Quantifying the nature and extent of native fauna by-catch during feral cat soft-catch leg-hold trapping

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Declaration

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

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Abstract

Feral cats devastate the Australian landscape and have been linked to a number of species extinctions through either predation or spread of diseases. Soft-catch leg-hold traps are routinely used to capture feral cats for research purposes or control, however by-catch is likely. Examination of by-catch data provided for six sites in Western Australia during the period 1997-2014 identified variability in by-catch across sites. This was attributed to differences in climate and landscape, the likely abundance of introduced predators prior to trapping and the experience of the trappers affecting when, where and how traps were set. Olfactory lures affected the taxonomy (with the exception of birds) of by-catch; reptiles were attracted to the PONGO lure (mix containing predator urine and faeces) used, but mammals were repelled. Reptiles may associate strong odours with food, while the mammals were cautious of the predatory species' scent. Non-native by-catch were injured in traps less than the native by-catch most likely because they were generally better able to withstand the pressure from closing jaws. Amongst the native fauna; birds were more likely to be severely injured due to their morphology, behaviour and weight; amongst non-avian fauna species, the larger the captured individuals, the less likely they were to be injured due to their ability to better withstand the trap pressure. Injury to by-catch species poses animal ethics concerns, as approval to trap may be denied based on frequency and severity of injury to native and target species alike. It also raises concern for species of conservation significance that already have dwindling populations, such as the woylie, and can least afford the added threat from trapping. Future trapping exercises should proceed cautiously, with care taken in the timing of trapping, the placement of traps and the setting of traps (especially the treadle pressure needed to close

the trap) to minimise the chance of by-catch and potential mortality. Additionally, by-catch welfare reports should be routinely prepared and examined to ensure best practice and on-going improvement.

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Chapter 1

1.1. Introduction

Evidence from historical sources (Abbott 2002) and population genetics research (Spencer *et al*. 2015) confirm that the cat *Felis catus* has been present on mainland Australia since European settlement (Burbidge *et al.* 1988 in Long 2003), colonising the continent by radiating from population centres in eastern and western Australia (Abbott 2002). Cats prey on small native mammals (Baynes 1979; Dickman 1996; Short 1999 in Abbott 2002) and are linked to the early continental extinction of several mammalian species (Denny and Dickman 2010; Doherty *et al*. 2016). Furthermore, they carry diseases such as toxoplasmosis, linked to the early declines of several *Dasyurus* spp. (Cross 1990 in Abbott 2002). In 1921 cats were briefly declared vermin due to their abundance (Long 1988). More recently, under the Federal *Endangered Species Protection Act 1992* (superseded by the *Environmental Protection and Biodiversity Conservation Act 1999*), predation by feral cats is listed as a Key Threatening Process (Denny and Dickman 2010). Feral cats now threaten 142 species and subspecies of Australian fauna (Commonwealth of Australia 2015a). Doherty *et al.* (2016) studied feral cat diet in Australia and identified 400 species of native and non-native vertebrate species regularly predated on by cats; including three critically endangered, five endangered, eight vulnerable, and 12 near-threatened species.

As our understanding of the level of threat that feral cats represent to our native Australian fauna has increased, so too has the demand for control measures on a landscape scale. However, cat control programs in Australia are still in their early stages with no nationwide cat management plan (Denny and Dickman 2010). The Commonwealth's threat abatement plan for feral cats does not stipulate any recommended method for their control, but instead lists multiple methods (Commonwealth of Australia 2015b). Baiting, shooting, exclusion fencing, cage trapping and leg-hold trapping are all mentioned, with common caveats being that the methods should be target specific and improve conservation outcomes for species threatened by cat predation (Commonwealth of Australia 2015b).

Historically, baiting has been advocated as the most cost-effective and least labour-intensive control for exotic predators, especially for wild dogs and foxes *Vulpes vulpes* where the economic loss to agriculture through predation of livestock, justifies the expenditure on baits and their delivery (Meek *et al.* 1995). This, however, it not a flawless method due to the low specificity associated with baits. This can threaten some of the larger carnivorous, native non-target species (Meek *et al.*1995).

With regard to feral cats, the Commonwealth threat abatement plan describes the use of two bait products: Eradicat®, which is a small kangaroo and chicken chipolata sausage containing the toxin 1080; and Curiosity®, which is similar to the Eradicat® but instead is injected with PAPP (para-aminopropriophenone) (Commonwealth of Australia 2015b; Commonwealth of Australia 2015a). These baits are designed to overcome palatability issues. Feral cats prefer live prey to carrion; only eating carrion as a last resort when other food sources are in short supply (Commonwealth of Australia 2015b). Therefore, having palatable baits somewhat overcomes this issue as even though the baits aren't live, they are more alluring to the cats.

The use of 1080 poison is beneficial because in western, and particularly south-western, parts of Australia, the native fauna have co-evolved with the plants producing fluoroacetate, the toxic principle of 1080, and generally have a high tolerance. However, not all species have the same level of tolerance and many are considerably lighter than cats, so they receive a higher dose for their body weight if they consume any of the baits. Therefore 1080 baits pose a varying level of risk to different species (Calver *et al*. 1989; Buckmaster *et al.* 2014). The humaneness of 1080 as a toxin is debated (Weaver 2006; Sherley 2007), and so one advantage of the Curiosity® bait is that it is a less controversial toxin. However, Australian native fauna have no resistance to PAPP, so the non-target risk profile is different. With both 1080 and PAPP not only is there a risk of native fauna consuming the bait and being poisoned, but there is also a low risk of secondary poisoning if native animals scavenge the fresh remains of cats that have been poisoned by a bait.

The most expensive forms of control described in the threat abatement plan are shooting and exclusion fencing. Shooting is unviable when the area of control is large or access is poor (Commonwealth of Australia 2015b). The time commitment of skilled labour means that shooting is typically only utilised on a small scale (Commonwealth of Australia 2015b). Exclusion fencing is also not ideal for widespread use because of costs of construction and maintenance. It is effective in protecting small areas supporting threatened species, but is not a standalone technique and requires other methods such as baiting, trapping and shooting to minimise the risk of feral cats breaking into the fenced area (Commonwealth of Australia 2015b), as well as the initial removal of feral cats from inside the fenced area. It also poses a threat to the native species that it is trying to protect in regard to the restriction of their movements and dispersal, therefore influencing the gene exchange with neighbouring populations (Commonwealth of Australia 2015b). Additionally, fire presents an increased risk to populations that are confined.

Trapping shares many of the same problems of cost and skilled labour requirements with fencing and shooting, as well as being most effective only on a small scale (Commonwealth of Australia 2015b). However it does offer opportunities to catch problem animals or to trap animals for tagging and releasing as part of ecological studies. There is a long history involving the use of snap traps in Australia to seize the animal by a limb, after which it is shot when the traps are cleared. At first steel jaw snap traps were used, but they are now regarded as inhumane. The injuries sustained by the individuals caught, by-catch included, are so serious (Tullar 1984 in Meek *et al.* 1995) that the use of these traps is now banned in most states of Australia (Meek *et al.* 1995). A modified version of this snap trap was necessary to reduce injury and suffering to target animals before they were shot, and to reduce injury to non-target species so that they could be released. Padded jaws were trialled, leading eventually to the final product of the soft-catch leg-hold trap (Meek *et al.* 1995). The use of soft-catch leg-hold trapping for feral cat control is also used for research and capture-and-release programs, with recorded injuries to the target animals limited to minor bruising and abrasions (Fleming *et al.* 1998). Within Australia, not all states and territories permit the use of leg-hold traps for the control of feral cats (Commonwealth of Australia 2015b); Tasmania, for instance, does not allow any leg-hold trapping unless an application to the Minister has been approved as described in the *Animal Welfare Act 1993*. As a result, trapping of cats in these areas is limited to cages (Commonwealth of Australia 2015b).

There is currently a variety of leg-hold traps available within Australia for the capture of a range of feral species. One particular manufacturer (J.C. Conner) claims that one of its products, the Jake trap, is “the best rubber padded trap on the market”, with the most attractive sales point being that it is entirely designed for heavy duty trapping (Western Trapping Supplies n.d). This claim differs from those made about other products such as the Duke® 1.5 trap, which is considerably more delicate and designed for animals as small as a rabbit *Oryctolagus cuniculus* (Western Trapping Supplies n.d). Lures are also sold to increase the chances of capture in traps.

The use of lures can alter the species being captured, and potentially increase the native fauna by-catch. Pawlina and Proulx (1999) identified that attractants at trap sites provoke a variety of responses amongst the fauna present. This response is dependent on previous knowledge of the attractant (from either individual experience, learning from conspecifics or having inherited a response), environmental cues, or the individual’s physiological condition and social status (Pawlina and Proulx 1999). Lures can range from simple visual attractants such as feathers and tinsel, to more complex attractants such as baits, scents and auditory lures that mimic prey distress calls or the calls of conspecific target species. Knowledge of the target species’ biology and ecology are critical in lure selection to ensure target specificity, and that by-catch species are not also likely to be attracted.

The ‘trap safety’ of these soft-catch leg-hold traps in regard to by-catch is not as clear and well-researched as with other methods of capture/control. Given that the native fauna potentially being captured by these traps are often much smaller and more fragile than the foxes and cats targeted in the trapping programs, their injuries could be more extensive and varied than those suffered by the target species. Some individuals experience a simple mild oedema (swelling) (Meek *et al.* 1995) whereas some others are killed (Fleming *et al.* 1998). Durham (1981) suggests that this variability is due to the difference in anatomy between various taxa. For example, unlike mammals, birds have minimal soft tissue in the leg to cushion injury to blood vessels, nerves and bones. It is also important to note that injury identification itself has its difficulties, as not all injuries are obvious and visible externally (Durham 1981). Additionally, some injuries will have a greater impact on the survivorship of the individual than first anticipated; for example, a predatory bird with an injured leg will have difficulty in hunting due to the decreased ability to grab and hold the prey, thus decreasing survivorship by risking starvation (Durham 1981).

It is also difficult to create a universal pain scale for the non-target animals because intensity depends on the localised pain area, and the level of pain experienced potentially differs depending on species, size, age and sex (Iossa *et al.* 2007). This becomes a serious issue when species of conservation concern are distressed or injured in traps (Iossa *et al.* 2007). Reducing a threatened population by even just one or two individuals, especially breeding adults, can have disastrous effects on the overall success of the species. If the species provides significant environmental services; such as the Woylie *Bettongia penicillata* (Garkaklis *et al.* 2004; de Tores and Start 2008), the ecosystem could be subsequently altered, risking the survivorship of the other species present as well; a cascade effect.

1.2. Aims

Through this project, I aim to

- Conduct a preliminary literature review to identify the current knowledge basis surrounding the welfare of by-catch species during leg-hold trapping,
- Identify the extent of by-catch from soft-catch[1] leg-hold traps from six locations across Western Australia; Boyicup Forest, Balban Forest, Perup Sanctuary, Francois Peron National Park, Mornington Sanctuary and Mount Gibson Sanctuary;
- Determine the effect that olfactory lures have on the composition of by-catch taxa at Francois Peron National Park;
- Identify factors that influence the occurrence and severity of injury; with particular focus on the individuals' weight and taxon, respectively;
- Identify the relative risk that feral cat soft-catch leg-hold trapping has in regards to species of conservation concern; and
- Develop a Standard Operating Procedure for the collection of data on by-catch welfare when trapping for feral cats using soft-catch leg-hold traps.

[1] Either padded or unpadded; excluding all interlocking toothed jaw traps.

1.3. Literature Review

Here, I summarise the current knowledge base surrounding the welfare of non-target captures in restraining traps (specifically leg-hold traps) using a systematic review. I sought to find information on the species of animals caught as by-catch in different types of soft-catch leg-hold traps, as well as the frequency of by-catch and the fate of those animals captured. By understanding the documented problems of these traps in the past, modifications to practice can be recommended to reduce not only the chance of by-catch, but also improve the prognosis for future by-catch animals.

Methods

Choice of review approach

Traditionally, reviews of literature in ecological studies take the form of a narrative review in which the reviewer surveys a wide range of literature and synthesises trends (Koricheva and Gurevitch 2013). However, this method does not specify the methods used in the literature searches, which makes it difficult to replicate and convince readers of the scope and thoroughness of the review (Koricheva and Gurevitch 2013). In contrast, the systematic review researches a precisely defined topic and follows definitive steps to ensure that the search strategy and criteria for decision making at each step can be repeated (Koricheva and Gurevitch 2013). In view of these advantages, a systematic review was conducted instead of a narrative review. The systematic review was conducted following the method described by Côté and Jennions (2013).

Selection of databases

For this literature review three databases were searched: Scopus, Publish or Perish and Web of Science. It was necessary to examine multiple databases as no single one provides a complete and accurate record of all research conducted on any given topic (Calver *et al.* 2013). Scopus covers a range of conventional journals, trade journals and conference proceedings, but until recently lacked information on books and book chapters (other than those in a named series) due to the diversity of publishers, languages and citation styles. However, use of the 'secondary documents' link allows citations to unlisted books and book chapters to be retrieved (Calver *et al.* 2013). Since mid-2013, Scopus has included books from over 30 publishers (Elsevier, 2014). Lastly, Scopus is further limited by lacking complete records prior to 1996, (Calver *et al.* 2013) although there is a project to extend the coverage to earlier years that has already made extensive progress (Elsevier, 2015).

Publish or Perish is freeware for automating searches in Google Scholar to retrieve information on citations for both authors and journals. It has a wide search range and accesses journals, books, book chapters, conference proceedings, grey literature, theses, blogs, and other websites (Calver *et al.* 2013). This allows documents excluded from databases such as Scopus to be accessed. However, this can also be problematic, as uncertainty surrounding the scope and retrieval of both incorrect citations and incorrectly cited references can make searches through Google Scholar problematic when used directly (Calver *et al.* 2013).

Web of Science is a well-known specialist database; a part of the Web of Science Core Collection since January 2014, that only contains the most significant journals, conference proceedings and books that are considered of primary relevance to the sciences (Testa 2006). Therefore, it has poor coverage of any publications from different research areas or in languages other than English. This is reflected in the lower counts of citations than other, broader databases (Harzing and van der Wal 2008). It is however, useful for identifying the most relevant documents with precision, thus reducing the amount of manual screening necessary.

These three databases counterbalance each other's flaws and, when used in unison, retrieve most, if not all, of the publications currently available for a given search provided they are used appropriately.

<u>Search terms and search methods</u>

A first search was conducted in all databases for the term "bycatch". The term "bycatch" was searched for in Scopus with the restriction of *AND NOT* "marine" (to exclude fisheries papers) in *Advanced Search*. These same terms and restrictions were used for the secondary documents also in Scopus. These two searches were both conducted on 22/6/16 and then exported into both Microsoft Excel spread sheets and EndNote Referencing. Publish or Perish was utilised for further searching. For this database the terms "bycatch" and "trapping" were entered in the field *ALL OF THE WORDS*, with the restriction of *NONE OF THE WORDS* "marine" and "fish" (to exclude fisheries papers). Again, this search was conducted on 22/6/16 and exported to both a Microsoft Excel spread sheet and EndNote Referencing. The third database utilised for this review was Web of Science. The terms *TOPIC* "bycatch" *AND TOPIC* "trapping" with the restriction of *NOT TOPIC* "marine" and in the fields of *TIMESPAN* "All years" and *SEARCH*

LANGUAGE “Auto” on the 23/6/16, with the results exported to both a Microsoft Excel spread sheet and EndNote Referencing.

The results from all three databases were cross-referenced to eliminate any duplications; Scopus against Web of Science and Publish or Perish, and Web of Science and Publish or Perish against each other. From there, the documents were screened based on criteria that involved removing any results that were either published by an organisation known for dealing with aquatic life or if anywhere in the title the topic of fish life/ aquatic life was mentioned. This left only papers dealing with terrestrial studies. These were then included or excluded based on relevance to soft-catch leg-hold trapping and welfare, with papers that did not consider either of these topics excluded.

