder and Kramer 2005). Regardless, the cause of stress is known as a stressor, and is defined as a stimulus perceived as a threat to the individual (Ladewig 1987; Moberg 1987). These stimuli are classified into psychic (those that affect the behaviour of the individual) or physical, which in turn are divided into internal (such as hypoglycemia) or external (such as cold, heat or other harmful stimuli located outside the individual). The presence of these stimuli can elicit a stress response in an individual to re-establish homeostasis. The response that occurs in the individual to these stimuli to re-establish homeostasis is known as stress response. This response consists of several physiological and behavioural mechanisms that attempt to neutralize the effects of these stressful stimuli (Reeder and Kramer 2005). Not all animals will initiate a stress response to the same stimulus since individuals will perceive a stimulus as stressful or not depending on its characteristics (Ladewig 1987; Wiepkema and Kolhaas 1993).

The stress response consists of a cascade of reactions initiated from the release of corticotropin-releasing hormone by the paraventricular nucleus of the hypothalamus and the central nucleus of the amygdala. There are 2 components in stress response: the behavioural component, in which behaviours such as escape, or the suppression of behaviours related to feeding and reproduction are activated, and the physiological component, in which the sympathetic nervous system (sympathetic–adrenal–medullary axis) and the hypothalamic-pituitary-adrenal axis are activated (Moberg 1987; Holst 1998; Reeder and Kramer 2005).

Selye (1946) characterized the stress response in 3 phases, currently called generalized adaptation syndrome and defined as including the alarm phase, where sympathetic nervous system stimulation occurs; the resistance phase, where the hypothalamic-pituitary-adrenal axis is activated; and the depletion phase, where glucocorticosteroids levels released by the adrenal gland remain elevated.

Stimulation of the sympathetic nervous system leads to the release of the catecholamines, norepinephrine and epinephrine within milliseconds after the onset of a stressor. Norepinephrine is released by peripheral nerves (sympathetic postganglionic neurons) and epinephrine by the adrenal medulla. Both catecholamines are responsible for increasing individual arousal, heart rate, lipolysis and gluconeogenesis that will provide energy to the individual during the stress episode (Reeder and Kramer 2005).

In the hypothalamic-pituitary-adrenal axis, the corticotropin-releasing hormone (CRH) moves to the anterior pituitary gland (adenohypophysis), triggering the release of the adrenocorticotropic hormone (ACTH). ACTH is released as a circulatory torrent where it travels to the cortex of the adrenal gland, causing the secretion of glucocorticosteroids (cortisol, corticosterone or both, depending on the species) (Guyton and Hall 2000; Reeder and Kramer 2005).

Glucocorticosteroids play an important role in the individual's metabolism in both basal conditions and stressful situations. In general, they increase available energy through an increase in gluconeogenesis, inhibition of glucose uptake, increased synthesis of triglycerides, mobilization of fats from reserve tissues or stimulation of protein synthesis in the liver (Verde and Gascon 1987). This release of glucocorticosteroids shows adaptive function after the presentation of stressful stimulus, although prolonged exposure to glucocorticosteroids (phase of depletion of adaptive syndrome) can have harmful effects on the individual such as hyperglycemia, insulin resistance, delayed healing, muscle atrophy, inhibition of growth or inhibition of the immune system.

In the stress response, the release of CRH, epinephrine, and norepinephrine occurs almost instantly after the perception of a stressful stimulus by the individual. The CRH release and increased levels of glucocorticosteroids can take up to several minutes and these elevated levels may remain for longer periods of time. This time lag in releasing the different components of the stress response ensures that individuals can redirect their energy balance and behaviour, depending on whether they must face an immediate stressful stimulus (which lasts seconds or minutes) or if they must face stimuli that can become stressful after a longer period of time (Reeder and Kramer 2005).

For the capture of wild carnivores, it is not only essential to know which method is the most effective, but also which method is the safest from the animal´s physiological point of view. Certain species of wild carnivores are effectively caught by padded leghold traps, although these methods can pose a serious threat to the physical integrity of the individual (Mowat *et al.* 1994). On the other hand, the capture of carnivores by using cage traps (a box-shape trap covered by metallic mesh) can be equally effective and physically safe for certain species (Kolbe *et al.* 2003), although may not be suitable for other species because of the risk of canine fractures when trying to bite the metal skeleton of the cage-trap (Furtado *et al.* 2008). This would not occur if a box trap were to be used, where the trap implies fully sheathed components (walls, floor, ceiling, doors).

Despite the use of different methods, the effects of capture on the physiology of carnivores remain, to some extent, unclear. Capture procedures can lead to high levels of anxiety, self-injury or even exhaustion with fatal consequences (Fernández-Morán 2003). Capture myopathy should be considered as one of the most important aspects to consider during the capture and handling of wild animals, and although it is more common to find this condition in ungulates and other taxa, it has also been described in carnivores (Williams and Thorne 1998; Cattet *et al.* 2003).

In this paper, I review major physiological parameters associated with the capture of animals, with attention to 4 major mediators: vital signs, hematological and immunological mediators, endocrine mediators, and serum biochemistry mediators (Table 1). I also address behavioural changes associated with a stress response.

Vital signs

From the vital signs considered, cardiac rate and body temperature have a more quantifiable measure in the stress response. In the face of a stressful stimulus, an individual's heart rate increases due to the release of catecholamines, and their body temperature increases (also called stress-induced hyperthermia) due to the activation of the sympathetic nervous system and the hypothalamus-pituitary-adrenocortical axis (Groenink *et al.* 1994). It should also be noted that changes in heart rate, as well as increases in body temperature, can be linked to an increase in the intensity of the physical activity without the need for stress (Broom and Johnson 1993; Cattet *et al.* 2003). While using these mediators as capture stress response biomarkers during trapping, researchers need to bear in mind that these vital signs are also essentially affected by the anesthetic procedures employed with captured carnivores. In such case, they will not reflect the stress response but rather the anesthetic protocol

Table 1. Examples of stress biomarkers used to assess the stress response in carnivore trapping, handling, transporting, anesthesia, surgery and/or manipulation.

Species	**Biomarker**	**Reference**
Brown bear (*Ursus arctos*)	Serum biochemistry, leukocyte coping capacity, behaviour	Cattet *et al.* 2003,2008; Esteruelas *et al.* 2016
American black bear (*Ursus americanus*)	Serum biochemistry	Powell 2005
Red fox (*Vulpes vulpes*)	Vital signs, hematology, serum biochemistry, endocrine and/or behaviour mediators	Kreeger *et al.* 1990; White *et al.* 1991; Marks 2010; Gethöffer *et al.* 2021
Stone marten (*Martes foina*)	Hematology, serum biochemistry, endocrine and behaviour mediators	Gethöffer *et al.* 2021
Iberian wolf (*Canis lupus signatus*)	Vital signs, hematology, serum biochemistry, endocrine and behaviour mediators	Santos *et al.* 2019
Sunda leopard cat (*Prionailurus javanensis*)	Serum biochemistry	Nájera *et al*. 2014
Eurasian otter (*Lutra lutra*)	Hematology, serum biochemistry	Fernandez-Moran 2003
European badger (*Meles meles*)	Leukocyte coping capacity, vital signs, serum biochemistry and/or behaviour	McLaren *et al.* 2003; Schütz *et al.* 2006

Hematological and immunological mediators

Physical methods of capture cause a stress response in the individual that is responsible for changes in the blood count. Epinephrine and norepinephrine catecholamines released after stimulation of the sympathetic nervous system causes contraction of the smooth musculature of the spleen. This splenic contraction is responsible for the release into the bloodstream of blood stored in the spleen, often leading to a higher hematocrit. This redistribution of erythrocytes is common, for example, in domestic felines after periods of excitement (Jain 1993; Brockus 2011). In the blood count, typical alterations of relative polycythemia are observed, with increases in hematocrit, total erythrocyte count, and haemoglobin concentration. This condition can also be observed in cases where the individual suffers from dehydration (Brockus 2011).

Changes in the blood count have been reported during chemical immobilization. Decreases in hematocrit, total erythrocyte count, and haemoglobin concentration have been described during chemical immobilization due to hemodilution by expansion of plasma volume and drug-facilitated abduction of erythrocytes in the spleen (Seal *et al.* 1972; Kocan *et al.* 1981; Cross *et al.* 1988; Chapple *et al.* 1991).

The white cell count may also be altered during the stress response. The release of epinephrine after stimulation of the sympathetic nervous system in response to fear or arousal is responsible for the leukocytosis and neutrophilia observed in the leukogram. Neutrophilia may be caused by the mobilization and redistribution of neutrophils from the marginal pool to circulation by increased heart rate and blood pressure (Webb and Latimer, 2011). The release of glucocorticosteroids after activation of the hypothalamus-adrenocortical axis in the stress response can also cause changes in the leukogram such as neutrophilia, lymphocytopenia, monocytosis and eosinopenia.

Neutrophilia in this case is produced by several mechanisms (Jain 1993; Young 2000; Webb and Latimer 2011):

- Decreased neutrophil migration from circulation to tissues.
- Increased release of neutrophils from the bone marrow.
- Movement of neutrophils from the marginal pool to circulation.

Lymphocytopenia is caused by a redistribution of circulating lymphocytes, which remain transiently sequestered in lymphoid tissue and bone marrow rather than entering the circulatory stream or lymphatic stream (Webb and Latimer 2011).

Based on the evidence that under a stressful event neutrophils increase in circulation while lymphocytes decline, a common method to measure stress using both types of white blood cells consists in the neutrophil-to-lymphocyte ratio (N:L or N/L; Davis and Maney 2018). This ratio can be a reliable method to index stress levels (Davis *et al.* 2008).

Other white blood cells changes include eosinopenia and monocytosis. Eosinopenia can be caused by an abduction of eosinophils in tissues (liver and spleen), by inhibition in their release by the bone marrow or by inhibition of cytokines responsible for the development of eosinophils and that induce apoptosis (Smith 2000; Young 2000; Webb and Latimer 2011). Monocytosis can be observed due to mobilization of the monocytes from the marginal pool to the circulatory (Webb and Latimer 2011).

Another method for quantifying the stress response in vertebrates is the leukocyte coping capacity (LCC), a proxy for stress quantifying oxygen radical production by leukocytes, with potential to develop in the short-term a valuable tool to unravel the stressful mechanisms of capture and handling procedures in wildlife (Huber *et al.* 2019).

After a stressful situation, leukocytes produce a quantifiable immune response known as the respiratory burst. During the respiratory burst, activated leukocytes accelerate oxygen uptake to release reactive oxygen species (ROS) that destroy bacteria (Halliwell and Gutteridge 2000; Ellard *et al.* 2001; Montes *et al.* 2004). It has also been demonstrated that stress affects the respiratory burst, as shown by decreases in certain species in association with stress caused by transport (McLaren *et al.* 2003) or trapping and handling (Gelling *et al.* 2009). By quantifying the reduction in the amount of ROS released by leukocytes in response to a secondary stimulus, one can assess the effect of the known or suspected stressor (Mian *et al.* 2005). Therefore, animals with a higher LCC will have greater potential to produce a respiratory burst and will be better able to respond to bacterial challenge after stress (Esteruelas *et al.* 2019).

Platelet count can also be altered by the stress response after activation of the sympathetic nervous system. The release of epinephrine can cause splenic contraction, which increases platelet count, since the spleen may contain up to 40% circulating platelets (Jain 1993; Bordeaux *et al.* 2011).

Other immunological stress biomarkers include neopterin and immunoglobulin A (IgA). Neopterin synthetized by monocytes and macrophages upon inflammatory cytokine stimulation could be a helpful marker to quantify acute stress-induced cellular immune stimulation (Breineková *et al.* 2007; Huber *et al.* 2019). Immunoglobulin A is the major antibody of mucosal immune defense in mammals and birds. Long-term examinations of IgA levels reveal consistent patterns with a suppression of the secretory form of the IgA after periods of psychological or physical chronic stress (Staley *et al.* 2018).

Endocrine mediators

The glucocorticosteroids, cortisol and corticosterone, are among the most frequently measured stress indicators in vertebrates (Wingfield *et al.* 1997; Baker *et al.* 2013). While cortisol is the main glucocorticosteroid of fish and most mammals, corticosterone is the main one for birds, amphibians, reptiles, rodents, and lagomorphs (Cockrem 2013).

Although cortisol is a reliable indicator of the stress response and has been widely used, it has been observed that increases in the concentration of this hormone do not necessarily appear with all stressful stimuli, or equate to stress levels (Terlouw *et al.* 1997; Sheriff *et al.* 2011). In addition, glucocorticosteroids are affected by multiple factors such as time of day or season. For example, many species have circadian rhythms and these can even disappear after prolonged periods of stress, handling, and anesthetic drugs (Arnemo and Caulkett 2007).

The sampling method can also contribute to elevations in cortisol, since sampling is always linked to a stressful situation, such as confinement or manipulation of the individual. To alleviate this problem, some researchers have developed electronic remote sampling devices, avoiding the capture and management of the individual (Cook *et al.* 2000).

Although cortisol is normally measured in plasma, it can also be measured in saliva and urine. Cortisol metabolites in faeces may be a powerful non-invasive tool in conservation biology, wildlife management or ecological studies as it is not necessary to capture individuals (Palme 2019). Although free cortisol concentration acutely rises in response to stressors, researchers must keep in mind that values tend to normalize after a few hours (Breuner *et al.*, 2013).

Plasma glucocorticoids rise within minutes of the onset of acute stress and return to baseline within 1 to 2 h after the stressor passes, and thus it is recommended to use this biomarker to quantify the acute stress of capture (Creel *et al.* 1997; Arnemo and Caulkett 2007; Delehanty and Boonstra 2009; Davis and Maney, 2018). Importantly, not all serum cortisol is biologically active. Cortisol bound to corticosteroid binding globulin is not biologically active, so only free serum cortisol is meaningful in measuring the stress response (Hammond 2016). Quantifying free cortisol is challenging, but costicosteroid binding globulin (CBG) can be measured alongside cortisol. The amount of free cortisol can then be estimated based on the law of mass action, from CBG molecular weight, affinity for cortisol and non-specific binding ratio, and from phylogenetically close species eventually available in the literature (Breuner *et al.*, 2013)

Serum biochemistry mediators

Serum enzymes

Elevations of certain serum enzymes have been described as indicators of muscle damage and stress during the capture and management of wildlife (Nielsen 1999).

Creatine kinase (CK)

This enzyme is critical for muscle energy production. It is a cytosolic enzyme that has its highest activity in skeletal muscle, heart muscle and the brain. The vast majority of serum CK has muscle origin, making this enzyme one of the most specific. It is the enzyme of choice for skeletal muscle damage. The plasma half-life of CK is short, so rapid processing of samples is recommended. In addition, although erythrocytes contain very little CK, in case of hemolyzed samples, CK may be falsely elevated. In some species with lower muscle mass such as domestic cats (*Felis catus*), slightly elevated values of this enzyme are considered more significant, although in anorexic cats, elevated CK values have been found without other muscle alteration (Hall and Bender 2011). Venipuncture or intramuscular injections, as well as irritating drugs (such as ketamine), may increase the activity of this enzyme (Hall and Bender 2011).

Aspartate aminotransferase (AST)

This enzyme is present in almost all cells, including erythrocytes. The serum activity of this enzyme is not specific to any tissue, although the liver and muscle are considered to be the main origin. Its plasma half-life is longer than the plasma half-life of CK. As with CK, sample hemolysis can result in falsely high values (Kramer and Hoffman 1997; Hall and Bender 2011).

Alanine aminotransferase (ALT)

This is a cytosolic enzyme. It is considered specific to the liver in domestic carnivores, although its activity can be increased with muscle damage in these species. Its half-plasma life is longer than in the previous ones (Kramer and Hoffman 1997).

Lactate dehydrogenase (LDH)

This is a cytosolic enzyme present in all tissues. Elevated LDH values usually originate from muscle, liver, and erythrocytes. It is considered less useful compared to AST and CK due to its lack of specificity and because its activity may be falsely elevated in cases of mild hemolysis (Hall and Bender 2011). During the capture of certain species of wild carnivores, the increase of this enzyme, together with AST and CK, has corroborated the diagnosis of rhabdomyolysis (Kreeger *et al.* 1990).

Aldolase (Aldolase A)

This is a cytosolic isoenzyme used in the research of musculoskeletal disorders. It has little clinical utility due to its low diagnostic sensitivity (compared to CK) and difficulty of being routinely measured in laboratories (Hall and Bender 2011).

Alkaline Phosphatase (AP)

This is a non-specific enzyme that can be found in the liver, bone, intestine and placenta. It can also be found as corticosteroid-induced isoenzyme, where the administration of exogenous corticosteroids or elevation of endogenous corticosteroids can result in a high value of this enzyme, as seen after the capture of wild canids (Kreeger 1990; White *et al.* 1991). In felids, it is believed that this type of corticosteroid-induced isoenzyme has no activity (Fernández and Kidney 2007). Alkaline phosphatase concentration is higher in juveniles, which should not be mistaken as a response to capture.

Total proteins

Plasma proteins have nutritional functions. They are involved in the maintenance of colloidal osmotic pressure, inflammatory, immune and coagulation processes, and they aid in the maintenance of acid-base balance (Evans 2011). Protein concentration may be altered by various factors such as age, gestation, lactation, health status, catabolic effect hormones (cortisol) or as a result of the chemical capture and immobilization process, and in blood pressure, colloidal osmotic pressure, lymphatic circulation or hemodilution (Seal *et al.* 1972; Kaneko 1997). Some authors have used an increase in total proteins, albumin or albumin/globulin ratio as indicators of dehydration during prolonged confinement and/or intense activity in capture processes in wild carnivores (Cattet *et al.* 2003; Powell 2005; Marks 2010).

Metabolites

Lactate

This is a waste metabolite of anaerobic glycolysis produced mainly by skeletal muscle, erythrocytes, brain, skin and renal medulla. This metabolite increases in certain domestic carnivore myopathies. Its value may also increase in case of struggle while handling a non-anesthetized individual during venipuncture, due to muscle activity (Evans 2011).

Urea

This is a waste metabolite that results from protein catabolism. The most important route of urea excretion is the kidney, although to a lesser extent it can be excreted by saliva, digestive tract or sweat. Although this metabolite has been linked to capture stress responses in wild ungulates, its role has not been shown as an indicator of stress in carnivores (Wolkers *et al.* 1994; Tripathi *et al.* 2011). Increases in urea concentration have been reported during bear (*Ursus* spp.) capture by snares, probably due to the effect of dehydration aggravated by intense exercise during attempts to escape (Cattet *et al.* 2003).

Creatinine

This is a compound of endogenous origin by the non-enzymatic conversion of creatine, which stores energy in the muscle in the form of phosphocreatine. It is excreted mainly by the kidneys, although a very small amount is excreted by the digestive system. A decrease in serum creatinine may be due to some muscle disease and generalized weakness, and its increase has been linked to kidney disease and implicated in cases of rhabdomyolysis. Males typically have higher creatinine values than females (Tripathi *et al.* 2011).

Glucose

Blood glucose is obtained from different sources: diet, glycogenolysis, and gluconeogenesis. In the stress response, released catecholamines promotes glycogenolysis in hepatocytes and myocytes. Cortisol released in the stress response contributes to the initiation of glycogenolysis, thereby increasing blood glucose. In cats, glucose concentration can be increased to 300 mg/dL due to stress (Evans 2011). This condition has also been observed in species of wild felids during capture procedures (Marco *et al.* 2000; García *et al.* 2010).

Bilirubin

This is a pigment produced by the degradation of the heme group of hemoglobin and myoglobin, and to a lesser extent by the degradation of porphyrins (Bain 2011). Elevated bilirubin values have been reported in certain species of trapped carnivores (Kreeger *et al.* 1990).

Electrolytes

Sodium

This is an extracellular electrolyte that maintains the osmolarity of extracellular fluid and is essential to the control of the hydration state. Hyponatremia has been reported in domestic carnivores as a result of intense exercise (Wright George and Zabolotzky 2011). The absorption of sodium by the proximal renal tubules through the action of catecholamines during the stress of capture can facilitate an increase in serum sodium (Kocan *et al.* 1981). Compared to different capture methods of wild carnivores, snares produce a more significant increase in sodium (Cattet *et al.* 2003; Marks 2010).

Potassium

This is an electrolyte found mostly in intracellular fluid. Although it is more common to observe elevations of this electrolyte in acid-base imbalances, hyperkalaemia may also be observed in cases where muscle degeneration or muscle necrosis occurs (Hall and Bender 2011). In cases of intense exercise, as it occurs in racing dogs, hypokalaemia may develop although the elimination route is not known in these cases (Wright George and Zabolotzky 2011).

Chlorine

This is the main anion of extracellular fluid and is a very important component of many secretions (e.g., gastric, saliva, sweat) (Wright George and Zabolotzky, 2011). Its levels have been found higher in physically immobilized animals than in those chemically immobilized (Peinado *et al.* 1993). In carnivores, the use of snares as a method of capture can cause higher levels of chlorine than when using trap cages (Marks 2010).

Behavioural mediators

The implementation of temporal and spatial analyses after capture and handling may expose some changes related to the stress experienced by the individual. Daily distances traveled during the first days following capture may be significantly lower than the average of the remainder of the telemetry follow-ups (Cattet *et al.* 2008; Santos *et al.* 2017). The psychological impact of trapping warrants further attention. The shorter distances traveled after the capture not only respond to a somatic base but also to psychological status, as it is recognized that post-traumatic stress disorder-like conditions can develop in animals, both in laboratory and free-living settings (Clinchy *et al.* 2011; Santos *et al.* 2017).

Conclusions

In today's research era, the use of informative physiological biomarkers can provide a new avenue for addressing the stress response of different capture methodologies. Most of these biomarkers are susceptible to the effects of human actions (e.g., noise, visual stimuli while approaching the trapped individual, handling) and anaesthesia, so data collected must be carefully interpreted. The analysis of the physiological changes must be carried out in conjunction with physical injuries and behavioral responses. The biomarkers discussed in this manuscript should be considered in any procedure involving the capture, transport, anesthesia, surgery, handling or any other manipulation of free-living carnivores under field conditions to assess the stress response and capture protocols, thereby avoiding severe physiological impacts that may have deleterious and long-lasting impacts on wildlife health and welfare.

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Chapter 14

Physiological and Behavioural Impact of Trapping for Scientific Purposes on European Mesocarnivores

Pedro MONTERROSO[1], Francisco DÍAZ-RUIZ[2], Pablo FERRERAS[3], and Nuno SANTOS[1]
[1]CIBIO/InBIO, Research Center in Biodiversity and Genetic Resources, University of Porto, Campus de Vairão, 4485-661 Vairão, Portugal. Email: nuno.santos@cibio.up.pt
[2]Biogeography, Diversity, and Conservation Research Team, Dept. Biología Animal, Facultad de Ciencias, Universidad de Málaga, Avda. Cervantes, 2, 29071 Málaga, Spain.
[3]Instituto de Investigación en Recursos Cinegéticos (IREC, CSIC-UCLM-JCCM), Ronda de Toledo, 12 13005 Ciudad Real, Spain.

Abstract − Wildlife trapping and handling entails multi-level consequences on captured individuals. These impacts may be expressed at the physiological and behavioural levels, starting at capture and potentially waning post-release over a variable period. We investigated the impact of trapping and handling on the physiological parameters of 6 species of southwestern European mesocarnivores from the families Canidae, Felidae, Mustelidae, Herpestidae, and Viverridae. These parameters were quantified in real time during the handling procedures, after the induction of chemical immobilization. Using a time-step approach, we further assessed the impact of trapping on the movement behaviour of a subsample of the mesocarnivores. A total of 195 mesocarnivores were captured with cage traps or neck snares, and aspects of their haematology, and blood chemistry parameters quantified in a subset of the cage-trapped animals. These biomarkers suggested mild dehydration, tissue damage, exertion, and activation of the immune response as consequences of live trapping. Eight European wildcats (*Felis silvestris*), 4 red foxes (*Vulpes vulpes*), and 4 stone martens (*Martes foina*) were also fitted with GPS-VHF radio-collars, and their movements tracked by conventional ground-based VHF and GPS telemetry. Movement behaviour was assessed as the mean distance to trapping sites over each week of monitoring and compared with the value under normal use of their home ranges (set as >13 wks post-capture). Our results showed evidence of reduced movements for up to 5 wks post-capture. Selected haematology, serum chemistry, anaesthesia monitoring, and movement behaviour parameters should become standard biomarkers of the reactive homeostatic response to live trapping, offering a finer comparison of live-capture techniques and protocols.

Introduction

Live capture is an essential tool in the research and management of free-ranging wildlife populations whenever non-invasive methods are not applicable (Bosson *et al.* 2012; Proulx *et al.* 2020). However, it induces an acute reactive homeostasis response in captured animals (Dantzer *et al.* 2014; Iossa *et al.* 2007). Effectively addressing and minimizing the acute response to trapping and handling is thus imperative on ethical, animal welfare, and conservation grounds (Proulx *et al.* 2020).

While live-trapping standards are in place, they mostly address the capture efficiency, selectivity, and clinical impacts of different models of live traps, as measured by pathological lesions assessed upon necropsy (Byrne *et al.* 2015; Proulx *et al.* 2020). Besides the injuries produced, sub-clinical effects of live trapping have been increasingly shown to affect not only wildlife welfare but also the scientific validity of research (Iossa *et al.* 2007; Cattet *et al.* 2008). Sub-clinical effects include reduced post-trapping movements (Santos *et al.* 2017), decreased body condition (Cattet *et al.* 2008), and breeding failures (Uher-Koch *et al.* 2015), among others (reviewed by Soulsbury *et al.* 2020).

Physiological biomarkers can be used to assess the reactive homeostasis response to live-trapping of wildlife (Powell and Proulx 2003; Marks 2010). Comprehensive panels of physiological biomarkers such as hormones and metabolites provide a finer approach to assess the sub-clinical impacts of live trapping, such as dehydration, activation of the immune system, and tissue and cellular damage (Powell and Proulx 2003; Cattet *et al.* 2008; Santos *et al.* 2017). Furthermore, behavioural biomarkers allow assessing the impact of the reactive homeostatic response to live-trapping on the medium-term fitness of captured animals. Movement was shown to be reduced for a variable period after capture in several carnivore species (Cattet *et al.* 2008; Santos *et al.* 2017). Furthermore, trapping was shown to influence space use on the vicinity of the capture site in the Egyptian mongoose *Herpestes ichneumon* (Travaini *et al.*, 1993).

This study aimed to investigate the impact of trapping and handling on some of the physiological parameters, measured under anaesthesia, of 6 species of southwestern European mesocarnivores from the families Canidae: red fox (*Vulpes vulpes*); Felidae: European wildcat (*Felis silvestris*); Mustelidae: stone marten (*Martes foina*), and European polecat (*Mustela putorius*); Herpestidae: Egyptian mongoose; and Viverridae: common genet (*Genetta genetta*). Furthermore, we assessed changes in the post-capture movement behaviour of 6 wildcats, 4 red foxes, and 4 stone martens fitted with GPS-VHF radio-collars.

Materials and Methods

Free-ranging mesocarnivores (*n*=195) from 6 species were captured between 2003−2017 across the Mediterranean ecoregion (Alcaraz *et al.* 2006) in the southwestern Iberian Peninsula (Figure 1): 79 red foxes, 37 Egyptian mongooses, 31 stone martens, 25 common genets, 20 European wildcats and 3 European polecats. Overall, the sample was evenly distributed between sexes (94 females and 100 males) but biased towards adults (119 adults vs. 42 subadults and 33 juveniles). Trapping was carried out throughout the year, including captures in all seasons (see seasons definition below).

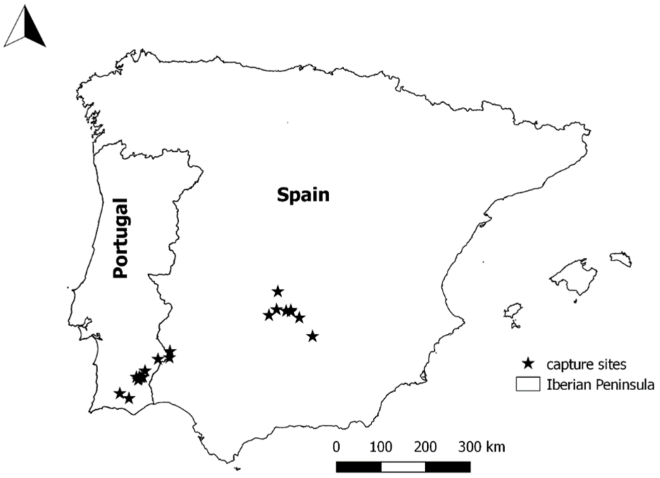

Figure 1. Location of the capture sites for the 195 mesocarnivores from 6 species in the Iberian Peninsula, 2013-2017.

