Possum (Trichosurus vulpecula) responses and preferences to novel objects in their environment

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By
Tim D. Sjoberg

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Abstract of a thesis submitted in partial fulfilment of the requirements for the Degree of Master of Science.

Possum (*Trichosurus vulpecula*) responses and preferences to novel objects in their environment

by

Tim D. Sjoberg

The Australian brushtail possum (*Trichosurus vulpecula* Kerr 1792) is a major conservation and agricultural pest in New Zealand, and is currently a focus of much research to improve control efficacy. Traps and toxins stored within bait stations are used to control possums in ground-based operations, yet few studies have investigated the influence of trap componentry and design on possum behavioural responses towards them.

This thesis describes pen and field research examining possum preferences in five main areas of research which include: testing possum attractiveness towards different colours, control device entrance geometry preferences, trap size entrance openings preferences, trap material attractiveness and trap orientation preferences. This information will be used to assist in designing and developing new, re-setting, permanent-set kill traps for the sustained control of possums in native forests or farmlands currently being developed at Lincoln University.

Captive possum preferences were recorded within laboratory pens via four-way cafeteria tests and analysed using multinomial log-linear models and Akaike Information Criterion. Black was the preferred colour (followed by Blue, Yellow and White) by both possum genders and weight classes (i.e. <2.5 kg). Possums expressed a preference for the more 'open' Square trap geometry shape (followed by the shapes Key, Diamond and Triangle), although this may be confounded with size. Possums chose the largest trap entrance size (120 mm diameter) over the smaller sized entranceways (100, 80 & 70 mm respectively). The test subjects expressed no preference towards the trialled materials (Wood, Plastic, Corflute & Metal), however, possums interacted with novel devices with the orientation "Timms" (i.e. straight front entrance) at significantly higher levels than any other design (“Warrior” i.e. angled front, “Henry”; i.e. vertical up entrance and “box”; i.e vertical down entrance).

The captive possum trials did succeed in quantifying possum preferences towards novel device designs, however, the field trials did not provide sufficient interactions to be included in the preference experiments, but did allow non-target (rodent and weka) bait take from novel possum control devices to be examined and discussed.

In conclusion, improving ground based possum control devices relies on increasing possum encounters and subsequent interactions with control devices. This research identified that black devices, with open, easily assessable entranceways and claw holds for front limb grip, could increase possum/device interactions over control devices currently being employed for possum control.

Keywords: Brushtail possum, traps, possum preferences, novel device designs.

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Chapter 1

General Introduction

The purpose of section one of this literature review is to first highlight the problems that brushtail possums pose to New Zealand's native species and economy, which organisations control possums and which techniques are currently being used for possum control in New Zealand, ending with recent possum trap development.

The second part of this chapter (section two) aims to understand the biology of the possum, and how each external component of a possum kill trap could be made more attractive or appealing to increase interaction rates, thereby increasing the efficiency of traps.

1.1 The possum problem in New Zealand

In New Zealand, predation and competition from introduced mammals has contributed to one of the highest extinction rates of native species in the world (Dowding & Murphy, 2001; Wilson, 2004; Wright, 2011). These invasive mammals are costly to New Zealand's economy and environment, threaten the survival of native species and spread disease (King, 1990), and have the potential to place native forest ecosystems under risk of total collapse (Wright, 2011). Ground-based control devices that animal pests find novel, investigate and subsequently interact with could increase harvest rates, effectively reducing pest populations at higher rates than conventional tools.

The Australian brushtail possum (*Trichosurus vulpecula* Kerr 1792) is one such introduced pest. Liberated throughout New Zealand from 1837 to 1922 by Acclimatisation Societies and other individuals in order to establish a national fur trade (King, 1990), it was estimated that by 1990 possums occupied over 91% of the country, and little evidence suggests that this has changed in the last two decades (Clout & Ericksen, 2000). Possums are now estimated to cost New Zealand over $110 million annually in damage to crops, forest ecosystem degradation and possum control operations (Animal Health Board, 2011). The possum is also considered by many as the most significant factor in the historic decline of native flora and fauna (Dowding & Murphy, 2001; Wright, 2011). It is also the only animal currently within New Zealand's border that has the potential to economically cripple New Zealand's export in beef, deer and dairy products due to its role as the main wildlife vector of Bovine tuberculosis (Tb) (Caley, Coleman & Hickling, 2001; Norton, Corner & Morris, 2005).