A second review of the same databases with altered search terms was also conducted in order to increase the chances of retrieving suitable documents. This review was used with the following modifications; Scopus was screened for “non-target” *AND* “leg-hold” with the restriction of *AND NOT* “marine” in *Advanced Search*, the secondary documents on Scopus were screened with the same terms and restrictions; Publish or Perish was screened for *ALL OF THE WORDS* “non-target”, “snap trap” and “leg hold” with the restriction of *NONE OF THE WORDS* “marine”; and finally Web of Science was screened in *ALL DATABASES* for *TOPIC* “non-target” *AND TOPIC* “snap trap” with the restriction of *NOT TOPIC* “marine”. Searched terms were altered based on the number of documents the search returned. The Scopus (including secondary documents) and Publish or Perish searches were conducted on 3/8/16 and the Web of Science was undertaken on the 8/8/16, with all following the exportation protocol as before with search results being saved in both Microsoft Excel spread sheets and EndNote Referencing folders.

The results were once again screened to exclude marine, aquatic or fish related topics, as well as those that did not relate to soft-catch leg-hold trapping. However this time, as few documents were returned, it was feasible to exclude returns based solely on the title of the document. It is important to realise the necessity for this general exclusion of anything non-terrestrial because by-catch is often used as a fisheries term and so the majority of the search results were in fact fish related.

Often, the next step in a systematic review is to narrow down results based on the quality of each study. However, as this review did not return many relevant documents, all information was considered valuable regardless of study quality.

Results

Literature found

Two searches through the three databases; Scopus (including secondary documents), Publish or Perish and Web of Science, returned 1049 documents (Table 1) of which only four were relevant (Table 1 and 2). Due to the low number of relevant documents returned, additional searches through the databases, independent of the systematic review, extended the range of relevant papers that were included.

Table 1. Documents retrieved from three databases (Scopus (including secondary documents), Publish or Perish, and Web of Science) and the number of those relevant to by-catch in leg-hold trap and/or injury sustained during such trapping.

Database	# Search	# Documents returned	# Documents relevant
Scopus	1	194	0
Scopus (secondary documents)	1	521	0
Publish or Perish	1	154	1
Web of Science	1	130	0
Scopus	2	25	3
Scopus (secondary documents)	2	0	N/A
Publish or Perish	2	17	0
Web of Science	2	8	0
			Total= 4

Table 2. Relevant documents including information on author, type of publication, country of research focus, and the type of results from each study; rate of by-catch or the trap-related injuries sustained by individuals.

Reference	Document type	Country of study focus	Type of results
Cross *et al.* (1998)	Journal	New Zealand	By-catch rate
Short, *et al.* (2002)	Journal	Australia	By-catch rate
Michalski *et al.* (2007)	Journal	Brazil	Trap-related injury
Iossa *et al.* (2007)	Journal	Europe and North America	Trap-related injury

Of those documents identified in the literature review, none focused their own studies (not referring to research by others) on both the rate of non-target by-catch and the subsequent injuries acquired within the same study (Table 2). They focussed on either the rate of by-catch (Table 3); usually very briefly and only as a way in which to determine the effect that it would have on the trapping efficiency results for the target species, or they drew attention to the injuries sustained (Table 4); not only by the non-target, but by the targeted species as well, in order to monitor the trap efficacy on intended catch only.

Table 3. Non-target species recorded within relevant studies, including the number of individuals from each species captured. Data from Iossa *et al.* (2007) were not included here as their results focussed on the compilation of by-catch results from multiple sources.

Non-target species	#Captured	Reference
Cat ***Felis catus***	22	Cross *et al.* (1998)
Hedgehog ***Erinaceinae sp.***	34	Cross *et al.* (1998)
Possum ***Phalangeriformes sp.***	3	Cross *et al.* (1998)
Harrier ***Circinae sp.***	24	Cross *et al.* (1998)
Magpie ***Cracticus tibicen***	1	Cross *et al.* (1998)
Rabbit ***Oryctolagus cuniculus***	47	Short *et al.* (2002)
Bettong ***Bettongia lesueur***	1	Short *et al.* (2002)
Little Crow ***Corvus bennetti***	2	Short *et al.* (2002)
White-eared Opossum ***Didelphis albiventris***	1	Michalski *et al*. (2007)
Big-eared Opossum ***Didelphis aurita***	4	Michalski *et al*. (2007)
Argentine Black and White Tegu ***Tupinambis merianae***	1	Michalski *et al*. (2007)

Iossa *et al.* (2007) collated extensive data (mainly from North America, but with some Australian studies) on injuries for animals caught in padded leg-hold traps, based on thousands of individuals from 10 species caught during seven separate studies. The only deaths recorded were of the Eurasian Otter *Lutra lutra* in one study; 9% of 43 animals died. The most heavily studied species was the Red Fox *Vulpes vulpes* (four studies, with 168 individuals). The fate of the individuals in these studies was varied (Table 4). In two studies, 36% and 53% of animals were uninjured (sample sizes 28 and 91 respectively), while in the other two, minor injuries dominated (93% of 30 and 79% of 19). While the large number of cells with low frequencies precluded a valid chi-squared analysis of the data (mean of the expected frequencies <6 (Zar 2010)), inspection of Table 4 suggests that the incidence and severity of injury varied across studies. This is indicative of the variation in local conditions, experience of users, or trap setting interacting to produce the injury profile for trapped animals.

Table 4. Variation in injury to Red Foxes captured in padded leg-hold traps from four separate studies identified in Iossa *et al.* (2007).

Study (#)	Sample Size (#)	No Injuries (%)	Minor Injuries (%)	Major Injuries (%)
1	30	-	93	7
2	19	-	79	21
3	28	36	21	43
4	91	53	43	4

By-catch rate

Cross *et al.* (1998) reported that during their studies of ferrets, the Victor® traps (a design of soft-catch leg-hold trap) used captured 84 non-target individuals from five different species (Table 3), with a by-catch rate of 15.5 individuals per 100 Corrected Trap Nights (CTNs) (536 CTN)[2]. Although the injuries sustained by the captured animals were not recorded, it was noted that the Victor® traps had a by-catch rate over three times that of the cage traps used (4.4 per 100CTNs) in the same study (Cross *et al.* 1998). Additionally, they had also left the by-catch individuals incapacitated or vulnerable to attack by other predators (Cross *et al.* 1998).

Short *et al.* (2002) focussed on the control of feral cats by trapping, and identified the burrowing bettong (*Bettongia lesueur*) as a by-catch risk because they were a common non-

[2]CTNs are the number of traps set during the removal trapping session minus 0.5x the number of traps sprung each night (Nelson and Clark 1973).

target capture. When burrowing bettongs were present, the use of foot hold traps was abandoned and cage traps were the preferred method. This study used Victor® Soft Catch size 1.5 traps with rubber inserts on the jaws (specifically designed to capture foxes and cats) to mitigate injury to the animals captured (Short *et al.* 2002). The Victor® Soft Catch traps were described as cheap, humane and effective; being the preferred choice in comparison to treadle snares[3] (Short *et al.* 2002). Again, the rate of by-catch was recorded; Victor® Soft Catch traps placed at funnel sets (barriers or pathways likely to channel the movement of cats and foxes) had an overall rate of 3.69 per 100 trap-nights (Table 3). There was no mention of the nature and extent of injuries sustained by captured individuals (Short *et al.* 2002).

Michalski *et al*. (2007) compared the efficiency of several bait types used in both box-traps and leg-hold traps. They sought to capture six carnivorous species; Jaguarundi *Herpailurus yagouaroundi*, Oncilla *Leopardus tigrinus*, South American coati *Nasua nasua*, Crab-eating fox *Cerdocyon thous*, Tayra *Eira barbara* and Lesser grison *Galictis cuja*, thus, by-catch was inclusive of all non-carnivores captured (Michalski *et al.* 2007). The capture rate for target and non-target species captured in leg-hold traps was 5.77% and 11.54%, respectively, with values corrected over 100 trap nights (Michalski *et al.* 2007). However, the authors focussed more on the injuries sustained by the captured individuals, both target and by-catch, than on the capture efficiency (Michalski *et al.* 2007). Of nine individuals from five by-catch species captured in the Victor® leg-hold traps (Table 3), only three animals received injuries; Big-eared opossum (*Didelphis aurita*) (n=2) and Tayra (n=1). The authors determined that leg-hold traps had a greater capture rate for target and non-target species combined than box-traps in the

[3] A noose tightens rather than jaws snapping shut.

area studied (Michalski *et al.* 2007). Although this study was unable to test for differences in the occurrence of injuries caused by box-traps and leg-hold traps, Michalski *et al.* (2007) did refer to results obtained by other researchers.

Trap-related injuries

All of the individuals captured in the leg-hold traps used in the studies identified by Michalski *et al.* (2007) showed only minor injuries (Crawshaw 1997 in Michalski *et al.* 2007). They claimed that when the trap is padded appropriately, the snap traps resulted in less injuries being sustained by the captured individual than box-traps (Crawshaw 1997 in Michalski *et al.* 2007). In another study, the main injuries sustained by the captured animal were caused by the animal attempting to escape, and in some cases self-mutilating (Balser 1965 in Michalski *et al.* 2007). Olsen *et al.* (1986) in Michalski *et al.* (2007) stated that in situations involving by-catch that is smaller than the target species, an increase in the injuries sustained is quite possible, but not always the case; they refer to an incident where only superficial injuries were sustained by small non-target species. Once again, leg-hold traps were the preferred trap type due to the higher capture rate and ease of transport when compared to box-traps (Michalski *et al.* 2007).

In reporting on the animal welfare standards of both restraining and killing type traps, Iossa *et al.* (2007) didn't report any by-catch rates, but instead focussed solely on the injuries to the animals and the accuracy of injury assessment scales. They noted that there was, in fact, no universal injury scale and that at the time of their study, there was no key threshold for animal welfare standards either (Iossa *et al.* 2007). The lack of reports in the scientific literature of trap-based injuries was also discussed, and was considered a contributing factor to the difficulty involved in comparing trapping techniques (Iossa *et al.* 2007). One of the studies analysed did account for trap-based injury, and reported that the majority of individuals captured by padded leg-hold traps received low injury scores; however subsequent survivorship was significantly reduced, potentially due to predation (Seddon *et al.* 1999 in Iossa *et al.* 2007). This study also mentioned that the body size of the individuals captured was inversely correlated with the extent of the injuries sustained; with smaller animals receiving more severe injuries (Seddon *et al.* 1999 in Iossa *et al.* 2007). Trap selectivity was examined, with attention drawn to the fact that the capture of non-target animals that are of conservation concern poses a serious threat to the species (Iossa *et al.* 2007). They concluded that many methods currently in use for trapping mammals are not humane and that current legislation has failed to ensure acceptable levels of welfare for a large number of captured animals (Iossa *et al.* 2007).

Discussion

By-catch rate of leg-hold traps compared to other trap types

There are several trap types that can be used when controlling invasive species; however the effectiveness of each is dependent on the target (Meek *et al.* 1995). Although the research conducted by Cross *et al.* (1998) did not actually target feral cats, the by-catch data are of interest. During their study, when Victor® traps were used, 84 non-target individuals were captured from five different species, resulting in a by-catch rate of 15.5 individuals per 100 CTNs (Table 3) (Cross *et al.* 1998). This is a much higher rate than when cage traps were used, (only 4.4 individuals per 100 CTNs) (Cross *et al.* 1998). This reduced target specificity of leg-hold traps is supported in research by Michalski *et al*. (2007), who also showed leg-hold traps having a much higher by-catch rate than the box-traps.

When the research compared 'Victor®' traps and treadle snares, the findings were reversed. Victor® traps had by-catch comprising 17.4% of the overall catch, whereas the treadle snares had 28.6% of the overall catch attributed to non-target species (Meek *et al.* 1995). This advantage is seen in research by Fleming *et al.* (1998); the soft-catch traps were significantly more selective (more-biased measure of selective efficiency) than the 'Padded Lane's' traps used. This exemplifies that although the leg-hold snap traps may not consistently have the lowest by-catch rate, they are far from having the highest.

<u>Variability of trap-related injuries</u>

Any capture device may cause injury, and it is unethical to use a trap that causes either serious injury or death for the majority of by-catch individuals. The literature currently available on the extent of injuries sustained by individuals provides variable animal welfare outcomes; both between species (Table 3) and within a single species (Table 4). Michalski *et al*. reported that in Crawshaw's (1997) study it was found that although injuries can occur, they are mostly superficial. Balser (1965 in Michalski *et al.* 2007) identified the cause of injuries sustained to be a direct result of attempts to break free from the trap; with some individuals self-mutilating during their escape attempt, rather than being due to the trap itself inflicting damage. This is supported by Powell and Proulx (2003) who state that it is possible for injuries to be sustained from struggling within the trap. To overcome this threat, Powell and Proulx (2003) suggest equipping traps with tranquilizing tabs; the tranquilizer is concealed (sometimes in a drug soaked cloth or rubber dispenser containing the drug) and attached to the trap so that when the captured animal chews at the trap, the drug is ingested. This will settle the animal and reduce the chances of injury from thrashing and self-harm, but not from the trap itself. However this method carries the risk of overdosing the animal as there is no certainty of the species of animal that is trapped, nor of the individual's size, and also ignores the increased risk of predation while sedated and held in the trap. This lack of severe injuries sustained by the captured individual is contradicted by Iossa *et al.* (2007) who identified many cases resulting in serious injuries to a number of trapped individuals. They attributed this to a few factors; the variation of body size within some species, the type of padded leg-hold traps being used, and a lack of universal injury scale for assessing severity (different scales were used for each research project).

Variation in body size is both an inter- and intra-species problem. This is highlighted by Balser (1965 in Michalski *et al.* 2007) who suggests that if the target species is larger than the by-catch species, the injuries to the by-catch will be greater; a prediction supported by Seddon *et al.* (1999 in Iossa *et al.* 2007). This has since been exhibited in a study by Cross *et al*. (1998) in which it was mentioned that when animals such as Harriers (*Circus* spp.) were captured, they were left incapacitated or vulnerable to predation after release due to the effects of trapping. This is potentially due to their morphology; particularly the presence of hollow bones in birds capable of flight. Short *et al.* (2002) made particular reference to a different species, the burrowing bettong, stating that these animals had the possibility of sustaining serious injury from the leg-hold traps. This risk was attributed to the size difference between them and the target species[4] (Short *et al.* 2002). The problem was overcome by not trapping in areas where the bettongs were present. Other than changing trapping schedules and risking bias within a study, the efficacy of the trap in relation to the size of captured individuals can also be increased by manipulating the tripping force of the trigger. By using a trigger with a heavy tripping weight, by-catch smaller than the targeted species cannot as effectively be trapped (Powell and Proulx 2003). This will then possibly reduce the potential for serious injury.

The variation in injuries resulting from trap type selection is described in Warburton (1992), who states that while using foot-hold traps; specifically Victor® Soft Catch traps, the injury scores sustained by the targeted individuals were much lower than when un-padded traps were used (Warburton 1992). This is consistent with research conducted on a variety of species by Tullar (1984), Olsen *et al*. (1986), Linhart *et aI*. (1988), Olsen *et al.* (1988), and Onderka *et al*. (1990) as described in Warburton (1992). The trap size is also an important factor to consider. Foothold traps clamp together to restrain the captured animal, thus the greater the size of the trap in relation to the animal being captured, the greater the impact of the trap on the individual (Powell and Proulx 2003). In addition to correct trap size selection, the location of the trap must also be considered. Powell and Proulx (2003) identified situations in which incorrect trap placement resulted in injury and possible death; for example, black oil drums are effective bear *Ursidae* spp. traps but when in direct sunlight become solar ovens. It would thus be reasonable to state that the variability of trap-related injuries is in part due to the inconsistency

[4] Mean weight of burrowing bettongs is 1.28kg (Burbidge and Short 2008), whereas the weight range for feral cats is 3.4-7.3kg (males) and 2.5-5.0kg (females) (Denny 2008).

of trap selection, setting and placement. The only way to stabilize the variation in injuries and minimize overall damage is to ensure a standard protocol in which selected traps are used.

Long term impact of injury

If the injuries sustained in traps are extensive enough to reduce survival or fecundity post-release, not only is concern raised for all species, but this is a particular issue for species of conservation concern (Iossa *et al.* 2007). Seddon *et al.* (1999 in Iossa *et al.* 2007) reported that even when only minor injuries were sustained by captured foxes, the survivorship of the individuals was reduced substantially. This was attributed to the animals' management of the injury, such as limping, which would increase its attractiveness to predators (Seddon *et al.* 1999 in Iossa *et al.* 2007). Less obvious injuries, such as broken teeth and claw loss have also been shown to negatively impact on the animals' survival, due to their decreased ability to catch prey (Patterson *et al.* 2003; Iossa *et al.* 2007).