The dataset here analyzed was generated in the scope of several unrelated studies on the ecology of mesocarnivores (Monterroso *et al.* 2009; Díaz-Ruiz *et al.* 2016; Santos-Silva *et al.* 2017; Ferreras *et al.* 2016; Santos *et al.* 2020) and further used to assess the sub-clinical impacts of trapping and handling. This approach follows the 3Rs principles of animal research applied to wildlife: *replacement* by non-invasive methodologies, *reduction* by maximizing the information obtained from each trapped animal, and *refinement* by using state-of-art trapping and handling methods (Lindsjö *et al.* 2016).

Trapping

Trapping was performed by 2 methods: i) cage-trapping, using double- and single-door cage-traps (Tomahawk ref. 109 106x38x38 cm and ref. 208 106x38x38 cm, USA, and VK1 ref. 150310 66x24x31 cm, Portugal, and 3 models of metal mesh traps between 95x45x50 cm to 152x45x50 cm, from Spanish suppliers, with mesh sizes between 20-52x15-52mm; and ii) neck-snaring with stop (Collarum® Fox model, Wildlife Control Supplies, EUA). Most animals were captured in the cage traps, except for 41 red foxes and 2 stone martens captured using Collarum neck snares. Several reward non-live or non-reward live baits, scent lures and their combinations were used as attractants. Traps were checked once or twice daily. No trap-alarms were available, so the time spent in trap is unknown. Whenever weather conditions were predicted to be extreme (maximum daily temperature >35ºC or total daily precipitation >10mm), cage traps and neck snares were deactivated to minimize exposure of the captured carnivores. Traps were always checked early in the morning and set as not to be easily detected by humans to minimize disturbance of the captured carnivores.

All trapping procedures were licensed by the nature conservation authorities Instituto de Conservação da Natureza e Florestas, Portugal (Licenses nr. 395/2011/CAPT/MANUS and 362/2012/CAPT/MANUS) and the Castilla-La Mancha Regional Government, Spain (Licenses nr. 02-227/RN-52, PREG-05-23, and PR-2013-05-04), according to Portuguese (Decreto-Lei 113/2013), Spanish (Real Decreto 53/2013) and European legislations (Directive 2010/63/EU) and followed international standards on the use of wild animals for scientific research (Sikes and Gannon 2011; Chinnadurai *et al.* 2016).

Anaesthesia

The protocol for the manipulation of trapped carnivores was previously described (Monterroso *et al.* 2009; Santos *et al.* 2020). Trapped carnivores were transferred to a restraint cage equipped with a sliding wall and covered with a dark blanket to reduce stimulus. All trapped carnivores were chemically immobilized by the intramuscular injection of ketamine (Imalgene®, Merial, France) and medetomidine (Domitor®, Merial, France) (Table 1). Immobilization was reversed by the intramuscular injection of atipamezole (Revertor®, Merial, France).

Table 1. Summary of anaesthesia for the 6 species of wild carnivores captured in the Iberian Peninsula: average ± SD dosage employed for each species, handling time from injection of anaesthetic drugs to injection of antidote, recovery time from injection of anaesthetic drugs to stationary.

Species	***n***	**Ketamine (mg/kg)**	**Medetomidine (mg/kg)**	**Handling time (min)**	**Atipamezole (mg/kg)**	**Recovery time (min**
Red fox (*Vulpes vulpes*)	79	4.17 ± 1.15	0.06 ± 0.02	35 ± 11	0.21 ± 0.13	65 ± 23
Egyptian mongoose (*Herpestes ichneumon*)	37	4.92 ± 5.38	0.17 ± 0.10	44 ± 12	0.75 ± 0.17	67 ± 18
Common genet (*Genetta genetta*)	25	7.05 ± 3.63	0.13 ± 0.05	53 ± 19	0.59 ± 0.24	94 ± 28
European wildcat (*Felis silvestris*)	20	3.78 ± 1.80	0.08 ± 0.04	31 ± 17	0.35 ± 0.20	46 ± 14
Stone marten (*Martes foina*)	31	10.0 ± 4.72	0.09 ± 0.08	29 ± 13	0.35 ± 0.12	65 ± 39
European polecat (*Mustela putorius*)	3	3.24 ± 0.17	0.06 ± 0.003	28 ± 4	0.27 ± 0.10	33 ± 3

The age of each animal was estimated by the dental eruption and wear, and classified as juveniles (deciduous teeth present), subadults (only permanent teeth, no wear detectable), or adults (slight to moderate wearing of the teeth) (Harris 1978; Anders *et al.* 2011). Gender was assessed by inspection of genitalia.

Sample collection and laboratory analyses

Blood samples were collected from a subset of the trapped mesocarnivores by venepuncture of the cephalic or saphenous veins, 4-54 min after administration of anaesthesia and preserved in EDTA (ethylenediaminetetraacetic acid) and clotting tubes, kept refrigerated and protected from sunlight and excessive agitation.

Whole blood in EDTA was analysed for 8 selected parameters (haematocrit, haemoglobin concentration, mean corpuscular volume, erythrocyte, leukocyte counts, neutrophile, and lymphocyte counts – Marks 2010). The microhematocrit technique was employed for the haematocrit, and the alkaline hematin technique for haemoglobin concentration (Lema *et al.* 1994). Blood cell counts were performed manually in a haemocytometer after staining with Natt and Herrick's solution, and the differential leukocyte count by identifying 200 leukocytes in Giemsa-stained blood slides (Voigt 2000).

Serum was analysed for 8 selected parameters (total protein, albumin, glucose, creatine kinase, aspartate aminotransferase, urea, sodium, and chloride – Marks 2010) in a commercial laboratory (Inno, Braga, Portugal) using a Sysmex XT-2000iV (Sysmex Corporation, Kobe, Japan) haematology analyser and a Mindray BS380 (Mindray Medical International Ltd, Shenzhen, China) clinical biochemistry analyzer.

Haematology and serum chemistry parameters were obtained from 69 animals (28 Egyptian mongooses, 16 red foxes, 14 European genets, 5 stone martens, 3 European wildcats, and 3 European polecats). Results are presented as the average and minimum-maximum values, as the low sample size does not allow to estimate reference ranges. All the mesocarnivores for which haematology and serum chemistry parameters were obtained were captured using cage traps, not allowing to compare the reactive homeostatic response between the 2 types of traps employed.

Telemetry

Eight European wildcats (3 adult males, 3 adult females, 2 subadult females), 4 red foxes (3 females, 1 male, all adults), and 4 stone martens (1 female, 3 males, all adults) were also fitted with species-specific radio-collars (88.6g for wildcat, 149.6g for red fox, 66.5g for stone marten). Six wildcats (2 adult males, 1 adult female and 2 subadult females) were tagged with VHF radio-collars (HLPM 3320, Wildlife Materials Inc., Murphysboro, Illinois, USA). Two adult wildcats (male and female), 4 foxes and 4 stone martens were tagged with VHF-GPS radio-collars (TGB-325315, TGB-318 and TGB-335, Telenax, Mexico).

Tagged animals were located by triangulation of VHF radio signal using directional antennas (4-element Telonicss, Mesa, Arizona, USA, model RA-14, and 3-element Yaggi antenna, Biotrack, Dorset, UK) and a portable receiver (Yaesus, Cypress, California, USA, model FT-290RII, and R-1000, Communications Specialists Inc., Orange, California, USA), and bearings were determined using either a lensatic or magnetic compass, or a handheld global positioning system unit equipped with electronic compass (GPSMap 60CS and E-Trex Summit, Garmin, Olathe, Kansas, USA). Triangulations were performed by a single researcher at different times of the day. Occasionally, tracking cycles were performed, during which animals were located at 1-h intervals between mid-afternoon and the end of the morning the following day. Triangulation consisted of at least 3 azimuths with an angle of no less than 30° between them, obtained within 15 min of each other (Kenward 2001). Additionally, locations were obtained from the GPS units once radio-collars were recovered from re-captured carnivores (*n*=8). Animals were located 7−90 times ($\bar{x}$ =33) by VHF method and 9−3,898 times ($\bar{x}$ =560) by GPS unit during radio-tracking periods of 45−275 d ($\bar{x}$=133 d).

Statistical analysis

The effect of trapping, anaesthesia, and handling on the haematology and serum chemistry parameters of mesocarnivores was assessed comparing their descriptive statistics with published reference ranges.

One-sample Wilcoxon signed rank test was used to test the differences between the median of the dataset and the measure of central tendency of the published reference ranges.

Reference ranges were not available for all parameters and species, and were established mostly from samples collected from captured animals, thus also incorporate the effect of capture. To minimize this effect, we privileged the use of reference ranges obtained from captive animals (Fowler *et al.* 1986; Kreeger *et al.* 1990a; Wolf 2009; Marco *et al.* 2000; Hein *et al.* 2012; ZIMS 2018), or from shot free-ranging animals (Marks 2010). We expected the impact of capture to be attenuated in captive animals as these are easily accessible, and somewhat habituated to human presence, although their management in captivity could influence the results (Kreeger *et al.* 1990b). Shot animals probably provide the best approximation to normal values of the physiological biomarkers (Kreeger *et al.* 1990b; Marks *et al.* 2010).

The effect of trapping on movement behaviour of captured individuals was assessed separately for each species using log-linear mixed models with 'distance' of each location to the capture site as the dependent variable, 'individual' animal as a random effect, and 'sex', 'age', 'season', and 'week' since capture as categorical fixed effects. The variables 'age' and 'season' were only included in the European wildcat models, as for the other species only adults were trapped during 1 season (spring).

Models including all these variables and their interactions were compared under an information-theoretical approach and the most supported model was selected by the AICc (Burnham and Anderson 2002). All the independent variables showed Pearson correlations <0.6 between them.

The packages "lme4" (Bates *et al.* 2014), and "ggplot2" (Wickham 2016) in R 3.6.1 (R Development Core Team 2021) were used. The marginal and conditional R2 of the models were estimated according to Nakagawa and Schielzeth (2013) implemented in the package "MuMIn" (Bartoń 2015).

Results

Physiology

Trapped mesocarnivores showed evidence of mild dehydration, as a tendency for the serum concentrations of total protein, albumin, and urea to be higher than the published reference ranges for captive animals of the same species (Figure 2). These tendencies were statistically significant in the red fox.

Tissue damage, particularly suggestive of myocyte injury, was consistent with the elevated serum concentrations of creatine kinase and aspartate aminotransferase in trapped carnivores of the 2 species for which reference values were available (Figure 3). These tendencies were statistically significant in the red fox.

A non-significant tendency for lower erythrocyte counts and higher mean corpuscular volume in all species for which reference values are available is consistent with the increased physical exertion of trapped mesocarnivores (Figure 4). Changes in haemoglobin and glucose concentrations were inconsistent across species.

A stress leukogram pattern comprising leukocytosis, neutrophilia, lymphopenia, and eosinopenia was present in all the species for which reference values were available (Figure 5). The differences were only significant in the species with larger sample size, the red fox and Egyptian mongoose.

Movement behaviour

The only species for which a significant effect of the weekly distance to the capture site was found was the European wildcat (Table 2). The European wildcat selected model yielded a conditional R^2=0.684, with the fixed effects accounting for most of the variation (marginal R^2=0.447). Controlling for the effect of the individual European wildcat, sex, and season, the distance from the capture site was significantly lower than in the reference class on the 3rd to 5th week post-capture (Table 3 and Figure 6).

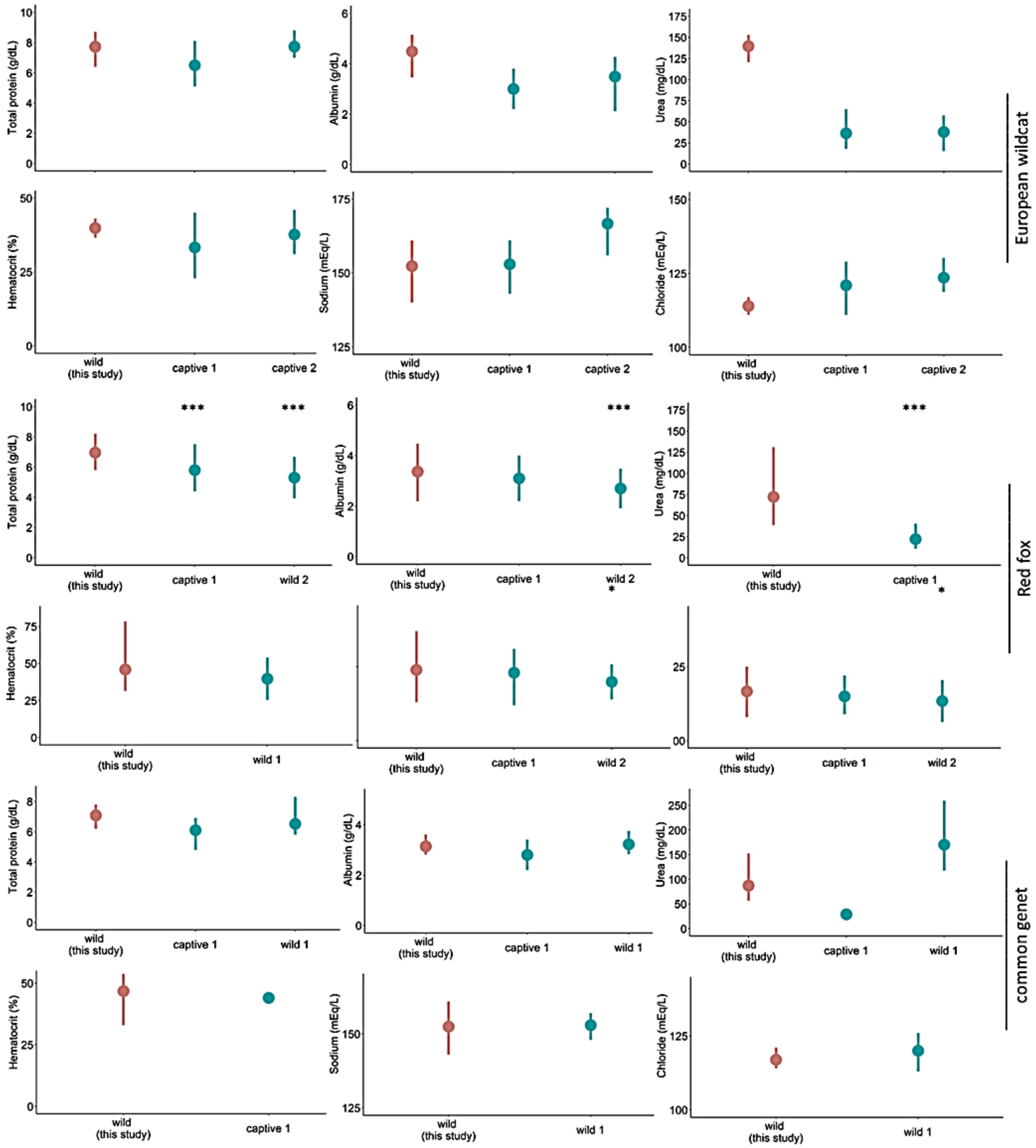

Figure 2. Physiological biomarkers of dehydration in the European wildcat, red fox, and common genet. Mean and range from this study (red), mean and reference range from captive and wild animals (blue). Captive 1: ZIMS (2018); captive 2: Marco *et al.* (2000) for the European wildcat; wild 2: Marks (2010) for the red fox, Millán *et al.* (2015) for the common genet.

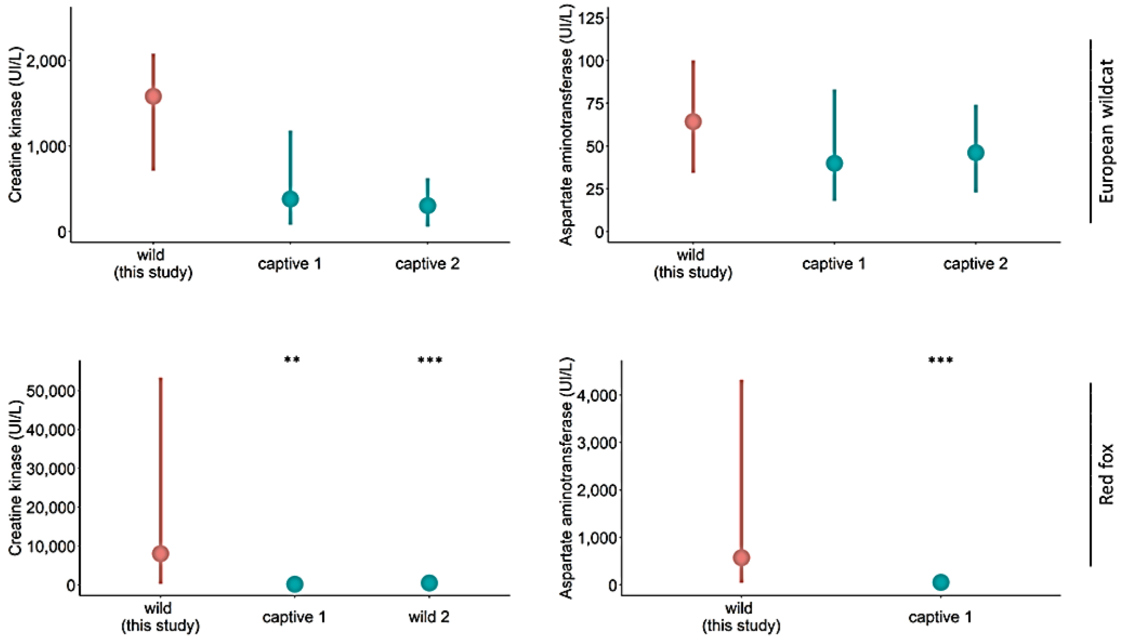

Figure 3. Physiological biomarkers of tissue damage in the European wildcat and red fox. Mean and range from this study (red), mean and reference range from captive and wild animals (blue). Captive 1: ZIMS (2018); captive 2: Marco *et al.* (2000) for the European wildcat; wild 2: Marks (2010) for the red fox.

Discussion

We characterised the homeostatic response to live-trapping and handling procedures on wild European mesocarnivores. We found evidence of sub-clinical impacts on physiological parameters suggestive of mild dehydration, tissue damage, exertion, and activation of the immune system on some of the species studied. Additionally, we found support for restricted movement patterns, likely related to trapping, for one of the species.

Across species, the serum concentrations of total protein, albumin, and urea tended to be elevated compared to the reference range from captive animals of the same species, suggesting dehydration. The differences were only statistically significant in the red fox, possibly due to the larger sample size in this species, although the tendency is similar across species. The haematocrit and serum concentrations of sodium and chloride were within the reference ranges, further suggesting the dehydration was mild (Ilkiw *et al.* 1989). The high serum urea concentration observed could also be caused by higher protein ingestion in the wild compared to captive mesocarnivores (Santos *et al.* 2020).

The serum concentrations of creatine kinase and aspartate aminotransferase tended to be higher than in captive conspecifics, sometimes markedly so, supporting that some degree of tissue damage was associated to the capture and handling protocol employed. While aspartate aminotransferase is found in many tissues, creatine kinase is fairly specific to myocytes (Takagi *et al.* 2001), suggesting the injuries occur mostly in the muscle tissue. Minor physical injuries were observed in the captured carnivores, mostly abrasions and superficial lacerations. Again, the differences were only statistically significant in the red fox (*n*=16), but not in the European wildcat (*n*=3).

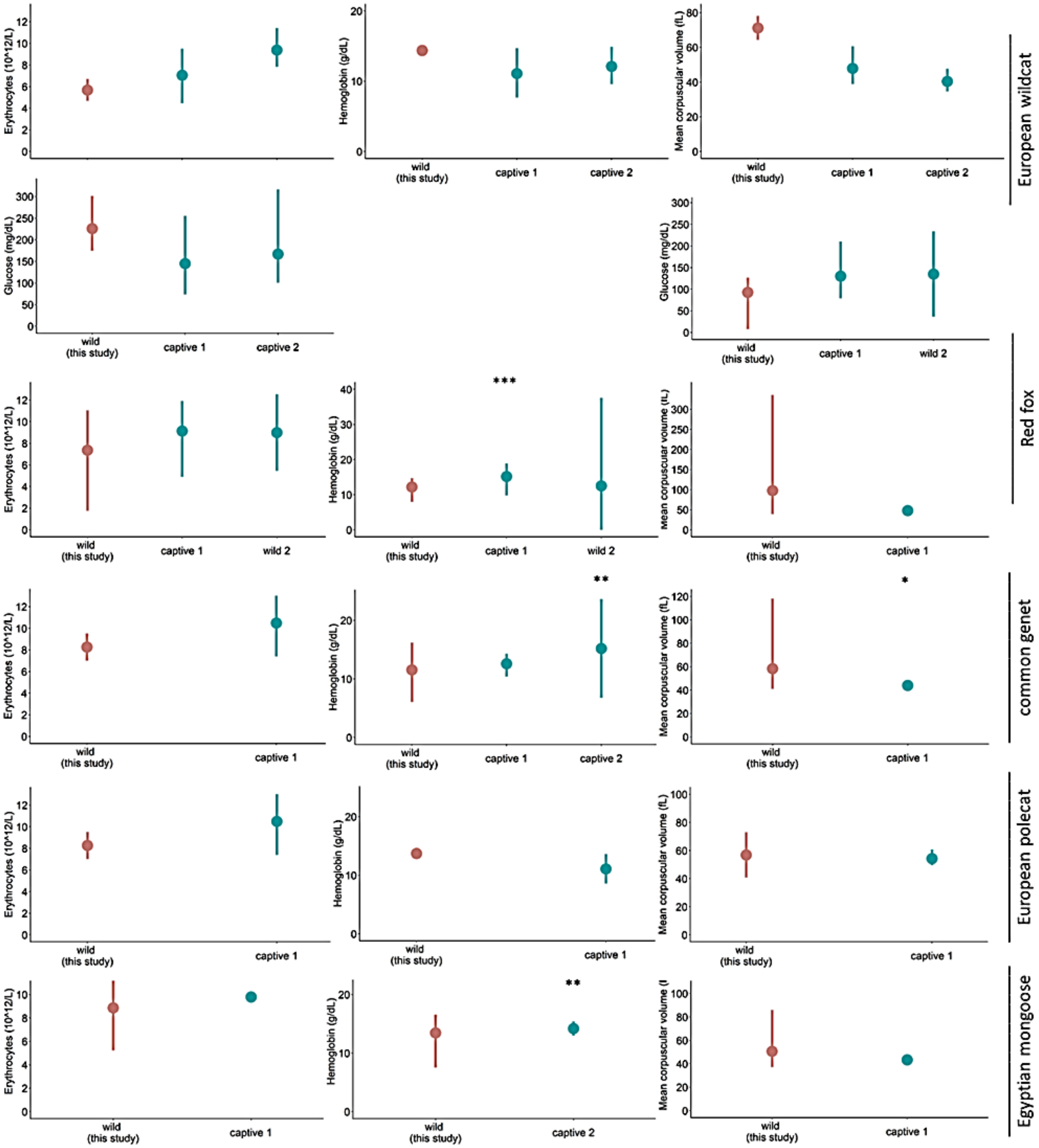

Figure 4. Physiological biomarkers of exertion in the European wildcat, red fox, common genet, European polecat, and Egyptian mongoose. Mean and range from this study (red), mean and reference range from captive animals (blue). Captive 1: ZIMS (2018) for all species except the European polecat (Wolf 2009) and Egyptian mongoose (Fowler *et al.* 1986); captive 2: Marco *et al.* (2000) for the European wildcat, Marks (2010) for the red fox, Hein *et al.* (2012) for the European polecat.

The erythrocyte count and mean corpuscular volume of trapped mesocarnivores tended to be lower than in captive conspecifics, although the differences were not statistically significant for any of the species for which reference ranges are available. Physical exertion induces oxidative stress in erythrocytes, which can lead to haemolysis and shrinkage of the erythrocytes (Van Beaumont *et al.* 1981; Oztasan *et al.* 2004). Haemoglobin and glucose concentration showed no clear pattern across species when compared to the reference ranges.

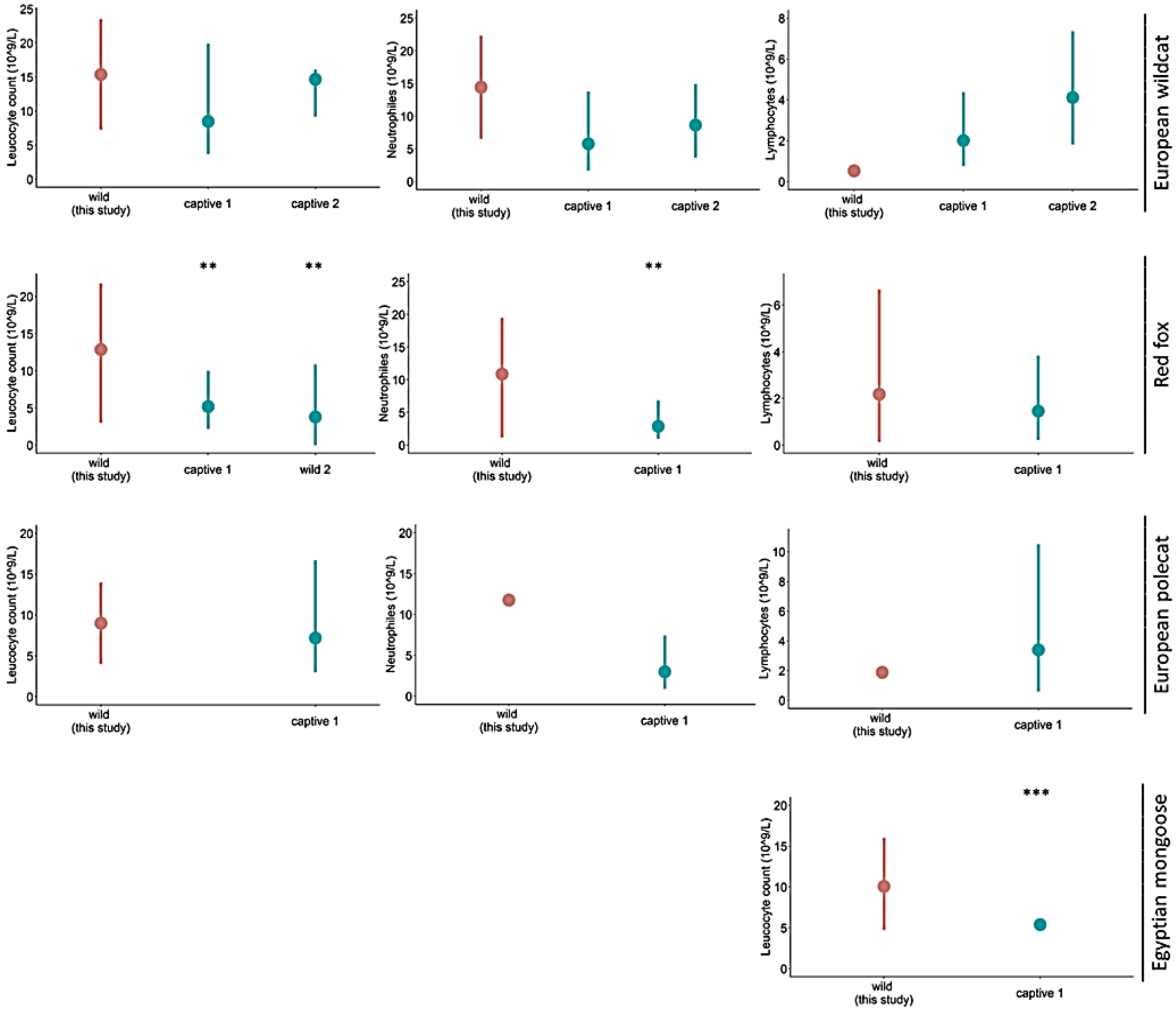

Figure 5. Physiological biomarkers of immune system activation in the European wildcat, red fox, European polecat, and Egyptian mongoose. Mean and range from this study (red), mean and reference range from captive animals (blue). Captive 1: ZIMS (2018) for all species except the European polecat (Wolf 2009) and Egyptian mongoose (Fowler *et al.* 1986); captive 2: Marco *et al.* (2000) for the European wildcat, Marks (2010) for the red fox, Hein *et al.* (2012) for the European polecat.

All mesocarnivore species for which reference ranges were available showed a stress leukogram, with leukocytosis and neutrophilia. The differences were statistically significant only for the species with larger sample size, the red fox and Egyptian mongoose.