Initial evidence of possums impacting on economic crops, forestry plantations or horticultural planting was noted early in the 19th century (Kirk, 1920). Possum selectively browse preferred plant species, defoliating and causing plant mortality within New Zealand's forest ecosystems. High possum densities within localised areas have been documented changing the plant structural community, shifting whole forests vegetation composition, by significantly reducing specific plants until only unpalatable plant species remain (Bellingham *et* al., 1999). It is now widely known that possums also directly predate and consume bird's eggs, chicks and adult birds (Brown, Innes & Shorten, 1993; Brown, Moller & Innes, 1996), and have also been recorded eating endangered land snails and other native invertebrates (Walker, 2003).

The brushtail possum is a cat-sized, nocturnal marsupial native to Australia and Tasmania (Clout & Ericksen, 2000). This herbivorous, arboreal import has experienced an 'ecological release' from its previous natural controls, allowing the it to reach significantly greater population densities than in its native home ranges (Cowan, 1990). Although home range sizes and population density comparisons exist between Australia and New Zealand (Table 1.1) it is difficult to accurately compare due to the differences in habitat types. However, the much lower densities and smaller home range sizes within Australia are generally attributed to the combined effects of the presence of large land-based predators (e.g. dingos, *Canis familiaris*), flighted predatory owls (*Ninox strenua*), the higher presence of native parasites and diseases (Viggers & Spratt, 1995), the lower nutrient content of the vegetation and foliage, and the increased browsing competition from other folivorous marsupials (Dungan *et* al, 2002).

Table 1.1 Possum home range comparisons between different vegetation types within their native Australia and introduced New Zealand (information retrieved from Montague, 2000)

		Home Range Area	*(ha)*	
	Vegetation Type	***Male***	***Female***	***Reference***
Australia	Open eucalyptus woodland	5	1.1	Dunnet 1964
	Open eucalyptus forest	3.7	1.7	Winter 1976
New Zealand	Pasture/scrub/willow	29.9	31	Brockie *et* al. 1995
	Podocarp-mixed broadleaf forest	24.6	18.3	Green 1984, Green & Coleman 1986

Although possums have been intensively managed by the way of toxic control since the mid 1950's, they are still a major concern to New Zealand conservation and primary industries (Norton, Corner & Morris, 2005). Recent advances in vertebrate pest control are allowing wildlife and Tb vector managers to achieve rapid high 'knockdown' of pest numbers after control treatments (Warburton & Thomson, 2002); however, removing the last few individuals is now becoming the focus of investigation and research (Paul Livingstone, personal communication, AHB 2011).

The cumulative ecological and environmental cost possums produce are currently immeasurable. Widespread control of possums sees thousands of tonnes of toxic baits being applied to our ecosystems annually, a practice which has continued now for over half a century to maintain some of New Zealand's conservation estates. Although the safety and risks associated with poison usage are relatively well understood, new ground-based control devices that encompass possum behavioural preferences are needed to increase the interaction and therefore capture rates of device, while also monitoring populations at low numbers and reducing non-target by-catch. Recent research estimates that traps can be highly inefficient at capturing possums. For example, Ball *et* al. (2005) found that there is only a 5% chance of probability in successfully capturing a possum using a leg-hold trap over one night of trapping, while Brown & Warburton (2012) found that the probability of a possum interacting with a blazed leg-hold trap varied between 66% and 22% at two different locations over one night. In both of these studies many possums trap encounters did not result in capture, and the later research by Brown & Warburton (2012) showed that in order to increase the interaction rates, control devices must be novel and provide the animal with enough confidence so that an interaction occurred. The concept of a possum 'walking by' (i.e. passing within close range but not interacting with a device) was initially suggested by Stephen Ball *et* al. (2005), when he found that there was only a five percent chance of catching a possum with a leg-hold trap, even when the trap was set at the centre of a possums home range. This research concluded that a possum 'walk by' past control devices is a common event and that the actual possum capture probability is low in magnitude and small in spatial scale.

1.2 Aims and objectives

Given that ground based control clearly has room for improvement, this study aims to practically assess the components of a possum kill trap design with the objective of developing a novel design that not only increases possum encounter rates, but installs higher confidence to interact with the control device. This will be done by researching possum preferences for colour, geometry, size, trap material and trap position within the landscape, as each or all of these trap components could have positive implications if preferences can be obtained.