Pathological response from trauma can also pose a threat. Hyper- and hypothermia are conditions relating to the rise or fall of an animal's body temperature (Nocturnal Wildlife Research Pty Ltd. 2008). This has been observed in many native species, such as echidnas *Tachyglossus aculeatus* and wombats *Vombatus ursinus*, which are unable to survive when exposed to undesirable temperatures for a period of time. Hyperthermia can also lead to further complications as it can result in capture myopathy (Nocturnal Wildlife Research Pty Ltd. 2008).

Capture myopathy is characterised by the acute degeneration of muscle tissue of an individual post-capture and restraint (Hulland 1993 in Nocturnal Wildlife Research Pty Ltd. 2008). It is most commonly reported amongst birds and mammals; individuals from 11 Australian macropod species in Australia have previously been either debilitated or died due to myopathy (Nocturnal Wildlife Research Pty Ltd. 2008). Survivorship of individuals with capture myopathy post-release is poor as degeneration of muscle causes them to appear slower or less alert, even after the initial trap injury has subsided. This increases their susceptibility to not only predation, but other factors that result in death weeks or even months later (Nocturnal Wildlife Research Pty Ltd. 2008).

Dependant young are also at risk, even though they themselves may not be captured. The ejection of pouch young, as seen in macropods such as swamp wallabies *Wallabia bicolor* and eastern-grey kangaroos *Macropus giganteus*; abortion, as demonstrated in a closely monitored puma *Puma concolor* post-release; death of the dependant offspring; and changes in offspring behaviour due to altered HPA (Hypothalamic-pituitary-adrenal axis) responsiveness in utero from prenatal stress, all threaten the offspring (Nocturnal Wildlife Research Pty Ltd. 2008).

The chances of these pathological responses negatively impacting an individual increase with the culmination of multiple responses, with the threat to the population increasing as more individuals are affected. Very few studies record post-release survival, making it difficult to determine trap performance. Welfare studies should employ capture-tag-release monitoring in order to determine integrated trap safety.

Limitations of current literature

Many trapping studies do not report on by-catch or trap-related injuries, making it difficult to determine trap safety. When trap-related injuries are recorded, the lack of consistency in recording poses a problem. Iossa *et al.* (2007) state that without a universal method for assessing injuries it is difficult to compare multiple findings from different researchers; at the time of their research, there was no consensus on the key thresholds for animal welfare standards in relation to the levels of injuries sustained in restraining traps.

Vague terms such as 'minor' and 'severe' are often used to describe the extent of injury without the inclusion of any scale or measurements. ISO (International Organization for Standardization) 10990-5 (1999 in Iossa *et al.* 2007) includes any size laceration under the one category, whereas Meek *et al.* (1995) separate them across three categories. Additionally, it is the culmination of multiple injuries that gives an overall ranking by Meek *et al.* (1995), whereas ISO 10990-5 (1999 in Iossa *et al.* 2007) allocates points to each injury to determine a combined score, adding yet another facet of inconsistency. Thus, an injury recorded as minor by one researcher may be recorded as severe by another. There is discrepancy yet again even within the one system; Meek *et al.* (1995) describe their categorisation system as being 'based' on work by others (Van Ballenberghe 1984), as opposed to following an already established system.

Injury classification differs at every step making the determination of trap safety across multiple projects extremely difficult when data are recorded and impossible when they are not. There is currently no trauma scale implemented universally (Iossa *et al.* 2007), nor is there an objective scoring system that integrates both physical injury and physiological response (Powell and Proulx 2003). Unless changes are made to the way trap-related injuries and their effect on captured animals (including by-catch) are recorded and categorized, it cannot be said with any certainty that the best techniques in trapping are currently being employed.

Conclusion

Although soft-catch leg-hold traps are not always the most target specific devices, this can be adjusted through correct and appropriate use, resulting in the potential decrease of injuries sustained by captured individuals. There is also a lack of recordings, and literature in general, related to trap-related injuries for captured non-target fauna. When the injuries were investigated, it was difficult to compare across studies because the categorisation systems were as inconsistent as the findings. It is clear that a universal injury assessment scale is required in order to determine the method with the highest efficacy and overall safety for the captured individuals and their dependants.

Chapter 2

2.1. Methods

2.1.1. Approach

Dr Peter Mawson, in his position as Director of Animal Health and Research at Perth Zoo, contacted various organisations currently (or previously) implementing trapping programs using soft-catch leg-hold traps in Western Australia and presented them with a project plan. They were then asked if they would be willing to offer their data for the project; all obliged with some only requesting to have their participation acknowledged in this document. This resulted in six trapping sites, with none being held in higher regard than the others. All of the trapping programs were conducted with differing purposes ranging from capture and release for tracking, through to pest removal, and as such the type and extent of information recorded also differed.

By having datasets from a range of locations across Western Australia the representativeness of the data increased. The use of six sites reduced the chance of climate or landscape variation skewing the results. Furthermore, the research was conducted over nearly two decades; reducing the chance of seasonal variation affecting results. As all datasets were collected with other projects in mind, there was no standardisation in the field data recorded, or the skill of the trappers themselves.

2.1.2. Site Description

Data were collected from six sites across Western Australia: Boyicup and Balban Forests, Perup Sanctuary, Francois Peron National Park, Mornington and Mount Gibson Sanctuaries. Trapping occurred between 1997 and 2015. The sites ranged in location from the Kimberley Region to the South West Region (Figure 1, Table 5).

Figure 1. Map of Western Australia identifying the six study sites (MapCustomizer, n.d).

Table 5. Location details of the six study sites

Map Reference	Location	Co-ordinates
1	Boyicup Forest	-34.28, 116.57
2	Balban Forest	-34.09, 116.35
3	Perup Sanctuary	-34.25, 116.14
4	Francois Peron National Park	-25.84, 113.56
5	Mornington Sanctuary	-17.51, 126.12
6	Mount Gibson Sanctuary	-29.61, 117.12

South-West (Boyicup Forest, Balban Forest and Perup Sanctuary)

Located within the south west of Western Australia, this region experiences a Mediterranean-type climate consisting of warm, dry summers and cool, wet winters (Yeatman and Wayne 2015). The wet season falls between May and August, with the area experiencing on average

700mm of rainfall annually (Hamilton and Rolfe 2011).The open forest and woodland supports dry sclerophyll type plants and an overstorey consisting of jarrah and marri (Yeatman and Wayne 2015; Hamilton and Rolfe 2011). The area is divided into a series of forest blocks with Boyicup and Balban Forest both located in the north (Balban more so than Boyicup) (Wayne *et al*. 2015).

Unlike much of Western Australia, Perup Forest is unsuitable for agriculture, however, before being gazetted in 1971 as a nature reserve, the forest was available for commercial timber harvesting; albeit only lightly and mostly limited to the northern portion, due to the poor quality of timber (Burrows and Christensen 2002). Fire, however, is a much more prominent threat. Given the Mediterranean-type climate and accumulations of flammable fuel, the region is prone to fire; records from 1938 describe infrequent but often intense wildfire and prescribed burns at intervals of 7-12 years (low to moderate intensity) followed by long periods of no burning (CALM (1998) in Burrows and Christensen 2002). In 1951, practically the whole forest was engulfed by wildfire, with the northern portion (including Balban) being burned by wildfire again in 1981 (Burrows and Christensen 2002). In 1977 and 1995 the Boyicup block experienced patchy, low-intensity prescribed burns (Burrows and Christensen 2002). These prescribed burns are currently in use within the region in an effort to provide a fire-induced habitat mosaic (Burrows and Christensen 2002).

The importance of the south west of Western Australia for conservation is emphasised in Department of the Environment and Energy (1996), which demonstrated the high concentration of taxa of conservation importance in this area. Between 1974 and 1999, six local mammalian species woylie, tammar wallaby *Macropus eugenii*, quenda *Isoodon obesulus*, chuditch *Dasyurus geoffroii*, numbat *Myrmecobius fasciatus* and western ringtail possum *Pseudocheirus occidentalis* were listed as threatened under Australian and Western Australian legislation (Burrows and Christensen 2002). Management action was implemented and lead to the delisting of three of these species (woylie, quenda and tammar wallaby) as threatened from the International Conservation Union Red List (IUCN) (Burrows and Christensen 2002). Unfortunately, the woylie population rapidly declined between 2001 and 2006, resulting in the species qualifying for re-listing as endangered by the IUCN (Groom 2010). Mammal trapping programs are maintained in the area in order to monitor populations of the woylie, quenda, chuditch and common brushtail possum *Trichosurus vulpecula* (Burrows and Christensen 2002).

In 1977 the first successful formal faunal reintroduction program released woylies from the Boyicup Block in the south to the northern section (Burrows and Christensen 2002). To eliminate the threat of foxes a control program commenced that year, with irregular baiting of 1080 until 1990 when regular baiting of the entire forest commenced using more sophisticated methods (Burrows and Christensen 2002). In 2010 a 2-meter-high wire fence was built around the sanctuary; intended to exclude foxes, rabbits and cats (Yeatman and Wayne 2015). Following the construction, an intensive program was undertaken to remove foxes and cats in the area; as well as western grey kangaroos, brush wallabies, some brushtail possums and all chuditch, deemed potential problem species, and in late 2010, 41 woylies were released into the sanctuary (Yeatman and Wayne 2015).

Gascoyne (Francois Peron National Park)

Located northwest of Perth in Western Australia's mid-west, the site is situated on the Peron Peninsula within Shark Bay (Department of Parks and Wildlife, n.d). Peron Peninsula experiences a semi-desert Mediterranean climate. The summer displays an average maximum daily temperature of 38^{o}C, with relatively dry, warm and moderately strong winds, while the winter has a much lower average maximum daily temperature of 21^{o}C with winds that are much lighter, cooler and more humid. The rainfall in the area averages at around 220mm per year, with the majority of it falling throughout April to September (Algar *et al*. 2007). The area is composed of *Acacia spp.* vegetation throughout red dunes and arid shrub lands (Department of Parks and Wildlife, n.d) with scattered birridas (evaporative salt pan) that vary in size and shape (Algar *et al*. 2007).

Peron Peninsula was a pastoral station until 1990 when the State Government purchased it and established Francois Peron National Park on the northern end (Algar *et al*. 2007). In 1994 Project Eden commenced on the peninsula in an effort to eradicate the introduced fauna, reconstruct the native fauna community, and to promote nature-based tourism focussing on the unique Shark Bay fauna (Morris *et al*. 2004). The 1050km^2 peninsula is joined to the mainland by a narrow strip with a barrier fence running across it in an effort to exclude foxes from reinvading (Algar *et al*. 2007). As well as the fence, an electronic recording of a dog barking (activated by movement sensors) and a cattle grid are also in place where the Denham road passes through the fence (Algar *et al*. 2007). Control of sheep *Ovis aries*, goats *Capra hircus* and foxes has proven successful; however feral cat control has been more difficult due to the significant number of prey species (Morris *et al*. 2004). Control programs were put in place on the peninsula that consist of both ground and areal baiting, and trapping using padded leg-hold traps, audio lures of cat calls (FAP)[5] and a blended mixture of faeces and urine (PONGO) (Algar *et al*. 2007).

Peron Peninsula was once home to 25 native mammal species (Morris *et al*. 2004). As part of Project Eden, a captive breeding centre aimed at providing animals for translocation was established (Morris *et al*. 2004). Between 1996 and 2002 there have been nearly 70 malleefowl *Leipoa ocellata* and 150 mammals bred and reared in captivity with 155 having been already released; the malleefowl and bilbies *Macrotis lagotis* were successful, however the mala *Lagorchestes hirsutus* and banded hare-wallabies *Lagostrophus fasciatus* were not (mostly due to cat predation) (Morris *et al*. 2004; Hardman *et al.* 2016). Populations of woylies were also reintroduced to the area from other wild populations but did not persist. However, the larger extant vertebrates have increased since the removal of pest species (Morris *et al*. 2004).

<u>Kimberley (Mornington Sanctuary)</u>

The Kimberley region spans a large area of Western Australia's north, and so consequently the climate ranges from semi-arid in the southern portion, through to sub-humid in the centre, with humid/perhumid and hyperhumid in the far north along the coast (Cresswell *et al.* 2011). Mornington Sanctuary is located within the central part of the Kimberley; with a tropical monsoon climate accompanied by temperatures exceeding 30°C during the day throughout the whole year (McGregor *et al*. 2016).

[5] FAP= felid attracting phonic.

As a result of the variable climate throughout the region, the vegetation and landscape are also inconsistent. There are extensive river systems and deeply excised gorges, mound springs, massive sandstones, razor backed ridges and scarps, and alluvial plains (Pepper and Keogh 2014). The vegetation within Mornington Sanctuary, specifically, is predominantly savannah woodland with sandstone ridges and complex rock substrates dissecting the area, as well as some major waterways in the Fitzroy River catchment (McGregor *et al*. 2016).

Evidence suggests that historically, the Kimberley has been a refuge for many species (Pepper and Keogh 2014). It is recognised as an area of endemism and supports more than 65 species of endemic fauna; however this is likely to be an underestimate, as every new venture into previously unexplored sections reveals new endemic species (Pepper and Keogh 2014 and included references).

Mornington Sanctuary covers 320,000ha of land currently owned and managed by the Australian Wildlife Conservancy for conservation; an ongoing venture since 2004 (Legge *et al*. 2011). Prior to this, Mornington had been operated as a cattle station, with a standing herd of around 6000 head extensively grazing on the land since the 1920s (Legge *et al*. 2011). 2004 saw 24,300 ha of land fenced, followed by the removal of stock animals such as cattle *Bos taurus*, horses *Equus caballus* and donkeys *Equus africanus asinus* (Legge *et al*. 2011). This was followed by a further 16,000 ha of land destocked in 2005, and by 2007 there were no horses or donkeys in the area, and fewer than 200 cattle had been recorded (Legge *et al*. 2011).

Unfortunately for the native wildlife present, the Kimberly region has many unique geological resources and as such has been adversely impacted by human development (Pepper and Keogh

2014). Activities threatening the biota include proposed mining operations, broad-scale agricultural industrialization, introduced domestic and feral herbivores, altered fire regimes, and the arrival of feral species such as the cane toad *Rhinella marina* (Pepper and Keogh 2014). The Department of Parks and Wildlife (2014) has since listed the Kimberley as a National Biodiversity Hotspot and created *The Kimberley Science and Conservation Strategy* (Department of Parks and Wildlife 2011) in an effort to conserve the region's natural and cultural values (Pepper and Keogh 2014).

Avon Wheatbelt (Mount Gibson Sanctuary)

Approximately 350 kilometres northeast of Perth lies Mount Gibson (Australian Wildlife Conservancy, n.d). This site is 132,500 hectares of property situated within the transition zone between the eucalypt-dominated South-west and the mulga-dominated Eremaean Botanical Provinces (Ruykys *et al.* 2015). The vegetation in this area consists of eucalypt woodlands containing Gimlet, Salmon and York gums as well as a variety of other threatened and declining flora. The landscape is varied; consisting of a lake, greenstone ranges and granite ridges, and sand plains (Australian Wildlife Conservancy, n.d). With consistently hot summers, it is the winter that varies. Local rainfall is inconsistent; with some years experiencing a winter rainfall similar to the driest parts of the wheatbelt, whereas other years must contend with the occasional very large summer downpours, as seen in the northern areas (Australian Wildlife Conservancy, n.d). Typically the summer temperatures range from 19-36^{o}C, whereas winter temperatures can be anywhere from 6-18^{o}C (Richards *et al*. 2011).

In 1878 the Mount Gibson Pastoral Lease was granted for the grazing of sheep, establishing a long history of pastoralism (Richards *et al*. 2011). In 2001 the Australian Wildlife Conservancy acquired the lease, and subsequently destocked the land; this included the removal of most sheep and goats, with only a small resident goat flock remaining (Richards *et al*. 2011). Fortunately, the station was never heavily stocked and so the damage to the soil and vegetation was minimal (Australian Wildlife Conservancy, n.d).

To date, 567 plant species have been confirmed in the area; however this number is presumed to be an underestimate, with the actual number being predicted at around 700-800 species (Australian Wildlife Conservancy, n.d). Due to the variable habitat and high diversity, the land once supported a rich mammal fauna. It is likely to have been home to at least 33 terrestrial mammal species at the time of European settlement (Ruykys *et al.* 2015). Unfortunately, this number has been cut nearly in half, with 13 of these species now extinct across most of their range, and three becoming globally extinct (Ruykys *et al.* 2015). Attempts to control feral animals in the area, particularly foxes, saw early management practices of baiting with 1080 between 2004 and 2007 (Richards *et al*. 2011).