We acknowledge that management under captivity in the carnivores used as reference might introduce bias in this analysis, as captive animals usually have access to food and water ad libitum and do not need to exercise as much as wild conspecifics. Although there is no way to control for this potential bias, the differences reported are likely informative and a reasonable approach to assess the sub-clinical effect of trapping on wild animals. The time carnivores spend on the trap can influence the reactive homeostatic response, as shown in other species (Santos *et al.* 2017). Unfortunately, this determinant of the physiological response to trapping could not be assessed in our sample, as no trap-alarms were available, and traps were checked once or twice daily. Furthermore, other factors, such as the anaesthesia protocol employed (Caulket and Arnemo 2015), can influence the physiological parameters analysed, making the interpretation of the observed patterns particularly challenging and somewhat ambiguous. The lack of published reference ranges for some species further impairs the general use of physiological parameters in the assessment of the homeostatic response to trapping in wildlife. It is necessary to make datasets of individual carnivores' physiological parameters publicly available, including fully characterized capture protocols, allowing the formal statistical analyses to assess differences between wild and captive animals and compare capture techniques and protocols.

We also report evidence suggestive of a negative effect of capture on the movement behaviour of the European wildcat. Trapped European wildcats tended to stay closer to the trapping site on the first few weeks post-capture, particularly on the 3rd-5th weeks, compared to the reference period (13th week onwards). This effect might be due to the physiological impacts of capture, such as the muscle injuries suggested by the physiology results. Minor physical injuries were observed on some of the captured carnivores, mostly abrasions and superficial lacerations, but not on those fitted with telemetry collars. Given that carnivores in our sample were followed by a mix of conventional VHF and GPS telemetry, we could not use more sensitive measures of movement behaviour, such as daily distances travelled or home range size, relying instead on an admittedly crude measure (distance to the trapping site). Nevertheless, the results generally agree with those on other species of carnivores showing reduced movement for some time after trapping (Cattet *et al.*, 2008; Santos *et al.*, 2017; Gese *et al.*, 2019). Together, these observations suggest that the impact of capture on movement behaviour might be pervasive under current trapping and handling procedures.

Table 2. Model selection of movement behaviour for each species. 'Individual' carnivore included as random effect. Only models with ΔAICc<2 from the most supported and the null model are shown. Random effects included in all the models.

Species	**Model**	**Fixed effects**	**df**	**AICc**	**ΔAICc**	**Model weight**
European wildcat	1	Intercept + season + sex + week	18	670.9	0	0.218
	2	Intercept + season + sex	5	671.4	0.54	0.166
	3	Intercept + sex + week	17	672.5	1.58	0.099
	4	Intercept + age + season + sex + week	19	672.5	1.62	0.097
	5	Intercept	3	678.1	7.16	0.006
Red fox	1	Intercept	3	1,399.5	0	0.694
	2	Intercept + sex	4	1,401.2	1.64	0.306
Stone marten	1	Intercept + sex	4	98.3	0	0.679
	2	Intercept	3	99.8	1.50	0.321

Table 3. Summary of the selected model of the distance to capture site for the European wildcat. 'Individual' carnivore included as random effect. 'Female', 'spring' and 'week>13th' as reference classes. Significant effects in bold.

Fixed effects	**β**	**Standard error (β)**	**95% confidence interval (β)**		**df**	***P*-value**
			Low	**High**		
Intercept	7.843	0.381	7.096	8.591	5.264	**<0.001**
Sex						
Male	0.879	0.348	0.196	1.562	4.958	0.053
Season						
Summer	-0.835	0.389	-1.597	-0.073	4.958	0.085
Week since capture						
1st	-0.255	0.134	-0.517	0.007	363.9	0.057
2nd	-0.147	0.149	-0.439	0.145	364.3	0.325
3rd	-0.623	0.145	-0.907	-0.339	363.5	**<0.001**
4th	-0.739	0.151	-1.034	-0.443	362.9	**<0.001**
5th	-0.587	0.187	-0.953	-0.220	361.9	**0.002**
6th	-0.260	0.230	-0.709	0.190	362.5	0.259
7th	0.172	0.322	-0.458	0.802	361.7	0.593
8th	-0.076	0.224	-0.515	0.363	360.2	0.734
9th	-0.103	0.213	-0.520	0.313	361.3	0.627
10th	0.156	0.208	-0.251	0.563	363.0	0.453
11th	0.209	0.170	-0.125	0.543	363.2	0.221
12th	0.009	0.138	-0.262	0.280	361.5	0.947
13th	-0.033	0.148	-0.323	0.256	360.6	0.821

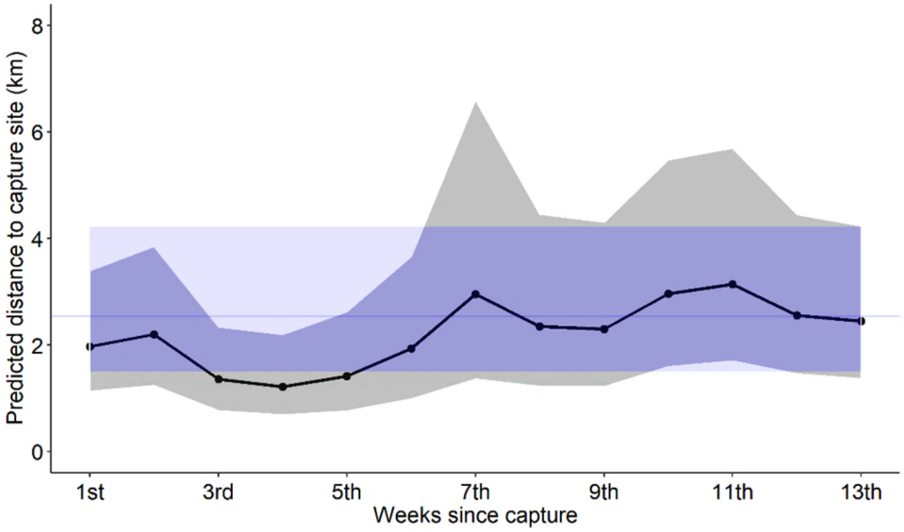

Figure 6. Predicted weekly distance to the capture site for the European wildcat. Average weekly distance of locations to the capture site with 95% confidence interval (grey) predicted by the log-linear mixed model controlling for the individual carnivore, sex, and season. Average weekly distance of locations to the capture site from the 13th week onwards with 95% confidence interval (blue).

The collation of datasets generated in various unrelated studies and their analysis for a different purpose, following the 3R's *Reduction* principle, allowed to characterize the homeostatic response to live-trapping, anaesthesia, and handling of 6 species of wild mesocarnivores. Nevertheless, the collation of data collected in unrelated studies on the ecology of mesocarnivores has drawbacks, e. g., physiological biomarkers were not available for all the captured animals, and do not allow to compare the types of traps employed. Overall, physiology and behaviour biomarkers suggest mild dehydration, tissue damage, exertion, and activation of the immune response as potential sub-clinical consequences of live trapping for research purposes. Such consequences might be integral to trapping wild animals, but the responses might vary between trapping protocols, underlining the need for further studies specifically on this subject.

Selected haematology and serum chemistry parameters should become standard biomarkers of the reactive homeostatic response to trapping. Other biomarkers could be useful for this purpose, particularly fecal glucocorticoid metabolites which reflect the activation of the hypothalamic–pituitary–adrenal axis in a timeframe compatible with the time carnivores spend on trap. Furthermore, detailed analyses of movement behaviour could be used to evaluate the short-term fitness consequences of live trapping, whenever the animals are followed by telemetry. These biomarkers could provide a finer comparison of different live capture techniques and protocols, following the 3R's *Refinement* principle.

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Chapter 15

Assessing Welfare while Capturing Free-ranging Sunda Clouded Leopards (*Neofelis diardi*) with Cage-traps: Effects of Physical Restraint on Serum Biochemistry

Fernando NÁJERA[1,2,3,4] and Andrew J. HEARN[3]
[1]The Bornean Wild Cats Veterinary Project, Department of Animal Physiology, Faculty of Veterinary Medicine, Complutense University of Madrid 28040, Madrid, Spain
[2]Current address: Saint Louis Zoo Institute for Conservation Medicine/ Saint Louis Zoo WildCare Institute, One Government Drive, Saint Louis, MO, 63110, USA. Email: fernanaj@ucm.es
[3]Wildlife Conservation Research Unit (WildCRU), Department of Zoology, University of Oxford, Oxford, OX13 5QL, UK
[4]Current address: Living Earth Collaborative, Washington University, Saint Louis, MO, 63110, USA

Abstract − Live capture of Sunda clouded leopards (*Neofelis diardi*) for research purposes is essential to provide much needed insights into this threatened species' ecological needs, but such invasive work may have unintended consequences on the captured animal's health. In this study, we undertook a health evaluation of 6 Sunda clouded leopards that were captured in cage-traps in Malaysian Borneo. To explore the potential negative effects on the animal's physiology, we obtained blood samples and used selected serum enzymes as capture-stress-related biomarkers, related to exercise rhabdomyolysis or traumatic injury to muscular tissue, and compared these values with those obtained from a control group of captive individuals. Of the biochemical parameters measured, only aspartate aminotransferase showed statistically significant differences with the control. The extreme elevation of this enzyme found in the captured individuals is closely related to muscle damage after prolonged and intense exercise while trying to escape. Another enzyme predominantly presented in skeletal muscle, creatinine kinase, suffered a marked elevation, although the difference with the control was not significant. Our cage-traps appear to offer a safe and reliable method for capturing Sunda clouded leopards as they do not cause physical injury. However, the time of restraint in the traps is considered to negatively influence some serum biochemistry parameters that may lead to serious physiological consequences. Although our small sample size limits our ability to formulate extensive recommendations, we conclude that those capturing felids in remote locations should utilize trap monitors to decrease the restraining time. We recommend that future research involving Sunda clouded leopards use this approach to assess the safety of their capture methods, to further refine and improve the capture of these felids.

Introduction

The Sunda clouded leopard (*Neofelis diardi*) is an elusive, medium-sized felid that inhabits the islands of Borneo and Sumatra. The International Union for Conservation of Nature categorizes this species as Vulnerable, and the Bornean subspecies (*N. diardi borneensis*) as Endangered, due to habitat loss and fragmentation and direct exploitation (Hearn *et al.* 2008, 2015), yet it remains as one of the least studied pantherine felids. Its ecology and biology are poorly known, hampering the development of conservation management efforts (Hearn *et al.* 2013). Live capture and chemical restraint of Sunda clouded leopards for research purposes is deemed essential to provide much needed insights into this species' ecological needs. To date, few attempts have been made to capture this species in situ, and there is a lack of information regarding the impacts of different capture approaches with which to develop best practices.

As a result of their efficacy, low cost and availability, cage-traps are widely used by researchers to capture wild cats, and a variety of designs are now used (e.g., Shindle and Tewes 2000; Kolbe *et al.* 2003; Grassman *et al.* 2004; Nájera *et al.* 2014, 2017). Although they are extensively utilized, the effects on the physiology of trapped felids remain unclear. Researchers frequently make judgements regarding the safety of such capture devices by examination of external injuries, and although scoring trap-related injuries and monitoring survival may reveal some relative differences in extreme welfare outcomes, trap injury and reduced survival caused by the capture methodology are endpoints of poor trapping welfare (Marks 2010).

To study the reactive homeostasis response during trapping procedures, certain hematological and serum biochemistry parameters may be used as stress indicators. Within the serum biochemistry stress mediators, the following intracellular serum enzymes are also considered muscle damage indicators: lactate dehydrogenase, aspartate aminotransferase and creatine kinase (Nielsen 1999; Fernández-Morán 2003; Nájera *et al.* 2014).

The effects of capture on serum biochemistry parameters have been intensively explored in certain carnivore taxa (e.g., canids, ursids), and the use of selected serum enzymes have aid in the diagnosis of exertional myopathy in fed red fox (*Vulpes vulpes*, Kreeger *et al.*, 1990), coyote (*Canis latrans*), American badger (*Taxidea taxus*) and black-footed ferret (*Mustela nigripes*) (Williams and Thorne 1996), northern river otter (*Lutra canadensis*; Hartup *et al.* 1999), mountain lion (*Puma concolor*, Wolfe and Miller 2005), and grizzly bear (*Ursus arctos*, Cattet *et al.* 2008a)

In this study, we explore the effect of trapping free-ranging Sunda clouded leopards by examining selected serum enzymes as capture-stress-related biomarkers, related to exercise rhabdomyolysis or by traumatic injury to muscular tissue while confined in the traps, and compared these values with those obtained from a control group of captive individuals.

Methods

Free-ranging clouded leopards (*n*=6; 3 females and 3 males) were captured during intermittent live-trapping operation periods in Sabah, Malaysian Borneo, between January 2008 and March 2014. Steel-mesh cage traps (2.5 × 1 × 1 m) were deployed in the Danum Valley Conservation Area/Ulu Segama Forest Reserve (N 4° 58', E 117° 46' / N 4° 59', E 117° 52') and the Lower Kinabatangan Wildlife Sanctuary (N 5° 24', E 118° 02') (Hearn *et al.* 2013; Nájera *et al.* 2017). Cage traps were located in areas where previous activity of clouded leopards had been recorded via camera-traps, and traps were camouflaged and protected from direct sunlight and rain whenever possible. Cage traps were monitored daily at first light, to minimise holding times. Wild-born, captive clouded leopards (*n*=6; 3 females and 3 males), housed at wildlife rescue centers (*n*=4) or zoos (*n*=2) in Malaysia and Indonesia, were used as control group. Both wild and captive clouded leopards were anesthetised with a mixture of medetomidine-ketamine or tiletamine-zolazepam delivered via dart (Nájera *et al.* 2017). This research, including the capture and handling protocols, was reviewed and approved by the Sabah Biodiversity Council, the Sabah Wildlife Department and the Department of Animal Physiology, Faculty of Veterinary Medicine, Complutense University of Madrid); (Permit reference number: BVP/PLI/12011/CDAUN0414812/1; Access license: JKM/MBS.1000-2 t2(9s)).

Blood samples for the serum biochemistry studies were obtained using 21-G needles attached to 5 mL disposable syringes. Venipuncture sites included jugular vein, cephalic vein and saphenous vein. Up to 12 ml were collected in etilendiaminotetracetic (EDTA), lithium-heparin-coated and serum (plain) tubes. Samples were kept at ±8ºC until processed, and all the samples were processed within 24 h. For the study of serum biochemistry, blood collected in lithium-heparin coated and plain tubes was centrifuged at 2500 rpm for 15 min, and the obtained plasma and serum was placed into eppendorf tubes and kept at ±8ºC until it was processed in a commercial laboratory (Gribbles Pathology, Sarawak/Sandakan, Malaysia). The clinical analyzer ADVIA 2400 Clinical Chemistry System (Siemens Healthcare, Erlangen, Germany) was utilized to obtain serum biochemistry values and the ISE Electrolyte Analyzer (Toa Medical Electronics, Hamburg, Germany) was used for the ion analysis. Cortisol was measured in a subset ($n= 4$) of the samples using the ADVIA Centaur XP Cortisol Assay analyzer (Toa Medical Electronics, Hamburg, Germany).

For the serum biochemistry study, mean, standard deviation and range was calculated for each of the parameters obtained and a Shapiro-Wilks test was used to test if they were distributed normally. To detect significant differences between origins (captive vs. free-ranging), data that did not follow a normal distribution were analyzed with the Mann-Whitney *U*-test. Normal distributed data were analyzed using Student's *t*-test (two-tailed, $P< 0.05$). Statistical analyses were performed with SAS 9.3 (SAS Institute, Cary, NC, USA).

During the physical examination, all individuals were considered healthy, and no abnormalities were observed which could affect the serum biochemistry values, therefore we included every sample in the study.

Results

None of the captured individuals showed external injuries due to capture. The results of 21 biochemical parameters are shown in Tables 1 and 2. Of the parameters tested, only the aspartate aminotransferase (AST) was found to be statistically significant, with cage-trapped levels up to 10 times higher than those in the control group. Another enzyme predominantly presented in skeletal muscle, creatinine kinase, suffered a marked elevation, although the difference with the captive population was not significant. Clouded leopard males presented higher CK values than females (males: 420.8±127.8 U/L, range 286-548; females: 293.3±209.4 U/L, range 106-521), although this difference was not statistically significant (Table 2).

Discussion

We present the first reference values for the serum biochemistry of Sunda clouded leopards, for both captive and free-ranging animals. Thus, despite the small sample size, the results obtained in this study represent the first insight into the serum biochemistry of this species and the potential negative effect on the animal's physiology resulting from restraint in live traps.

Most of the serum biochemistry values described in this study are found within the normal reference range for the mainland clouded leopard (Teare 2002), domestic cat (Bush 1991; Jain 1993; Kaneko *et al.* 1997; O'Brien *et al.* 1998), or other wild felid species (Hawkey and Hart 1986; Marco *et al.* 2000; García *et al.* 2010). Some of the differences observed in the serum biochemistry values on this study may be explained due to individual variations, sample size and/or capture methodology. As described in other wild felid species, differences may also be explained depending on the species variability, muscle damage, muscle mass, stress or nutritional or reproductive conditions (Garcia *et al.* 2010). It is important to highlight that our captive data may not necessarily represent a true baseline, since all captive individuals were wild-born, and held in often sub-optimal conditions that may have resulted in elevated stress levels. This could explain the lack of significant differences of some of the parameters.

Aspartate aminotransferase was the only muscular enzyme found to be statistically significant from the control, with cage-trapped levels up to 10 times higher than those in the control group. The substantial elevation of this enzyme could be a result of muscle damage during the capture and handling procedure, as has previously been reported in research on several wild cat species (Beltrán *et al.* 1991; Weaver and Johnson 1995; García *et al.* 2010; Nájera *et al.* 2014) and other wild carnivores (Cattet *et al.* 2008b). Since

Table 1. Serum biochemistry values[a] [*n*] reported for captive and free-ranging Sunda clouded leopard (*Neofelis diardi*).

	Captive		**Free-ranging**		***P***
Parameter (unit)	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	
Cholesterol (mg/dL)	38.85(±16.34)[6]	18.36-55.8	44.1(±4.28) [4]	41.4-50.4	0.91
Sodium (mEq/L)	151.7(±1.37) [6]	150-154	149(±5.79) [5]	139-153	0.78
Potassium (mMol/L)	4.67(±0.39)[6]	4-5.1	4.28(±0.28) [5]	4-4.7	0.17
Chloride (mEq/L)	119.0(±2.83)[6]	115-122	113.2(±3.49) [5]	110-119	0.06
Urea (mg/dL)	116.7(±57.87)[6]	50.4-187.2	107.1(±15.49) [6]	86.4-127.8	0.81
Creatinine (mg/dL)	2(±0.22)[6]	1.61-2.21	1.57(±0.5) [6]	1-2.35	0.15
Uric Acid (mg/dL)	0.45(±0.31)[4]	0.18-0.9	64.62(±144) [5]	0.28-322.2	0.6
Calcio (mg/dL)	9.61(±0.29)[4]	9.3-9.94	8.89(±0.67) [4]	8.02-9.62	0.15
Phosphate (mg/dL)	6.45±1.25)[4]	4.64-7.33	5.9(±0.65) [4]	5.54-6.87	0.47
Total Protein (g/dL)	7.85(±0.33)[6]	7.4-8.2	8.27(±0.59) [6]	7.5-9.3	0.1
Albumin (g/dL)	3.5(±0.7)[6]	2.7-4.2	2.53(±1.3) [6]	1-3.8	0.19
Globulin (g/dL)	4.32(±0.58)[6]	3.7-5.2	5.77(±1.38) [6]	4.4-7.4	0.1
AP (U/L)	26.83(±11.18)[6]	17-46	21.67(±11.89) [6]	9-35	0.4
Total bilirubin (uMol/L)	2.18(±1.17)[6]	1-4	3.66(±3.71) [5]	2-10.3	0.9
GGT (U/L)	5.83±6.27)[6]	1-18	4.2(±2.17) [5]	3-8	0.8
AST (U/L)	28.5(±11.81)[6]	16-49	117.8(±139.6) [6]	48-401	*0.02
ALT (U/L)	56.83(±26.39)[6]	40-110	70.50(±38.93) [6]	30-142	0.3
CK (U/L)	247(±228)[3]	106-510	423(±113) [5]	286-548	0.2
LDH (U/L)	241.7±(123)[3]	134-376	691.4(±336.5) [5]	396-1102	0.07
Glucose (mg/dL)	122.0(±11.47)[4]	106.2-133.3	118(±72.06) [4]	70.2-225.2	0.3
Cortisol (ug/dL)	24.3(±4.75)[4]	17.3-27.8	35.53(±12.64) [4]	19.2-48.4	0.2

[a] Values reported as mean, standard deviation in round brackets, sample size in square brackets. ALT: alanine aminotransferase, AST: aspartate aminotransferase, AP: alkaline phosphatase, GGT: gamma glutamyl transferase, CK: creatinine kinase, LDH: lactate dehydrogenase. * Parameter statistically different (P≤0.05)

Table 2. Serum biochemistry values[a] [*n*] reported by sex for Sunda clouded leopard (Neofelis diardi).

	Males		**Females**		***P***
Parameter (unit)	**Mean (± SD)**	**Range**	**Mean (± SD)**	**Range**	
Cholesterol (mg/dL)	41.49(±16.52)[4]	18.36-55.8	40.57(±11.27)[6]	18.54-50.4	0.9
Sodium (mEq/L)	151.2(±1.48) [5]	149-153	149.8(±5.46) [6]	139-154	0.85
Potassium (mMol/L)	4.74(±0.27)[5]	4.4-5.1	4.28(±0.35) [6]	4-4.9	0.09
Chloride (mEq/L)	115.8(±4.32)[5]	111-122	116.8(±4.54) [6]	110-122	0.78
Urea (mg/dL)	112.8(±41.38)[6]	50.4-176.4	111(±43.94) [6]	55.8-187.2	0.93
Creatinine (mg/dL)	2.02(±0.33)[6]	1.4-2.35	1.55(±0.42) [6]	1-2.09	0.09
Uric Acid (mg/dL)	0.41(±0.34)[4]	0.18-0.9	64.66(±144) [5]	0.18-322.2	0.89
Calcio (mg/dL)	9.34(±0.47)[3]	8.82-9.74	9.2(±0.73) [5]	8.02-9.94	1
Phosphate (mg/dL)	6.5 (±0.9)[3]	5.54-7.33	5.98(±1.05) [5]	4.64-5.21	0.77
Total Protein (g/dL)	7.88(±0.31)[6]	7.5-8.2	8.23(±0.63) [6]	7.4-9.3	0.28
Albumin (g/dL)	3.05(±1.09)[6]	1-4	2.98(±1.24) [6]	1-4.2	1
Globulin (g/dL)	4.85(±0.94)[6]	4-6.6	5.23(±1.59) [6]	3.7-7.4	0.81
AP (U/L)	22.83(±14.5)[6]	9-46	25.67(±8.21) [6]	12-34	0.63
Total bilirubin (uMol/L)	1.60(±0.55)[5]	1-2	3.9(±3.23) [6]	2-10.3	0.05
GGT (U/L)	7.40(±6.58)[5]	1-18	3.17(±0.41) [6]	3-4	0.34
AST (U/L)	50.5(±23.21)[6]	22-90	95.83(±150.4) [6]	16-401	0.87
ALT (U/L)	46.50(±9.52)[6]	30-58	80.83(±39.07) [6]	40-142	0.11
CK (U/L)	420.8(±127.8)[4]	286-548	293.3(±209.4) [4]	106-521	0.49
LDH (U/L)	718.3±(386)[4]	697.5-1102	327.3(±191.3) [4]	134-561	0.34
Glucose (mg/dL)	137.3(±61.88)[4]	84.6-225.2	102.7(±26.55) [4]	70.2-126.1	0.49
Cortisol (ug/dL)	23.9 (±7.06)[4]	17.3-32.6	35.93(±10.97) [4]	25.7-48.4	0.23

[a] Values reported as mean, standard deviation in round brackets, sample size in square brackets. ALT: alanine aminotransferase, AST: aspartate aminotransferase, AP: alkaline phosphatase, GGT: gamma glutamyl transferase, CK: creatinine kinase, LDH: lactate dehydrogenase.

AST levels remain elevated in blood longer than CK, we assumed that AST values would better reflect severe muscle damage, since clouded leopards could be trapped for long hours; some of them were confined in the traps for times up to 15 h (Latimer *et al.* 2003; Cattet *et al.* 2008b).

The marked elevation registered for AST was associated with an elevation in CK in every wild-caught individual. This enzyme represents a reliable diagnostic marker for muscle damage in humans and animals (Latimer *et al.* 2003; Krefetz and McMillin 2005; Cattet *et al.* 2008b). Although not statistically significant, the free-ranging group presented higher values in all individuals, probably due to the physical exertion that free-ranging clouded leopards experienced while trying to escape from the traps (Figure 1). We hypothesized that free-ranging male clouded leopards present higher CK than captive clouded leopards since they are under intense physical activity due to the control of their territories, which also may explain the difference in this enzyme. In addition, clouded leopard males presented higher CK values than females (Table 2). Sunda clouded leopards exhibit substantial sexual dimorphism; males are typically about 200% the weight of females (Hearn *et al.* 2018), and present higher muscular development

Figure 1. Sunda clouded leopard captured in a cage trap trying to escape.

The highest value of CK found within the captive group belongs to a male that needed several venipunctures in order to obtain the required quantity of blood for the analysis. Its high CK could then be explained, in part, by the contamination of blood with intracellular fluid from skeletal muscle during venipuncture (Fernandez-Moran 2003). Puncture of the jugular vein frequently requires repeated probing with the needle in subcutis, which would contaminate the sample with CK from skeletal muscle (MacWilliams and Thomas 1992).

Another muscle damage biomarker, lactate dehydrogenase (LDH), was remarkedly higher in the free-ranging group. As it is reported following the capture of other carnivore species, higher values of this enzyme, along with higher values of AST and CK, may indicate the presence of rhabdomyolysis during the capture event (Kreeger *et al.* 1990). While the absence of trap entry times for some individuals from the study prevents us from examining the potential effect of trap retention times on serum enzyme levels, it is noteworthy that highest CK and AST values were associated with the individuals with the longest recorded holding times (CK:521 U/L, AST: 401 U/I, holding time: 15 h). Further studies should incorporate the effect of holding times in serum biochemistry parameters to gain understanding of the impact of holding times while cage trapping. While holding times may play a important role in the elevation of selected serum enzymes, the physiological impact of the remaining variables during the capture should be considered as well, such as drug delivery (e.g., darting vs. pole-syringe, or hand injection via squeeze-cage); and approach of the trapped individual (e.g., avoiding noises or fast movements, few people as possible). During capture, these variables may illicit additional stress in the individual and should be accounted for.

It is quite possible that the anaesthetic drugs used in this study could have had an impact on the serum biochemistry. In domestic cats, an intramuscular injection of ketamine-midazolam, resulted in a significant decrease in glucose plasma level (Heidari *et al.* 2017). Significant higher values in albumin, triglycerides, total protein and cholesterol were found in cats chemically immobilized with a combination of ketamine-dexmedetomidine-butorphanol, in comparison with cats anesthetised with dexmedetomidine-butorphanol (Volpato *et al.* 2016). The use of a combination of tiletamine-zolazepam-xylazine-tramadol for chemical restraint in cats showed significant changes in AST, alkaline phosphatase (AP), and creatinine after drug administration, but all these changes were within biologically acceptable limits (Li *et al.* 2012). In our study, the anaesthetic protocols used for the immobilization were dependent on drug availability at the time of capture/physical examination. Due to sample size limitations, we were unable to explore the correlation between anaesthesia regime and serum biochemistry values. Nevertheless, based on our literature search with domestic cats, our highly elevated muscle enzymes did not appear to be affected by the anaesthetic combination used. We recommend that future studies assessing serum biochemistry values consider the potential effect of the drugs used, if two or more anaesthetic combinations are administered.

Higher mean value for alanine aminotransferase (ALT) was also found in the free-ranging group. Higher values for AST and ALT have been found in other free-ranging felid species such as Iberian lynx (*Lynx pardinus*), bobcat (*Lynx rufus*), and leopard cats (*Prionailurus javanensis*) (Fuller *et al.* 1985; Beltrán *et al.* 1991; Nájera *et al.* 2014) in comparison with captive felids derived from muscle damage by struggling, exhausting exercise while trapped or handled (Weaver and Johnson 1995; Marco *et al.* 2000).

Glucose and plasma cortisol, 2 parameters related to stress, show no marked differences between both groups but the maximum value of the reference range are found in the free-ranging group. Mean glucose levels are similar in both groups, although they remain higher in comparison with domestic cat, since the latter suffers less stress while being handled or sampled. Glucose values were found to be similar to other wild felid species, which are easily stressed during handling or capturing events (García *et al.* 2010).

There were no significant differences in plasma cortisol between free-ranging and captive clouded leopards. Although further studies will be required to determine what levels of cortisol represent a physiological abnormality in this species, the values expressed in this study seemed high. Higher values are found in the free-ranging group, probably due to the short-term stress response because of the capture, darting and handling as described in other species of wild carnivores (Fernández-Morán 2003). The sub-optimal housing conditions experienced by the captive animals in Malaysia and Indonesia may have resulted in relatively higher stress levels.