This is important, as few studies within New Zealand have researched actual animal preferences in trap design, with previous focus generally on animal welfare investigation concentrating on impact momentum and clamping force thresholds (Warburton & Hall, 1995) or direct comparison of the efficiency of one trap with another (Warburton & Orchard, 1996; Nutman, Gregory & Warburton, 1998). It is thought that by improving the novelty and installing confidence between the control device and the animal, that the efficacy in possum control devices such as traps, bait stations and monitoring tools can be increased. Increasing possum kill rates has the potential to make control operations more efficient, lower costs and could allow for devices to be more effective at lower population density sites. This could potentially lead to a reduction in the number of traps or bait stations needed for a control area.

This thesis begins with a literature review providing a general description of current pest control practices in New Zealand, including the main users of possum control tools, an overview of tools and methods used, how ecological considerations should be incorporated into trap design, the role of external stimuli to control animal behaviour and assessing the strength of possum preferences to novel devices. This is followed by the main body of research, aimed at assessing possum preferences of colour, geometry, size, material and trap position to attempt an increase interaction rates in a laboratory setting, then field studies undertaken at two different locations within the South Island.

Literature review – Section One

1.3 Literature review introduction : Possum control and techniques

1.3.1 **Possum control in New Zealand**

The New Zealand Forest Service was given responsibility for controlling possum populations on Crown land and to prevent further spread in 1956 (Montague, 2000). The New Zealand Forest Service started the first aerial poisoning campaigns using carrot 1080 baits (sodium fluoroacetate) for possum control (Rammell & Fleming, 1978). From the onset of aerial 1080 usage, public concerns about potential poisoning of harvestable animals such as deer (*Cervus* sp.), non-target animal deaths and other human health issues were all raised (Eason *et* al., 2011; Wright, 2011). Control was not only attempted using aerial 1080, but also with ground-based approaches using toxic baits containing cyanide, phosphorus and 1080, combined with trapping and shooting.

In 1967, further research indicated that possums were an important wildlife vector of bovine tuberculosis (Tb) to cattle and farmed deer (O'Neil & Pharo, 1995). Soon afterwards, the Department of Agriculture contracted the New Zealand Forest Service to undertake more extensive, large-scale aerial 1080 applications, in the hope of reducing Tb infected possums interacting with susceptible livestock. These Tb vector control operations attempted to create a 'disease-free' barrier zone between farmed livestock and wild possum habitat; however, constant reinvasion by possums into pasturelands continued to hamper Tb free status in some farming regions of New Zealand, such as Westland (Coleman *et al*., 1994). In 1987, The New Zealand Government transferred the indigenous forest protection role from the New Zealand Forest Service to the newly formed Department of Conservation (DOC). At this time growing evidence suggested that possums impacted not only on native vegetation, but also on native birds.

Leathwick, Hay & Fitzgerald (1983) published research showing the tattered remains of a kokako (*Callaeas cinerea wilsoni*) nestling found in the King Country that was believed to have been predated on by a possum. Other direct observations using infrared video cameras in the early 1990s confirmed Leathwick's *et al*. early report of possum predation of native bird species (Brown, Innes & Shorten, 1993; Brown, Moller & Innes, 1996). Possum predation evidence now includes video footage for the North Island brown kiwi (*Apteryx australis mantelli*), North Island saddleback (*Philesturnus carunculatus fufusater*), kereru (*Hemiphaga novaeseelandiae*) and kea (*Nestor notabilis*) (Innes, Crook & Jansen, 1994; Brent Barrett, Centre for Wildlife Management and Conversation, Lincoln University, personal communications, 2012).

1.3.2 **Who controls possums in 2012?**

Currently, possum control is administered by the Animal Health Board (AHB), with the actual control undertaken by the Department of Conservation (DOC), Regional Councils, fur trappers and private landowners attempting to protect private farm or forest productivity (Animal Health Board, 2010/2011; Wright, 2011).

Animal Health Board

The AHB is an Incorporated Society overseen by the Agriculture Minister; it has representatives from the farming sector and Regional governments with the goal of eradicating bovine tuberculosis (Tb) from New Zealand. Possums are the major reservoir host of TB in New Zealand and as such, most of the AHB operations involve controlling the spread of TB from possums and other wild animal hosts (Animal Health Board, 2010). The AHB has a total budget of around $80 million per year, of this $30 million is Crown, $6 million from local governments and the remainder obtained from industry levies from DairyNZ, Beef and Lamb New Zealand the New Zealand Deer Industry and others (Animal Health Board, 2010/2011).

Much of the AHB funded possum control is undertaken using ground-based control techniques on private farmland or on forest margins, although aerial 1080 is sometimes used (Reddiex *et* al., 2007). These control operations aim to rapidly reduce possum numbers into low densities, to slow the rate of re-invasion back into pasturelands, and then to achieve the eradication of TB from infected wildlife (such as removing a source population of infected possums within an isolated forest patch).