In an effort to conserve the threatened mammals of southwestern Australia, the Australian Wildlife Conservancy established the Mount Gibson Wildlife Sanctuary (Australian Wildlife Conservancy, n.d). This sanctuary has the largest cat and fox-free area on mainland Western Australia; 7800ha surrounded by a feral-proof fence (Australian Wildlife Conservancy, n.d). Within this refuge, there are 19 unique habitat types (Ruykys *et al.* 2015) and plans in place to release at least 10 regionally extinct mammalian species (Australian Wildlife Conservancy, n.d).

Thus, this area plays a critical role in ensuring a future for 14% of Australia's nationally threatened mammals (Australian Wildlife Conservancy, n.d).

2.1.3. Trapping

Trapping protocols varied across the six sites. In regard to the location of the traps, some sites had traps placed within a fenced area (Mt Gibson), scattered around an open area (Francois Peron, Boyicup, Balban and Mornington Sanctuary), or both inside and out (Perup Sanctuary). The use of attractants and trap sets also varied across sites. Three sites recorded the use of a lure or attractant; FAP and Fpongo[6] were both used at Perup Sanctuary, a combination of fresh urine and faeces from a domestic cat and local soil, along with a visual attractant at the back of a bower (a covered recess made of vegetation) were used at Mornington Sanctuary, and Francois Peron used 29 combinations of lures and set combinations (Table 6).

Table 6. Lures and sets used at Francois Peron National Park.

1.	Dpongo Leg-hold[7]	***16.***	Yeast-Leg-hold
2.	Dpongo and FAP Leg-hold	***17.***	Dpongo Leg-hold Full High Barrier
3.	Fpongo Leg-hold	***18.***	Fpongo Leg-hold Full High Barrier
4.	Fpongo and FAP Leg-hold	***19.***	Dpongo Leg-hold Full Low Barrier
5.	FAP Leg-hold	***20.***	Fpongo Leg-hold Full Low Barrier
6.	Dpongo Leg-hold Raised	***21.***	Dpongo Leg-hold Half High Barrier
7.	Dpongo and FAP Leg-hold Raised	***22.***	Fpongo Leg-hold Half High Barrier
8.	Fpongo Leg-hold Raised	***23.***	Fpongo Leg-hold Full High Barrier Platform
9.	Fpongo and FAP Leg-hold Raised	***24.***	Dpongo Leg-hold Full High Barrier Platform
10.	FAP Leg-hold Raised	***25.***	Fish Leg-hold Full Low Barrier
11.	Leg-hold	***26.***	Fish Leg-hold Full High Barrier
12.	Cage and Rabbit	***27.***	Fish Leg-hold Full High Barrier Platform
13.	Cage and Dpongo	***28.***	Dpongo Leg-hold Full Barrier Fur
14.	Cage	***29.***	Fpongo Leg-hold Full Barrier Fur
15.	Leg-hold-Funnel		

[6] Fpongo= feline faeces and urine
[7] Dpongo= canine faeces and urine

Additionally, the trapping effort and area varied across sites. Perup Sanctuary had only 10 trap nights whereas the others had considerably more; Boyicup had 409, Balban had 669, Mornington had 1112 and Mt Gibson had 4762. The total number of trap nights was not recorded for Francois Peron National Park, but trapping was conducted from 1997-2005. Differences in the skills of trappers were also noted with not all sites employing highly skilled researchers; both Balban and Boyicup relied on local residents to assist in the trapping programs. This may affect not only how the traps were set, but also how the animals were restrained and potentially the risk of injury to the animals.

Consequently, information regarding specific trap placement and lay-out, as well as ratios of lures place (such as olfactory and non-olfactory) was inconsistent and not available in full at any site. All of these confounding factors were taken into consideration in data analysis and, where possible, assessed. Comparisons across sites were only made if the sampling was consistent or if any inconstancies could be safely removed without compromising results.

2.1.4. Data Organisation

The data were pooled across all the sites and added to an Excel spread sheet for analysis. Each of the entries was assigned to an injury category (Table 7) based on a scale identified in Meek *et al.* (1995) that was based on the categories originally developed by Van Ballenberghe (1984);

Table 7. Categorisation of injury types for comparison of injuries associated with soft-catch leg-hold traps.

Category	Injury Description
Category 1	slight foot/leg oedema, no lacerations or broken bones.
Category 2	moderate oedema, lacerations less than 2.5cm long, no broken bones and joints.
Category 3	lacerations at least 2.5cm long, visible tissue damage, no tendon damage, one metacarpal or phalanx bone broken.
Category 4	combinations of deep, wide lacerations, severed tendons, broken metacarpals, broken radius or ulna bones and joint dislocations.

In addition to the categories outlined in Table 7, Category 0 was created. Further modifications included; if there was no injury to the individual, it was assigned to category 0; if the individual was initially released unharmed and injuries were later observed it was assigned category 0 as the injuries cannot be guaranteed as a result of trapping; if records showed an injury occurred but no description was provided then category 0 was assigned to the individual; abrasions were considered a laceration of less than 2.5cm; a compressed muscle was considered equal to a moderate oedema; any broken ankles or legs were assigned to category 4; and any individual that died or required euthanasia due to injuries sustained was assigned category 4. If multiple injuries were sustained by the individual, the categorization was allocated based on the most severe of these injuries.

In some cases weights of non-target animals were recorded. When they were not, the steps set out in Figure 2 were applied.

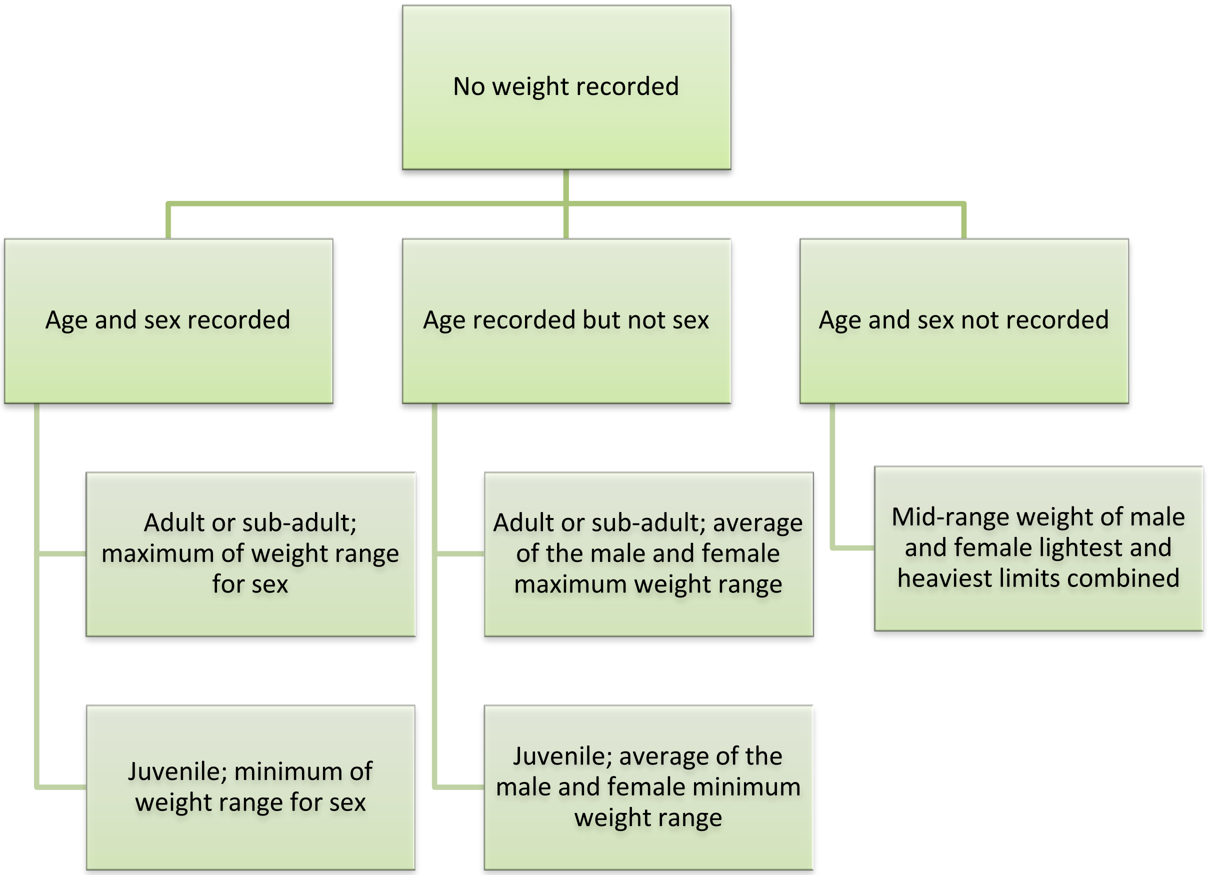

Figure 2. Sequence of steps for determining weights of individuals when none was recorded.

The species' weights were taken from Van Dyck and Strahan (2008) and Department of Education and Training (n.d) for mammals; Johnstone and Storr (1998) and (2004) for birds; and McIlroy *et al.* (1985) and Mike Bamford[8] (pers. comm.) for reptiles.

All animals captured were described as either non-target or target. Given the aims of this study, regardless of lure type used or the purpose of the original studies collecting the data, only cats were classified as the target species. Non-target species included all other individuals captured;

[8] Personal Communication with Mike Bamford (bamford.consulting@iinet.net.au).

this consisted of both native and non-native species. In analyses that required more specificity, the non-target species were separated into their respective native and non-native groups.

2.1.5. Analysis

Once the data were organised and all entries were complete, Excel was used to generate multiple graphs and tables to better visualise the data and aid in analysis. Statistica 13 (Dell Inc. 2015) was also used when more than 225 data series per chart was necessary, as Excel was unable to process this. Statistical analyses were carried out using online routines in VassarStats (http://vassarstats.net) and SPSS version 24 (IBM Corp 2016).

Chi-square

The Chi-square test is widely utilised throughout all branches of biology (Dytham 2003). It allows assessment of whether observations are occurring at random or in association, thus the null hypothesis is always that the observed and expected frequencies are not different from each other (Dytham 2003). If the occurrence of the observations is random, then the chi-square will not be significant (Dytham 2003). Unlike standard binomial procedures, it extends on this logic and allows analysis of situations where there are more than two categories of possible outcome (Lowry 2015).

For this project, chi-square was used to assess the association between the injuries the native fauna by-catch received and the taxa sustaining them. The Chi-square test can give misleading results if expected frequencies are low (Zar 2010). Recommendations on how to deal with small expected frequencies vary. The most conservative view is that no expected frequency should be less than five, although other authors state that no more than 20% of expected frequencies should be less than five and no expected frequency should be less than one. In reviewing the literature, Zar (2010) recommended that to test at a significance level of 0.05, the expected values should have a mean ≥6. Therefore my analysis combined the number of individuals that had no injuries (uninjured), had an injury ranging from category 1 to 3 (intermediate), or had category 4 (severe) injuries, resulting in a total of 3 levels of injury. This met both Zar's (2010) criterion and also the more conservative one that no expected frequency should be less than one.

Logistic Regression

Logistic regression allows assessment of the influence of predictor variables, which may be categorical or continuous, on a binary dependent variable. In this case, the predictor variables were the weight of the individual and the taxon it belongs to, while the dependent variable was whether or not it was injured by trapping. A logistic regression was chosen instead of a linear regression model as the outcome variable for the logistic regression is binary (injured or not injured) as opposed to continuous (Hosmer and Lemeshow 2004).

Spearman Rank-Order Correlation

The Spearman rank-order correlation allows a statistical measure of the strength and direction of a relationship between paired data (Lowry 2015). This was useful when investigating the effect that the weight of an individual (in this case Log_{10} of mass (kg)) had on the severity of the injuries sustained (category 0-4).

Chapter 3

3.1. Results

3.1.1. By-catch

3.1.1.1. Extent of by-catch

A total of 431 non-target individuals, including 232 individuals from native species, were captured across the six sampling sites. Across four of these sites (Boyicup, Balban, Perup, and Mt Gibson), there was consistently more non-target by-catch being trapped than targeted species (Figure 3). At Perup Sanctuary only non-target species (eight individuals) were trapped. Mornington and Francois Peron contrasted this with 19 targeted and seven non-target by-catch, and 3455 targeted and 355 non-target by-catch being trapped, respectively (Figure 3).

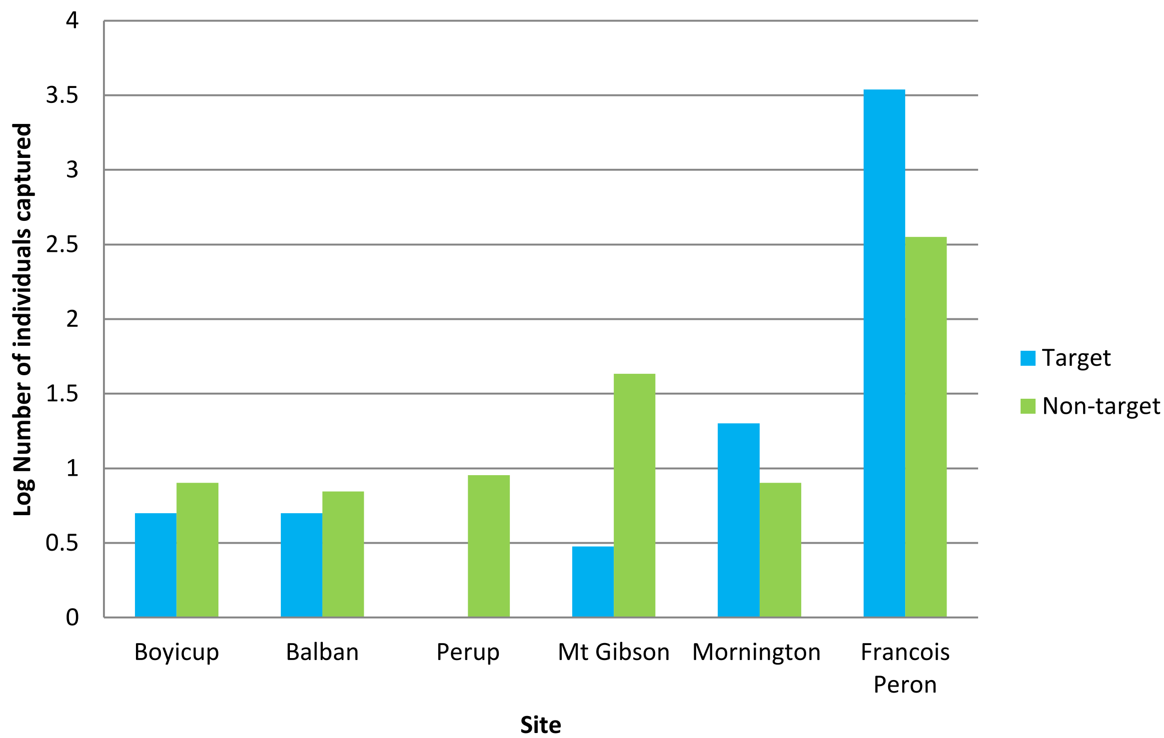

Figure 3. The $\log_{10}$ of the total number of target species (cats) captured as well as the total non-target by-catch trapped at each site.

3.1.1.2. Effect of olfactory lures on by-catch

There was no significant difference between the type of lure used and the taxon of the individuals captured (Table 8). However, there did seem to be a relationship between the use of olfactory attractants and the taxon of by-catch. Reptiles appeared to be more readily attracted to olfactory lures than any other used (22:14), whereas mammals were repelled (28:74) and birds had no connection (18:24) (Table 8). No statistical analysis could be performed as information regarding trapping effort, which could alter the above ratios, was not available for all sites.

Table 8. The number of native by-catch individuals captured from each taxon when different lure types were used.

Taxon	Olfactory Lure (#captured)	Other Lure (#captured)
Bird	18	24
Mammal	28	74
Reptile	22	14

3.1.2. Injuries

To compare injuries between native and non-native fauna in by-catch, data were combined to form the categories uninjured, intermediate injury (combining category 1, 2 and 3 together; animals survived) and category 4 (injuries were severe and often resulted in death) (Table 9). Intermediate and severe injuries occurred significantly more frequently amongst native fauna (χ_2^2= 14.22, p= 0.001). The percentage deviations were greatest for intermediate (+57.2% for native by-catch, -66.7% for non-native by-catch) and severe (+15.8% for native by-catch, -18.4% for non-native by-catch) injuries (Table 9).