Although we could not find significant differences in the uric acid levels from both study populations, we highlight the remarkable high level in the free-ranging group. This difference could be explained in the fasting period that trapped clouded leopards experienced, that could increase the serum uric acid (Maclachlan and Rodnan 1967), or by differences in the clouded leopards' diets, since the free-ranging group may have access to higher purine contents in their prey (e.g., visceral organs, Kaneko *et al.* 2014) while the captive group is usually fed on chicken/chicken carcasses.

Although with limitations, monitoring selected serum biochemistry parameters gave us a preliminary insight of the capture-related stress that cannot be known from a physical examination. Adding other physiological indicators such as leukocyte profiles, neutrophil/lymphocyte ratio, leukocyte coping capacity, fecal glucocorticoids (Proulx *et al.* 2022), and/or behavior into this equation would have resulted in a better understanding of the stress response during the capture events.

Despite the low number of Sunda clouded leopards sampled here, and although further research will be required to establish capture protocols, this study may serve to help understanding the physiological response of this species to trapping events. The cage-traps used in this study appear to be a safe and reliable method for capturing Sunda clouded leopards as they allegedly do not cause physical injury to individuals. However, we showed that the time of restraint in the traps can negatively influence some parameters of blood biochemistry that may lead to serious physiological consequences in captured animals. Although our small sample size limits our ability to formulate extensive recommendations, we conclude that those capturing felids in remote locations should utilize trap alarms, wherever possible, to decrease the restraining time. Investigation of other type of traps such as box traps, where animals have no visual stimuli while captured, may also be considered in this scenario. We recommend that future research involving Sunda clouded leopards use this approach to assess the safety of their capture methods, and to further refine and improve the capture of these felids.

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Chapter 16

Trapping within The Context of Conservation and Reintroduction Programs: The Iberian Lynx (*Lynx pardinus*) as A Case Example

Fernando NÁJERA[1,2,3,4], Tere del REY-WAMBA[5], and Guillermo LÓPEZ[5]
[1]Department of Animal Physiology, Veterinary College, Complutense University of Madrid 28040, Madrid, Spain
[2]Asistencia Técnica de la Dirección General de Medio Natural y Biodiversidad, Plaza de Cardenal Siliceo 4, 45071 Toledo, Spain
[3]Current address: Saint Louis Zoo Institute for Conservation Medicine – Saint Louis Zoo WildCare Institute, One Government Drive, Saint Louis, MO, 63110, USA. Email: fernanaj@ucm.es.
[4]Current address: Living Earth Collaborative, Washington University, St. Louis, 1 Brookings Drive, St. Louis, MO 63130, USA.
[5]Agencia de Medio Ambiente y Agua de Andalucía, Puerto de Málaga Cara Sur, Lonja del Puerto s/n C.P 29001 – Málaga, Spain.

Abstract − The Iberian lynx (*Lynx pardinus*) is a trophic-specialist, medium-sized felid that inhabits Spain and Portugal. With less than 100 individuals in 2002, the IUCN listed the species as Critically Endangered. As of then, comprehensive conservation measures were implemented resulting in more than 700 individuals by 2015. The Iberian lynx was then downlisted to Endangered by the IUCN. The effectiveness of these conservation measures demanded deep knowledge of the species at every ecological level. Due to their conservation status, trapping lynx for research purposes must adhere to specific considerations. The justification for this procedure mainly includes tagging (e.g., radio-collaring), health evaluations, translocations and/or emergency situations. Since the late 1990s, cage traps have remained the safest method to capture this species because 1) external injuries are minimal, and 2) fatal accidents are virtually nonexistent. Nevertheless, cage-trapping lynx needs to fulfill the following requirements: adequate dimensions of the trap, swing-up closing door, correct mesh gauge to avoid injuries to paws, face and/or dentition, adequate trap location to avoid extreme weather and human disturbance, and trap checks no longer than 8 h, depending on weather conditions. To minimize capture stress and create recommendations during lynx trapping, we used the neutrophil/lymphocyte (N:L) ratio as a biomarker for capture stress. After the evaluation of 109 captures in which time of capture and time when handling started were recorded, we conclude that, although cage-trapping lynx is the safest method of capturing this species, decreasing times between capture and individual processing may help to decrease injuries and stress during these events. Following these recommendations will diminish the potential negative physiological responses of trapping while recovering an imperiled felid.

Introduction

Capturing and handling carnivores must be conducted with scientifically sound protocols and high standards of animal welfare (Proulx *et al.* 2012). Some of the species included in this taxon are being trapped yearly by researchers for various conservation, demographic, physiological, and behavioural studies (Hearn *et al.* 2013; Miller *et al.* 2013; Vickers *et al.* 2015; Mancinelli *et al.* 2018). In threatened carnivores, moreover, trapping must be scientifically justified and adhere to specific considerations of selectivity and safety (Proulx *et al.* 2012; Virgós *et al.* 2016).

The Iberian lynx (*Lynx pardinus*) is an endemic medium-sized felid (Ferrer and Negro 2004) that has experienced a successful conservation story during the last 2 decades. At the turn of the 21st century, it was found to be the most endangered felid species on Earth, with only 90 individuals secluded into 2 small populations in Andalusia, Southern Spain (Cabezas-Diaz *et al.* 2009; Simón *et al.* 2012). In 2002, while the IUCN categorized the Iberian lynx as Critically Endangered, a comprehensive conservation program was implemented (including habitat and food restoring, mitigation of threats, genetic management, captive breeding and reintroductions), which was able to reverse the former decline of the species (Simón *et al.* 2012). In 2015, when the population reached >700 individuals, the IUCN downlisted it to Endangered. In 2020, 1,111 individuals were detected throughout the current 8 population nuclei. In order to be effective, the actions included in the conservation program needed a deep knowledge of both 1) the ecology of the species, and 2) the threats affecting its populations. Although some relevant information could be gathered using noninvasive techniques and previous research, live capture and handling remained necessary to equip lynx with GPS/radio-collars to gather scientific understanding of the species' biology (Proulx *et al.* 2012), to evaluate causes of mortality (López *et al.* 2014), to monitor disease risks and assess population health (Nájera *et al.* 2021), and to carry out some conservation actions such as translocations (Simón 2013). Thus, the main reasons of capturing and handling Iberian lynx included radio-collaring, health evaluations, translocations and/or health care in emergencies.

Beginning in the 1980s, routine live trapping of Iberian lynx for research purposes has been conducted mainly using padded leg-hold traps and cage traps, although other methods such as tele-anesthesia (both remote-controlled or by a blow pipe; see Ryser *et al.* 2005) or direct capture with a net were exceptionally used. Since the beginning of the Iberian lynx conservation program in 2002, a specific trapping protocol with cage traps baited with live prey has been employed on a routine basis due to logistics simplicities, the high selectivity, the low occurrence of external injuries, and the absence of fatal accidents. Moreover, this protocol has also been improved during this time period. Its requirements include adequate trap location (to maximize lynx capture and avoid extreme weather, while eluding human disturbance), adequate cage traps–minimum dimensions of 200 cm x 100 cm x 100 cm–swing-up closing door and correct gauge mesh (5 cm x 5 cm- to avoid injuries to paws and/or dentition). Also, the handling team should be composed of at least 2 trained people. Finally, we additionally require other measures to minimize the physiological response during capture events that may disrupt the homeostasis of the individual, resulting in distress (e.g., minimal time spent in the trap, handling in dark conditions, minimum handling time, anaesthesia when necessary, etc.).

The time spent in the trap is known to affect stress in many carnivores (Proulx *et al.* 2012). In the Iberian lynx trapping protocol, this parameter has been modified over time. The initial protocol included from 6 checks per day (in case of small cubs or pregnant females) to 3 checks per day (in case of non-breeding adults). As of 2015, trap alarms (Mink Police ®) were employed in all trappings, so time spent in the trap was reduced to a maximum of 1 h. Several stress biomarkers may be used to address the response of a mammal to capture and handling, including vital signs, haematology mediators and immunological markers, endocrine mediators and serum biochemistry mediators. Within the mammal clade, neutrophils are a type of white blood cell that are the primary phagocytic leukocyte, and proliferate in circulation in response to infections, inflammation and stress (Jain 1993). Lymphocytes are involved in a variety of immunological functions such as immunoglobulin production and modulation of immune defense (Campbell 1996). Based on the evidence that under a stressful event, neutrophils increase in circulation while lymphocytes decline, the N:L ratio is a common and reliable method to index stress levels (Davis *et al.* 2008; Davies and Maney 2018). The aim of this work is to evaluate how time spent in the trap affects the stress of Iberian lynx. For that, we explore the neutrophil/lymphocyte (N:L) ratio as a stress biomarker in relation to time spent in the trap.

Material and Methods

During 2007-2020, a total of 464 Iberian lynx captures with cage-traps were conducted in Andalusia (Spain) summing routine campaigns focused on epidemiological surveillance, radio-tracking and genetic management (for further details see Simón 2013). Injuries related to capture method were recorded when they occurred. I n 23.5% of the captures (n = 109), the precise time of capture was recorded. Handling time (HT) (i.e., time to handling a lynx) was considered as the period of time elapsed between the capture of the lynx and the beginning of the anaesthesia practiced in all cases. HT ranged from 0 to 1,588 minutes (i.e., > 1 d). Age (known by routine photo-trapping monitoring; see Simón 2013) and sex were recorded in all cases. As part of the routine checkup, 1 ml of blood was taken from the cephalic vein to perform a hemogram including differential leukocyte count. As a direct indicator of stress (Davies *et al.* 2008), Neutrophil:Lymphocyte (N:L) ratio was calculated for all 109 cases.

For ulterior analyses, HT was split in <270 min and ≥270 min. This cut-off time was chosen based on the time realistically needed to carry out the procedures during lynx captures (e.g., times between trap visits, transportation of the lynx to our field clinic or preparation of the field anesthesia theatre, lynx chemical immobilization). Animals were classified as cub (< 1 yr old), subadult (1-3 yrs old), adult (3-10 yrs old) or senile (> 10 yrs old). The N:L ratio was log-transformed to fit a normal distribution. To explore the effect of HT on the stress indicator N:L, we performed a univariate general linear model using log-transformed N:L as dependent variable and sex, age, HT and the interactions among them as factor predictor variables with SPSS 21.0 software package(IBM 2012). Stepwise backwards selection procedure was followed until all the factors remaining in the model increased significantly the fit of the model (see Johnson and Omland 2004).

Results

Out of the 464 Iberian lynx captures practiced during the study period, 123 (26.5%) showed superficial lacerations (ranging from 0.3 to 4.1 cm diameter) on the cheeks, 97 (20.9%) showed damage to claws (4 cases – 0.8% – suffered the total break of at least 1 claw), 12 (2.5%) showed cuts related to imperfections of cage-trap (e.g., broken wire mesh), and 4 (0.8%) suffered canine fractures (Figure 1). Other minor injuries, including loss of hair and oral lacerations, were detected in isolated cases. In captures where HT was <270 minutes, lesions occurred in 0.03% of the cases.

Age and HT showed to be significantly affecting the N:L ratio (Table 1). Sex showed no effect on the N:L ratio (Df = 1,103; P = 0.7). Mean N:L ratio increased with age, adults and senile individuals showing significantly higher values than in cubs and subadults (Df = 3,104; P = 0.001) (see Figure 2). Similarly, animals with HT < 270 min showed significantly lower values of N:L ratio than those with HT > 270 min (see Figure 3).

Discussion

Cage traps remain an effective method for trapping medium-sized felids (Shindle and Tewes 2000; Kolbe *et al.* 2003; Grassman *et al.* 2004; Nájera *et al.* 2017). Our results show that our specific trapping protocol with cage traps is a reliable, efficient and safe method for capturing Iberian lynx. Although cage traps are not recommended for the capture of larger felids due to risk of physical injury (i.e., canine fractures while trying to bite the metal skeleton of the trap; Furtado *et al.* 2008), in our case, neither severe injuries nor fatal accidents were recorded during our study period. Canine fracture (crown fracture), a concerning damage that may affect the individual´s fitness and may lead to reduce hunting capabilities, thus affecting the overall health and survival of the individual (Collados *et al.* 2018), was only recorded in less than 1%

Figure 1. Main injuries in wild Iberian lynx captured in cage traps during routine campaigns between 2007 and 2020. A. Abrasion in left cheek. B. Broken nail. C. Partial canine fracture. D. Nail erosion. E. Localized alopecia. F. Oral laceration.

Table 1. Results of the univariate general linear model exploring the effects of sex, age and time of handling (TH) over neutrophil/leukocyte ratio in 109 Iberian lynx captured between 2008 and 2020.

Variable	**Df**	**F**	***P***
Age	3, 104	6.12	0.001
HT	1, 104	11.10	0.001
Sex	1, 103	0.11	0.742

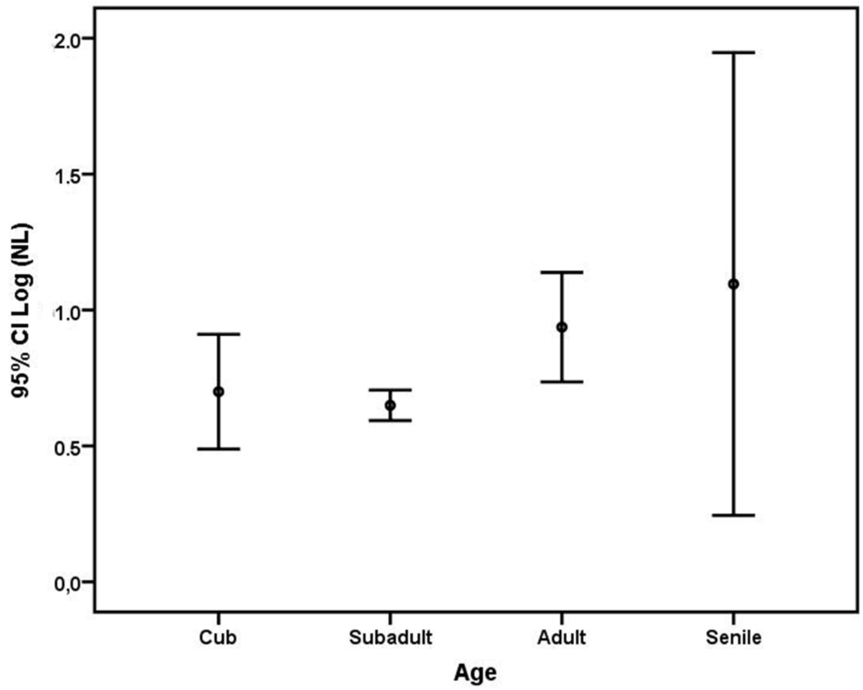

Figure 2. Chart showing 95% Confidence Interval of the Neutrophil/lymphocyte ratio in relation to age groups (cub, subadults, adults and senile) in 109 captured Iberian lynx between 2008 and 2020.

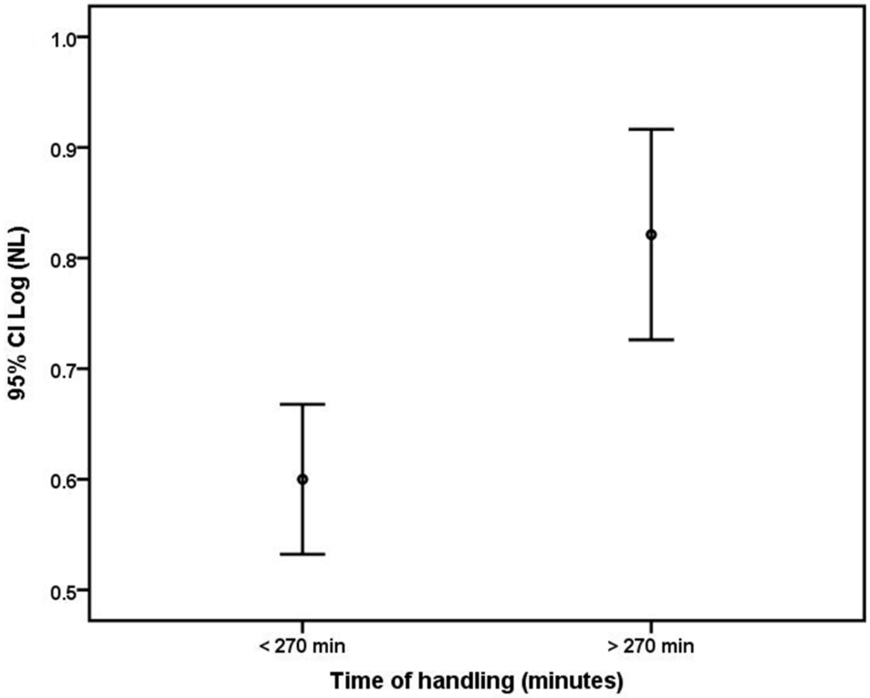

Figure 3. Chart showing 95% Confidence Interval of the Neutrophil/lymphocyte ratio in 109 captured Iberian lynxes between 2008 and 2020 handled <270 minutes or >270 minutes after capture.

of the captures. A cell size of the wire netting of 5 cm x 5 cm would decrease the occurrence of tooth fractures as captured individuals would be prevented from biting the wire (Potoçnik *et al.* 2002). The most recorded physical injuries in this study were superficial lacerations/abrasions of the face skin. This finding is in agreement with capture events in other small and medium felids such as the European wildcat (*Felis silvestris*; Potoçnik *et al.* 2002), the ocelot (*Leopardus pardalis*), the jaguarondi (*Herpailurus yagouaroundi*; Widmer *et al.* 2017) and the Canada lynx (*Lynx canadensis*; Mowat *et al.* 1994).

As a preventative measure to avoid physical injuries, a correct maintenance of cage traps is essential. Moreover, handling time is an important factor, both increasing the risk of injuries and provoking capture stress. The presence and extent of physical injuries remains a standard method to evaluate a trap safety in felids (Mowat *et al.* 1994; Widmer *et al.* 2017), however, physical injuries caused by traps represent just one index of potential stress and suffering (Iossa *et al.* 2007). Investigating physiological biomarkers of stress is still under-utilized in these taxa (Nájera *et al.* 2014). As for other free-ranging species (canids; for coyotes *Canis latrans*, see Gates and Goering 1976), when using the N:L ratio as an indicator of capture stress, neutrophil counts were significantly increased while lymphocytes decreased. In red fox (*Vulpes vulpes*), the N:L ratio may not be immediately detectable after short periods of stress, although it was informative about trapping stress while individuals were held in padded leg-hold traps for 2 h (Kreeger *et al.* 1990). Also, red foxes captured in box traps showed significantly higher N:L ratio compared to free ranging foxes (White *et al.* 1991). Marks (2010) determined whether common haematology and blood biochemistry values might assist in determining the relative welfare outcomes arising from the capture of red foxes by treadle-snares, padded leg-hold traps, cage traps, netting and sampling by shooting. He concluded that, among other indiators, N:L appeared to provide a useful general indicator of capture stress. This is in agreement with previous work carried out with European badgers (*Meles meles*) while monitoring neutrophil activation in transport stress (Montes *et al.* 2004). Although monitoring N:L ratio may have limitations (e.g., it does not give information about hydration status or muscle exertion) if solely used as biomarker of the capture stress response, it provides a valuable general indicator of comparative capture stress that is less affected by handling and sampling than the hypothalamic-pituitary-adrenal axis hormones (Marks 2010).

On the basis of this research, means to avoid a HT >270 min should be implemented in all Iberian lynx capture protocols. We also conclude that: 1) trap alarms should always be used to allow the trapping team to act as soon as a capture occurs; 2) handling after capture should be further reduced to <270 min; and 3) anaesthesia should be practiced as soon as possible (where the capture took place if conditions such as weather are adequate).

Our study showed the relevance of using a stress biomarker while evaluating the capture stress in an endangered felid. We conclude that the study of physiological stress biomarkers represents a meaningful tool to assess a trap safety within a conservation program. Recommendations derived from the use of capture stress indicators should be implemented in management protocols to ensure the species' safety and welfare in conservation plans.

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Chapter 17

International Mammal Trapping Standards − Part I: Prerequisites

Gilbert PROULX[1], Benjamin L. ALLEN[2,3], Marc CATTET[4], Pauline FELDSTEIN[1], Graziella IOSSA[5], Paul D. MEEK[6], Thomas L. SERFASS[7], and Carl D. SOULSBURY[5]
[1]Alpha Wildlife Research & Management Ltd, 229 Lilac Terrace, Sherwood Park, Alberta, T8H 1W3, Canada. Email: gproulx@alphawildlife.ca
[2]Centre for Sustainable Agricultural Systems, Institute for Life Sciences and the Environment, University of Southern Queensland, Toowoomba, Queensland, 4350, Australia.
[3]Centre for African Conservation Ecology, Nelson Mandela University, Port Elizabeth 6034, South Africa.
[4]Department of Environment, Government of Yukon, Whitehorse, Yukon, Canada.
[5]School of Life Sciences, University of Lincoln, Brayford Pool, Lincoln, UK.
[6]Vertebrate Pest Research Unit, NSW Dept. Primary Industries, PO Box 530, Coffs Harbour NSW, 2450, Australia.
[7]Department of Biology and Natural Resources, Frostburg State University, Frostburg, Maryland, 21532, USA.

Abstract − In this paper, we set out the prerequisites for the development of killing and restraining trap systems to capture mammals for research, wildlife management and conservation, fur trapping, animal control, and any other activity involving the trapping of a mammal in a mechanical trapping device. We selected them with the main intent of developing new trapping standards that will improve animal welfare as per our current state of knowledge, and with realistic, achievable objectives based on state-of-the-art trapping technology. The proposed new standards should be applicable to all terrestrial and semi-aquatic mammal species. They should be based on animal testing in semi-natural environments and on traplines, with high trap thresholds of acceptance, low times to irreversible unconsciousness for killing trap systems, an understanding of the impacts of trapping on physical form, behaviour and physiological function, adequate trap checking times and handling of the captured animals, and high capture selectivity. Furthermore, the implementation of improved trapping standards would include the mandatory publication of findings for peer-review and public education. We believe that the prerequisites that we lay out for the development of new mammal trapping standards will address many of the welfare concerns voiced by the scientific community and the public in the last two decades. It will lead to improved animal welfare and spur continuous improvement in the efficacy and innovation in trapping technology.

Introduction

Industries continuously drive for improvement in standards. For example, over the last 50 yrs, there has been a drive for increased energy efficiency in construction (Economidou *et al.* 2020), and better training and certification standards for electric vehicles (Brown *et al.* 2010), thereby forcing manufacturers to continually innovate and improve their products to the benefit of users and the environment. Likewise, standards in environmental management and occupational health have evolved over the years (De Oliveira and Coelho 2010). Animal welfare is no different. Throughout the recent decades, there has been a growing shift to improve animal welfare, particularly in captive and production systems (Mellor 2016). Wild animal welfare is generally less considered (Hampton and Hyndman 2019). In the past, because the fur market showed reluctance in driving innovation of trap devices, the threat of a trade embargo by the European Community was necessary to ban steel-jawed leghold traps, and develop humane trapping standards (European Community, Government of Canada, and Government of the Russian Federation −ECGCGRF 1997). However, recurring criticism of these standards (Powell and Proulx 2003; Iossa *et al.* 2007; Fogelsinger 2017; Zuardo 2017; Proulx *et al.* 2020) suggests that trapping standards need to be re-written to include state-of-the-art trapping technology, and properly address cultural concerns regarding mammal trapping.

Globally, the standards for trapping mammals are fragmented. For example, the standards of the International Organization for Standardization (ISO; 1999a, b) cover the process of testing mammal traps, whilst those of the Agreement on International Humane Trapping Standards (AIHTS; ECGCGRF 1997) set thresholds for acceptable injuries (for restraining traps) and time to irreversible unconsciousness (TIU, for killing traps) for furbearer species. However, these standards have been found to be inadequate because they are not representative of state-of-the-art trapping technology and animal welfare science (Iossa *et al.* 2007; Powell and Proulx 2003; Proulx *et al.* 2020) (Table 1). The standards, developed during the early 1990s, are now nearly 30 yrs out of date. Moreover, they apply to only a limited sub-group (19 furbearing species) of mammals, whereas it is known that many traps used to catch "pest" species are inadequate because they cause pain and suffering (e.g., Baker and Sharp 2015; Baker *et al.* 2017). Hence, there is a compelling need to revisit and update mammal trapping standards to ensure animal welfare for all trapped mammals, and implement proper procedures during trap assessment and use on traplines.

The scientific community is not alone in raising concerns about the mammal trapping standards. Indeed, animal welfare organizations and the public have questioned the ethical treatment of captured animals (Animal Welfare Institute 2021), the fate of non-target species including pets and endangered species (The Fur-Bearers 2021; Villeneuve and Proulx 2022), deficient trapper and public education about humane trapping (Feldstein and Proulx 2022; Stevens and Proulx 2022), and the poor enforcement of trapping regulations (CBC News 2016; Feldstein and Proulx 2022).

In order to address the concerns of the scientific community and the public about mammal trapping, we chose to breakdown the development of new mammal trapping standards into 3 interrelated publications:

I. Prerequisites of new mammal trapping standards (this paper).
II. Standards for killing trap systems (Proulx *et al.* 2022a).
II. Standards for restraining trap systems (Proulx *et al.* 2022b).

In this paper, we set out the prerequisites for the development of killing and restraining trap systems to capture mammals for research, wildlife management and conservation, fur trapping, animal control, and any other activity involving the trapping of a mammal in a mechanical trapping device. We took into consideration Proulx *et al.*'s (2020) review of issues associated with past standards (Table 1), papers that addressed wildlife welfare concerns such as Iossa *et al.* (2007) and Soulsbury *et al.* (2020), and assessment protocols that have been repeatedly successful in previous trap research and development programs. Unfortunately, such protocols are relatively scarce and have been employed by a limited number of research teams (Table 2). For this reason, in many instances, we had to refer to the same researchers and organizations whose work encompassed a variety of mammal species.

We believe the following prerequisites are the essential building blocks of progressive international mammal trapping standards. We selected them with the main intent of developing new trapping standards that will improve animal welfare as per our current state of knowledge, and with realistic, achievable objectives based on state-of-the-art trapping technology that we implemented in Proulx *et al.* (2022a,b).

A glossary is provided in an Appendix to explain the terminology used throughout the manuscript.

Table 1. Main issues raised by Proulx *et al.* (2020) regarding the need to update AIHTS trapping standards to improve animal welfare and capture efficiency and selectivity.

Issues	**Reasons of concern**	**References**
The list of mammal species included in the AIHTS is incomplete.	AIHTS are fur-trade standards. They identified 19 furbearer species only. The list should include all trapped mammal species regardless of the reason for which they are captured.	Talling and Inglis 2009 Baker et el. 2012 Zuardo 2017
There is a need to implement state-of-the-art trapping technology.	The AIHTS standards have relatively low animal welfare performance thresholds of acceptance for traps. When developed, the AIHTS standards did not reflect state-of-the-art trapping technology, and they are still out of date.	Powell and Proulx 2003 Proulx *et al.* 2012
Times to irreversible unconsciousness (TIUs) in animals captured in killing trap systems need to be reduced.	TIUs that are significantly lower than those used by AIHTS can be achieved, at least for some smaller species.	Proulx 1999a Proulx *et al.* 2012 Blue Angel 2017
There is a need to improve the performance thresholds of killing trap systems.	The AIHTS performance thresholds require that traps be humane in 49% of captures. Such performance thresholds are markedly lower than those used by researchers 35 years ago, and they have not been updated since the signing of the agreement in 1997.	Proulx 1999a Powell and Proulx 2003 Proulx *et al.* 2012
It is necessary to expand on animal welfare indicators to detect stress, injury and physiological disturbances in animals captured in restraining traps.	The assessment of restraining traps is basically limited to physical injuries incurred in a trap. The assessment of animal welfare requires a more comprehensive approach, including physiological and behavioural changes, and it should include the long-term effects of trapping on animals.	Mason and Mendl 1993 Proulx *et al.* 1993 Mellor and Reid 1994 Warburton *et al.* 1999 Cattet *et al.* 2008 Marks 2010 White *et al.* 2021
Trap-testing procedures must be improved.	AIHTS allow for the use of trap assessment protocols that do not involve animals such as computer-based evaluations. However, to date, only sequential animal-based studies have resulted in trap innovation.	Barrett *et al.* 1989 Proulx *et al.* 1989a Onderka 1999 FIC 2021
Standards should apply to all mechanical trapping devices and methods currently in use.	AIHTS indicate that parties of the agreement may derogate from the agreed standards for the use of some traps such as killing neck snares. Also, underwater traps received little attention in the past, even though the acceptability of drowning as a killing method is problematic.	Andrews *et al.* 1993 ECGCGRF 1997 Ludders *et al.* 1999, 2001 Proulx and Rodtka 2017
Standard operating procedures are needed for the use of certified traps on traplines.	It is not sufficient to identify restraining traps that can hold animals with minor injuries, or killing traps that can render animals unconscious quickly. Trap assessments must also include trap components and sets, as well as handling methods.	Proulx *et al.* 2012 Serfass et al. 2017 Serfass 2022
There is a need to discuss animal handling and euthanasia.	AIHTS do not address animal handling and dispatching, in spite of technical advancements in this area.	AAZV 2006 Proulx *et al.* 2012 Warburton 2015 Leary *et al.* 2020
There is a need to develop protocols to assess capture efficiency and species selectivity.	Many factors affect trap efficiency and selectivity. Trapping systems should be assessed and developed to capture specific species and avoid non-target ones.	CGSB 1996 ISO 1999a,b Pawlina and Proulx 1999 Virgós *et al.* 2016

Table 2. Reference protocols used in the development of prerequisites.