During 2009, the AHB funded control of possums and other Tb carriers over 3.4 million hectares (Animal Health Board, 2010). Approximately 3 million hectares of this was controlled using trapping and ground poisoning, with the remainder controlled using aerial 1080 (Animal Health Board, 2010; ERMA annual report, 2010). The AHB tender out the majority of the control operations to private contractors, with the tender process usually administered by the Regional Councils.

Department of Conservation

New Zealand has over 2,700 native plant and animal species that are currently at risk of extinction, but DOC is only actively managing 10% of the 2,700 considered as threatened (DOC annual report, 2007). DOC's management is often focused on direct pest control, concentrating on possums, rats (*Rattus rattus*), stoats (*Mustela erminea*) and other pest mammals (Wright, 2011).

In 2009, DOC managed 1.3 million hectares of crown land – over one eighth of the public conversation estate (Wright, 2011), of this, 1080 was aerially applied to 174,000 hectares to control both possum and rats. In 2009/2010, ~ $22 million was spent killing possums, rats and stoats, which is about 8% of DOC's annual budget (DOC annual report, 2011)

Local and Regional Governments

In addition to the AHB-funded possum control, Local and Regional Councils control other pest mammals within their territorial boundaries. Which animals are controlled is related to which specific animal is considered the most damaging within their territories. For example; Environment Canterbury also control Bennett's wallaby (*Macropus rufogriseus*) in large-scale operations around the hill country of South Canterbury, while in 2011 the Waikato Regional Council spent $169,695 directly controlling koi crap (*Cyprinus carpio*) and rabbits (*Oryctolagus cunuculus*) (Waikato Regional Pest Management Strategy, 2011).

Around two million hectares are managed by Regional Councils throughout New Zealand, mainly controlling possum and rabbit populations (Bay of Plenty, Wellington, Canterbury and Otago Regional Council's); however, only a smaller proportion of this land is actively managed each year. Regional Councils use a combination of ground-based control methods and aerial applications of 1080 in small operations. In 2009, aerial 1080 was conducted on 1.4% of the total area controlled by all Regional Councils (Wright, 2011).

Other possum controllers

Private landowners use a variety of control methods to reduce the impact and damage possums incur on their productivity, or to remove nuisance individuals. Fur trappers also remove possums from both private and crown land mainly using traps and cyanide poison. Approximately 1.5 million possums are killed each year by fur trappers (Steve Hix Personal communication, Connovation Ltd, 2012).

1.4 Current techniques used for possum control

Several techniques are currently used in New Zealand for controlling possum populations; common control methods include poisoning, trapping, shooting and physical barriers such as predator-proof fencing (Warburton & Cullen, 1995; Montage & Warburton, 2000). Most of these techniques continue to be important tools in the ongoing management of possum populations. Biological control of possums had also been suggested to be a long-term, cost-effective control solution for control (Cowan 1996), and as such, heavy investment into biological control research during the past quarter century occurred. However, this research has currently failed to achieve the desired results of usable control tool and research funding has subsequently swung back to improving existing aerial and ground-based control tools (James Ross, Lincoln University, personal communication, 2012).

1.4.1 **Toxic baiting**

Toxic baits are the most commonly used tools for controlling possums, in both aerial and ground-based applications (Warburton & Cullen, 1995). The widespread use of poisons is probably the most controversial aspect of vertebrate pest management in New Zealand, in particular, the use of aerially delivered sodium fluoroacetate (1080) (Wright, 2011).

The use of 1080 has been opposed by various groups and communities since the mid 1950's, with concerned groups demanding a more environmentally friendly, species specific and humane method of possum control (Fraser, 2006). In a 2011 Crown report on 'Evaluating the use of 1080: predators, poisons and silent forests' Wright, (2011) suggested that 1080 should continue to be used for possum control in New Zealand, and that the associated risks of using 1080 are acceptable, considering the significant impacts that uncontrolled possums populations would have on conservation estates and the agricultural industry. However, despite the proven environmental safety of 1080 usage, there is still much public opposition to its use (Eason *et* al., 2011). Development and trials on new possum toxins and novel poison delivery systems are currently being developed and trialled (e.g. sodium nitrite is currently being investigated as a new possum toxin at Lincoln University; Shapiro *et* al. 2011). The development of these new possum control poisons and devices will give wildlife and Tb managers extra tools for managing pest populations, and could subsequently reduce the usage of 1080 in the not so distant future.