Table 9. Number of by-catch individuals (native and non-native species) in each category (uninjured, intermediate, and severe). Percentage deviation (indicating the extent to which the observed result differed from the expected) is displayed next to each value. Fox captures were included in results as only feral cats are recognised in this project as the target species.

Injury Category	Native	Non-native
Uninjured	167 (-7.7%)	169 (+8.9%)
Intermediate	22 (+57.2%)	4 (-66.7%)
Severe	43 (+15.8%)	26 (-18.4%)
Total=	**232**	**199**

3.1.2.1. Predictors of injury

Within the 232 animals trapped as native by-catch, 65 individuals were injured or died (Table 10). The fate of an individual was associated significantly with the taxon it belonged to (χ_4^2=

11.31, p= 0.023). Mammals had the highest rate of individuals being unharmed, whereas the birds incurred the largest proportion of category 4 injuries (Figure 4); thus birds were also far more likely to be killed (%deviation= +76.4) than any other taxon (Table 10). Overall, any given individual was likely to be unharmed, however when injury did occur, it was mostly severe (category 4), with some resulting in death (Figure 4; Table 10).

Table 10. Number of individuals from all three taxons of native by-catch (bird, mammal and reptile) in each of the summarised injury categories (uninjured, intermediate and severe). Percentage deviation is also displayed next to the corresponding value.

Injury Category	Bird	Mammal	Reptile
Uninjured	32 (-14.5%)	107 (+7.7%)	28 (-7.4%)
Intermediate	3 (-39.2%)	14 (+7%)	5 (+25.5%)
Severe	17 (+76.4%)	17 (-33.5%)	9 (+15.6%)
Total=	**52**	**138**	**42**

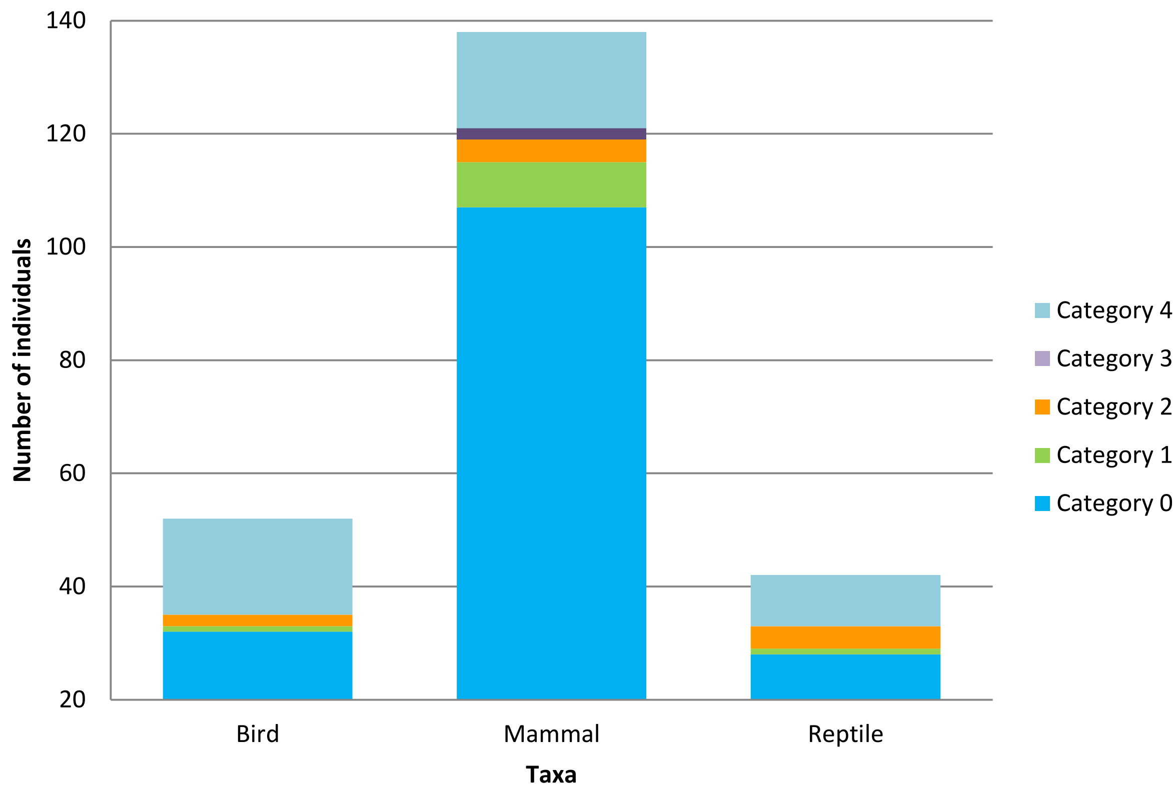

Figure 4. The distribution of injury categories (Table 7) amongst birds, mammals and reptiles from the native species by-catch. As per the modifications to Table 7, category 0 represents individuals with no injuries.

To determine why this is, a logistic regression analysis was run with predictors of taxa and mass, and a binary dependant variable of uninjured or injured (combining all categories of injury and death). 'Bird' was used as the reference taxon; this was due to the list being organised alphabetically; this was to avoid bias. The predictors as a set reliably distinguished between injured and not injured (χ^2_3= 19.861, $p< 0.05$). The model explained 6.4% (Nagelkerke R^2) of variance in injury and correctly classified 74.8% of cases. The Wald criterion demonstrated that being classified as a bird or mammal, and the individual's mass, all made significant contributions to predicting injury (p= 0.047, p= 0.019, and p=0.002, respectively). Being classified as a reptile was not a significant predictor of injury (p=0.423). The Exp(B) value (odds ratio) indicates that when the mass of an individual is raised by one unit (1kg) the risk of injury falls by 0.0039 (Table 11). To calculate the effect of an individual's mass on the severity of injury sustained, a Spearman rank-order correlation coefficient was calculated. A significant relationship was identified (r_s= -0.252), highlighting that when an injury occurred, the lighter individuals sustained category 4 injuries more often than those that were heavier. Additionally, it was uncommon for a category 1-3 injury to be sustained regardless of mass (Figure 5).

Table 11. Results of logistic regression analysis for all three taxa of native by-catch (bird, mammal, reptile), using the predictors of taxa (categorical), weight (continuous), and the weight x taxa interaction. The dependant variable was whether or not the individual sustained an injury. Significant results are indicated with an asterisk (*).

Variable	B	SE	Wald	df	Sig.	OR
Bird	-	-	6.125	2	0.047*	-
Mammal	-0.763	0.326	5.483	1	0.019*	0.466
Reptile	-0.361	0.451	0.641	1	0.423	0.697
Mass	-0.039	0.013	9.292	1	0.002*	0.961
Constant	-0.216	0.309	0.488	1	0.485	0.806

B, b coefficient (Logit); SE, standard error; df, degrees of freedom; Sig., significance level; OR, odds ratio.

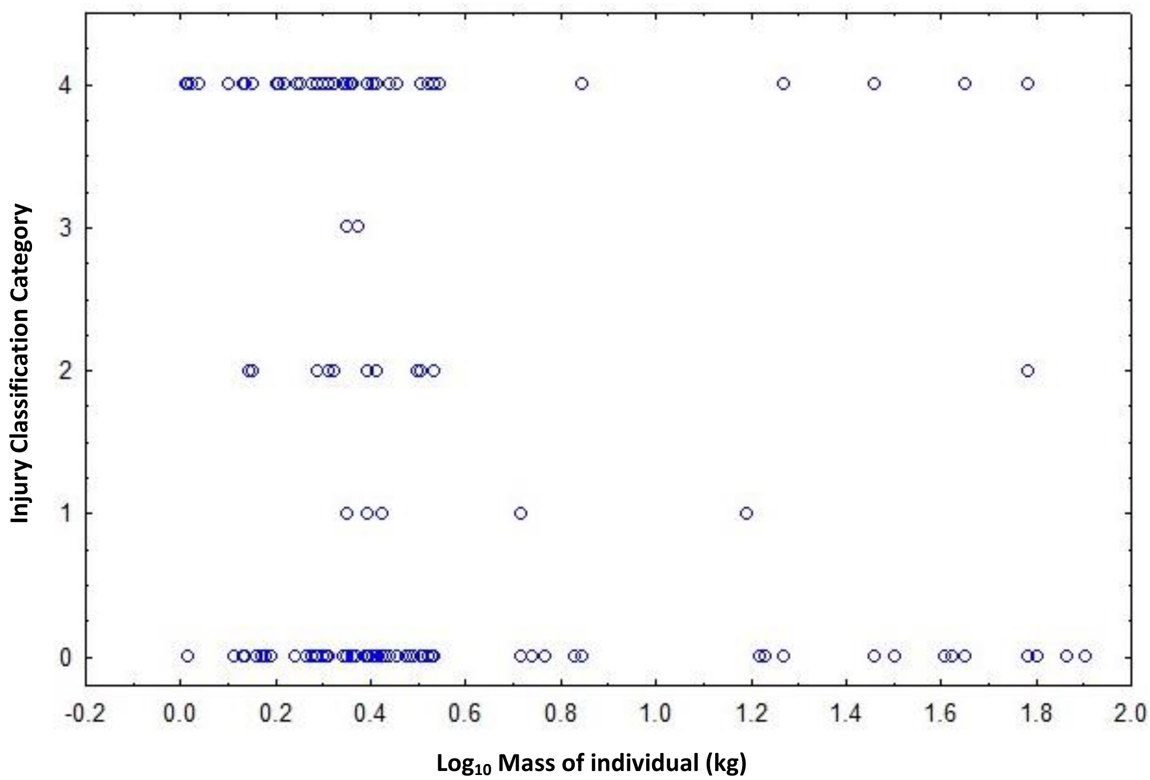

Figure 5. The relationship between a captured individual's mass and the level of injury they sustained (Table 7). Again, note that category 0 represents individuals with no injuries.

3.1.2.2. Conservation implications

The concern for native species listed under the IUCN and DPaW conservation categories was validated, with 20 out of 31 trapped (Table A1a) individuals of conservation concern having sustained injuries or died. Seven of these 20 individuals were critically endangered and of those, over 71% (5) suffered category 4 injuries (Figure 6).

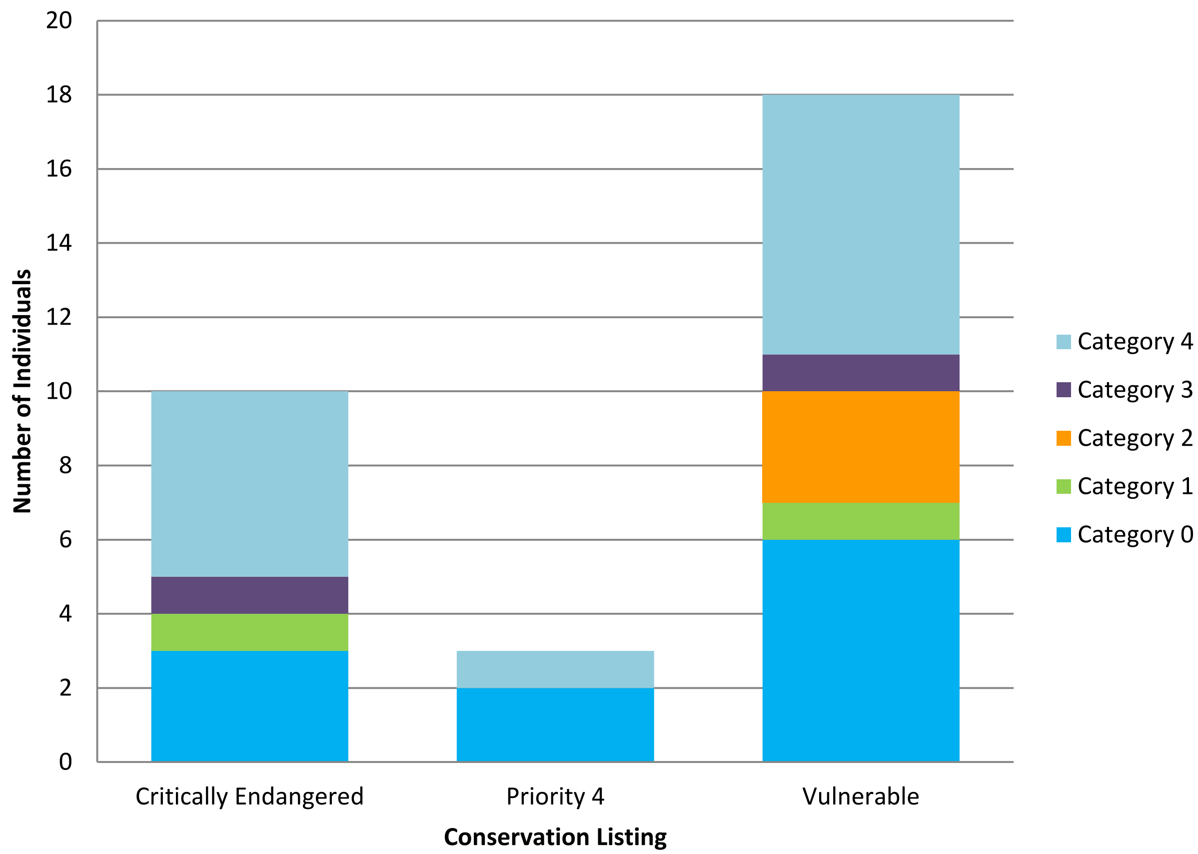

Figure 6. The severity of injuries sustained (Table 7) by individuals currently listed as either critically endangered, priority 4 or vulnerable as per IUCN and DPaW classification. Again, category 0 represents individuals with no injuries.

Chapter 4

4.1. Discussion

4.1.1. By-catch

The ratio of target to non-target captures varied across the six sites; Mornington Sanctuary and Francois Peron National Park both had more target than non-target captures, whereas at the other four sites by-catch out-numbered the target species. Olfactory lures were attractive to reptiles, repellent to mammals and had no effect on birds.

4.1.1.1. Extent of by-catch

The soft-catch leg-hold traps captured more by-catch than targeted individuals at four out of the six sites. Both Mornington and Francois Peron sites captured considerably more target species than non-target; with the latter capturing almost 10 times as many targeted individuals than by-catch. Previous studies have noted that soft-catch traps, like the ones used throughout this project, are not the most selective option (more-biased measure of selective efficiency) and have a reputation for trapping by-catch (Fleming *et al*. 1998). However, Turkowski *et al.* (1984) state that unlike other trap types, the efficiency of snap traps (such as soft-catch leg-hold traps) can be increased, with respect to reducing smaller by-catch animals, by increasing the pan tension (the force required to release the trigger plate, allowing the trap jaws to close). The efficiency of soft-catch traps is highly variable depending on a variety of factors. Linhart *et al*. (1986) state that the efficiency (measured by trap speed, spring success rates, target capture rates and subjective assessments of field performance) of padded jaw traps under varying environmental conditions (soil moisture and type, as well as temperature) was less than the alternative unpadded traps used. In contrast, Fleming *et al*. (1998) recorded that they were just as efficient and selective when compared to the toothed steel-jawed traps, and were less injurious, thus questioning the use of the unpadded traps altogether. Fleming *et al*. (1998) also noted that there are difficulties associated with determining trap efficiency; specifically regarding bias. Population demographics, expertise of the trappers, seasonal variation, site characteristics and previous exposure of the targeted population to trapping can all contribute to the bias in results (Fleming *et al*. 1998).

Factors influencing results

Due to the nature of this study and the lack of consistency in reporting of findings amongst the projects, there are many factors that could potentially confound the outcomes identified. These include climate and landscape, fauna community structure and trapping technique. Additionally, the use of lures and attractants also proved influential.

Climate and Landscape

As the data were collected from multiple sites scattered across Western Australia, environmental factors such as landscape, climate and seasonal variations could affect the demographics of non-target populations at each site. Landscape is variable in both structure and species composition. Individual species of animals are not evenly distributed across the land, and certain species will be present in some regions and not others (McCullough 1996).