Subject	References
Mammal trapping technology − research and development, including acceptance threshold levels, times to irreversible unconsciousness, assessment criteria for trapping systems, capture efficiency and selectivity	Meek *et al.* 1995; Ludders *et al.* 1999; Proulx 1999a; Morriss and Warburton 2014; Proulx *et al.* 2012; Virgós *et al.* 2016; Meek *et al.* 2019; Proulx 2018; Caravaggi *et al.* 2021; Allen *et al.* 2022; Proulx 2022a; Serfass 2022
Animal behavioural and physiological responses	Cattet *et al.* 2003a,b, 2008; Proulx 2018; Marks 2010; Gese *et al.* 2019; Monterroso *et al.* 2022; Nájera 2022; Nájera and Hearn 2022; Nájera *et al.* 2022
Anxiety and psychological responses to capture	Mark *et al.* 2004; Proulx 2018
Physical injuries associated with restraining trap systems	Olsen *et al.* 1986; Onderka *et al.* 1990; Proulx *et al.* 1993; Byrne and Allen 2008; Marks 2008
Handling and releasing animals	Proulx *et al.* 2012; Soulsbury *et al.* 2020
Trap alert systems	Marks 1996; Larkin *et al.* 2003; O'Neill *et al.* 2007; Meek *et al.* 2020
International standards	Powell and Proulx 2003, Iossa *et al.* 2007; Proulx *et al.* 2020; Feldstein and Proulx 2022

Mammal species, traps and trapping systems

Trapping standards should apply to all terrestrial and semi-aquatic mammal species that are captured in mechanical killing or restraining trap systems throughout the world. Mammals of all genera and species are being captured in scientific studies to assess distributions, population characteristics, habitat requirements, conservation genetics, diseases, and for translocation projects (Proulx 2022b). Mammals are also captured for subsistence (food, clothing and handicraft) in aboriginal cultures, fur (trade and enjoyment of the outdoors), pest and predator control, including invasive species, and various wildlife management programs (Proulx 2022b).

Mechanical traps are devices that have mechanical energy if they are in motion and/or if they are at some position relative to a zero-potential energy position. These include killing (rotating-jaw traps, mousetraps, planar traps, neck snares with and without springs) and restraining (leghold/foothold traps, box/cage traps, neck cable restraints, leg snares) traps. Mechanical traps do not include enclosures, net projectiles, harpoons, glue traps, water bucket traps, pitfall traps or similar capture devices.

To effectively test trap performance, it is essential to determine the momentum and the clamping force of tested trap models, particularly those of killing traps and restraining leghold traps. The momentum is a measure of the impact that a striking bar can deliver to an object. It is the product of the velocity of a striking bar multiplied by its equivalent mass. The clamping force is the steady-state force exerted on an animal by the jaw(s) of the trap after the striking force has been delivered.

The average momentum and clamping force of killing traps are plotted on a threshold graph where traps with killing potential must rate above a threshold line specific to a species (see Figure 1). If such a line does not exist, researchers should use that for a species of similar size, recognizing that interspecific variations exist. Traps that are plotted below the threshold line may not be powerful enough to humanely kill an animal of a specific species. For example, if a threshold line exists for a specific target species, or for a species of similar size, traps rating above the line may have the potential to pass biological tests (Figure 1). In this example, Trap no. 3 should be subjected to subsequent biological tests, as per Figure 1. However, Trap nos. 1 and 2 would not have the potential to pass biological tests, where ≥85% of animals must lose consciousness in ≤90 s (see *Trap thresholds of acceptance and TIUs*, below) and, therefore, should be modified or rejected.

In the case of power killing snares, the mechanical characteristics of the spring(s), and the constant pulling force on the noose, can be evaluated. A mechanical evaluation of restraining traps such as legholds needs to be conducted to establish striking and clamping forces that are too high and likely to lead to significant injury. In the case of box/cage traps, the pan tension or the pulling force to activate the trap, which may affect trap closure, capture efficiency and injuries caused by the closing door, may be evaluated for different species. As with killing traps, mechanical evaluations of restraining traps can eventually lead to the production of threshold graphs that may be used to distinguish traps that can potentially restrain specific species without injuries from those that would seriously injure the animals.

Different procedures, equipment and software exist to assess momentum and clamping force of both killing and restraining traps. Zelin *et al.* (1983) assessed momentum with a trap simulator. Cook and Proulx (1989) used a digital waveform analyzer, accelerometers, and a load cell to measure momentum and clamping forces of killing traps. Warburton and Hall (1995) used a trap simulator, oscilloscope and load cell to determine momentum and clamping force. Baker *et al.* (2012) used a piezoelectric load cell. Meek *et al.* (2019) used a Photron Fastcam SA7 video camera and Photron FASTCAM Viewer software to measure closure speed. Johnson *et al.* (1986) used an oscilloscope and an electronic stopwatch to measure clamping force. In all cases, many tests must be conducted with different traps of a specific model to assess the variation in both the momentum and clamping force.

Acceptable killing and restraining traps lose their power over time due to metal fatigue, and they should be replaced when their impact momentum and clamping forces fall below acceptable levels. Most conventional traps will last several years with regular servicing and replacement of rubber pads, springs and other components as needed. Nevertheless, if traps fail to meet the necessary energy levels, they should be discarded.

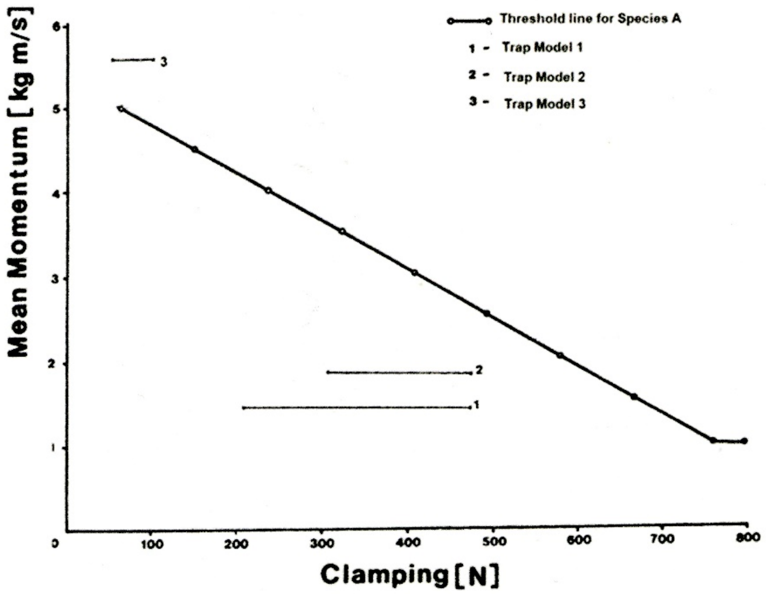

Figure 1. Kill threshold line developed for a specific species based on the testing of traps which had to render ≥70% of test animals unconscious in <180s (Proulx 1997). In a series of tests where traps would have to render ≥85% of test animals within <90 s (see text), only Trap no. 3 may have some potential to succeed in biological tests.

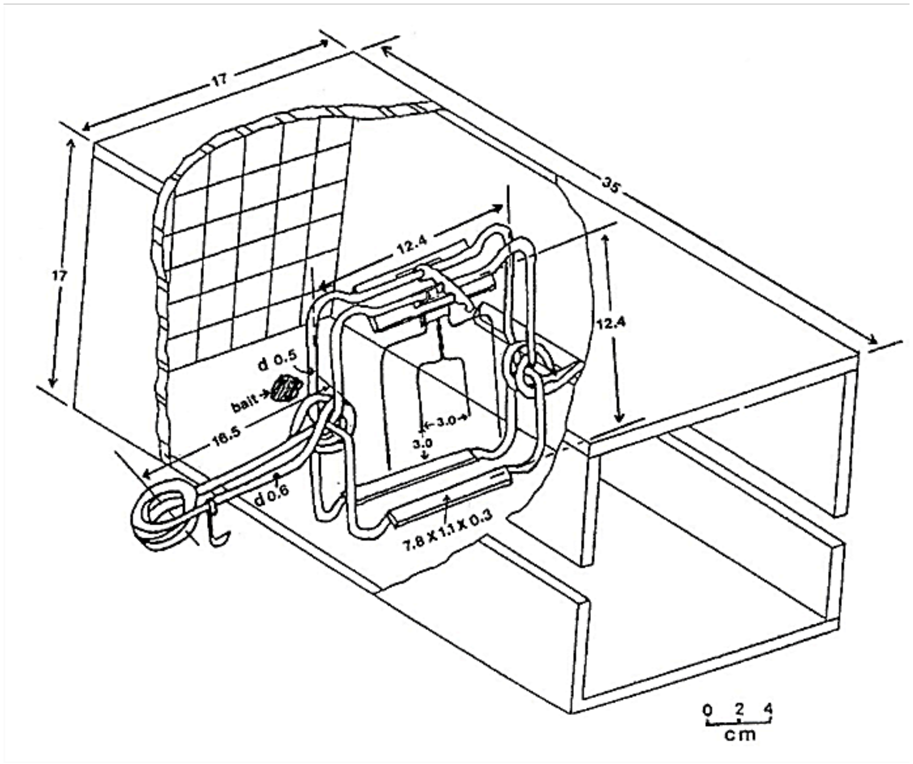

Figure 2. Example of a detailed killing trap system for the C120 Magnum trap set in a cubby box (Proulx 1999a).

In the past, most trap assessments focused on a trap model rather than a whole trapping system which encompasses 1) a trap with specific dimensions, shape, power, and attachments (e.g., chain, swivels, locks); 2) a trigger with a specific shape and operation; and 3) a set with a specific placement of the trap, and bait or lure (Figure 2). Mammal trapping standards should refer to trapping systems, and not just individual trap models. Trapping systems rather than traps should be certified and used on traplines.

Tests with animals

Using animals in trap testing is unavoidable, as it helps ensure that mammals will be properly captured and avoids the possibility of many animals unnecessarily suffering on traplines during field tests or subsequent use. Initial tests with animals should be conducted in semi-natural environments with only a small number of animals, recognizing Russell and Burch's (1959) "3Rs" principle of reducing the number of test animals. Semi-natural environments refer to spacious enclosures that are modified to resemble natural environments, e.g., which include trees, fallen deadwood, shrubs and openings (Figure 3). Initial tests with large animals (e.g., wolves *Canis lupus*, dingoes *C. familiaris*, bears *Ursus* spp., lions *Panthera leo*) may not be feasible in semi-natural environments and should then be carried out on traplines only. Irrespective of where initial testing is conducted, all animal husbandry and research procedures must be approved by an institutional Animal Care & Use Committee with members possessing appropriate expertise in the wildlife husbandry, health care, and research relevant to trapping and handling.

Tests in semi-natural environments should preferably involve the use of animals that are live-captured in the wild and given sufficient time to acclimate to a semi-natural environment before any test is conducted. Because capture and handling is likely to cause stress, with concomitant changes to behaviour and physiology (Cattet *et al.* 2014; Nájera and Hearn 2022), the period of acclimation should be closely monitored to ensure animals are truly acclimated before initiating approach tests (see *Approach tests*, below). Monitoring should include video analyses of behaviour (Caravaggi *et al.* 2017) and repeated measurement of stress levels by non-invasive methods (Table 3), such as fecal glucocorticoid metabolite analysis (Keay *et al.* 2006; Franceschini *et al.* 2008; Rothschild *et al.* 2010) and/or hair cortisol analysis (Heimbürge *et al.* 2019; Kallioski *et al.* 2019).

Figure 3. Trap testing in semi-natural environments (Photos: G. Proulx©).

Table 3. Useful physiological indicators for assessing the welfare outcomes of trapping.

Biological sample	**Indicator(s)**	**Effected by:**	**References**
Feces	Glucocorticoid metabolites	stress (over days)	Keay *et al.* 2006
Hair	Cortisol	stress (over hours to days)	Cattet *et al.* 2014; and Kallioski *et al.* 2019
Whole blood	Hematocrit	hydration	Kreeger *et al.* 1990; Beltrán *et al.* 1991; Latimer *et al.* 2003; and Cattet *et al.* 2003a
	Hemoglobin	hydration	
	Neutrophil-to-lymphocyte ratio	stress and/or inflammation (over minutes to hours)	
Blood serum or plasma	Albumin	hydration	Kreeger *et al.* 1990; Warburton *et al.* 1999; Cattet *et al.* 2003a; Powell 2005; and Cattet *et al.* 2008
	Amylase	physical exertion	
	Aspartate aminotransferase (AST)	muscle injury	
	Total bilirubin	muscle injury	
	Chloride	hydration	
	Cortisol	stress (over minutes to hours)	
	Creatine kinase (CK)	muscle injury	
	Lactate dehydrogenase	physical exertion	
	Myoglobin	muscle injury	
	Total protein	hydration	

The testing of animals in semi-natural environments corresponds to a series of evaluations described as follows (Proulx *et al.* 2012):

1. Approach tests

Animals are allowed to approach traps wired in the set position so that the traps can be triggered but cannot close completely and injure the animals. The animals should not be channelled or forced into traps; they should move as they wish within their environment, and they should approach traps on their own free will. The tests are video-recorded and the behaviour of naive animals (i.e., that presumably had never approached the tested trap before) is remotely monitored. These tests are safe for the animals and can be carried out with any type of killing or restraining trap system. They aim to determine if animals will be struck in vital regions in the case of killing traps (Figure 4), or properly captured by a limb in leghold traps, or that the body is entirely contained in box/cage traps. Once a killing or restraining trap system has passed the approach tests, kill tests or capture tests with restraining traps may be conducted. To avoid learned behaviour influencing the results of tests, animals used in approach tests cannot be used in subsequent tests.

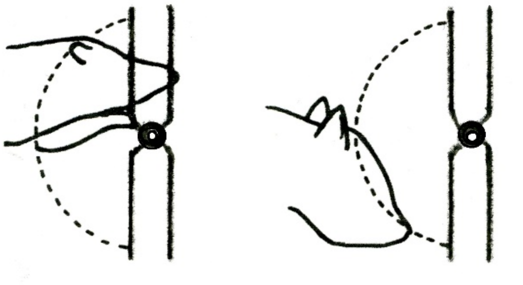

Figure 4. Determination of striking locations of a rotating-jaw trap in approach tests based on video recordings (after Proulx *et al.* 1989b).

2a. Kill tests

Using the same trapping system as the one tested with approach tests, the killing ability of the trap, which is allowed to close completely, is determined in semi-natural environments. Upon activation of the trap, researchers quickly access the struck animal to monitor its state of consciousness based on the loss of corneal and palpebral reflexes or any other specifically proven suitable substitute parameter. If a trapping system meets the expected performance threshold level and TIU (see *Trap thresholds of acceptance* below; Table 4), it is further tested on traplines.

2b. Restraining tests

Researchers remotely observe and record the captured animal for behavioural signs of injury or distress. After a set time, consistent with the average time that an animal would remain restrained in a trap on a trapline, researchers release the animal from the trap. The animal should be observed for any sign of physical injury. Before the animal is released, hair and/or feces are collected to compare pre- and post-capture stress levels. Hair can be collected from the animal before capture tests with devices such as barbed wire, glue or adhesives, or brushes placed at the entrance of the den box (Kendall and McKelvey 2008). Blood may also be collected for haematological and biochemical analyses, followed by a comparison of select physiological indicator values with established species-specific values (Table 3; Teare 2013). In the case of captures involving specific limbs (e.g., leghold traps) or other parts of the body (e.g., cable-restrain traps), animals may be anaesthetized and x-rayed or, if judged necessary, euthanized and necropsied to assess injuries (Table 5). If a trapping system meets the criteria of acceptation for restraining traps (see below), it is further tested on traplines.

3. Trapline tests

Testing killing and restraining trap systems on traplines is necessary to ascertain their ability to meet the performance levels observed in semi-natural environments.

Trap evaluation tests should ideally be conducted during the same period when trapping will likely occur on traplines. For example, traps used for fur trapping in the northern hemisphere are tested during late fall and winter months (e.g., Barrett *et al.* 1989). On the other hand, northern pocket gophers (*Thomomys talpoides*) are captured in summer only and traps should therefore be tested from April to the end of September (Proulx 1999b). Testing should avoid extreme heat and cold conditions (Sharp and Saunders 2011).

Table 4. Outcomes in semi-natural environments for killing trap systems to be expected, at a 95% confidence level, to render ≥85% of the animals irreversibly unconscious within a pre-determined time period of 90 s for most mammal species, and 30 s for small mammals (mouse, vole, etc.). Tests are judged successful when animals lose consciousness within the pre-determined period (either 90 s or 30 s).

Number of tests	**Number of successful tests**	**Number of failures**
10	10	0
28	27	1
37	35	2

Table 5. Injury-scoring system for the assessment of restraining trap systems, based on Tullar (1984), Olsen *et al.* (1986, 1988), Onderka *et al.* (1990), Hubert *et al.* (1996), Phillips *et al.* (1996), and ISO (1999b).

Injury	**Points assigned**
Claw loss	2
Minor skin lacerations	5
Oedematous swelling or haemorrhage of limbs	15
Cutaneous laceration, sub-cutaneous soft tissue maceration or erosion (contusion)	15
Periosetal erosion	15
Severance of minor tendon or ligament (each)	25
Amputation of digit (each)	30
Permanent tooth fracture exposing pulp cavity (each)	30
Gum abrasion or deep cut	30
Major laceration on foot pads or tongue	30
Severe joint haemorrhage	30
Joint luxation at or below the carpus or tarsus	30
Self-mutilation of captured limb	50
Rib fracture (simple or comminuted)	50
Eye lacerations	50
Skeletal muscle degeneration	50
Simple fracture at or below the carpus or tarsus	50
Compression fracture	50
Limb ischemia	50
Oedematous swelling of neck or face	50
Deep laceration of neck	75
Any fracture or joint luxation on limb above the carpus or tarsus	100
Compound or comminuted fracture at or below the carpus or tarsus	100
Any amputation above the digits	100
Spinal cord injury	100
Internal organ damage and bleeding	100
Disembowelment	100
Severance of major tendon or ligament	100
Compound rib fractures	100
Ocular injury resulting in partial vision loss or blindness of an eye	100
Myocardial degeneration	100
Paralysis (partial or total) of any limb	100
Death	100

In the past, all trapping devices that had successfully passed mechanical evaluations, and biological tests in semi-natural environments, were also found successful on traplines (Barrett *et al.* 1989; Proulx and Barrett 1993; Proulx *et al.* 1994), i.e., the strike locations and lesions were consistent with those that were found to be effective in tests conducted in semi-natural environments. For traps not tested in semi-natural environments, this was not always found to be the case (Proulx 1999b).

We realize that some countries or research organizations may not have the resources to develop semi-natural environments. Approach and other tests with killing or restraining traps can also be conducted entirely in the wild with cameras that are strategically mounted to observe traps and animals. Traps can still be wired in the set position for approach tests, and video-recorded events can be analysed in the laboratory. Likewise, kill tests can be carried out on traplines in much the same way. When conducting kill tests, researchers can note capture time, and irreversible loss of consciousness based on the loss of the corneal reflex. During daylight, the blinking of the eyelids can be observed. During nighttime, interruption of the eyeshine (reflection of the camera light from the tapetum lucidum of the eyes) due to the blinking of the eyelids confirm that the animal is still conscious (Proulx 2018). When conducting tests with restraining traps, researchers can use video-recordings to determine time of capture, and changes in the behaviour of the animals during specific time periods. The assessment of killing and restraining trap systems in the wild may take more time than in semi-natural environments depending on the density of target animals, and if modifications to the trapping systems are required to go forward with kill tests.

4. Long-term tests

It is important to conduct long-term assessments of animals captured in and released from restraining trap systems to assess the impacts of trapping and trap models on the behaviour, physiology, and survival of the animals (Seddon *et al.* 1999; Cattet *et al.* 2008; Gese *et al.* 2019). During trapline tests or research studies, captured animals should be properly identified and/or radio-collared before release. When re-captured, the physical and physiological characteristics of the animals should be thoroughly evaluated (e.g., Seddon *et al.* 1999; Cattet et al 2008). When possible, the movement patterns (e.g., daily movement rates) and space use of radio-collared animals should be evaluated over time (Gese *et al.* 2019; Monterroso *et al.* 2022).

Trap thresholds of acceptance

Annually, many mammals are captured globally in killing or restraining traps (Proulx *et al.* 2020). It is therefore vital to ensure that traps being used meet minimal standards of performance. Key criteria used to assess trap performance are TIUs for killing trap systems, and levels of physical injuries, and behavioural and physiological changes, for restraining trap systems (as recommended by Proulx *et al.* 2020).

In an assessment protocol, if a test trap successfully kills 9 out of 9 animals according to specific criteria, the success rate is 100%. However, it is inconceivable to suggest that the tested trap model would successfully kill 100% of all animals captured on traplines according to the specified criteria. With the normal approximation to the binomial distribution (one-tailed test), however, researchers can predict the expected performance of the tested traps in a large population of captured animals (Proulx *et al.* 2020). In the past, the following equation was used:

$$P(X) = \frac{n!}{X!(n-X)!} p^X q^{n-X}.$$

where *n* is the number of independent tests. Each test may result in 1 of 2 outcomes, “success” or “failure”, with the probabilities *p* and *q*, respectively. Therefore, if a trap model successfully kills 9/9 animals in compound tests, it can be expected, at a 95% confidence level, to kill ≥70% animals of a target species captured on traplines (one-tailed test) (Fleiss 1981; Proulx *et al.* 1989a, 2020). In accordance with Russell and Burch’s (1959) “3Rs” principle (*replacement, reduction, refinement*), the use of the normal approximation to the binomial distribution allows one to properly test a trap model and keep the number of test animals to a minimum.

With past standards, AIHTS-certified traps were deemed acceptable with an estimated performance level of 49% (Proulx *et al.* 2020). However, Canadian research conducted in semi-natural environments, and subsequently on traplines, showed that killing performance levels, based on the normal approximation to the binomial distribution, most often ranged from 83% to 95% for American marten (*Martes americana*), American mink (*Neovison vison*), and Arctic fox (*Vulpes lagopus*) (Barrett *et al.* 1989; Proulx and Barrett 1993; Proulx 1999c; Proulx *et al.* 1994). Therefore, a minimum estimated performance level of 85% appears to be realistic. In tests conducted in semi-natural environments, a killing trap system would have to render 10/10 test animals irreversibly unconscious within a specified time period to meet this minimum performance level (Table 4). In New Zealand, Morriss and Warburton (2014) used this performance level when testing traps for ship rats (*Rattus rattus*) and stoats (*Mustela erminea*). This performance level would be 36% higher than the performance level used in AIHTS (ECGCGRF 1997). The 85% minimum performance level is based on the most stringent trap research and development protocols that have been repeatedly found successful in the last 35 yrs (Morris and Warburton 2014; Proulx *et al.* 2020), but this minimum performance level will undoubtedly be increased as we strive for improvement. Hopefully, such performance levels will exceed 90% in the near future, and eventually get closer to 100% (Soulsbury *et al.* 2020).

The determination of the performance level of a trap, and a minimum performance level of 85% as determined with the approximation to the binomial distribution, should be conducted both with killing and restraining trap systems. In the USA Best Management Practices, White *et al.* (2021) used a mean cumulative injury score injury of <55 points to assess restraining traps. But the use of an average is not comparable to a standard based on a minimum performance level because mean cumulative injury scores are affected by extremes For example, in a sample of 20 animals where individual scores may be 5 - 5 - 5- 5- 5- 5- 5- 5- 5- 5- 5- 5- 5- 5- 10- 15 - 90- 95 - 95 - 90 (as may be observed with restraining traps for northern raccoons *Procyon lotor* – G. Proulx, unpublished personal observations), the mean score is 23.5, and therefore is acceptable according to White *et al.* (2021) because the mean score is <55 points. This trap would also be approved on the basis of AIHTS, because 16/20 or 80% of animals have an injury score <50 points. However, with a result of 16/20 acceptable captures, the true ability of the trap to capture animals with little or no injury would actually be 62% using a one-tailed binomial test (see Proulx *et al.* 2020), or in other words, 38% of all trapped animals could likely suffer unacceptable pain and distress when captured in such restraining traps. This indicates that the ‘standards’ recommended by White *et al.* (2021) and AIHTS can grossly misrepresent the true performance of traps, concealing substantial welfare impacts.

Time to irreversible unconsciousness (TIU) in the assessment of killing trap systems

Time to irreversible unconsciousness is the period of time elapsed between when an animal is struck by a trap and the irreversible loss of sensibility and consciousness based on the loss of corneal and palpebral reflexes or any other specifically proven suitable substitute parameter. Time to irreversible unconsciousness has been set at 180 sec for more than 40 yrs (FPCHT 1981; Proulx *et al.* 2012). In AIHTS standards, TIUs have been reduced to ≤45 sec and ≤120 sec for a few small- and medium-sized mammals (ECGCGRF 1997), respectively, but increased to 300 sec for most furbearer species. On the basis of performance levels obtained in previous studies with rodents and carnivores (Proulx 1999a), time to irreversible loss of consciousness can generally be reduced to ≤90 sec, so we see no reason why acceptable TIUs should be as high as 300 sec. With new technology and materials developed in recent decades, TIUs should be reduced to ≤60 sec for many species, particularly small rodents (e.g., Proulx 1999b; Blue Angel 2017; Proulx *et al.* 2020; Ågren *et al.* 2022; Gedhun *et al.* 2022). As it might not be realistic to develop killing traps for very large herbivores and carnivores, mechanical restraining traps or alternative trapping systems (e.g., corrals) may be the only acceptable options for these species.

Criteria for the assessment of restraining trap systems

In the past, most restraining traps were assessed on the basis of injures they caused to animals, and little consideration was given to the impact of traps on the behaviour and physiology of trapped individuals (Proulx *et al.* 2020). Through years of research, however, there is now enough knowledge to develop an assessment program incorporating physical, behavioural, and physiological criteria (Kreeger *et al.* 1990; Cattet *et al.* 2003a; Marks 2010; Monterroso *et a.* 2022; Nájera and Hearn 2022).

Physical evaluations −injuries

One of the easiest ways to compare injuries from one trap type to another is to assign a point value to each injury that corresponds with their severity, and then add the point values to obtain a single injury score suitable for statistical analysis (Proulx *et al.* 1993; Meek *et al.* 1995; Fleming *et al.* 1998; Onderka 1999). An injury-scoring system can be developed and applied to captured animals that are anesthetized to enable safe handling. It can also be developed and applied to captured animals that are humanely killed to allow for the performance of a full necropsy. Table 5 provides an example of a comprehensive injury-scoring system that can be applied to animals that are evaluated by necropsy. Using this system, injuries are considered serious (≥50 points) when they are likely to impact the welfare and survival of released animals, or when a series of minor injuries (<50 points for each injury) amount to ≥50 points and have a compounded effect on the welfare or survival of released animals.

A restraining trap system that holds 10/10 (or 27/28; Table 4) animals with a cumulative injury score <50 points may be expected, at a 95% confidence level, to hold ≥85% of target animals for a predetermined time period without serious injuries.

Behavioural evaluations

Knowing that qualitative assessments of behaviours may also be valuable for determining animal welfare (Wemelsfelder *et al.* 2001; Fleming *et al.* 2016; Allen 2019), the total amount of time for each activity should be recorded for each trapped animal to quantify the amount of time an animal spends in distress during a specific capture period. Using observations collected during the tests and the video analyses, behaviours may be classified as follows:

- Distress indicators: fighting, biting, pulling or disturbing the trapping system, self-mutilation, whining, and signs of anxiety such as increased ambulation, restlessness, increased vigilance, or disengaged from the environment and depressed.
- Calmness indicators: sleeping, immobility (not caused by an injury or depression), quietness, no signs of anxiety or disturbance.