1.4.2 **Types of toxins used**

Vertebrate toxic agents (VTAs) used for possum control in New Zealand are divided into two groups, anticoagulant and non-anticoagulant agents. Anticoagulant VTAs include brodifacoum and pindone, these 'slower acting' compounds work by being absorbed via a palatable cereal bait, the ingested compound then makes its way to the animals liver where it interferes with the synthesis of vitamin K-dependent clotting factors (Eason & Spurr, 1995). Once the anticoagulant agent has gathered within the liver, the compounds prevent blood clotting from occurring, mainly causing death by haemorrhaging (i.e. death via blood loss). Often this process takes several days or even weeks for the compounds to accumulate by binding to the liver at high enough concentrations to start working (Eason & Wickstrom, 1997), reducing the potential of animals becoming bait shy to anticoagulants as animals ingest the toxin over a longer time period. The attributes of anticoagulants are summarised in the following Table 1.2).

Table 1.2: Summary of anticoagulant toxins

Anticoagulants	Advantages	Disadvantages	Bait types
Pindone	Less persistent than brodifacoum	Not effective on possums	Carrot bait
	Antidote	May cause primary or secondary poisoning when used at high sowing rates	Oat bait
Brodifacoum	Effective against possums that have developed poison/bait shyness	Primary and secondary poisoning of non-targets can occur	Cereal bait
	Antidote	Primary and secondary poisoning of non-targets can occur	

Non-anticoagulant

The other form of VTAs used for possum control in New Zealand are the non-anticoagulant agents, these acute (or also known as 'fast acting') compounds include: sodium fluoroacetate (1080), potassium cyanide, sodium cyanide, phosphorus and cholecalciferol. All of the previously mentioned poisons cause death via different means, but usually occurring 'rapidly' after bait consumption. The attributes of non-anticoagulants are summarised in Table 1.3.

Table 1.3: Summary of non-anticoagulant toxins

Non-anticoagulant	Advantages	Disadvantages	Bait types
Sodium fluoroacetate (1080)	Highly effective Cost-effective Biodegradable and not persistent (expect in carcasses)	Secondary poisoning of dogs No antidote Can generate bait shyness Controversial, especially aerial operations	Paste Carrot bait Cereal bait
Cyanide	Not persistent No secondary poisoning Humane	Paste is hazardous to users	Paste Pellet (Feratox®)
Phosphorus	Effective	Inhumane No antidote Secondary poisoning risks	Paste
Cholecalciferol	Effective Low secondary poisoning risk Low toxicity to birds	Expensive	Paste Hard bait

1.4.3 **Non-toxic control techniques**

Non-toxic techniques are also extensively used for controlling possums in New Zealand, and are especially important for managing possum populations in smaller areas or at sites where the use of toxins is not desirable and/or there are major non-target risks. Trapping, shooting, chemical repellents and physical barriers are all used as alternatives to poisons for possum control (with poison usage predominately occurring in large control operations due to its efficiency and cost effectiveness at quickly reducing possum numbers).

1.4.4 **Trapping**

Traps have several advantages over toxins, including the ability of traps to effectively control possums over small areas and the avoidance of bait shyness because animals are not subjected to active-acting poisons. Trapping is also not weather dependent and traps can remain active over much longer time periods (Warburton & Orchard, 1996). Additionally, the use of traps is generally more acceptable to the public then poisons (Fraser, 2006).

Trapping of the possums in New Zealand has historically relied upon the use 'live-capture' leg-hold traps since the early 1920's (Warburton & Orchard, 1996); however, leg-hold trap usage appears unlikely to continue due to the rising opposition from animal welfare groups. In an attempt to improve animal welfare, all live-capture traps must be checked once every 24 hours. Whilst this can reduce suffering it also adds to labour, time and cost in operations.

An alternative to live capture involves the use of kill traps. These first became available within New Zealand during the late 1970's (Bruce Warburton, personal communication, Landcare Research 2012). Models originating from fur trapping North America species were later imported from the United States and field evaluated by Landcare Research Ltd. The resulting study conducted by Warburton & Orchard (1996) concluded that these traps were generally not capture-efficient or acceptably humane. However, the concept of possum kill traps was initiated and New Zealand-made kill traps started to become developed, manufactured and sold to wildlife managers and the general public.