For example, emus *Dromaius novaehollandiae*, echidnas and wedge-tailed eagles *Aquila audax* occur at all six sites, but only Francois Peron National Park contained bilbies. This is due to human influence on the landscape with a reintroduction program occurring at Francois Peron National Park that saw 55 captive-bred bilbies reintroduced to the area from 2000-2002 (Mawson 2004). Additionally, modifications to the landscape have altered the presence of dingoes *Canis lupus dingo*; originally widespread across all six sites (Corbett 2008), they are now only present at Mornington Sanctuary due to the extensive control programs undertaken at the other five sites. Crows *Corvus sp.,* however, occur at all six sites, but only those at Balban Forest, Boyicup Forest, Perup Sanctuary and Mount Gibson Sanctuary are of the same species; despite the Mediterranean-type climate at the South-West sites (Yeatman and Wayne 2015) being so different from the varying climate experienced at Mount Gibson Sanctuary.

Even within these climatic regions segregation occurs; as populations are usually distributed across suitable patches of habitat separated by undesirable areas (McCullough 1996). This is seen in the South West region (Perup Sanctuary, Balban Forest and Boyicup Forest); brown falcons *Falco berigora* are found at both forest blocks but not at Perup Sanctuary, and sheep are present on farmland adjacent to Boyicup Forest but not the other two sites, despite the close proximity of all three sites. Ultimately, the landscape as well as past and present use, whether across climatic regions or habitat blocks, strongly influences the presence of different species and subsequently those that are at risk of being trapped. Consequently, some sites may contain more 'trap-happy' species that will increase the by-catch rate, whereas others may be populated by timid species that are more cautious of traps, resulting in fewer by-catch individuals (Table A1c). This 'trapability' is also variable amongst individuals within the same species (and even population) that may behave differently from each other as an individual response to the area they inhabit, as seen in emus (Davies *et al.* 1971). Despite being known to occur at all sites, emus were only trapped at Francois Peron National Park (Table A1c).

Seasonal variation and weather changes can affect trapping success as a result of the change in food availability, individuals' behaviour and trap performance (Pawlina and Proulx 1999). Smith and Blessing (1969) identified that the 'trapability' of old-field mice *Peromyscus polionotus* decreased when other food sources were available. This has been suggested to also occur in larger mammals, specifically, racoons *Procyon lotor* (Pawlina and Proulx 1999). However, food is not the only driver for changes in animal behaviour, with weather and atmospheric variables, as well as reproductive status, altering activity patterns and mobility amongst individuals (Pawlina and Proulx 1999). Increased air temperature and time between rainfall events have previously shown to have a negative relationship with the trap success of valley pocket gophers *Thomomys bottae,* for example (Cox and Hunt 1992). It has also been noted that changes in weather conditions can affect the traps themselves; wind, rain, wave action, vegetation or mud can trip sensitive triggers, and frozen soil caught between the jaws of padded traps can cause them to fail (Wiener and Smith 1972; Parker 1983; Linhart *et al*. 1986). This effect on the traps would pose a larger threat to the sites in the Southern Forests (Balban, Boyicup and Perup) as they experience a wetter climate; 700mm average of rainfall p.a (Hamilton and Rolfe 2011), than the more Northern sites such as Francois Peron National Park, which has on average only 220mm of rainfall p.a (Algar *et al*. 2007).

Predation

The very nature of each site could confound the by-catch results. Balban and Boyicup were open forest blocks, whereas Perup Sanctuary and Mount Gibson Sanctuary were both fenced areas. This allows for free predator access throughout Balban, Boyicup and the surrounding forest, but confinement of native species at Perup and Mount Gibson Sanctuaries. This could be responsible for the discrepancy in data in regard to target and non-target captures. A much higher rate of non-target to target captures was recorded for both Mount Gibson and Perup Sanctuary (despite the prior removal of a number of native species from within the Perup site, therefore depleting the populations of these species) (Hamilton and Rolfe 2011), presumably due to the predator proof fences excluding feral cats and foxes (traps within the enclosure were set to catch any lingering cats post-removal or those that breached the fence). It would also be reasonable to conclude that prey species of the feral cat would be more abundant in areas from which cats are excluded; thus a higher population density of native species would increase the chance of by-catch. The high capture rate for rabbits at Mount Gibson Sanctuary, and brush-tail possums at Perup Sanctuary could reflect this (Table A1c). Additionally, movement of species between habitats could confound the results. Being open and contiguous, both Balban and Boyicup allow for free movement between the forest blocks and therefore the chance of catching any individual, whether target or not, is strongly affected by local movements. In contrast, being fenced, both Mount Gibson and Perup Sanctuaries have no emigration of individuals, thereby increasing the chance that any individual will be captured.

Trapping Technique

The experience of trappers and the nature of data that they recorded also varied amongst the sites. Some of the sites sampled in the project were done so entirely by researchers and government officers; Francois Peron National Park (DPaW), Mornington Sanctuary and Mt Gibson Sanctuary (AWC), whereas others recruited volunteers with little to no expertise in trapping; trapping at Boyicup Forest was conducted by members of the Warren Catchment Council as well as DEC[9], with Balban additionally utilizing the local farming community. This difference in skill amongst workers could alter the findings at each site. Skinner and Todd (1990) concluded that a trap performance increase from 55% to 91% after a year was largely due to the increased experience of the trappers. It could be expected that the accuracy of data recordings, such as correct species identification or accurate injury descriptions, would vary with skill of workers. However, it was the data from Francois Peron National Park that had some entries lacking a species name and instead only stating the taxonomic group. This highlights that if it is not the skill level of trappers that is responsible for incomplete entries, that in fact the amount of data to be recorded was variable across the sites. Alternatively, it could also be reflective of the trappers' experience; in order to avoid a misidentification, a broad taxon may be used when a species cannot be confirmed.

The trap placement and sets used also differed both between sites and within a single site (e.g. Francois Peron). This variation could influence the efficiency of trapping by either increasing the by-catch rate; placing traps in bushland known to be rich in native species, or increase the target captures; traps along roads and tracks are more likely to capture cats than in bushland as

[9] Department of Environment and Conservation (now known as Department of Parks and Wildlife).

the track allows for clear views for hunting and the ability for cats to traverse the same distance faster than if travelling through thick bushland. The problems of inconsistency in the placement and setting of traps has been previously identified as a potential source of variation in trap efficiency by Berchielli and Tullar (1980). Without all the sites being surveyed by the same trappers for the same purpose, such as the recording of injury and by-catch rate, there will always be inconsistency in recordings.

4.1.1.2. Effect of olfactory lures on by-catch

Finally, the use of lures and attractants can influence the by-catch results. Using attractants at trap sites can provoke varied responses amongst wild animals, both target and by-catch (Pawlina and Proulx 1999). Attractants can range from visual lures, such as feathers or tinsel, to olfactory lures such as food or scents. The response of the individual depends on previous knowledge (past experience, acquired from other individuals, or inherited), environmental cues, or its physiological condition and social status (Pawlina and Proulx 1999). Both conditioned and socially learned avoidance have been previously observed in species managed with electric fences; the individuals avoided the fence after either being previously shocked themselves, or after watching others being shocked (McKillop and Sibly 1988). Alternatively, trapping may have a more pleasant and attractive outcome by offering the opportunity for food (Pawlina and Proulx 1999). This attraction has been observed across mammalian species, such as voles *Microtus* spp., where larger, dominant individuals will prevent smaller, subordinate individuals from entering traps that could be perceived as a food source (Kikkawa 1964;

Boonstra and Krebs 1978). The use of various scents and odours is also known to alter animal behaviour.

The individual lures used at Francois Peron National Park had no clear effect on the taxon of by-catch trapped. However, on a broader scale, the type of lure used; Olfactory (stimulating the sense of smell) or otherwise, did show a definite relationship with the taxa of by-catch. Although birds were indifferent to either lure type, olfactory lures repelled the mammals and attracted the reptiles. The effect that olfactory lures had on the response of reptiles and mammals can be a result of several factors.

The survival of a prey species is dependent on its ability to recognise a predator, in most cases through detection of specific chemical cues, and respond accordingly (Apfelbach *et al.* 2005). The scat avoidance hypothesis explains the avoidance of prey animals to their predators' faeces as a way to reduce predation risk (Banks *et al.* 2002). This aversion due to predator scents has been identified in several mammalian species (Pawlina and Proulx 1999). Sullivan *et al*. (1985), for example, noted that hares *Lepus americanus* avoided seedlings scented with bobcat *Lynx rufus* and lynx *Lynx canadensis* faeces, and lynx, bobcat, wolf *Canis lupus*, coyote, fox and wolverine *Gulo gulo* urine, and weasel anal gland secretions. Evidence suggests this modification of behaviour is due to the predator odour triggering a flight response in the prey (Bolles 1970; Müller-Schwarze 1972; Stoddart 1976). In particular, Takahashi *et al.* (2005) identified fear-related responses in rodents that were exposed to cat odour; such as the PONGO used at sites throughout this project. Therefore, as feral cats are known predators of all of the mammals present in this study, it is reasonable to deduce that potential mammalian by-catch would actively avoid the PONGO laced traps.

Reptiles, on the other hand, are attracted to strong odours and pungent baits (Smith 2004). Smith (2004) conducted a study looking at ways to increase the capture rates of carrion-eating Varanid lizards. The baits used consisted of raw pork or chicken, fresh fish and rotting fish; a variety of meats with varying pungency. The effectiveness of the traps used was related to the pungency of the bait, with the strong smelling baits having the highest capture rate (Smith 2004). The rotting fish, arguably the strongest smelling bait, was the most attractive to the varanids (Smith 2004). The olfactory attractants used at Francois Peron National Park, with the exception of one set type that used rabbit, utilised PONGO made from either cat or dog urine and faeces; undoubtedly very pungent. Thus, armed with the knowledge that reptiles, particularly varanids, are attracted to pungent, rotting odours, it could be expected that they would respond positively to the PONGO baits and have an increased risk of capture compared to other taxa.

4.1.2. Injury

The severity of trap-related injuries was related to taxon, with birds being the mostly likely to be severely injured. This was due to the weights of individuals within each taxon; as weight decreased, the chances of being injured increased. A substantial risk to protected species (such as the woylie) within trap sites was also identified.

Obviously wildlife researchers do not set traps with the intention of inflicting pain, however sometimes this does occur (Proulx and Barrett 1989). In such cases, the question of why this happens must be addressed. Although this study did not identify any trends indicating that native species were more likely to be injured than non-native (as either target or by-catch), there was a significant relationship between the severity of injuries sustained and whether or not the individual was native. Both intermediate and severe injuries occurred far more often amongst the native fauna than the non-native. This could be due to the overall durability of the non-native species captured (cat, fox, goat, rabbit and sheep); attributed collectively to a quadrupedal gate, morphology, and general behavioural variations when compared with the native species captured. These species use all four limbs to move, thus when trapped still have three legs free to manoeuvre into a position that doesn't apply pressure to any wounds sustained and further injure the individual. They also have solid bone structures that would presumably be less likely to be impacted by a leg-hold trap. Further studies on the force required to fracture a bone of these species would need to be undertaken in order to quantify this inference. The goats and sheep that were trapped had the advantage of having a larger calculated mass (as per Figure 2) than the target species; goats average a weight between 15-79kg (Long 2003), so a trap set to the weight of a cat (1.1-5.8kg) (Long 2003) would not apply enough pressure to seriously injure the trapped individual. As a result of these findings, further analysis was conducted on the role that taxon (bird, mammal and reptile) and weight played in determining occurrence of injury amongst native species captured. Non-native by-catch was excluded from this analysis to ensure focus on specifically the native species.

4.1.2.1. Predictors of injury

One of the factors identified as a potential predictor of injury was the taxon of the individual captured. This was particularly notable in the birds, with severe injuries occurring far more frequently (76.4%) than expected.

Durham (1981) reported 173 birds of prey that had incurred trapping injuries from leg-hold traps that were intended for furbearers. Carnivorous birds are opportunistic scavengers that are attracted to carrion such as that used as bait in leg-hold traps (Durham 1981). This would increase the attractiveness of the trap to scavenging birds and subsequently the chances of their capture. It is also possible that the foraging behaviour of the individual bird species affects the rate of capture; species that forage on the ground are far more likely to be captured than those that forage above ground level (Peitz *et al.* 2001).

Once the bird is caught, the type and severity of injuries sustained can vary greatly from individuals in other taxa. This project identified just under one third of the birds captured sustained a category 4 injury, and less than 6% incurred any minor to intermediate injuries (category 1-3). By comparison, just over 12% of mammals (the target species taxon) received category 4 injuries and less than 11% received minor to intermediate injuries. Durham (1981) attributes this sort of discrepancy in injury to anatomical differences between birds and mammals.

Arguably the most apparent difference between the two taxa is that unlike mammals, the skeleton of birds is composed of lighter (by comparison to size), hollow bones (Dumont 2010). This allows birds the ability of flight without a massive metabolic cost (Dumont 2010), but also places them at risk of incurring serious injuries from leg-hold traps. A study by Dumont (2010) identified that even though birds on average had denser bones than those of similar sized mammals, they are often thin-walled and long. This would result in birds being unlikely to withstand the snapping pressure of a trap. The soft tissue present in bird and mammal limbs also differs, with birds having less muscle mass, and therefore cushioning to the bones, nerves and blood vessels; instead, they have long tendons (Durham 1981). Additionally, when compared to mammals, birds have a reduced vascular supply to their extremities; meaning that when an injury does occur, they have a decreased ability to heal or fight infection resulting in the likelihood of the limb seizing, regardless of visible injury (Durham 1981). This is important to note as the categorisation of injuries used in this project classed individual injuries across taxa as being of equal impact on the individual and did not account for differences in anatomy. Thus, on the occasion that a bird appeared to receive a minor injury or no injury at all, this could in fact be misrepresentative of the severity of trauma to the limb. It also did not take into account the necessity of certain limbs for each taxon. Predatory and perching birds rely heavily on the full use of both legs for grabbing and holding onto prey, and equal distribution of their weight so as not to deteriorate the epithelium of the footpad (Durham 1981). The wings must also be free of injury otherwise the individual will not only be vulnerable to predation, but also have a decreased predatory ability itself (Durham 1981). Thus, when an injury is visible, the full extent of the impact may not be immediately recognised and result in a delayed death of the individual; this was not investigated in this project as injury assessment was conducted immediately before release from the trap only. Consequently, the extent of injury and negative impact on the bird life captured throughout this study could be severely underestimated.

The mass of the individual was also investigated as both a potential source of variation in the occurrence and severity of trap-related injuries. There was a statistically significant relationship between the mass of the individual captured and the occurrence of injury. It was also identified that the severity of injury sustained was significantly related to the mass of the individual, with those that were lighter being more likely to sustain a category 4 injury than those that had a larger mass. This trend has been previously noted by Powell and Proulx (2003), who stated that by-catch, smaller than the target especially, can potentially suffer severe injuries. This greater risk of injury for smaller animals is also identified by Seddon *et al.* (1999 in Iossa *et al.* 2007). During their study, Short *et al.* (2002) were forced to modify their trapping techniques for cats when the much smaller burrowing bettong was present because of this very reason, in an effort to reduce the chance of "excessive injury" being sustained. This relationship is transparent when the mechanism of foot-hold traps is examined. Foot-hold traps consist of two jaws (in this instance they were padded) that clamp together to hold the animal's limb Powell and Proulx (2003). In order for the trap to clamp shut, the trigger must be tripped; this is only possible if the individual captured either equals or exceeds a particular weight, usually that of the target species Powell and Proulx (2003). In fact, Powell and Proulx (2003) claim that by correctly matching the size of the leg-hold trap to the target species and using the correct set, injury can be minimised and the rate of by-catch reduced, respectively. However, if the trigger plate of the trap has a light tripping force or a smaller-than-target-species individual applies excess weight to the trigger plate (i.e. by landing or falling), the jaws will clamp around the by-catch with enough force to restrain a larger, presumably more durable, individual. This can be seen in smaller bipedal animals such as macropods that use hopping as a form of locomotion, putting them at risk of landing on the trigger plate with exaggerated force and triggering a trap despite their size.

<u>4.1.2.2. Animal ethics implications</u>

Animal ethics is a multifaceted and particularly sensitive topic in wildlife management. Ethics is defined as "a system of moral principles, by which human actions and proposals may be judged good or bad, or right or wrong" (Macquarie University 1988). Ethics committees are tasked with identifying potential risks in research applications and deciding if the outcome (reward) is worth the potential effects to the animals involved. The *Australian Code for the Care and Use of Animals for Scientific Purposes* 8th edition (2013) provides an ethical framework and governing principles to assist the decision making process and outlines the responsibilities of all personnel involved, as well as the processes for accountability (National Health and Medical Research Council 2013). Underpinning the entire code is an obligation to respect animals and thus the responsibility to ensure that the care and use of animals is ethically acceptable (National Health and Medical Research Council 2013).