An animal will show signs of distress at capture time, and sporadically during the capture period (Proulx *et al.* 1993; Bergvall *et al.* 2017). However, if an animal is observed for only 1 h after capture, it will likely show signs of distress for the whole time period. On the other hand, if the animal is observed for 8 h or overnight, then it might spend the first hour trying to escape and then give up and spend the remainder of the time not distressed. An animal's behaviour should be assessed over a period representative of what happens on traplines. We consider that distress signs should represent ≤50% of the time spent in the trap. A restraining trap system could be judged acceptable if it is expected, at a 95% confidence level, to hold ≥85% of target animals without distress for ≥ 50% of the captivity time. However, because of the possible subjectivity of some observations, we believe that the acceptability of a trap based on behaviour should be done in conjunction with data on injuries and physiological changes.

Physiological evaluations

There are significant challenges to using physiological measurements for the assessment of restraining traps, including the difficulty in acquiring individual baseline data, and the confounding influence of other factors (e.g., time in trap, weather, sun exposure, presence/absence of other animals, etc.) in addition to the method of capture or type of trap. One way to address the baseline data issue is by testing restraining traps in semi-natural environments and repeatedly measuring stress levels using non-invasive methods (such as fecal glucocorticoid metabolite analysis; Keay *et al.* 2006; Franceschini *et al.* 2008; Rothschild *et al.* 2008) and/or hair cortisol analysis (Heimbürge *et al.* 2019; Kallioski *et al.* 2019) before and after an animal is trapped. This approach enables trap assessments to be conducted on an individual basis, with each animal serving as its own control. A less sensitive approach to addressing the baseline data issue is by comparing blood results from captured animals against reported references ranges for conspecifics of the same sex and similar age (Teare 2013; Monterroso *et al.* 2022; Nájera 2022; Nájera and Hearn 2022).

We recommend against collecting serial blood samples from animals prior to and following capture, and then comparing pre- and post-capture blood results, because differences in blood values cannot be easily interpreted. The chemical or physical restraint needed to collect blood from a free-ranging (pre-capture) animal will undoubtedly cause rapid change to several parameters of interest (Table 3), especially indicators of stress. Thus, pre-capture blood sampling is unlikely to provide true baseline values.

The confounding effects of non-trap factors can be minimized by the careful planning of restraining trap assessments in the semi-natural environment. For example, traps should be set in similarly shaded locations, animals should be held in the trap for the same duration before release, and trapped animals should be handled and released by following a standardized set of procedures.

Understanding the physiological responses to different methods of capture and handling enables the selection of methods to minimize the risk of injury, distress, or death at the time of capture and in the days that follow (Cattet *et al.* 2003a). An evaluation of physiological function can also provide insight into effects that may not be apparent through behavioural observations or injury scores. For example, the analysis of stress hormone levels in feces, hair, or blood may suggest that animals perceive the restraining trap environment as "stressful," even if they appear visibly calm in the traps (Lynn and Porter 2008). Similarly, conclusions based on injury scores may suggest that 2 traps are similar, but physiological evaluations may show that one trapping device causes more stress, muscle damage and dehydration than the other (Marks 2010).

Overall evaluation

A restraining trap system that holds 10/10 animals without serious injuries (≤50 points), frequent signs of distress or exertion (≤50% of the capture time), or significant physiological stress effects may be expected, at a 95% confidence level, to hold ≥85% of target animals for a specific time period without welfare concerns.

Criteria for the assessment of submersion trap systems

In the AIHTS certification and implementation process, the Fur Institute of Canada considers that any jaw type trap (body gripping or leghold) set as a submersion set that exerts clamping force on a muskrat (*Ondatra zibethicus*), and maintains the animal underwater, is considered acceptable (FIC 2021). While submersion sets are controversial and considered unacceptable by many (Ludders *et al.* 1999, 2001), they are being used for several species other than muskrat, e.g., northern raccoon, American mink, northern river otter (*Lontra canadensis*), nutria (*Myocastor coypus*) and North American beaver (*Castor canadensis*) (Michigan Department of Natural Resources 2021; Missouri Department of Conservation 2021). Because submersion sets involve the use of either killing or restraining traps with the intent of killing the animal underwater, trapping systems must be assessed for their effectiveness to quickly render animals unconscious, and to hold animals without serious physical injuries, high distress, and significant physiological changes (Serfass 2022). Criteria for the assessment of submersion trap systems must therefore include those used for killing and restraining trap systems.

In semi-natural environments, a submersion trap system that renders 10/10 test animals irreversibly unconscious within a specified time period (e.g., 90 s) and holds these10 animals without serious injuries (≤50 points) may be expected, at a 95% confidence level, to hold ≥85% of target animals for a specific time period without welfare concerns. Because submersion trap systems should quickly render animals irreversibly unconscious, we do not believe that behavioural and physiological changes need to be assessed. Importantly, killing trap systems that may have met criteria of acceptation on land may not be acceptable in underwater systems due to the impact of water on trap striking and clamping forces. Similarly, restraining trap systems that were judged acceptable on land may not be acceptable underwater where captured animals may get tangled or may twist their bodies and suffer significant limb damages (G. Proulx, personal observations on traplines).

Handling and releasing animals

When handling restrained animals, total processing time should be minimized to reduce stress and injury (Soulsbury *et al.* 2020; Nájera *et al.* 2022). Where appropriate, drugs may be used in research to anaesthetize or euthanize animals captured in restraining traps. The efficacy and safety of a drug based on empirical evidence in a target species should be the primary consideration in selecting a drug protocol. Consult Cattet *et al.* (2005), Kreeger and Arnemo (2007), and Proulx *et al.* (2012) for the selection and administration of immobilizing drugs, and preventing medical emergencies.

The release of animals that were previously used in semi-natural environments or restrained on traplines should take into consideration the following (Soulsbury *et al.* 2020):

- Are animals healthy enough to be released, including having recovered fully from any procedures or anaesthesia?
- Release the animals as soon as it is feasible to do so, with attention paid to conspecifics and dependent young, time of day, and the likelihood of animals being harmed during the release.
- On traplines, release site should be as close to capture site as possible.
- The animals pose no danger to public health, animal health or the environment.

Semi-natural environment test animals may be released for the reestablishment of a population within its historical range, the augmentation of an extant population to improve reproductive success or increase genetic variation, or the maintenance of evolutionary potential under environmental change (Proulx and Aubry 2020).

Trap checking times

Killing trap systems do not always kill animals quickly. Animals that are being restrained in such trapping devices may take hours or even days to die depending on the trapping device, the capture location, the physical condition of the animals, and the environmental conditions (Proulx and Rodtka 2019). Likewise, the longer animals spend in restraining traps, the greater the risk of injuries and physiological stress (Proulx *et al.* 1989c,1994; Haulton *et al.* 2001). For fur trapping in North America, Proulx and Rodtka (2019) suggested that killing trap systems be visited ≤12 h. This allows one to ensure that killing trap systems are fully functional because animals avoiding capture may disturb a trap site and render the set ineffective. Also, although the killing or restraining trap system may have successfully passed the simulated environment tests, there is still a possibility for traps to malfunction. Depending on study objectives and species, traps may be visited more frequently to minimize the impact of environmental conditions on captured animals. For example, restraining traps for Richardson's ground squirrels (*Urocitellus richardsonii*) should be set during daylight only and visited at least twice during this period to avoid heat exhaustion (Proulx *et al.* 2011). Kamler *et al.* (2008) checked live-traps set for black-backed jackals (*Canis mesomelas*) at sunset, midnight and sunrise. McGregor *et al.* (2016) remotely checked traps set for feral cats (*Felis silvestris catus*) every 6 h.

Whenever possible, trappers should aim for short trap checking time periods as long as they do not impact on the capture efficiency of the trapping systems. When traplines are very long (i.e., hundreds of kilometers), the traplines may be subdivided into sub-sections to allow for reasonable time checks, or more personnel should be hired to monitor them within a reasonable time period. Traps can also be equipped with a motion-sensitive alarm unit (Nolan *et al.* 1984; Marks 1996; Larkin *et al.* 2003; Ó Néill *et al.* 2007) that allows false positives but not false negatives, and one that notifies users when battery power is low or when a trap has fired (Powell and Proulx 2003; Meek *et al.* 2020). An alarm unit is valuable where there is an effective cellular phone network. Meek *et al.* (2020) used the iridium or satellite network. When the alarm unit senses trap activation, it places a call to the researcher's phone directly or sends an alarm to a defined device. As useful as such devices are, however, their unreliability means that the use of an alarm unit is not a substitute for an appropriate schedule of visits to the trapping systems. Finally, if restraining traps have been accepted according to a specific time period, trap checking times should be based on such a time period. An alarm unit can then be used to determine the exact time of capture of the target animals, and to check traps at a distance to determine if non-target animals have been captured and must be released.

Trapping system selectivity

It is essential that trapping systems be as selective as possible, i.e., they do not capture non-target species. A trap may meet minimal standards of performance according to specific criteria for a specific species, but it may not be acceptable for another species of similar size (Proulx *et al.* 2020). Therefore, if trapping systems are not selective, they may cause undue pain and suffering to non-target species. Furthermore, if they capture many non-target species, they cannot be considered capture-efficient.

The capture selectivity of a trapping system is species specific, i.e., it relates to the number of animals of a target species only. All other captures of other species are considered non-target captures. Capture selectivity should be calculated using a selectivity index such as the Savage's W index (Manly *et al.* 2002):

$$W = Capture\ proportion/population\ proportion$$

where the numerator alone (*capture proportion*) is the number of captured target animals/total number of captured animals. The denominator (*population proportion*) is that proportion of the entire population of possible trapped animals (of all species) made up of members of the target species. A trapping system is deemed selective in a specific test area with a specific species assemblage if capture selectivity W is greater than 1.

Capture efficiency

Capture efficiency is a consideration of primary importance to trappers and is evaluated in trap testing to determine whether a trap that is humane is likely to be used by trappers. The testing of traps for the fur trade in North America required that experimental traps be tested against control traps, which are the most popular traps used by trappers in a region. Proulx *et al.* (2020) explained how this approach may be misleading, depending on the control trap being used. Nevertheless, using popular traps as comparators to an experimental trap is still being recommended in research (Caravaggi *et al.* 2021). However, in the past, some traps which were independently approved on welfare grounds in various research programs have been hastily and incorrectly rejected because of efficiency concerns. We believe that a trap with high performance levels from an animal welfare point of view and reduced capture efficiency has more value than one that does not meet animal welfare concerns but is highly efficient.

Capture efficiency relates to the number of animals of the target species captured during the test period. Abundance of target animals in the traps is weighed by the total number of trap-nights for each trap system, e.g., experimental trap vs. control trap. Capture efficiency is usually calculated as follows:

$$Capture\ efficiency = (Number\ of\ individuals\ captured\ /Number\ of\ traps\text{-}nights) \times 100$$

This method assumes that all traps are available for the target species. If tests for capture efficiency and selectivity are carried out in similar ecosystems within a same landscape, there are no concerns about the species assemblage and the relative abundance of target species. However, if tests are conducted in different regions with different ecosystems, some abundant non-target species in a particular region may be more attracted to test traps than control traps, and vice versa, thus biasing the true assessment of capture efficiency. Therefore, capture efficiency must take into consideration trap selectivity.

Findings should be peer-reviewed and published

All findings relative to trap assessment and development, particularly those of certified traps, should be published in peer-reviewed journals to allow members of the scientific community to evaluate protocols and conclusions. In the past, concerns regarding the reliability of research outcomes have led biomedical scientists to request that findings be reported in publications that include hypothesis generation, experimental design, control and execution, statistical analysis, discussion, and conclusion (Puhan *et al.* 2012; Jarvis and Williams 2016). The same is required for research and assessments that lead to the certification of traps that may have significant impacts on the welfare of captured animals. Recent articles have called for journals to play an active role as "critical control points" in protecting animal welfare in field work (Brook *et al.* 2015; Field *et al.* 2019; Soulsbury *et al.* 2020).

Discussion

The AIHTS (ECGCGRF 1997) and ISO (1999 a,b) mammal trapping standards have been criticized by scientists and environmental groups because they are not, and never were, representative of state-of-the-art trapping technology and were unacceptable from an animal welfare point of view (Proulx *et al.* 2020). We believe that the prerequisites that we laid out for the development of new mammal trapping standards will meet many of the concerns voiced by the scientific community and the public in the last 2 decades, and significantly improve animal welfare when trapping. However, we do not believe that the resulting standards will be the be-all and end-all of trapping. There is still much more work to be done to further improve these standards. It is important to note that, with the implementation of the ISO and AIHTS standards in the late 1990s, manufacturers focused on the production of trapping devices that would meet these standards, and there was little or no development of new technology to improve animal welfare thresholds, TIUs, and trap designs. The prerequisites described here will allow for standards to implement some of the technology that was available but unused in the late 1990s, new knowledge on killing and restraining traps, and new behavioural and physiological assessments.

With technology and material improvement, more effective trap components and designs will be developed in the future. Also, new killing traps that render mammals irreversibly unconscious during time periods shorter than those included in these standards, or restrain animals with little or no injuries and distress, will be developed. In the light of these developments, and a further increase in our understanding of the physiology of trapped animals, the standards based on our prerequisites will hopefully be improved in the near future. We propose that the killing and restraining trap system standards be re-visited every 5 yrs to incorporate new developments and consider societal shifts in attitudes towards some trapping methods (e.g., Ludders *et al.* 1999; Stevens and Proulx 2022). Prerequisites and standards should be re-written every 10 yrs to improve upon thresholds of acceptation and identify new improvements to trappings systems. Ultimately, new standards should aim to produce killing trap systems that would cause instant irreversible unconsciousness, and restraining trap systems that would cause no injury, pain or suffering (Broom 2022). Also, whenever possible, traps that had been accepted with outdated standards should be refurbished to meet the new standards, or replaced with new trapping systems after a grace period that would take into consideration the time period required to make new trapping devices available for the market.

In the last 20 yrs, researchers from different countries working on an array of mammal species have established common trends in the effects of trapping on mammals, e.g., steel-jawed leghold traps cause more injuries than padded-leghold traps (Olsen *et al.* 1986; Meek *et al.* 1995; Serfass *et al.* 1996), and the physiological impacts of trapping can be substantial (Cattet *et al.* 2003a; Gelling *et al.* 2009; Marks 2010). There is enough available knowledge to develop an assessment program incorporating behavioural and physiological indicators (vs. White *et al.* 2021). However, due to the complexity of physiological data and their interactions among themselves and environmental conditions, we need to further investigate indicators that may be useful to broaden our understanding of the impact of trapping on animal welfare.

Some animal welfare requirements are difficult to meet when trapping wild mammals. For example, supplying restrained animals with water to avoid dehydration is a challenge, particularly in arid regions. However, it could be done by attaching water bottles to small cages or using automatic water dispensers for medium- and large-sized animals. Research has also been carried out to address psychological conditions such as anxiety and depression experienced by captive animals (Marks *et al.* 2004). Through research in laboratory, simulated environment and field work, we may be able to identify new means to address such issues (Proulx 2022a). New trap components may also be developed to lessen physical stress on animal limbs, and reduce injuries when animals are captured in cage traps.

One of the most frustrating aspects of past standards has been the lack of leadership in research/assessment organizations to transfer information to the public and the scientific community through publications in peer-reviewed scientific journals (Proulx *et al.* 2020) and in trade and popular magazines (Stevens and Proulx 2022). Peer-review of trap research and development findings is vital to ensure that proper methodology has been employed for the certification of traps (e.g., Caravaggi *et al.* 2021). The implementation of state-of-the-art trapping standards, and the production of certified traps, need to be promoted to trappers and the public through a series of education programs to properly inform people about the need for mammal trapping, and the use of effective trapping systems (Stevens and Proulx 2022).

Whilst we recognize that there is considerable cultural and legislative variability across countries, we believe that effective international trapping standards will become reality only if governments and trappers make an effort to streamline their actions according to standards and assessment protocols that will result in the implementation of high animal welfare criteria. Insistence on such improvements to animal welfare are happening in other disciplines (e.g., agricultural production; Broom 2022), and will soon be required of trappers more than they are already. Accommodating for cultural peculiarities can unfortunately result in the traditional use of inhumane trapping devices such as killing neck snares (Proulx *et al.* 2015), or protocols that are neither rigorous nor scientific (Iossa *et al.* 2007; Proulx *et al.* 2020). Inciting all countries, particularly those involved in fur trapping, to adopt new standards will undoubtedly be a challenge. However, in the past, the use of ISO standards was not mandatory and was not part of any binding agreement impacting on the trade of goods or the legitimacy of traps used to capture mammals (Proulx *et al.* 2020). The use of ISO standards by countries or research organizations was entirely voluntary, and this could be done with new standards. If the scientific community endorses these prerequisites and resulting standards (Proulx *et al.* 2022a,b), and environmental organizations and the public support them, then such changes will happen at the political level. In the past, because of ethical concerns, such changes were catalysed by the European Community's threat of banning fur products from countries failing to stop the use of "steel-jawed" leghold traps and implementing international standards. Hopefully, fur trappers, researchers, and wildlife managers will see the benefits of implementing new mammal trapping standards based on our prerequisites before such threats return.

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Appendix − Glossary

Anaesthesia: This is a state of controlled, temporary loss of sensation or awareness resulting from the administration of drugs. In the context of trapping, anaesthesia is used for the chemical restraint of animals, and to relieve pain and stress (see Proulx *et al.* 2012).

Animal Care and Use Committee: This Committee intends to ensure that the highest animal welfare standards are maintained along with the conduct of robust scientific research through the supervision, coordination, training, guidance, and review of every project proposed to include the use of vertebrate animals. The committee composition is generally designed to be broad enough to represent both scientific and public interests (Canadian Council on Animal Care 2006).

Animal welfare: This is the state of the animal's body and mind. The Office International des Epizooties (OIE 2017) defines animal welfare as 'how an animal is coping with the conditions in which it lives'. Animal welfare research involves collecting physical, behavioural and physiological data to make careful, objective inferences about the state of the animals.

Bait: Foods used to entice an animal in a trap. The use of live animals should be avoided.

Clamping force: The steady-state force exerted on an animal by the jaw(s) of the trap after the striking force has been delivered.

Corneal reflex: Also known as the blink reflex, the corneal reflex is an involuntary blinking of the eyelids elicited by stimulation of the cornea (such as by blowing air or touching by a foreign body).

Control trap: Most popular trap used by trappers in the region where test traps are being evaluated on traplines.

Cubby: A small, enclosed space made out of materials (wood, plastic) (see Figure 2), or dug into a river bank.

Death: The irreversible cessation of all vital functions especially as indicated by permanent stoppage of the heart, respiration, and brain activity.

Euthanasia: Process causing rapid loss of consciousness and death without causing pain, distress or anxiety. In the context of this paper, it is the practice of ending the life of a trapped animal with minimal pain (see Proulx *et al.* 2012).

Killing trap: Device used on land or underwater to both capture and kill an animal.

Lure: Scent used to entice animals in traps. It relates to conspecific odors, fluids or excretions.

Momentum: A measure of the impact that a striking bar can deliver to an object. Momentum is the product of the velocity of a striking bar by its equivalent mass.

Non-target species: Species that is not intended to be captured in a trapping system.

Palpebral reflex: Involuntary blinking of the eyelids elicited by touching the skin around the eye (i.e., the periocular skin).

Pan tension: The tension or pressure required to trigger or activate the trap.

Pan trigger: The treadle or plate usually in the centre of the trapping device, which may operate on a cam-lever principle. When an animal steps on the pan, the trigger is released and the trap activates and closes.

Restraining trap: Device used to live-capture an animal. It includes leghold traps, leg snares and box/cage traps. Restraining traps are also used in killing trap systems to capture and kill semi-aquatic mammals underwater.

Strike location: This is the location on the body where the animal is struck by trap jaws. For rapid loss of consciousness, animals must receive a single strike in the head-neck region (preferably above C3), which causes maceration of the brain or severe haemorrhage, cervical spinal cord maceration or severance (Proulx *et al.* 1989a; Onderka 1999); or a double-strike in the head-neck and thorax regions (Proulx *et al.* 1989a), which results in tracheal occlusion or severance, and cardiac or aortic rupture (Onderka 1999).

Target species: Species that is intended to be captured in a specific trapping system.

Test animal: Animal used in biological tests.

Trapline: A series of traps set in an area by researchers, pest controllers or fur trappers.

Trap-night: One trap set for one night.

Trap set: This relates to the location, surroundings, components (e.g., swivels, chains, spikes, locks, etc.), and baits or lures used when installing a trap for the capture of an animal. Two identical traps set differently may produce different results from an animal welfare, capture-efficiency and selectivity point of view.

Trigger: A device that releases a spring or catch, and so sets off a mechanism to release striking jaw(s) or door(s).

Unconsciousness: This is a state which occurs when an animal loses its ability to maintain an awareness of self and environment. Unconsciousness can be determined with the loss of corneal and palpebral reflexes.

Chapter 18

International Mammal Trapping Standards − Part II: Killing Trap Systems

Gilbert PROULX[1], Benjamin L. ALLEN[2,3], Marc CATTET[4], Pauline FELDSTEIN[1], Graziella IOSSA[5], Paul D. MEEK[6], Thomas L. SERFASS[7], and Carl D. SOULSBURY[5]

[1]Alpha Wildlife Research & Management Ltd, 229 Lilac Terrace, Sherwood Park, Alberta, T8H 1W3, Canada. Email: gproulx@alphawildlife.ca

[2]Centre for Sustainable Agricultural Systems, Institute for Life Sciences and the Environment, University of Southern Queensland, Toowoomba, Queensland, 4350, Australia.

[3]Centre for African Conservation Ecology, Nelson Mandela University, Port Elizabeth 6034, South Africa.

[4]Department of Environment, Government of Yukon, Whitehorse, Yukon, Canada.

[5]School of Life Sciences, University of Lincoln, Brayford Pool, Lincoln, UK.

[6]Vertebrate Pest Research Unit, NSW Dept. Primary Industries, PO Box 530, Coffs Harbour NSW, 2450, Australia.

[7]Department of Biology and Natural Resources, Frostburg State University, Frostburg, Maryland, 21532, USA.

Abstract − In this paper, we propose standards for killing trap systems based on Proulx *et al.*'s (2022) prerequisites, which provide context and explanations for our approach. Our aim is to identify assessment protocols that are based on the scientific method, and that include evaluation parameters and threshold levels of acceptation, and laboratory and field procedures, to recognize mammal trapping systems that are acceptable from an animal welfare, and capture efficiency and selectivity, point of view. The testing of killing trap systems consists of 4 steps: 1) Mechanical evaluation; 2) Approach tests in semi-natural environments; 3) Kill tests in semi-natural environments; and 4) Kill tests on traplines. Based on the normal approximation to the binomial distribution, acceptable killing trap systems are expected, at a 95% confidence level, to render ≥85% of the animals irreversibly unconscious in ≤ 90 sec for most mammal species, and ≤30 sec for small mammals (mouse, vole, etc.). We recommend that standards be continuously updated based on the development of new designs and technology.

Introduction

There is an undeniable need to implement state-of-the-art trapping technology for all trapped mammal species regardless of the reason for which they are captured: use more stringent performance levels, improve trap testing procedures, develop standard operating procedures or protocols on how to use certified trapping systems in the field, and assess capture selectivity and efficiency (Iossa *et al.* 2007; Proulx *et al.* 2012, 2022). In this paper, we propose standards for killing trap systems based on Proulx *et al.*'s (2022) prerequisites, which provide context and explanations for our approach.

Mammal species

Trapping standards will apply to all terrestrial and semi-aquatic mammal species that are captured in mechanical killing trap systems throughout the world. It is important to note, however, that killing traps may not be used in countries like Australia except for pest mice and rats.

Types of traps

These standards relate to all traps that have mechanical energy if they are in motion and/or if they are at some position relative to a zero-potential energy position. These include rotating-jaw traps, mousetraps, planar traps, and neck snares with and without springs.

Threshold of acceptance & times to irreversible unconsciousness

Based on the normal approximation to the binomial distribution, acceptable killing trap systems are expected, at a 95% confidence level, to render ≥85% of the animals irreversibly unconscious in ≤ 90 sec for most mammal species, and ≤30 sec for small mammals (mouse, vole, etc.).

Objective

Our aim is to identify assessment protocols that are based on the scientific method, and include evaluation parameters and threshold levels of acceptation, and laboratory and field procedures for a proper evaluation of mammal trapping systems that are acceptable from an animal welfare, capture efficiency, and selectivity point of view. Unfortunately, such protocols are relatively scarce and have been employed by a limited number of research teams. For this reason, in many instances, we had to refer to the same researchers and organizations whose work encompassed a variety of mammal species.

A glossary is provided in an Appendix to explain the terminology used throughout the manuscript.

Standards for killing trap systems

The following protocols are largely based on the Canadian research and development program criteria that are more stringent than the ISO and AIHTS standards (Proulx *et al.* 2020) and produced state-of-the-art trapping devices from 1985 to 1993. The protocols of the program were used to some extent though not entirely for the development of ISO and AIHTS standards (Proulx *et al.* 2020) and have been partially or fully replicated by research teams such as Warburton and Moffat (2007) and Morris and Warburton (2014) when implementing NAWAC's (2019) research guidelines.

The testing of killing trap systems consists of 4 steps (Figure 1). Some of them are being conducted in semi-natural environments. However, as pointed out by Proulx *et al.* (2022), all procedures can be carried out in the wild. This is particularly true for large animals (e.g., wolves *Canis lupus*, dingoes *C. familiaris*, bears *Ursus* spp., lions *Panthera leo*) which are difficult and expensive to acquire in sufficient numbers from the wild and house in research facilities for extended periods of time.

All research procedures involved in the testing of killing trap systems must be approved by an institutional Animal Care & Use Committee with members possessing appropriate expertise in the wildlife husbandry, health care, and research relevant to trapping and handling.

Step 1 − Mechanical Evaluation

Trap clamping force and impact momentum (striking force) are widely accepted proxies of trap welfare performance among traps with springs (Proulx *et al.* 2020). The evaluation of these forces is highly recommended to assess the potential of traps to meet specific threshold of acceptance and reduce the number of animals used in trap assessment. Researchers can use different equipment (see Proulx *et al.* 2022) to assess the following:

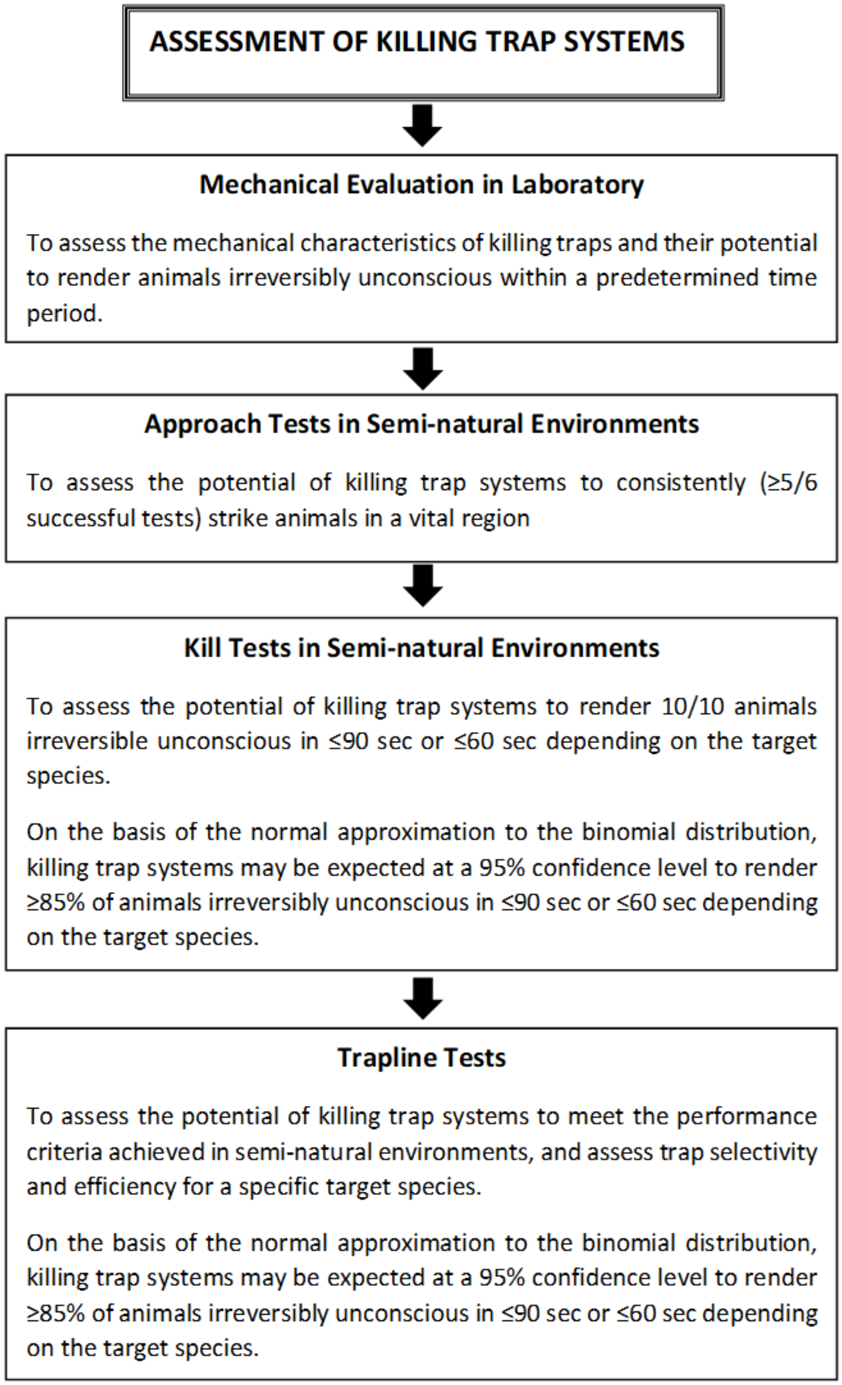
Momentum

This is the product of the velocity of a striking bar by its equivalent mass. Important steps include:

- Select several traps of the tested model at a relevant trap opening for the target animal species.
- Determine the effective mass of the striking component.
- Determine the impact velocity.
- Calculate the impact momentum (p) of the trap, expressed in kg.m/sec, using the following formula:

$$p = me\,.v$$

where me is the is the equivalent mass of the trap (striking component) at the strike location expressed in kg, and v is the velocity of the striking bar at a specified opening expressed in m per sec.