Five general types of kill traps are used to control possums within New Zealand. They are the neck-hold traps (e.g. Timms, Sentinel and Warrior), single or double-strike body-catch traps (e.g. Fenn, Conibear traps), drug-delivery traps (e.g. Stinger), electrocution traps (e.g. Electrostrike) and multiple kill, self-setting traps (e.g. Henry trap). Traps associated with the break-back, body-catch, drug-delivery and electrocution mode of actions have generally not been accepted or widely used, with the neck-hold possum kill traps being the most popular used in New Zealand. Apart from the newer multiple-kill traps, none of the trap are designed to render the animal immediately insensible, therefore all death is unlikely to be pain or distress free (Nutman *et* al., 1998).

Any new kill trap must now meet international welfare standards which state that the targeted animal must be rendered irreversibly unconscious within three minutes in class “B” kill traps and that leg-hold or cage traps should not cause severe injuries and must be checked within 12 hours of sun rise on the day after setting the live capture trap (Animal Welfare Act 1999, Biosecurity New Zealand). However, some animal welfare groups argue that three minutes of animal pain should be substantially reduced to immediate death (Muth *et* al., 2006). Although such rapid death is technically possible, user safety and non-target impacts impose real constraints on the size and power of kill traps (Domigan, 2011).

The Timms possum kill trap (K.B.L. Rotational Moulders, Palmerston North) was the first of such successful possum trap on New Zealand’s market (Warburton & Orchard, 1996) and its effectiveness at rendering animal’s unconscious and ease of setting has led to its wide acceptance, particularly with possums around home gardens, tree crops and easily accessible areas (Figure 1.1). However, the Timms trap has limitations for wildlife managers and commercial trappers due to its bulk, single killing ability and its overall, low effectiveness (Steve Hix, Connovation Ltd, personal communication, 2012) as well as its recent failure at NAWAC animal welfare testing (NAWAC guidelines, Landcare Research, 2008). The Timms trap mode of action involves the crushing of the common carotid arteries, stopping the blood supply to the brain and subsequent death (Nutman *et* al., 1998) and some possums were still conscious beyond the three-minute mark; however, most died soon after.

Improvements in trap design lead to the Warrior trap (Connovation Ltd, Auckland). The Warrior (Figure 1.1) derives its killing mechanism from its powerful, spring-like metal jaws which render possums unconscious by clamping down to block arteries and prevent the blood supply to the brain (Ian Domigan, Lincoln University, personal communication, 2011). Warrior traps are currently maintaining 35% of the New Zealand possum kill trap market (Domigan, 2011). Recent investment in pest control research has seen advances in the technology employed in possum kill traps, and as such, traps with the ability to kill multiple possums without servicing are being researched and developed. The Henry Trap (GoodNature Ltd, Wellington) is the first commercially-available and widely used multiple-kill trap and has the ability to kill up to 12 possums before servicing is required (Figure 1.1). Triggered by pulling down on a bait block, the Henry trap delivers a metal spike through the possums head and is powered by compressed air canisters.

Figure 1.1: Three possum traps commonly used in New Zealand, from left to right the Warrior, Henry and Timms traps.

Commercial trappers, pest control staff and wildlife managers require a kill trap that is light weight, compact, reliable and maintains the same high capture rates as the traditional leg hold traps. The Warrior trap is one such control device on the market that is commonly used by trappers and wildlife managers due to its compact size, catch reliability and cost. The Henry trap with its multiple kills is increasing in popularly and usage with over 2000 units sold to DOC, Regional Councils and community conservation groups, with varying success to date (Elaine Murphy, DOC, personal communication, 2012). However, with minimal labour input needed, this multiple kill device has numerous advantages over single kill traps. For example, the reduction of labour costs in checking and resetting a trapping line could significantly free up labour to undertake more tasks such as monitoring or controlling other areas. The advantages and disadvantages of traps are summarised in Table 1.4.

Table 1.4: Summary of advantages and disadvantages of trapping control techniques

Advantages	Disadvantages
Reduces non-target risk	Expensive
Don’t have to be checked daily (unless leg holds)	Possums can became trap shy if not set correctly
Effective in small areas	
Can be used without a licence	

1.4.5 **Shooting**

Shooting at night using a spotlight to locate possums is labour intensive but very target specific. The appeal of shooting over other control methods is that some people find it a source of recreation and fur recovery can be undertaken (Montague, 2000); however, it is extremely unlikely that shooting alone is a viable technique for possum control (Montague, 2000). The advantages and disadvantages of shooting are summarised in the following Table 1.5.