Caution is taken when the use of animals is required for a research project to be undertaken; but even more so when harm may be inflicted upon the animal (National Health and Medical Research Council 2013). It is stated that "steps must be taken at all times to safeguard the wellbeing of animals" with the safety of animals being held as a higher priority than the completion of research; going as far as to state that if any unanticipated harm comes to an animal, the project must not be continued until action has been taken to alleviate pain and distress to the animal (National Health and Medical Research Council 2013). Thus, in situations where injury to an animal has not only been identified as a potential risk, but actually proven to occur (such as the use of soft-catch leg-hold trapping throughout this project) it would be reasonable for an Ethics Committee to be hesitant in approving the research request; potentially resulting in the overall rejection of the project.

<u>4.1.2.3. Conservation implications</u>

Aside from the animal ethics implications, by-catch during trapping exercises becomes a serious problem when individuals of conservation concern are involved (Iossa *et al.* 2007). During this study, 31 IUCN and DPaW conservation listed individuals were captured, with 21 sustaining injuries. The woylie, a critically endangered species, was captured on numerous occasions (Table A1b) with 70% of those captures resulting in some form of injury. This is a concern because this species is now naturally occurring in just three locations (Upper Warren region, Dryandra woodland and Tutanning nature reserve) in Western Australia, and provides significant environmental services (Pacioni *et al.* 2011; de Tores and Start 2008). These include the dispersal of fungal spores and seeds as well as increasing water filtration in soils through their diggings; additionally, burrowing traps seeds and organic matter in the soil thus increasing chances of seed survival (Garkaklis *et al.* 2004; de Tores and Start 2008). When captured in wire cages, woylies become agitated and can be physically injured, undergo capture myopathy (acute degeneration of muscle tissue) or eject pouch young. Females have been known to abandon their young by either throwing the pouch young when threatened, or leaving “young at foot” at the nest until it is deemed safe to return (de Tores and Start 2008). These behaviours can also be expected for leg-hold trapping, due to stress being the major driving factor for the individual’s actions. Therefore, it would be reasonable to assume that if the woylies trapped as by-catch in this study had been monitored, at least some of the individuals may have developed capture myopathy. This can cause major issues for newly established/ reintroduced populations as they are far less tolerant to this increase in mortality; potentially setting back reintroduction programs by years. However, not all individuals that were captured in this study had severe injuries, with only half receiving a category 4 injury and just under one third receiving no injury (Table A1b). Alternatively, feral cat predation has been found to be a contributing factor to the decrease in this species’ range across the country (de Tores and Start 2008). Thus, successful translocation of the species relies on the exclusion of the introduced predators, such as foxes and cats (de Tores and Start 2008). In order to both remove the introduced predator and simultaneously not threaten the newly established population, trapping should, wherever possible, precede the reintroduction of individuals. Some risk remains, though, if predators are able to re-enter the area later and the need for further management arises.

4.2. Recommendations

Oversight of future trapping practices should focus not only on the target species but also the potential by-catch in the study site in regard to morphology, behaviour and conservation status. When trapping for feral cats, caution should be taken if species with weaker bone structures (such as birds) and similar mass (or ability to apply the same pressure to the trigger plate) are present so as to ensure that the traps aren’t set in a manner that puts these non-target individuals at risk. Attention should also be placed on the behaviours of potential by-catch species. For example, raised sets (traps placed on a platform above ground level) can be used to reduce the occurrence of trapping ground dwelling by-catch; varanids are attracted to strong odours, thus when varanids are present, alternative baits should be considered; carnivorous birds scavenge the carrion commonly used in traps, thus a structure such as a bower (a shelter made of surrounding vegetation to create a shady recess) should be used to shield the bait from overflying birds. Most of all, trapping practices should proceed with caution when species of conservation concern are present. If exclusion of these species as by-catch cannot be achieved and the end result of the project does not justify the risk, cessation of the project should be strongly considered until such aims can be met, and the project has approval from appropriate Animal Ethics Committee/s.

Trappers should be fully trained in the correct use and placement of the traps, as well as the correct handling and injury assessment of both the target and potential by-catch species. Training sessions before field work commences should be undertaken to ensure that all participants are well aware of what is required and expected during the trapping exercise. This will hopefully reduce the occurrence of by-catch and severity of injury to those individuals that are trapped, as well as ensuring the correct procedure if a non-target animal is injured.

4.2.1. Precautionary Principle

As with many projects, there are weaknesses in the data used in this project, such as over 80% of the by-catch data being recorded at the one site (Francois Peron National Park) (Table A1c), and inconsistencies in its recording. In this situation, it is recommended that the precautionary principle be applied. The precautionary principle "requires that we take action to protect the environment in advance of conclusive scientific evidence that harm will occur from some new or continuing human activity" (Deville and Harding 1997). This then raises the question of how cautious we need to be; a question answered by Figure 7.

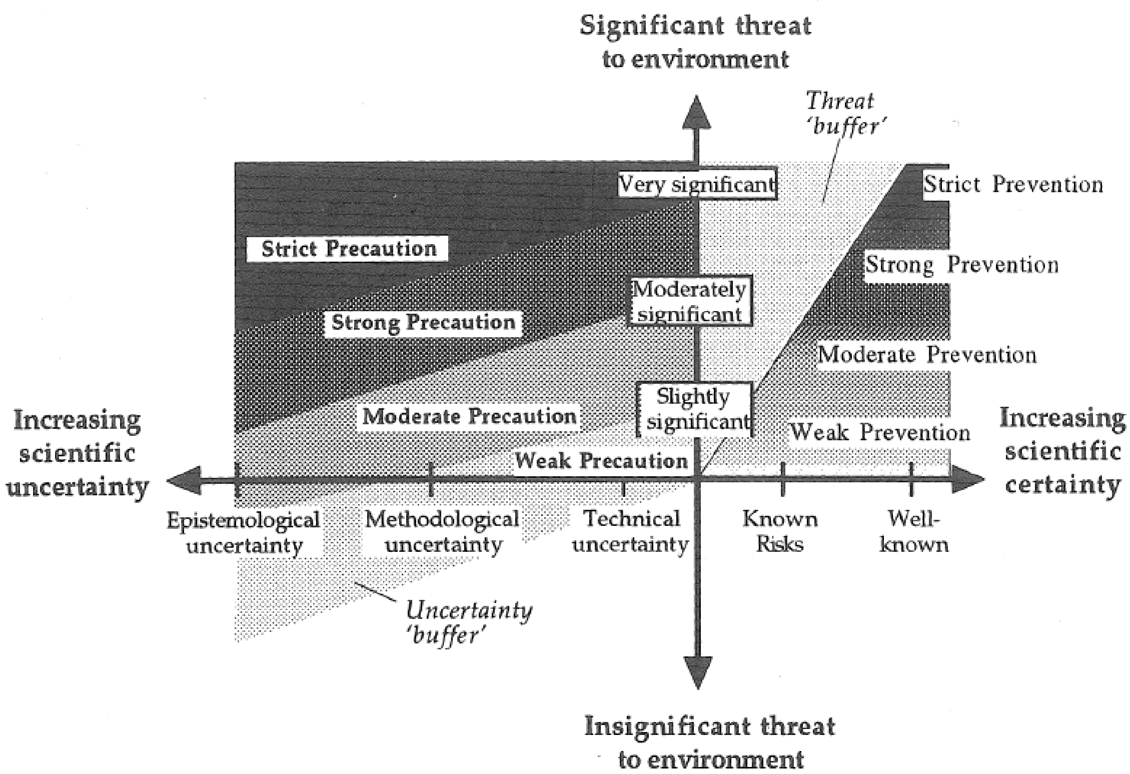

Figure 7. Determining Degrees of Precaution (Deville and Harding 1997).

Figure 7 illustrates the balance between the significance of the threat and the level of scientific certainty (evidence). The scale ranges in intensity of precaution; when scientific certainty is low (inconclusive evidence), and prevention; when the certainty is high (conclusive evidence), depending on the perceived threat (Figure 7). When applying the principle to this project, attention must be placed on the data used and the fact that it is, to a degree, flawed and thus the scientific certainty can at best be described as "known risks". However, given the threat that a negative outcome is catastrophic, this places the project firmly in the 'threat' buffer. The ‘threat’ buffer accounts for the dangers associated with errors in judgement when the threat is significant (Deville and Harding 1997). This buffer is useful to encourage decisions on reducing by-catch to be addressed with caution (Deville and Harding 1997). Thus, adapting the principle to this project would see soft-catch leg-hold traps being used to remove cats but also ensuring, to the best of the trappers’ ability, that they adhere to all recommendations provided aimed at reducing by-catch rate and injury occurrence/ severity previously stated.

Given that science is constantly advancing and developing new and improved methods for many practices, an Environmental Management System (EMS) should be in place as part of organisational management. An EMS is an effective way of integrating a precautionary approach into the management of activities that may affect the environment by assessing the effectiveness of the system as a whole (Deville and Harding 1997) (Figure 8).

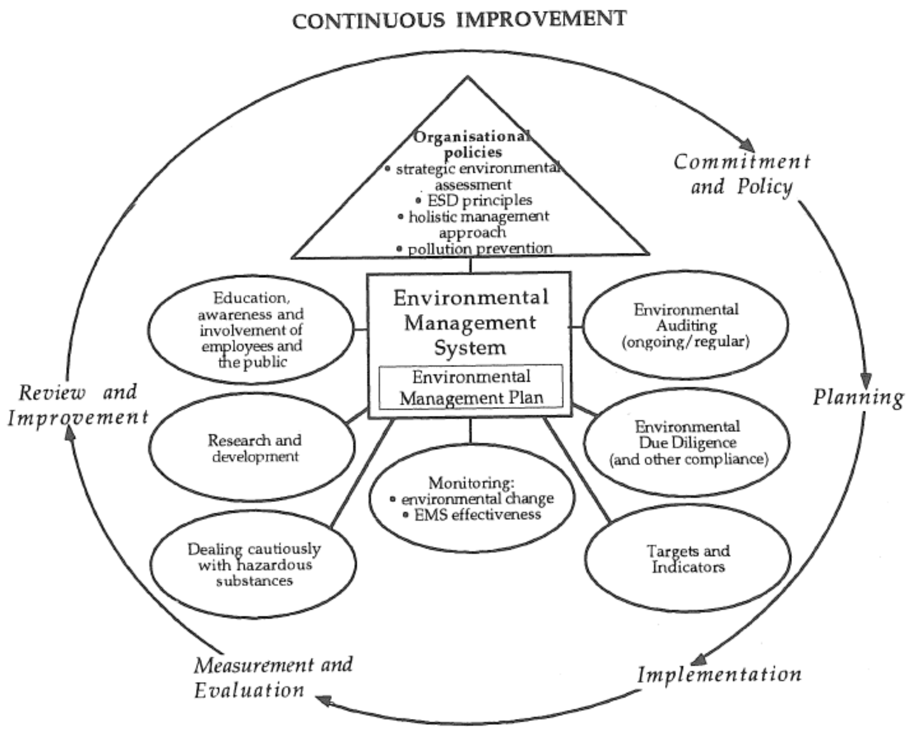

Figure 8. Facilitating the Precautionary Principle: Integrating an EMS with organisational policy and management strategies for continuous environmental performance improvement (Deville and Harding 1997).

Figure 8 illustrates a system in which practices are being constantly monitored in a feedback-response system by which problems can be addressed early. Again, adapting the feedback-response system to this project would involve the recording of by-catch rate when soft-catch leg-hold traps are in use and recording the injuries, in detail, sustained by any of the by-catch. This would allow constant feedback of information and thus any faults or weaknesses in current procedures could be addressed before the issues increase in severity. This system is described by Deville and Harding (1997) to allow "continuous improvement". This can only be accomplished if the correct data are collected in the field; hence I propose a Standard Operating Procedure (SOP) for the collection of data regarding by-catch rate and injuries.

Chapter 5

5.1. Standard Operating Procedure

A Standard Operating Procedure (SOP) is included in this chapter. It has been prepared as an independent document and as such includes corresponding references and appendix.

2017

Standard Operating Procedure

Data collection during feral cat soft-catch leg-hold trapping

By-catch Ethics

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Acknowledgements:

Several documents were utilised while compiling this SOP. The main structure, formatting and standard content reflect that of the Department of Parks and Wildlife's Standard Operating Procedure: Cage traps for live capture of terrestrial vertebrates (SOP No: 9.2) (2013). I would like to acknowledge the contributions of the Perth Zoo Veterinary Department for providing the images used throughout this document. I would also like to thank Dr Peter Mawson (Director of Animal Health and Research at Perth Zoo) and Assoc. Prof. Mike Calver (Associate Dean of Learning and Teaching at Murdoch University) for their contributions to improving this document.

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1. Purpose

Trapping can be a successful method for removing feral cats from native bushland. One of the most commonly used trap types is the Victor® 1.5 soft-catch leg-hold trap. The trap consists of two padded jaws and a treadle; when an animal applies enough weight to the treadle (set to the weight of the target species) the jaws will clamp shut to restrain the animal. Baits and lures can be used in conjunction with the traps as attractants in an attempt to increase capture rates. Examples include fish, rabbit *Oryctolagus cuniculus* and a mixture of cat urine and faeces known as PONGO®.

Unfortunately, given the nature of the traps, by-catch is likely. Non-target animals of equal or lower weight than the target species are most susceptible. Species that are much smaller or more fragile than the target are more susceptible, because the jaws close with a force intended for a much more resilient species. This can result in injuries that range from a simple bruise or cut to severe mutilation or death. The occurrence of injuries is unfortunate for any species, but is particularly problematic for species of conservation concern. These are often species with already dwindling population numbers that can't afford the added impact on their population numbers.

Welfare assessments of the non-target species captured during leg-hold trapping exercises have been previously studied. However, incomplete and inconsistent data have constrained the reliability of results (Iossa *et al.* 2007). This is a direct result of there being no requirement for trappers to record the welfare of non-target species captured during trapping exercises; currently only the number and species captured are required for most Ethics Committees. This makes assessments of trap safety particularly difficult and can impede advancement in feral cat soft-catch leg-hold trapping.

This Standard Operating Procedure (SOP) provides guidelines for the type of information to be recorded as well as the detail required. Sample field data sheets are provided.

2. Scope

This SOP has application to all personnel and volunteers involved in the checking of Victor® 1.5 soft-catch leg-hold traps during feral cat trapping exercises. It may also be used as a guide for any consultants, researchers or other individuals trapping feral cats with soft-jaw traps to report by-catch welfare outcomes as part of their studies and animal ethics reporting obligations. All personnel and volunteers involved in soft-catch leg-hold trapping projects that pose a risk to non-target species are required to be familiar with the content of this document.

3. Definitions

Animal Handler/ Handler: A person listed on an application that will be responsible for handling animals during the project.

Data Recorder: A person required to record data during the trapping exercise.

Injury: Restricted to only physical damage inflicted upon the body of an individual animal.

Trap: specifically Victor® 1.5 soft-catch leg-hold traps only.

4. Procedure Outline

4.1. Information

Table 3 may be printed (or another document similar may be used, ensuring the same information is recorded) and must be filled out for each individual animal captured.

4.2. Technique

All animals mentioned below must be dealt with in accordance with the following SOPs.

- Trapped animals must be handled in accordance with Department of Parks and Wildlife (DPaW) SOP 10.2: *Hand Restraint of Wildlife*.
- If any first aid is to be administered to a captured animal, it is to be done so as outline in DPaW SOP 14.2: *First Aid for Animals*.
- Should assessment of injury necessitate euthanasia, it is to be performed by approved personnel and in accordance with DPaW SOP 15.1: *Humane Killing of Animals under Field Conditions in Wildlife Management*.
- All evicted pouch young are to be cared for as described in DPaW SOP 14.1: *Care of Evicted Pouch Young*.

The following steps are to be followed during the checking of previously set traps.

1. Each by-catch animal is to be identified and all requirements outlined in Table 3 are to be recorded. If the individual has pouch young or young-at-foot the welfare of the young must also be assessed, provided doing so does not contradict the objectives of DPaW SOP 14.1. In this situation, Table 4 (or the equivalent) must be completed. Pouch young can be located as per Figure 1.

Figure 1. Marsupial pouch young (Perth Zoo, n.d).