Mechanical Evaluation in Laboratory

To assess the mechanical characteristics of killing traps and their potential to render animals irreversibly unconscious within a predetermined time period.

Approach Tests in Semi-natural Environments

To assess the potential of killing trap systems to consistently (≥5/6 successful tests) strike animals in a vital region

Kill Tests in Semi-natural Environments

To assess the potential of killing trap systems to render 10/10 animals irreversible unconscious in ≤90 sec or ≤60 sec depending on the target species.

On the basis of the normal approximation to the binomial distribution, killing trap systems may be expected at a 95% confidence level to render ≥85% of animals irreversibly unconscious in ≤90 sec or ≤60 sec depending on the target species.

Trapline Tests

To assess the potential of killing trap systems to meet the performance criteria achieved in semi-natural environments, and assess trap selectivity and efficiency for a specific target species.

On the basis of the normal approximation to the binomial distribution, killing trap systems may be expected at a 95% confidence level to render ≥85% of animals irreversibly unconscious in ≤90 sec or ≤60 sec depending on the target species.

Figure 1. Sequential series of tests to assess the killing potential of trapping systems.

For killing traps to be used in submersion systems, determine the impact velocity underwater.

Clamping force

This is the steady-state force exerted on an animal by the jaw(s) of the trap after the striking force has been delivered. Important steps include:

- Select several traps of the tested model.
- Determine the force on a load cell at different openings that are relevant for the target species.

Threshold graph

Plot momentum and clamping force values on a pre-existing threshold graph for the target species and specific threshold acceptance values (see Cook and Proulx 1989), or use these values for the development of such a graph in conjunction with animal test results obtained in semi-natural environments (see below). If a threshold graph does not exist, researchers can use the graph of a species of similar size, even though it is recognized that there are interspecific variations. Traps that are plotted below the threshold line may not be powerful enough to kill an animal of a target species for specific threshold acceptance values (Proulx *et al.* 2022).

Step 2 −Approach tests in semi-natural environments

Initial tests with animals should preferably be conducted in semi-natural environments with only a small number of animals (see Prerequisites −Proulx *et al.* 2022). Approach tests aim to ensure that animals are being struck in vital regions; this minimizes the risks of subjecting animals to undue pain and suffering, and it increases the possibility of traps to succeed. Animals are allowed to approach traps wired in the set position so that the traps can be triggered but cannot close completely and injure the animals (Proulx *et al.* 1989a). These tests are safe for the animals and can be carried out with any mammal species and any type of killing trap system (Proulx 1999a).

Testing underwater trapping systems in semi-natural environments may be conducted in large tanks. Approach tests can be video-recorded through transparent sides, or with specialized underwater equipment (e.g., Hermann *et al.* 2020)

Test personnel

Researchers must know how to set the tested killing trap system properly and operate other equipment associated with the trap-testing process (e.g., video recording equipment).

Test animals

Tests should preferably involve the use of animals that were live-captured in the wild, and kept in captivity for a short period of time. Animals are individually introduced in semi-natural environments and allowed a period of acclimation to new environmental conditions before any test is conducted. Animals should not be channelled or forced into traps; they should move as they wish within their environment, and they should approach traps on their own free will. A different animal must be used for each test. Animals used in approach tests cannot be used in subsequent killing tests (see below).

Trap testing period

Approach tests should be conducted during the same period when trapping usually occurs on traplines. For example, traps used for fur trapping in North America are tested during late fall and winter months.

Trapping system preparation

A different trap must be used for each test. All traps must be prepared as they would be used on traplines. Depending on target species, they may have to be boiled, dyed, waxed, or just washed to remove human or manufacture scents. Traps must be set as they would be on traplines, i.e., with the same sets. Finally, the same baits or lures should be used to attract the animals in killing trap system tests in semi-natural environments and on traplines. Trapping systems should be as selective as possible for the target species. With the exception of specific trapping systems such as those set underwater, animals should be able to approach the trigger and bait from only one direction to ensure consistency in strike location. Take specific measurements such as the exact location of the trap within a cubby, distance of the trigger from the bait, length of the trap anchor chain or wire, etc. Photograph the trap and set from different angles.

Video-recordings and strike locations

Animal approaches are recorded with cameras. The actual time of trap firing is denoted by release of the trigger. Video recording must be thoroughly analyzed to determine if the animals would have been struck in vital regions if traps had been allowed to close completely. For rapid loss of consciousness, animals must receive a single strike in the head-neck region (preferably above C3), which causes maceration of the brain or severe haemorrhage, cervical spinal cord maceration or severance (Proulx *et al.* 1989a; Onderka 1999); or a double-strike in the head-neck and thorax regions (Proulx *et al.* 1989b), which results in tracheal occlusion or severance, and cardiac or aortic rupture (Onderka 1999).

Adjustments

If the analysis of the videos indicates that the trigger needs to be modified, or the trap set must be changed by positioning the bait at a different height or distance, etc., adjustments must be made and approach tests repeated with new animals to ensure their proper positioning in the trap.

Evaluation

A killing trap system can proceed to kill tests if ≥5/6 animals used in approach tests would have been struck in vital regions.

Step 3 −Kill tests in semi-natural environments

Test personnel

Researchers must know how to set the tested killing trap system properly, diagnose the loss of corneal and palpebral reflexes to assess unconsciousness, determine time of death with a stethoscope and other diagnostic signs, and have the capability of intervening in situations where traps malfunction or animals are in a distress state.

Animal preparation

All animals are acclimated to the semi-natural environments as in approach tests.

Trap preparation

As in approach tests, but traps are allowed to close completely and strike the animals. A different trap is used for each kill test. Verify specific measurements such as the exact location of the trap within a cubby, distance of the trigger from the bait, length of the trap anchor chain or wire, etc., that have been used in approach tests. Photograph the killing trap system from different angles.

Video-recordings

As in approach tests.

Kill tests

All tests are remotely monitored by researchers. Upon activation of the trap, researchers quickly access the animal to monitor its state of consciousness. Researchers must avoid making unnecessary noise, and keep their voice low to not cause more anxiety to the struck animal.

If the animal is struck in vital regions, observers monitor the state of consciousness based on the loss of corneal and palpebral reflexes. A lens cleaner or equivalent apparatus may be used to test the eye reflexes, i.e., by blowing air in the eye (corneal reflex) and touching the corner of the eye (palpebral reflex). The loss of eye reflexes is indicative of a loss of consciousness.

Monitor the heartbeat with a stethoscope. Death is confirmed if the heart has stopped beating for over 60 sec. Other deaths indicators: the tongue has gone flaccid and does not respond to pinching or squeezing, the jaw muscle tone has been lost, and the lower jaw is floppy.

Animals that have been struck in vital regions and are conscious after the pre-determined time period may be left in the trap for 1 more minute before being euthanized using procedures appropriate for the test species (AAZV 2006; AVMA 2020). This extra time allows researchers to determine how close the trap is to meeting the period to unconsciousness required by protocol. Animals struck in non-vital regions must be euthanized immediately.

Animals that are struck and escape correspond to unsuccessful tests where the animals did not lose consciousness within the pre-determined time. Researchers must capture this animal and euthanize it if it has been seriously injured. These animals cannot be re-used in tests involving the killing trap system.

Data recording

Record date of the test, animal identification number, age and sex, time of loss of corneal and palpebral reflexes and heartbeat, strike location (including the distance between the tip of the nose of the animal and the trap jaw at point of impact), macroscopic observations (presence of fluids and discharge, exposed bones, cuts, abrasions, etc.). Properly photograph the animal in the trap and its general position at the trapping system. Photograph the strike location, before and after the removal of the trap. Place the labelled carcass in a bag and have the animal necropsied by a pathologist. If this cannot be done straight away, freeze the carcass until later examination by a pathologist. Care should be taken to not damage the carcass during handling and transport.

Post-mortem evaluations

Necropsies should be conducted by experienced wildlife pathologists who can identify trap-caused trauma. Radiographs may be necessary to detect the presence of minute pathological changes.

Evaluation

Traps are successful if they rendered 10/10 animals (or 27/28, etc.; Table 1) irreversibly unconscious in ≤90 sec or ≤30 sec depending on the target species with inevitable subsidence into death.

Table 1. Outcomes in semi-natural environments for killing trap systems to be expected, at a 95% confidence level, to render ≥85% of the animals irreversibly unconscious within a pre-determined time period of 90 s for most mammal species, and 30 s for small mammals (mouse, vole, etc.). Tests are judged successful when animals lose consciousness within the pre-determined period (either 90 s or 30 s).

Number of tests	Number of successful tests	Number of failures
10	10	0
28	27	1
37	35	2

Step 4 a −Killing trap system tests on traplines: threshold level of acceptance

Testing killing trap systems on traplines is necessary to ascertain, at a 95% confidence level, the ability of traps to render ≥85% of animals irreversibly unconscious in ≤90 sec or ≤30 sec depending on target species, and to assess the capture-efficiency and selectivity of the trapping system.

*Test personne*l

Researchers must be familiar with the killing trap system and the procedures to follow when retrieving captures. If fur trappers are employed to assist researchers in the field, individuals should be competent and conscientious. They should be aware of new trap technology developments and/or have experience with experimental traps or traps like the experimental traps in order to ensure task familiarity.

Traplines

Traplines should not be located near human dwellings (Villeneuve and Proulx 2022). Traps should be tested on ≥2 traplines, under comparable ecological conditions (considering not only vegetation type, but also weather, season, species assemblage, etc.), while accounting for temporal variation in selectivity. If tests are conducted in landscapes with different ecological conditions, researchers must take into account population proportion (in order to consider animal availability), and calculate correct values of the Savage *W* index (or similar index) (Virgós *et al.* 2016). Previous animal population abundance estimates can be obtained from previous studies in the trapline areas, or by applying standard census techniques (e.g., Sutherland 2006; Long *et al.* 2008; O'Connell *et al.* 2011).

Killing trap system sample size and spacing

At least 30 experimental traps and 30 control traps (if judged necessary to assess capture efficiency−Proulx *et al.* 2022) are recommended per trapline although the exact trap numbers should be calculated using power analysis consistent with the objectives of the study (Meek *et al.* 2019). If tested killing trap systems are compared to control killing trap systems, these need to be sufficiently spaced on the trapline to maintain trap independence.

Trap preparation and set

Killing trap systems must be identical to those used in semi-natural environments. Verify specific measurements such as the exact location of the trap within a cubby, distance of the trigger from the bait, length of the trap anchor chain or wire, etc., that have been used in kill tests in semi-natural environments. Photograph the killing trap system from different angles.

Video-recordings

A least 1 but preferably 2 cameras should be mounted above ground, and oriented on the tested killing trap system. Cameras should provide a good view of the trap and the target animal once captured. However, cameras produce sounds that are well within the perceptive range of most mammals' hearing and produce illumination that can be seen by many species (Meek *et al.* 2014, 2016), and they should be well camouflaged to not impact on the behaviour of animals approaching traps (Proulx 2018). Camera(s) should be set on the video mode, solidly secured to trees, metal posts, etc., and locked to prevent any tampering of the memory cards by animals or people. A similar setup can be done underwater (e.g., Helmholz *et al.* 2016; Hermann *et al.* 2020)

Trap visits

Killing trap systems should be visited ≤12 h after setting or re-setting traps. This allows one to ensure that killing trap systems are fully functional because animals avoiding capture may disturb a trap site and render the set ineffective. Also, although the killing trap system may have successfully passed the semi-natural environment tests, there is still a possibility for animals to be captured in non-vital regions, or for non-target animals to be found alive in the traps. Animals found alive in killing trap systems should be humanely euthanized.

Traps can also be equipped with a motion-sensitive alarm unit (Nolan *et al.* 1984; Marks 1996; Larkin *et al.* 2003; Ó Néill *et al.* 2007) that allows false positives but not false negatives, and that notifies a researcher when battery power is low or when a trap has fired (Powell and Proulx 2003; Meek *et al.* 2020). This is a valuable approach where an effective satellite communication network exists. It is noteworthy to mention that an alarm unit is not a substitute for an appropriate schedule of visits of the trapping systems

Data recording

Record time and dates of when the trap is set and checked. If the trap fired without capturing an animal, examine the trap for hair, blood, etc., thus suggesting the animal escaped or was taken by a scavenger. Look for animal tracks and other signs near the trap site. Note any disturbance to the set, and trap anomalies such as frame bending, trigger malfunction, etc. Video recordings may be useful to cross-validate observations.

If the trap captured an animal, assign an animal identification number, and record species, age and sex, strike location (including the distance between the tip of the nose of the animal and the trap jaws at point of impact), macroscopic observations (presence of fluids and discharge, exposed bones, cuts, abrasions, etc.), and any change to the trapping system that resulted from the capture, e.g., bait still present or not, cubby or surroundings show signs of struggle, etc. Properly photograph the animal in the trap and its general position at the trap site. Photograph the strike location, before and after the removal of the animal from the trap. Secure camera the memory cards. Place the labelled carcass in a bag and freeze it until later examination by a pathologist. Because freezing the carcass may affect the histopathological evaluation, it is better to perform the necropsy as soon as possible or leaving the carcass in a refrigerator if the necropsy can be performed during the next 1−3 d. Care should be taken to not damage the carcass during handling and transport.

Post-mortem evaluations

Animals should be necropsied by experienced wildlife pathologists who can identify trap-caused trauma. Radiographs may be necessary to detect the presence of minute pathological changes.

Evaluation

Determine the proportion of captures with strike locations and injuries (lesions) that are consistent with those observed in successful kill tests in semi-natural environments. Determine the killing performance of the trap using the normal approximation to the binomial distribution. Killing trap systems will be judged successful if strike locations and injuries (lesions) in ≥85% of the captured animals of the target species are consistent with those observed in successful kill tests in semi-natural environments. Then, the killing trap system will be expected, at a 95% confidence level, to render animals irreversibly unconscious in ≤90 sec or ≤30 sec depending on the target species.

Example: If a trap renders 10/10 animals irreversibly unconscious within 90 s in semi-natural environments − and therefore is expected, at a 95% confidence level, to render ≥85% of the animals irreversibly unconscious within this time period− it is eligible for testing on traplines. If, on traplines, the trap captures 79 (99%) out of 80 animals, and strike locations and lesions correspond to those observed in successful tests in semi-natural environments, the trap performance is estimated at 94% on the basis of the normal approximation to the binomial distribution (one-tailed test). Therefore, trapline tests confirmed that, at a 95% confidence level, the trap can be expected to render ≥85% of the target animals irreversibly unconscious in ≤ 90 s.

Step 4 b −Killing trap system tests on traplines: capture efficiency

Data recording

Carefully record the species for each captured animal on the trapline. The capture efficiency of a trapping system is species specific, i.e., it relates to the number of animals of a target species only.

Data analysis

Capture efficiency of a trapping system relates to the number of animals of the target species captured during the test period. Abundance of target animals in the traps is weighed by the total number of trap-nights for each killing trap system, e.g., experimental trap vs. control trap. Capture efficiency is usually calculated as follows:

Capture efficiency = (Number of individuals captured /Number of traps-nights) x 100

This method assumes that all traps are available for the target species. Also, it does not account for the fact that the species assemblage and relative species abundance in test areas may vary among regions. As a result, some abundant non-target species in a particular region may be more attracted to test traps than control traps, and vice versa, thus biasing the true assessment of capture efficiency. Therefore, capture efficiency must take into consideration trap selectivity.

Evaluation

The number of animals of a target species captured in the test killing trap system may be compared to capture success levels reported in previous studies (e.g., Proulx 1999b), or, if applicable, to the capture success of a control killing trap system.

Step 4 c −Killing trap system tests on traplines: capture selectivity

Data recording

The capture selectivity of a trapping system is species specific, i.e., it relates to the number of animals of a target species only. All other captures from other species are considered non-target captures.

Data analysis

Capture selectivity should be calculated using a selectivity index such as the Savage's *W* index:

W = Capture proportion/Population proportion

where *Capture proportion* (the numerator) is the number of captured target animals/total number of captured animals; and *Population proportion* (the denominator) is that proportion of the entire population of possible trapped animals (of all species) made up of members of the target species. It is noteworthy to mention that other indices may be used to calculate selectivity (see Pielou 1977; McClanahan and Mangi 2004).

Evaluation

A trapping system is deemed selective in a specific test area with a specific species assemblage if capture selectivity W is greater than 1.

Step 5 −Sturdiness and safety

We recommend that researchers wear the necessary protective equipment to minimize injuries when working with large killing traps. For large trapping devices that can cause significant injuries to users, a release device (e.g., a rope or pliers to compress springs, shears to cut through wire, etc.) must be kept in proximity to the user if a trap was to fire on the individual's hands. Traps must be inspected for their sturdiness, ease of setting, and reliability (e.g., all the springs are properly attached and fire well), which can impact on their ability to adequately capture an animal.

Exemptions

All homemade killing trap systems should be subject to these standards (in contrast with ECGCGRF 1997). There are no exemptions to kill trapping systems used for the capture of terrestrial and semi-aquatic mammals.

Points to consider

In the past, the assessment of killing trap systems rarely occurred without some structural development. Modifications to the trap itself or to the set are common (Proulx 1999a). Consideration should be given to modify killing trap systems that show potential but failed because of low striking or clamping forces. A modification of the striking jaws or springs may suffice to boost momentum and clamping force, and pass the stepwise evaluation process (Proulx 2022).

As Proulx *et al.* (2022) pointed out, killing trap systems for large mammals (e.g., canids, ursids and felids) may not be suitable as such traps would be dangerous to other wildlife species and to the users. Killing neck snares (with or without springs) have been repeatedly found inhumane and unselective (Proulx *et al.* 2015) and should not be considered for these species. We recommend that the capture of large animals be conducted with restraining traps that cause little or no injury.

Finally, trap testing and development may lead to new designs and technology that will significantly improve animal welfare. For this reason, the above standards should be continuously updated, and re-written and upgraded every 10 yrs (Proulx *et al.* 2022).

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Appendix − Glossary

Animal Care and Use Committee: This Committee intends to ensure that the highest animal welfare standards are maintained along with the conduct of robust scientific research through the supervision, coordination, training, guidance, and review of every project proposed to include the use of vertebrate animals. The committee composition is generally designed to be broad enough to represent both scientific and public interests (Canadian Council on Animal Care 2006).

Animal welfare: This is the state of the animal's body and mind. The Office International des Epizooties (OIE 2017) defines animal welfare as 'how an animal is coping with the conditions in which it lives'. Animal welfare research involves collecting physical, behavioural and physiological data to make careful, objective inferences about the state of the animals.

Bait: Foods used to entice an animal in a trap. The use of live animals should be avoided.

Camera: Also known as a remote trail or game camera in the northern hemisphere, it is a camera that is triggered by either a passive infrared sensor (heat-in-motion) or the interruption of a light beam (active infra-red) by an animal. The camera is left unattended in the field. Photographs or videos are recorded on memory cards. Some models allow users to access images from their cellular phone where there is telecommunication coverage.

Corneal reflex: An involuntary blinking of the eyelids elicited by stimulation of the cornea (such as by blowing air or touching by a foreign body).

Control trap: Most popular trap used by trappers in the region where test traps are being evaluated on traplines.

Cubby: A small, enclosed space made out of materials (wood, plastic), or dug into a river bank.

Death: The irreversible cessation of all vital functions especially as indicated by permanent stoppage of the heart, respiration, and brain activity.

Euthanasia: Process causing rapid loss of consciousness and death without causing pain, distress or anxiety. In the context of this paper, it is the practice of ending the life of a trapped animal with minimal pain (see Proulx *et al.* 2012).

Lure: Scents used to entice animals in traps. These are related to conspecific odors, fluids or excretions.

Non-target species: Species that is not intended to be captured in a trapping system.

Palpebral reflex: Involuntary blinking of the eyelids elicited by touching the skin around the eye (i.e., the periocular skin).

Restraining trap: Device used to live-capture an animal. It includes leghold traps, leg snares and box/cage traps. Restraining traps are also used in killing trap systems to capture and kill semi-aquatic mammals underwater.

Striking components: Parts of the trap that close and come into contact with an animal's body. Usually referred as striking jaws or bars.

Target species: Species that is intended to be captured in a specific trapping system.

Test animal: Animal used in biological tests.

Times to irreversible unconsciousness (TIUs): Period of time elapsed between the time when an animal is struck by a trap and the irreversible loss of sensibility and consciousness based on the loss of corneal and palpebral reflexes or any other specifically proven suitable substitute parameter: Time to irreversible unconsciousness has been set at 180 sec for more than 40 yrs (FPCHT 1981; Proulx *et al.* 2012). In AIHTS standards, TIUs have been set at ≤45 sec and ≤120 sec for a few small and medium-sized mammals (ECGCGRF 1997), respectively, and 300 s for most furbearer species. On the basis of performance levels obtained in previous studies with medium-sized rodents and carnivores (Proulx 1999a), time to irreversible loss of consciousness can generally be minimized to ≤90 sec. With new technology and materials developed in recent decades, Proulx *et al.* (2020) suggested that TIUs be reduced to less than 60 sec for many species, particularly small rodents (e.g., Proulx 1999c; Blue Angel 2017).

Trapline: A series of traps set in an area by researchers, pest controllers or fur trappers.

Trap-night: One trap set for one night.

Trap set: This relates to the location, surroundings, components (e.g., swivels, chains, spikes, locks, etc.), and baits or lures used when installing a trap for the capture of an animal. Two identical traps set differently may produce different results from an animal welfare, capture-efficiency and selectivity point of view.

Trapping systems: In the past, most assessments focused on a trap model rather than a trapping system which encompasses 1) a trap with specific dimensions, shape, power, and attachments (e.g., chain, swivels, locks); 2) a trigger with a specific shape and operation; 3) a set with a specific placement of the trap, and bait or lure. The trapping system that will be used in the field must be identical to the system used in the assessment of a specific trap model in semi-natural environments (Proulx *et al.* 2012).

Trap performance in trap standards: This is the normal approximation of the true performance of a trap. In the real world where hundreds of thousands of animals may be captured, it is necessary to predict the performance of traps according to specific criteria (Proulx *et al.* 2020). For example, in an assessment protocol, if a test trap successfully kills 9/9 animals according to specific criteria, the success rate is 100%. However, it is inconceivable to suggest that the tested trap model would successfully kill 100% of all animals captured on traplines according to the specified criteria. Researchers can approximate the true performance of traps by using the normal approximation to the binomial distribution (Proulx *et al.* 2020). A trap model that successfully killed 9/9 (100%) animals in semi-natural environments could be expected, at a 95% confidence level, to kill ≥70% animals of a target species captured on traplines (one-tailed test approximation to the normal distribution) (Fleiss 1981; Proulx *et al.* 1989a, 2020).

Trap treatment: This is the preparation of a trap before use in semi-natural environments and on traplines. New traps are typically covered in oil to prevent rusting during storage and transport. This can be removed from the traps by a variety of methods including soaking in vinegar-bicarbonate of soda, cold-soaking in clean water, or adding local native bark and leaves or commercial trap dyes into the mix. Colouring, staining or dying is used to remove the metallic shine of the trap. Coating traps with a thin layer of wax is believed to assist preventing trap mechanism jamming under snow conditions and also helps reduce scents from traps. Some traps such as mousetraps purchased in hardware stores, or some newly purchased cage traps, do not require any treatment before use.

Trigger: A device that releases a spring or catch, and so sets off a mechanism to release striking jaw(s) or door(s).

Unconsciousness: This is a state which occurs when an animal loses its ability to maintain an awareness of self and environment. Unconsciousness can be determined with the loss of corneal and palpebral reflexes.

Waxing: Part of the process of preparing traps for deployment or storage by coating them with wax or similar protectant/lubricant.

Chapter 19

International Mammal Trapping Standards − Part III: Restraining Trap Systems

Gilbert PROULX[1], Benjamin L. ALLEN[2,3], Marc CATTET[4], Pauline FELDSTEIN[1], Graziella IOSSA[5], Paul D. MEEK[6], Thomas L. SERFASS[7], and Carl D. SOULSBURY[5]

[1]Alpha Wildlife Research & Management Ltd, 229 Lilac Terrace, Sherwood Park, Alberta, T8H 1W3, Canada. Email: gproulx@alphawildlife.ca
[2]Centre for Sustainable Agricultural Systems, Institute for Life Sciences and the Environment, University of Southern Queensland, Toowoomba, Queensland, 4350, Australia.
[3]Centre for African Conservation Ecology, Nelson Mandela University, Port Elizabeth 6034, South Africa.
[4]Department of Environment, Government of Yukon, Whitehorse, Yukon, Canada.
[5]School of Life Sciences, University of Lincoln, Brayford Pool, Lincoln, UK.
[6]Vertebrate Pest Research Unit, NSW Dept. Primary Industries, PO Box 530, Coffs Harbour NSW, 2450, Australia.
[7]Department of Biology and Natural Resources, Frostburg State University, Frostburg, Maryland, 21532, USA.

Abstract − In this paper, we propose standards for restraining trap systems based on Proulx *et al.*'s (2022a) prerequisites, which provide context and explanations for our approach. Our aim is to identify assessment protocols that are based on the scientific method, and that include evaluation parameters and threshold levels of acceptation, and laboratory and field procedures, to recognize mammal trapping systems that are acceptable from an animal welfare, and capture efficiency and selectivity, point of view. The testing of restraining trap systems consists of 3 steps: 1) Mechanical evaluation for leghold trapping devices; 2) Restraining tests in semi-natural environments; and 3) Restraining tests on traplines. On the basis of the normal approximation to the binomial distribution, a restraining trap system is acceptable if, at a 95% confidence level, it holds ≥85% of the animals without serious injuries (<50 points), signs of distress or exertion during ≥50% of captivity time, and without significant elevated stress, exertion or dehydration for the duration of the captivity period. We recommend that these standards be implemented and continuously updated as new designs and technology is developed.

Introduction

On the basis of Proulx *et al.*'s (2020) review, it is clear that mammal trapping standards need to be revisited to implement state-of-the-art trapping technology and improve capture efficiency and species selectivity. In the case of restraining traps, there is a need to expand the assessment of restraining traps and take into account physical, behavioural, and physiological changes caused by traps. Furthermore, more stringent performance levels and improved trap testing procedures are required (Iossa *et al.* 2007; Proulx *et al.* 2012, 2022a). In this paper, we develop standards for restraining trap systems based on Proulx *et al.*'s (2022a) prerequisites, which provide context and explanations for our approach.

Mammal species

Trapping standards will apply to all terrestrial and semi-aquatic mammal species that are captured in mechanical restraining trap systems throughout the world.

Types of traps

These standards relate to all mechanical traps that have mechanical energy if they are in motion and/or if they are at some position relative to a zero-potential energy position. Restraining traps correspond to mechanical traps used to live-capture an animal. They include leghold traps, leg snares, neck cable restraints, and box/cage traps. Restraining traps may also be used in killing trap systems to capture and kill semi-aquatic mammals underwater. When used as underwater killing trap systems, however, the assessment of restraining traps must be conducted under killing and restraining trap system standards (Proulx *et al.* 2022a,b).

Threshold of acceptance

On the basis of the normal approximation to the binomial distribution, acceptable restraining trap systems are expected, at a 95% confidence level, to hold ≥85% of target animals for a specific time period without serious injuries (≤50 points), signs of distress or exertion (≤50% of the capture time), and significant physiological stress changes.