Table 1.5: Summary of advantages and disadvantages of shooting as a control technique

Advantages	Disadvantages
Recreation	Small area control only
High public acceptance	Labour intensive
Generally humane	

1.4.6 **Chemical repellents**

Repellents have been used for the reduction of possum-browse damage to young trees, particularly forestry plantations; however, these repellents are not widely used in New Zealand. Crozier & Ledgard (1988) found that egg and paint formulations reduced browse damage to pine seedlings by captive possums compared with no treatment seedlings, while Morgan & Woolhouse (1995) reported that predator odours based on urines, faeces or other natural occurring secretions of predators (such as dogs), were effective at reducing possum browse damage for over 50 days. The advantages and disadvantages of chemical repellents are summarised in the following Table 1.6**Error! Reference source not found.**.

Table 1.6: Summary of advantages and disadvantages of chemical repellents

Advantages	Disadvantages
Reduces damage to seedlings	Expensive
High welfare	Short term
Good public acceptance	

1.4.7 **Physical barriers**

Predator-proof fencing is not generally regarded as a population control technique, but is nevertheless seen as an important tool in creating wildlife sanctuaries for sensitive areas such as breeding or nesting grounds of endangered flora and fauna (Clapperton & Day, 2001; Scofield, Cullen & Wang, 2011). Predator-proof fencing prevents re-establishment, movement or access by the placement of a wire fence that mammalian animals are unable to dig under, climb over or squeeze through. Fenced areas still require the initial eradiation of pests inside a newly finished established area, while intensive monitoring and control is still needed surrounding the inside and outside perimeters to prevent future reinvasion (Scofield, Cullen & Wang, 2011; Reynolds & Tapper, 1996). Reynolds and Tapper (1996) noted that predators will quickly exploit weak areas along the fence line and breaches will occur periodically (e.g. from damaged fences from slips or fallen trees), therefore other forms of pest control should always accompany predator proof fencing.

Tree guards and tree bands are not used on any large scale for possum protection (Montague, 2000); however, guards and bands are successful at restricting or excluding possum as they form an impassable barrier to climb over and can be used to protect older, significant trees. The advantages and disadvantages of physical barriers are summarised in the following Table 1.7.

Table 1.7: Summary of advantages and disadvantages in physical barriers for possum control

Advantages	Disadvantages
Prevents re-invasion	Expensive start-up costs
	Control still needed
	Long term maintenance costs

1.4.8 Lessons from the Literature

The cumulative ecological and environmental costs inflicted by possums are currently immeasurable. Widespread control of possums sees thousands of tonnes of pesticide baits being applied to ecosystems annually and this has continued now for over half a century to maintain New Zealand's conservation estates and supress disease transmission. When controlling possums over large areas, the use of aerially distributed 1080 is the most economic method in reducing possum numbers compared with trapping. However, target and non-target animal welfare and public concerns attached to poison usage are constantly putting wildlife and TB vector managers under pressure to develop alternatives and increase the use of ground-based techniques such as traps.

The only current viable option for wide spread ground control of possums is trapping, but for traps to work effectively they must have high encounter and then physical interaction (setting off a trap) rates which results in death. This means that we harvest animals faster than they can breed in order to maintain a population below carrying capacity.

General introduction – Section 2: Animal behaviour

1.5 Trapping background

Given the above research needs, the second section of this chapter aims to understand the possum, and how each external component of a possum kill trap could be made more attractive or appealing to the investigating animal, thereby increasing the efficiency of traps.

Kill trap designs have historically relied upon individual knowledge, ingenuity and workmanship to invent and produce working trap designs, often without incorporating the target animal behaviour (Domigan, 2011). Frequently trap designers are more confident working with one material over another (i.e. metal over plastic) and have therefore developed traps from familiar materials. This development is consistently done without incorporating animals behaviour or general preferences. Accordingly, there is very little published research or investigative studies conducted on general possum preferences towards trap entrance geometry, the size of the traps entrance, the materials used in possum traps that could possibly be made more attractive, or simply which trap orientation could create the highest investigation and subsequent interaction frequency.

It is widely accepted that possums are curious animals and given time, individual possums will find and possibly even interact with a control device within their territory (Ball *et* al., 2005). However, by designing possum traps which incorporate their preferred behavioural choices this could significantly increase capture rates or decrease the time until capture, thus reducing labour costs in trap servicing or significantly increasing capture rates with a self-setting, multiple-kill device.