2. If injuries have occurred, they are to be assessed and classified in accordance with the following criteria.

Table 9: Modification of the injury classification table used by Meek et al. (1995); originally based on a system developed by (Van Ballenberghe 1984).[10]

Category	Injury Description
Category 1	Slight foot/leg oedema (swelling), no lacerations or broken bones.
Category 2	Moderate oedema, *compressed muscle*, lacerations less than 2.5cm long, no broken bones and joints.
Category 3	Lacerations at least 2.5cm long, *abrasions*, visible tissue damage, no tendon damage, one metacarpal or phalanx bone broken.
Category 4	combinations of deep, wide lacerations, severed tendons, broken metacarpals, broken radius or ulna bones, *broken ankle or leg* and joint dislocations, *death or requiring euthanasia*

While there are several different injuries that may be encountered, there are some common wounds that can occur; lacerations (Figures 2 and 3), tissue damage (often seen as an oedema) (Figure 4), and broken bones (obvious if it is an open fracture, but if the fracture is closed it can be mistaken for tissue damage if only an oedema is visible) (Figures 5, 6 and 7). Examples of these common injuries can be observed across the mammals, reptiles and birds:

[10] Modifications are featured in *italics*.

1. Laceration

Figure 2. Woylie *Bettongia penicillata* hind leg laceration (Perth Zoo, n.d).

Figure 3. Reptile leg laceration (Perth Zoo, n.d).

2. Tissue Damage (oedema)

Figure 4. Canid joint oedema (Perth Zoo, n.d).

3. Broken Bone

Figure 5. Bird left leg closed fracture. Note that the bone has not pierced the skin and so externally appears to be only an oedema (Perth Zoo, n.d)

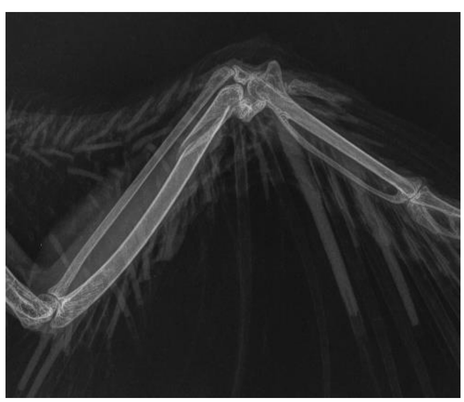

Figure 6. Bird left wing closed fracture. Again, the fracture would only present as swelling externally (Perth Zoo, n.d).

Figure 7. Bird wing open fracture. Note in this case the bone has broken the skin and the fracture is fully visible (Perth Zoo, n.d).

3. The outcome of the individual is to be determined:

- Release with no medical intervention.
- Administer first aid in accordance with DPaW SOP 14.2, and release.
- Euthanize individual as per DPaW SOP 15.1.
- Other (must be specified in Table 3).

5. Level of Impact

5.1. Animal Welfare

The potential animal welfare impacts of soft-catch leg-hold trapping are similar to those described in DPaW SOP No 9.2 for cage traps. These include:

- capture myopathy (particularly in macropods)
- trap-related injury
- hypothermia
- hyperthermia
- dehydration
- starvation
- predation
- stress
- self-mutilation

5.2. Individual Welfare

Potential animal welfare impacts to the individual being examined include:

- stress
- hypothermia (particularly pouch young being examined out of the pouch.)
- hyperthermia (reptiles in particular are at risk of overheating from being confined in warm hands whilst examination is in progress.)
- parental abandonment (fleeing of the parent if the young are trapped)
- excessive pain (handling of an injury can increase the pain experienced.)

6. Ethical Considerations

To reduce the level of impact that trapping and handling have on the welfare of captured individuals, several ethical considerations can be made when performing soft-catch leg-hold trapping in areas where by-catch is likely.

6.1. Trap Placement

Trap placement can have major implications on both the likelihood of by-catch and the subsequent welfare of by-catch. Traps should be placed in areas that are not known to be rich in by-catch (if possible) and are not exposed to the elements (sunlight, heat/ cold, rain/ water). If conditions are variable, such as shade movement throughout the day or water levels rising with high tide, considerations must be made in order to ensure protection of the captured individual until it is removed. Traps must also not be placed in areas that leave the captured individual open to predation; open areas making the trapped individual completely visible to potential predators, or setting the trap near an ants' nest/ high ant activity. Traps must also not be placed at entrances to hollows, burrows, dens, or any other obvious nest site as these may house by-catch species. It is recommended that traps not be placed in areas that will make retrieval of the captured individual difficult (e.g. large logs or slippery surfaces).

6.2. Trap Setting

The treadle on the traps must be set for the specific weight of the target species and, if padded, the rubber padding must be properly maintained and applied to the jaws. There must be no sticks or roughage that may get caught in the trap when it is sprung to ensure a clean closure of the jaws.

6.3. Weather

Trapping should be avoided during extreme weather conditions (very hot or cold, heavy rain and/or strong winds). This can be achieved by planning ahead and ensuring monitoring of both long-range and daily weather forecasts. If sudden weather changes occur, effort should be made to remove (or unset) all live traps until conditions are favourable again for trapping. This will ensure that animals are not exposed to harsh conditions whilst restrained in a trap and that set trap can be checked and cleared in a timely manner.

6.4. Breeding Season

Wherever possible, traps are not to be set during known breeding seasons of the likely by-catch species. This will reduce the chances of a lactating mother being separated from dependant young and the likelihood of injury or separation of dependant young. If breeding seasons cannot be avoided (dramatic differences across likely present species resulting in combined year-round breeding or species present that breed throughout the year) then care in trap placement should be the priority.

6.5. Handling Time

Handling time must be kept to an absolute minimum to reduce stress to the animal and the likelihood of additional injury to the animal (struggling or thrashing). The animal must only be handled long enough to identify all the features listed in Table 3. Captured individuals must be released within 24hours of capture to ensure that normal activity is not disrupted. If nocturnal species are captured and need to be held for a short period, they must be kept in suitable housing until dusk, at which point they are to be released near the capture site.

6.6. Pouch Young and Dependant Young

Many species of macropod will eject pouch young if trapped or handled. If this occurs, steps outlined in DPaW SOP 14.1 *Care of evicted pouch young* must be followed. Additionally, Table 4 must be completed to assess the impact that trapping has had on the ejected pouch young. If a captured animal has 'young at foot', the wellbeing of the offspring must also be assessed **only if doing so does not cause additional stress or harm to the individual**. Again, Table 4 must be completed.

6.7. Capture Myopathy

Capture or exertional myopathy is characterised by the acute degeneration of muscle tissue of an individual post-capture and restraint (Studdert *et al.* 2012). It is most commonly seen in species of birds and mammals (Nocturnal Wildlife Research Pty Ltd. 2008). Initial symptoms of an individual with capture myopathy include a drooping head and neck, laboured breathing, tremors, lethargy and lack of coordination or paralysis. If an animal is suspected to be suffering from capture myopathy, a record must be made when completing Table 3.

7. Competencies and Approvals

All personnel participating in soft-catch leg-hold trapping where the potential for by-catch is likely must satisfy the minimum competency requirements outlined in Table 2. This ensures that all personnel are adequately trained and have the necessary knowledge to minimise any potential impacts that the trapping may have on the welfare of by-catch species.

Note: Table 2 outlines the <u>minimum</u> requirements for basic soft-catch leg-hold trapping. More complex studies may require higher levels of competency and as such, competency requirements should be modified to suit the project being undertaken.

Table 10: Competency requirements for animal handlers assessing by-catch injury and welfare, based on that outlined by DPaW (2013).[11]

Competency Category	Competency Requirement	Competency Assessment
Wildlife licenses	License to take fauna for scientific purposes (Reg 17) OR License to take fauna for educational or public purposes	Provide SF licence number Provide TF licence number
Formal Qualifications and certificates	Tafe qualifications in fauna management and handling OR CALM Mammal Conservation Course (1992-1995) OR CALM/DEC/DPaW Fauna Management Course (1997-) OR *Bachelor Degree in Science/ Conservation Biology/ Biology*	Provide course year, TAFE facility Provide course year Provide course year *Provide course year of completion*
General skills and experience	Relevant knowledge *of likely by-catch* species' biology and ecology	Personnel should be able to correctly identify the likely *by-catch* species to be captured in cage traps for the site/s being studied. This knowledge may be gained through sufficient field experience and/or consultation of field guides and other literature. Estimated total time in field:

[11] Modifications and additions are featured in *italics*.

		Minimum 1 year involved in similar projects.
Fauna survey and capture skills/experience	Experience in setting and use of *soft-catch leg-hold traps* AND	Personnel should be confident identifying the best locations to set traps and how to set traps so that the mechanism works and animal welfare is considered at all times. This knowledge may be gained through sufficient field experience and/or consultation of literature. Estimated total time in field: Minimum 1 year involved in similar projects.
	Experience in safely removing by-catch from traps *AND*	*Personnel should be trained in the safe removal of fauna from traps. This knowledge may only be gained from relevant training and experience.* *Estimated total time in field: Minimum 1 year involved in similar projects.*
	Training and experience in trap hygiene and disease *risk management for zoonotic diseases.*	Personnel should be familiar with hygiene procedures. This knowledge may be gained through sufficient field experience and/or consultation of literature. Estimated total field time: Minimum 1 year involved in similar projects.
Animal handling and processing skills/experience	Experience in handling terrestrial mammal fauna AND	Personnel should be confident handling and restraining the range of *mammalian by-catch* species

		likely to be captured. This knowledge may be gained through sufficient field experience and/or consultation of literature. Estimated total time in field: Minimum 1 year involved in similar projects.
	Experience in handling terrestrial herpetofauna *AND*	Personnel should be confident handling and restraining the range of *by-catch* species likely to be captured. This knowledge may be gained through sufficient field experience and/or consultation of literature. Estimated total time in field: Minimum 1 year involved in similar projects.
	Experience in handling avian species *AND*	*Personnel should be confident handling and restraining the range of avian by-catch species likely to be captured. This knowledge may be gained through sufficient field experience and/or consultation of literature.* *Estimated total time in field: Minimum 1 year involved in similar projects.*
	Experience in wound assessment *AND*	*Personnel should be able to confidently identify common wounds likely to be inflicted upon by-catch. This knowledge may be gained through sufficient field*

		experience and/or consultation of literature. *Estimated total time in field: Minimum 1 year involved in similar projects.*
	Relevant skills in fauna first aid	*Personnel should be able to adequately apply first aid to injured animals if necessary. This knowledge maybe gained through*

8. Occupational Health and Safety

8.1. Animal-inflicted injuries

Handling of wildlife, especially individuals already agitated from being restrained in a leg-hold trap, is dangerous and can result in injuries to personnel. All injuries sustained should be treated as soon as possible to prevent infection or worsening condition. If injuries are severe, medical attention should be sought. Any injuries should be reported via the appropriate Occupational Health and Safety (OHS) reporting system.

8.2. Trap-related injuries

Soft-catch leg-hold traps can be dangerous if handled incorrectly; applying pressure to the treadle of an open trap, not setting it fully before releasing the jaws, etc. All traps should be handled by qualified personnel to avoid injury. However, if injury does occur, then as with animal-inflicted injuries, the wound should be appropriately treated and if severe medical attention sought. In the instance of injury, the appropriate OHS forms must be completed.

8.3. Zoonosis

Wildlife can carry a variety of diseases, some of which are transferrable to humans. Protocol on minimising the risk of zoonosis is contained in DPaW SOP16.2: *Managing disease risk in wildlife management*.

8.4. Allergies

If personnel have any allergies to the wildlife materials; hair, feathers, urine, faeces, etc., correct Personal Protective Equipment (PPE) such as gloves and long sleeves to protect skin exposure must be used. Personnel with **severe** allergies should not participate in the activities outline in this SOP.

9. Further Reading

The following DPaW Standard Operating Procedures have been mentioned throughout this document as required reading in order to participate in activities outlines in this SOP. Additional SOPs are also suggested;

SOP 10.2 Hand restraint of wildlife

SOP 11.1 Transport and temporary holding of wildlife

SOP 14.1 Care of evicted pouch young

SOP 14.2 First aid for animals

SOP 15.1 Humane killing of animals under field conditions in wildlife management

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11. Appendix

Table 3: By-catch welfare assessment table. A new row is to be completed for each individual captured.

#	Species	Age (A/SubA/J)*	Sex (M/F)	Weight (kg)	Pouch Young (Y**/N)	Lactating (Y**/N)	Young at foot (Y**/N)	Injury Category (1-4)	Injury Description	Outcome (R, FA, E)***

***A= Adult, SubA= Sub Adult, J= Juvenile. **Table 4 must be completed. ***R= released, FA= first aid administered, E= euthanasia.**

Table 4: By-catch young welfare assessment table. A new row is to be completed for each individual captured.

#	Species	Injury (Y/N)	Injury Description

Chapter 6

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6.2. Appendix

Table A1a. Species of conservation concern (currently listed as either critically endangered, priority 4 or vulnerable as per IUCN and DPaW classification) captured at each of the six sites. Also noted for each individual was the taxa they belong to, their weight, and the severity of injury sustained (Table 7). Again, category 0 represents individuals with no injuries.

Location	Species	Taxa	Weight (kg)	Category (0-4)
Francois Peron	Bilby	Mammal	0.6	4
Francois Peron	Bilby	Mammal	0.8	4
Francois Peron	Bilby	Mammal	0.8	4
Francois Peron	Bilby	Mammal	1.05	0
Francois Peron	Bilby	Mammal	1.05	2
Francois Peron	Bilby	Mammal	1.05	2
Francois Peron	Bilby	Mammal	1.1	2
Francois Peron	Bilby	Mammal	1.29	4
Francois Peron	Bilby	Mammal	1.375	3
Francois Peron	Bilby	Mammal	1.75	0
Francois Peron	Bilby	Mammal	1.85	4
Francois Peron	Bilby	Mammal	2.5	4
Boyicup	Chuditch	Mammal	0.92	0
Francois Peron	Mala	Mammal	0.65	4
Francois Peron	Malleefowl	Bird	1.65	0
Francois Peron	Malleefowl	Bird	1.65	0
Francois Peron	Malleefowl	Bird	1.65	0
Francois Peron	Malleefowl	Bird	1.65	1
Balban	Tammar	Mammal	6	0
Balban	Tammar	Mammal	6	0
Boyicup	Tammar	Mammal	6	4
Francois Peron	Woylie	Mammal	0.76	4
Francois Peron	Woylie	Mammal	1.05	4
Francois Peron	Woylie	Mammal	1.2	4
Francois Peron	Woylie	Mammal	1.24	0
Francois Peron	Woylie	Mammal	1.24	0
Francois Peron	Woylie	Mammal	1.24	1
Francois Peron	Woylie	Mammal	1.24	3
Boyicup	Woylie	Mammal	1.24	4
Francois Peron	Woylie	Mammal	1.3	4
Francois Peron	Woylie	Mammal	1.7	0

Table A1b. The number of woylies captured that sustained each of the 5 injury categories (Table 7). Again, category 0 represents individuals with no injuries.

Category (0-4)	Number of Woylies
Category 0	3
Category 1	1
Category 2	0
Category 3	1
Category 4	5

Table A1c. Species captured at each of the six sites. The number of individuals from each species is displayed under their respective sites, with a grand total of individuals from each species shown in the far right column, and a grand total of species at each site shown in the bottom row.

Species/ Sites	Balban	Boyicup	Francois Peron	Mornington Sanctuary	Mt Gibson	Perup	Grand Total
Australian Raven						1	1
Babbler			1				1
Bilby			12				12
Bird			1				1
Blue Tongue Goanna			1				1
Bobtail			1				1
Brown falcon					2		2
Brushtail Possum		3				7	10
Chuditch		1					1
Corvid					6		6
Crested Bellbird			2				2
Crow			17				17
Dingo				7			7
Eagle			1				1
Echidna	1		7		10		18
Emu			12				12
Euro			72				72
Fox	4	4					8
Goanna			28		6		34
Goat			15				15
Goshawk			1				1
Grey Shrike-Thrush			1				1
Hopping Mouse			1				1
Little eagle					1		1
Lizard			2				2
Mala			1				1

Malleefowl			4				4
Possum	3						3
Rabbit			158		17		175
Sheep		1					1
Shingle Backed Skink			4				4
Tammar	2	1					3
Tawny Frogmouth			1				1
Thick Billed Grass Wren			1				1
Woylie		1	9				10
Grand Total	**10**	**11**	**353**	**7**	**42**	**8**	**431**