Objective

Our aim is to describe assessment protocols that are based on the scientific method, and that include evaluation parameters and threshold levels of acceptation, and laboratory and field procedures, to identify mammal trapping systems that are acceptable from an animal welfare, and capture efficiency and selectivity point of view. Unfortunately, such protocols are relatively scarce and have been employed by a limited number of research teams. For this reason, in many instances, we had to refer to the same researchers and organizations whose work encompassed a variety of mammal species.

A glossary is provided in an Appendix to explain the terminology used throughout the manuscript.

Standards for restraining trap systems

The following protocols are largely based on the Canadian research and development program criteria, which were more stringent than the ISO and AIHTS standards (Proulx *et al.* 2020), and produced state-of-the-art trapping devices from 1985 to 1993. The protocols of that program were also used to some extent though not entirely for the development of ISO and AIHTS standards (Proulx *et al.* 2020).

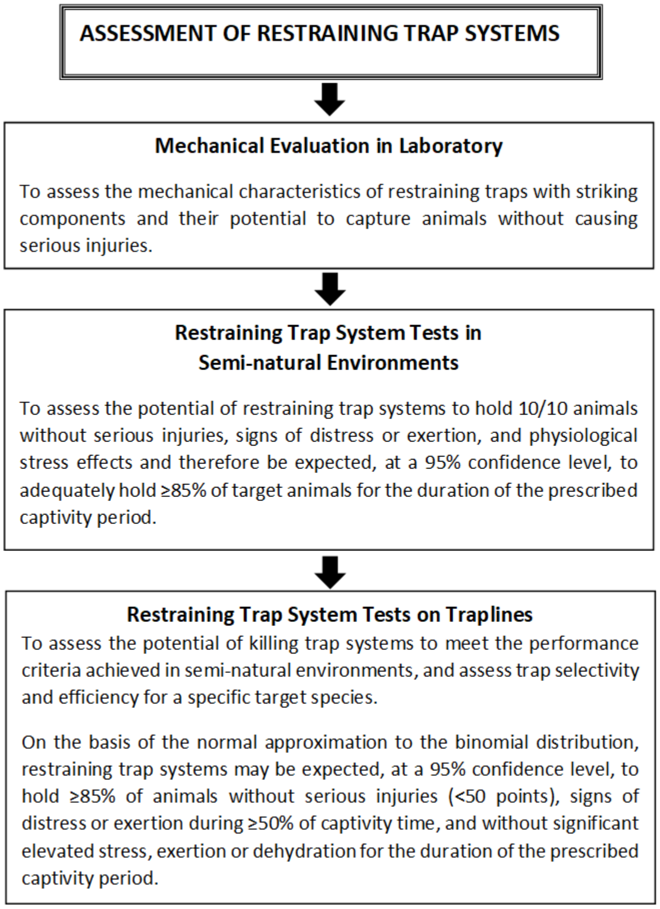
All research procedures involved in the testing of restraining trap systems must be approved by an institutional Animal Care & Use Committee with members possessing appropriate expertise in the wildlife husbandry, health care, and research relevant to trapping and handling. The testing of restraining trap systems consists of 3 steps (Figure 1). Although one of the following steps is conducted in semi-natural environments, Proulx *et al.* (2022a) explained that all procedures can be carried out in the wild if necessary. This is particularly true for large mammals, such as the common wombats (*Vombatus ursinus*), Cape porcupines (*Hystrix africaeaustralis*), capybara (*Hydrochoerus hydrochaeris*), grey wolves (*Canis lupus*), dingoes (*C. familiaris*) to acquire in sufficient numbers from the wild and house in research facilities for extended periods of time.

Step 1 −Mechanical evaluation

Trap clamping force and impact momentum (striking force) are widely accepted proxies of trap welfare performance among traps with springs (Proulx *et al.* 2020). The evaluation of these forces is highly recommended to assess the potential of traps to meet specific thresholds of acceptance and reduce the number of animals used in trap assessment.

For restraining traps with a striking component such as leghold traps, the EGG trap, and the likes, a mechanical evaluation needs to be conducted to establish striking and clamping forces (e.g., Proulx *et al.* 1993) that are too high and lead to major physical injuries.

Researchers can use different equipment (see Proulx *et al.* 2022a) to assess the following:



ASSESSMENT OF RESTRAINING TRAP SYSTEMS

Mechanical Evaluation in Laboratory

To assess the mechanical characteristics of restraining traps with striking components and their potential to capture animals without causing serious injuries.

Restraining Trap System Tests in Semi-natural Environments

To assess the potential of restraining trap systems to hold 10/10 animals without serious injuries, signs of distress or exertion, and physiological stress effects and therefore be expected, at a 95% confidence level, to adequately hold ≥85% of target animals for the duration of the prescribed captivity period.

Restraining Trap System Tests on Traplines

To assess the potential of killing trap systems to meet the performance criteria achieved in semi-natural environments, and assess trap selectivity and efficiency for a specific target species.

On the basis of the normal approximation to the binomial distribution, restraining trap systems may be expected, at a 95% confidence level, to hold ≥85% of animals without serious injuries (<50 points), signs of distress or exertion during ≥50% of captivity time, and without significant elevated stress, exertion or dehydration for the duration of the prescribed captivity period.

Figure 1. Sequential series of tests to assess restraining trap systems.

Momentum

This is the product of the velocity of a striking bar multiplied by its equivalent mass. Important steps include:

- Select several traps of the tested model at a relevant trap opening for the target animal species.
- Determine the effective mass of the striking component.
- Determine the impact velocity.
- Calculate the impact momentum *(p)* of the trap, expressed in kg.m/sec, using the following formula:

$$p = me \, . v$$

where *me* is the is the equivalent mass of the trap (striking component) at the strike location expressed in kg, and *v* is the velocity of the striking bar at a specified opening expressed in m per sec.

Clamping force

This is the steady-state force exerted on an animal by the jaw(s) of the trap after the striking force has been delivered. Important steps include:

- Select several traps of the tested model.
- Determine the force on a load cell at different openings that are relevant for the target species.

Threshold graph

Use the momentum and clamping force values to produce threshold graphs that may be used to distinguish traps that can potentially restrain specific species without injuries from those that would seriously injure the animals. Traps that are plotted above the threshold line may be too powerful to restrain an animal of a target species without causing injuries. Traps that are plotted too far below the threshold line may not be powerful enough, reducing capture efficiency and causing unnecessary distress and potential injury to animals that are captured and then free themselves after a struggle.

Step 2 − Restraining trap system tests in semi-natural environments

Test animals

Tests should preferably involve the use of animals that were live-captured in the wild, and kept in captivity for a short period of time. Animals are individually introduced in semi-natural environments and allowed a period of acclimation to new environmental conditions before any test is conducted. Because capture from the wild is likely to cause stress, with concomitant changes to behaviour and physiology, the period of acclimation should be closely monitored to ensure animals are truly acclimated. Monitoring should include video analyses of behaviour (Caravaggi *et al.* 2017) and repeated measurement of stress levels by non-invasive methods, such as fecal glucocorticoid metabolite analysis (Keay *et al.* 2006; Franceschini *et al.* 2008: Rothschild *et al.* 2008) and/or hair cortisol analysis (Heimbürge *et al.* 2019; Kallioski *et al.* 2019). Trap tests are conducted during the same period when trapping should occur, e.g., traps used for fur trapping in the Northern Hemisphere are tested during late fall and winter months.

Test personnel

Researchers must know how to set the tested traps properly and operate other equipment associated with the trap-testing process (e.g., video recording equipment), have a general knowledge of animal behaviours (calm, agitated, fighting), and have the capability of intervening in situations where traps malfunction or animals are in distress.

Trap preparation

A different trap must be used for each test. All traps must be prepared as they would be used on traplines. Depending on target species, they may have to be boiled, dyed, waxed, or just washed to remove human or manufacture scents. Traps must be set as they would be on traplines, i.e., with the same sets. Finally, the same baits or lures should be used in semi-natural environments and on traplines. With the exception of specific trapping systems such as those set underwater, trapping systems should be as selective as possible for the target species. Take specific measurements such as the exact location of the trap within a cubby, distance of the trigger from the bait, length of the trap anchor chain or wire, etc. In hot weather, make sure to provide animals with overhead cover and, if possible, access to water. When testing cage/box traps in the winter, provide animals with protection and insulating material in the live-trap. Photograph the trapping system from different angles.

Test duration

The duration of a test starts with the activation of the trap and the capture of the animal. The duration of the test may vary with local legislation, species, and trap types. For some species, it may last 2-3 h (e.g., diurnal rodents during summer months or animals with high metabolic rates such as shrews; Proulx *et al.* 2022a), or up to 12 h for furbearers in North America (Proulx and Rodtka 2019) or predators in Australia (Meek *et al.* 2019a). We recommend that test duration reflects the time period animals will be kept captive on traplines.

At the end of the test, the animals are anaesthetized with an intramuscular injection. Hair and/or fecal samples should be collected to compare cortisol and/or glucocorticoid metabolite levels with values recorded during the acclimation and pre-capture period. Blood may also be collected for hematological and biochemical analyses, followed by a comparison of select physiological indicator values with established species-specific values (Teare 2013). Thereafter, the animals are euthanized using procedures appropriate for the test species (AAZV 2006; AVMA 2020).

Video-recordings

At least 1 camera should be mounted above ground, and oriented on the tested restraining trap system. The camera should be well camouflaged to not impact on the behaviour of animals approaching the trapping system. The camera should provide a good view of the trap and the target animal once captured. It should be set on the video mode, solidly secured to trees, metal posts, etc., and locked to prevent any tampering of the memory cards by animals. Testing underwater trapping systems can also be done with specialized underwater equipment (e.g., Helmholz *et al.* 2016; Hermann *et al.* 2020).

Data recordings

Record date of the test, animal identification number, age and sex, time of loss or heartbeat (death caused by euthanasia), strike location in the case of leghold traps with striking components or neck cable restraints, and macroscopic observations (presence of fluids and discharge, exposed bones, cuts, abrasions, etc.). Properly photograph the animal in the trap and its general position at the trapping system. Photograph the strike location, before and after the removal of the trap. Retrieve the camera memory card. Place the labelled carcass in a bag and have the animal necropsied by a pathologist. If this cannot be done straight away, freeze the carcass until later examination by a pathologist. Care should be taken to not damage the carcass during handling and transport.

Post-mortem evaluation

A detailed necropsy of the limb held in a leghold trap and the whole body should be conducted by experienced wildlife pathologists who can identify trap-caused trauma. Radiographs may be necessary to detect the presence of minute pathological changes. Rate injuries according to Table 1. Trapping systems are successful if they hold 10/10 (or 27/28; Table2) animals with a cumulative injury score <50 points.

Behavioural evaluation

The total number of min/behavioural activity should be tabulated for each trapped animal to quantify the amount of time an animal spends in distress during the capture period. Using video-recordings, classify behaviours as follows:

- Distress indicators: fighting, biting, pulling or disturbing the trapping system, self-mutilation, whining, and signs of anxiety such as increased ambulation, restlessness, increased vigilance, or disengaged from the environment and depressed.
- Calmness indicators: sleeping, immobility (not caused by an injury or depression), quietness, no signs of anxiety or disturbance.

Distress signs should represent ≤50% of the time spent in the trap. Traps are successful if they hold 10/10 animals without distress for ≥ 50% of the captivity time. However, because of the possible subjectivity of some observations, we believe that the acceptability of a trap based on behaviour should be done in conjunction with data on injuries and physiological changes.

Physiological evaluation

As soon as the animal is anaesthetised, collect biological samples (hair, feces, and/or blood) to assess changes in physiological indicators. Process samples as soon as possible as per laboratory protocols. Traps are successful if they hold 10/10 animals without significant elevated stress, exertion or dehydration for the duration of the captivity period.

Overall evaluation

A restraining trap system that holds 10/10 animals without serious injuries, signs of distress or exertion, and significant physiological stress effects may be expected, at a 95% confidence level, to adequately hold ≥85% of target animals for the duration of the prescribed captivity period.

Step 3 a −Restraining trap system tests on traplines: threshold level of acceptance

Testing restraining trap systems on traplines is necessary to ascertain, at a 95% confidence level, the ability of traps to hold ≥85% of animals without serious injuries, signs of distress or exertion, and physiological stress for the duration of the captivity period.

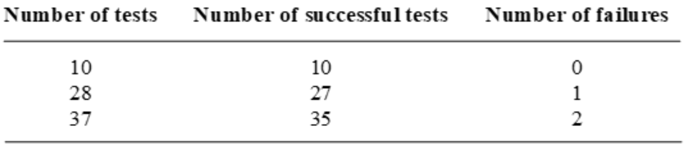
Test personnel

Researchers must be familiar with the restraining trap system and the procedures to follow when retrieving captures. If fur trappers are employed to assist researchers in the field, individuals be competent and conscientious. They should be aware of new trap technology developments and/or have experience with experimental traps or traps similar to the experimental traps in order to ensure task familiarity.

Table 1. Injury-scoring system for the assessment of restraining trap systems, based on Tullar (1984), Olsen *et al.* (1986, 1988), Onderka *et al.* (1990), Hubert *et al.* (1996), Phillips *et al.* (1996), ISO (1999), and Onderka (1999).

Injury	**Points assigned**
Claw loss	2
Minor skin lacerations	5
Oedematous swelling or haemorrhage of limbs	15
Cutaneous laceration, sub-cutaneous soft tissue maceration or erosion (contusion)	15
Periosetal erosion	15
Severance of minor tendon or ligament (each)	25
Amputation of digit (each)	30
Permanent tooth fracture exposing pulp cavity (each)	30
Gum abrasion or deep cut	30
Major laceration on foot pads or tongue	30
Severe joint haemorrhage	30
Joint luxation at or below the carpus or tarsus	30
Self-mutilation of captured limb	50
Rib fracture (simple or comminuted)	50
Eye lacerations	50
Skeletal muscle degeneration	50
Simple fracture at or below the carpus or tarsus	50
Compression fracture	50
Limb ischemia	50
Oedematous swelling of neck or face	50
Deep laceration of neck	75
Any fracture or joint luxation on limb above the carpus or tarsus	100
Compound or comminuted fracture at or below the carpus or tarsus	100
Any amputation above the digits	100
Spinal cord injury	100
Internal organ damage and bleeding	100
Disembowelment	100
Severance of major tendon or ligament	100
Compound rib fractures	100
Ocular injury resulting in partial vision loss or blindness of an eye	100
Myocardial degeneration	100
Paralysis (partial or total) of any limb	100
Death	100

Table 2. Test outcomes for restraining traps that can be expected, at a 95% confidence level, to hold ≥85% of target animals for a specific time period without serious injuries (≤50 points), signs of distress or exertion (≤50% of the capture time), and significant physiological stress changes.



Number of tests	Number of successful tests	Number of failures
10	10	0
28	27	1
37	35	2

Traplines

Traplines should not be located near human dwellings (Villeneuve and Proulx 2022). Traps should be tested on ≥2 traplines, under comparable ecological conditions (considering not only vegetation type, but also weather, season, species assemblage, etc.), while accounting for temporal variation in selectivity. If tests are conducted in landscapes with different ecological conditions, researchers must take into account population proportion (in order to consider animal availability), and calculate correct values of the Savage

W index (or similar index) (Virgós *et al.* 2016). Previous animal population abundance estimates can be obtained from past studies in the trapline areas, or by applying standard census techniques (e.g., Sutherland 2006; Long *et al.* 2008; O'Connell *et al.* 2011).

Restraining trap system sample size and spacing

At least 30 experimental traps and 30 control traps (if judged necessary to assess capture efficiency–Proulx *et al.* 2022a) are recommended per trapline although the exact trap numbers should be calculated using power analysis consistent with the objectives of the study (Meek *et al.* 2019b). If tested restraining trap systems are compared to control restraining trap systems, then these need to be sufficiently spaced on the trapline to maintain trap independence.

Trap preparation and set

Restraining trap systems must be identical to those used in semi-natural environments, if such environments are used. Verify specific measurements such as the exact location of the trap within a cubby, distance of the trigger from the bait, length of the trap anchor chain or wire, etc., that have been used in tests in semi-natural environments. In hot weather, make sure to provide animals with overhead cover and, if possible, access to water. When using cage/box traps in the winter, provide animals with protection and insulating material in the live-trap. Photograph the restraining trap system from different angles.

Video-recordings

At least 1 but preferably 2 cameras should be mounted above ground, and oriented on the tested restraining trap system. Cameras should provide a good view of the trap and the target animal once captured. However, cameras produce sounds that are well within the perceptive range of most mammals' hearing and produce illumination that can be seen by many species (Meek *et al.* 2014, 2016) and they should be well camouflaged to not impact on the behaviour of animals approaching traps (Proulx 2018). Camera(s) should be set on the video mode, solidly secured to trees, metal posts, etc., and locked to prevent any tampering of the memory cards by animals or people.

Trap visits

Restraining trap systems should be visited ≤12 h after setting or re-setting traps. The maximum time duration of an animal in a trap should be the same as that used in semi-natural tests. Trap visits allow one to ensure that restraining trap systems are fully functional because animals avoiding capture may disturb a trap site and render the set ineffective. Also, although the restraining trap system may have successfully passed the semi-natural environment tests, there is still a possibility for animals to be seriously injured, or for non-target animals to be captured.

Traps can also be equipped with a motion-sensitive radio alarm (Nolan *et al.* 1984; Marks 1996; Larkin *et al.* 2003; Ó Néill *et al.* 2007) that allows false positives but not false negatives, and that notifies a researcher when battery power is low or when a trap has fired (Powell and Proulx 2003; Meek *et al.* 2020). This is a valuable approach where an effective satellite communication network exists. It is noteworthy to mention that the use of an alarm unit is not a substitute to scheduled trap visits. If restraining traps have been accepted according to a specific time period, trap checking times should be based on such time period. An alarm unit can then be used to determine the exact time of capture of the target animals, and to check traps at a distance to determine if non-target animals have been captured and must be released.

Captured animals are anaesthetized with an intramuscular injection. Blood may be collected for hematological and biochemical analyses, followed by a comparison of select physiological indicator values with established species-specific values (Teare 2013). Thereafter, the animals are euthanized using procedures appropriate for the test species (AAZV 2006; AVMA 2020).

Data recording

Record time and dates of when the trap is set and checked. If the trap fired without capturing an animal, examine the trap for hair, blood, etc., thus suggesting the animal may have escaped or was taken by a scavenger. Look for animal tracks and other signs near the trap site. Note any disturbance to the set, and trap anomalies such as frame bending, trigger malfunction, etc. Video recordings may be useful to cross-validate observations.

If the trap captured an animal, assign an animal identification number, and record species, age and sex, strike location in the case of leghold, legsnare devices, or neck cable restraints, macroscopic observations (presence of fluids and discharge, exposed bones, cuts, abrasions, etc.), and any change to the trapping system that resulted from the capture, e.g., bait still present or not, cubby or surroundings show signs of struggle, etc. Properly photograph the animal in the trap and its general position at the trap site. Photograph the strike location, before and after the removal of the animal from the trap. Secure the memory cards. Place the labelled carcass in a bag and freeze it until later examination by a pathologist. Because freezing the carcass may affect the histopathological evaluation, it is better to perform the necropsy as soon as possible or leaving the carcass in a refrigerator if the necropsy can be performed during the next 1−3 d. Care should be taken to not damage the carcass during handling and transport.

Post-mortem evaluations

A detailed necropsy of the limb held in a leghold trap and the whole body should be conducted by experienced wildlife pathologists who can identify trap-caused trauma. Radiographs may be necessary to detect the presence of minute pathological changes. Rate injuries according to Table 1. Determine the performance of the tested trap using the normal approximation to the binomial distribution. Trapping systems are successful if, at a 95% confidence level, they hold ≥85% of animals with a cumulative injury score <50 points for the duration of the captivity time (Table 2).

Behavioural evaluation

The total number of min/behavioural activity should be tabulated for each trapped animal to quantify the amount of time an animal spends in distress during the capture period. Using video-recordings, classify behaviours as follows:

- Distress indicators: fighting, biting, pulling or disturbing the trapping system, self-mutilation, whining, and signs of anxiety such as increased ambulation, restlessness, increased vigilance, or disengaged from the environment and depressed.
- Calmness indicators: sleeping, immobility (not caused by an injury or depression), quietness, no signs of anxiety or disturbance.

Distress signs should represent ≤50% of the time spent in the trap. Traps are successful if, at a 95% confidence level, they hold ≥85% of animals without distress for ≥ 50% of the captivity time.

Physiological evaluation

Process blood samples as soon as possible as per laboratory protocols. Traps are successful if, at a 95% confidence level, they hold ≥85% of animals without significant elevated stress, exertion or dehydration for the duration of the captivity period.

Overall evaluation

On the basis of the normal approximation to the binomial distribution, a restraining trap system is successful if, at a 95% confidence level, it holds ≥85% of the animals without serious injuries (<50 points), no signs of distress or exertion during ≥50% of captivity time, and no significant elevated stress, exertion or dehydration for the duration of the prescribed captivity period.

Step 3 b −Restraining trap system tests on traplines: capture efficiency

Data recording

Carefully record the species for each captured animal on the trapline. The capture efficiency of a trapping system is species specific, i.e., it relates to the number of animals of a target species only.

Data analysis

Capture efficiency of a trapping system relates to the number of animals of the target species captured during the test period. Abundance of target animals in the traps is weighed by the total number of trap-nights for each trapping system, e.g., experimental trap vs. control trap. Capture efficiency is usually calculated as follows:

Capture efficiency = (Number of individuals captured /Number of traps-nights) x 100

This method assumes that all traps are available for the target species. Also, it does not account for the fact that the species assemblage and relative species abundance in test areas may vary among regions. As a result, some abundant non-target species in a particular region may be more attracted to test traps than control traps, and vice versa, thus biasing the true assessment of capture efficiency. Therefore, capture efficiency must take into consideration trap selectivity.

Evaluation

The number of animals of a target species captured in the test restraining trap system may be compared to capture success levels reported in previous studies (e.g., Proulx 1999b), or, if applicable, to the capture success of a control restraining trap system.

Step 3 c −Restraining trap system tests on traplines: capture selectivity

Data recording

The capture selectivity of a trapping system is species specific, i.e., it relates to the number of animals of a target species only. All other captures from other species are considered non-target captures.

Data analysis

Capture selectivity should be calculated using a selectivity index such as the Savage's *W* index:

$$W = Capture\ proportion/Population\ proportion$$

where *Capture proportion* (the numerator) is the number of captured target animals/total number of captured animals; and *Population proportion* (the denominator) is that proportion of the entire population of possible trapped animals (of all species) made up of members of the target species. It is noteworthy to mention that other indices may be used to calculate selectivity (see Pielou 1977; McClanahan and Mangi 2004).

Evaluation

A trapping system is deemed selective in a specific test area with a specific species assemblage if capture selectivity *W* is greater than 1.

Step 3 d −Restraining trap system tests on traplines: sturdiness and safety

We recommend that researchers wear the necessary protective equipment to minimize injuries when working with large restraining traps. For large trapping devices that can cause significant injuries to users, a release device (e.g., a rope or pliers to compress springs, shears to cut through wire, etc.) must be kept in proximity to the user if a trap was to fire on the individual's hands. Traps must be inspected for their sturdiness, ease of setting, and reliability (e.g., all the springs are properly attached and fire well), which can impact on their ability to adequately capture an animal.

Exemptions

All homemade restraining trap systems should be subject to these standards (in contrast with ECGCGRF 1997). There are no exemptions to restraining trap systems used for the capture of terrestrial and semi-aquatic mammals.

Handling and releasing animals

The release of animals that were previously restrained should take into consideration the following (Soulsbury *et al.* 2020):

- Are animals healthy enough to be released, including having recovered fully from any procedures or anaesthesia?
- Release the animal as soon as it is feasible to do so, with attention paid to conspecifics and dependent young, time of day, and the likelihood of an animal being harmed during the release.
- Release site should be as close to capture site as possible.
- The animal poses no danger to public health, animal health or to the environment.

Points to consider

In the past, the assessment of restraining trap systems rarely occurred without some development. Modifications to the trap itself or to the set are common (Proulx 1999). Consideration should be given to modify restraining trap systems that show potential but failed because of high striking or clamping forces, improper trigger system, or unreliable set. A modification of the striking jaws or springs may suffice to reduce mechanical forces and pass the stepwise evaluation process (Proulx 2022).

Concerns about the wellbeing of restrained animals, e.g., thirst and hunger, and psychological conditions such as anxiety and depression, need to be further studied to improve restraining trap systems. Through research in laboratory, simulated environment and field work, we may be able to identify new means to address such issues. New trap components may also be developed to lessen physical stress on animal limbs, and reduce injuries when animals are captured in cage traps. With the development of new designs and technology, the above standards should be continuously updated, and re-written and upgraded every 10 yrs (Proulx *et al.* 2022a).

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Appendix – Glossary

Animal Care and Use Committee: This Committee intends to ensure that the highest animal welfare standards are maintained along with the conduct of robust scientific research through the supervision, coordination, training, guidance, and review of every project proposed to include the use of vertebrate animals. The committee composition is generally designed to be broad enough to represent both scientific and public interests (Canadian Council on Animal Care 2006).

Animal welfare: This is the state of the animal's body and mind. The Office International des Epizooties (OIE 2017) defines animal welfare as 'how an animal is coping with the conditions in which it lives'. Animal welfare research involves collecting physical, behavioural and physiological data to make careful, objective inferences about the state of the animals.

Bait: Foods used to entice an animal in a trap. The use of live animals should be avoided.

Camera: Also known as a remote trail or game camera in the northern hemisphere, it is a camera that is triggered by either a passive infrared sensor (heat-in-motion) or the interruption of a light beam (active infra-red) by an animal. The camera is left unattended in the field. Photographs or videos are recorded on memory cards. Some models allow users to access images from their cellular phone where there is telecommunication coverage.

Control trap: Most popular trap used by trappers in the region where test traps are being evaluated on traplines.

Cubby: A small, enclosed space made out of materials (wood, plastic), or dug into a river bank.

Death: The irreversible cessation of all vital functions especially as indicated by permanent stoppage of the heart, respiration, and brain activity.

Euthanasia: Process causing rapid loss of consciousness and death without causing pain, distress or anxiety. In the context of this paper, it is the practice of ending the life of a trapped animal with minimal pain (see Proulx *et al.* 2012).

Lure: Scents used to entice animals in traps. These are related to conspecific odors, fluids or excretions.

Non-target species: Species that is not intended to be captured in a trapping system.

Palpebral reflex: Involuntary blinking of the eyelids elicited by touching the skin around the eye (i.e., the periocular skin).

Restraining trap: Device used to live-capture an animal. It includes leghold traps, leg snares and box/cage traps. Restraining traps are also used in killing trap systems to capture and kill semi-aquatic mammals underwater.

Striking components: Parts of the trap that close and come into contact with an animal's body. Usually referred as striking jaws or bars.

Target species: Species that is intended to be captured in a specific trapping system.

Test animal: Animal used in biological tests.

Trapline: A series of traps set in an area by researchers, pest controllers or fur trappers.

Trap-night: One trap set for one night.

Trap set: This relates to the location, surroundings, components (e.g., swivels, chains, spikes, locks, etc.), and baits or lures used when installing a trap for the capture of an animal. Two identical traps set differently may produce different results from an animal welfare, capture-efficiency and selectivity point of view.

Trapping systems: In the past, most assessments focused on a trap model rather than a trapping system which encompasses 1) a trap with specific dimensions, shape, power, and attachments (e.g., chain, swivels, locks); 2) a trigger with a specific shape and operation; 3) a set with a specific placement of the trap, and bait or lure. The trapping system that will be used in the field must be identical to the system used in the assessment of a specific trap model in semi-natural environments (Proulx *et al.* 2012).

Trap treatment: This is the preparation of a trap before use in semi-natural environments and on traplines. New traps are typically covered in oil to prevent rusting during storage and transport. This can be removed from the traps by a variety of methods including soaking in vinegar-bicarbonate of soda, cold-soaking in clean water, or adding local native bark and leaves or commercial trap dyes into the mix. Colouring, staining or dying is used to remove the metallic shine of the trap. Coating traps with a thin layer of wax is believed to assist preventing trap mechanism jamming under snow conditions and also helps reduce scents from traps. Some traps such as mousetraps purchased in hardware stores, or some newly purchased cage traps, do not require any treatment before use.

Trigger: A device that releases a spring or catch, and so sets off a mechanism to release striking jaw(s) or door(s).

Unconsciousness: This is a state which occurs when an animal loses its ability to maintain an awareness of self and environment. Unconsciousness can be determined with the loss of corneal and palpebral reflexes.

Waxing: Part of the process of preparing traps for deployment or storage by coating them with wax or similar protectant/lubricant.