Recent research has estimated the probability of catching individual possums through modelling field data, radio- telemetry and use the of GPS collars on possums. Ball *et* al., (2005) found that there is only a 5% chance of successfully capturing a possum using a leg-hold trap over one night. Ball *et* al., (2005) also reported that a single leg-hold trap located in the centre of a possums home range had a 50% chance of capture success over 14 nights, while it took almost 60 days to have a 95% chance of capturing that individual. Brown & Warburton (2012) reported that the probability of a single possum interacting with a blazed leg-hold trap was 66% and 22% at two different experimental locations, over one night. In both of these studies, many possums trap visitations did not result in capture and the later research by Brown & Warburton (2012), suggested that the nights between first encounter and first capture varied from 0 - 6 nights.

A large component of research on stoat (*Mustela ermine*) control has also focussed on trap components such as orientation, tunnel design, materials used, colours and even tunnel shapes (Dilks *et* al., 1996; Brown, 2001; Hamilton, 2004; Domigan & Hughey, 2008). Unfortunately, this basic behavioural research has been largely over-looked over for possum traps. We do know that some kill traps catch at higher rates than others, yet no published literature gives a definitive reason why, and there is no clear indication from the literature as to what attributes of a kill trap might increase possum efficacy.

This thesis focuses on three current possum kill traps. The "Timms" trap (KLB, Palmerston North), the "Warrior" (Connovation Ltd, Auckland) and the new multiple-kill device "The Henry" trap (Goodnature Ltd, Wellington). These were all chosen for this study because of their historical use in possum control, their successfulness with controlling possums with the Department of Conservation (DOC), Tb managers and community conservation groups, and the Henry traps recent innovation and high publicity and device componentry (Table 1.8). This research does not investigate which of the three traps is the most efficient, nor is this a quality control report comparing one trap to another. This study aims to research possum preferences towards trap components and whether interactions can be increased by designing control devices that targets possum behavioural preferences.

Table 1.8: Componentry make-up of the Timms, Warrior and Henry traps

Trap Components	**Colour**	**Shape of Opening**	**Size of opening (longest points)**	**Material**	**Landscape orientation**
Timms	Yellow	Key	110x80mm	Plastic	Horizontal
Warrior	Black	Square	120x90mm	Metal	Usually vertical
Henry	White, Black	Elongated Pentagon	90x80mm	Plastic	Vertical

Although traps are made from a wide range of materials, thought over the trigger mechanism must be considered, for example; some metals rust faster than others and could hinder trap efficiency if sitting dormant for long periods, potentially becoming locked in place without the trap being able to fire. The Henry trap has a plastic trigger, although plastics can break down with UV light (Dean Jenkins, Award plastics, personal communication, 23 April, 2012), the trigger is situated inside the trap where no direct sunlight and it is protected from debris blocking the trigger. Actual trap trigger placement is not investigated in this research and therefore has not been detailed in the above table.

1.5.1 Possum dominance in relation to trapping success

Dominance hierarchies develop and are prevalent within possum populations, both in the wild and captivity (Jolly, 1976; Biggins & Overstreet, 1978; Oldham, 1986). The function of dominance within possums has not been determined, but for many other well-researched animals, dominant males breed more frequently and dominant females produce more offspring than subordinates (Hirotani, 1994; Owens & Owens, 1996). In possums, dominance is related to age and/or bodyweight within gender, but females (the lighter sex) are generally dominant over males (Jolly, 1976; Cowan, 1982).

The behaviour used to establish dominance has been described by Winter (1976) and Biggins & Overstreet (1978). Possums weighting greater than 2 kg are presumed sexually mature (Jolly et al., 1995) and in this experiment, any possums weighting greater than 2.5 kg was considered dominate and therefore categorised as a 'heavy' possum. Dominate or 'heavy' possums are of concern when undertaking control operations because as Spurr & Jolly (1999) found, subordinate possums will only approach feed stations once the dominant possums were absent. Therefore, if control operations are to succeed the removal of dominant individuals should first be attempted, because if dominate possums are not removed, subordinate possums are less likely to interact with the control devices. This thesis not will not only investigate possum preference towards a series of trap components, but aims to answer which specific componentry will attract the dominate individuals and whether possum gender influences behavioural preferences.

1.5.2 **Possum vision – the influence of colour**

Since possums are nocturnal mammals, they have enlarged, bulbous eyes that have increased sensitivity to light, with their retinas also containing more rods than humans, enabling them to remain active under low light conditions (Smyth, 1975). Thomas and Maddigan (2004) reported that possum vision can only discriminate colours in the middle to long wavelengths in normal light conditions (i.e green, yellow, brown or orange) with red being less effective due to its longer wavelengths (Figure 1.2). Short wavelength colours are therefore seen more readily for animals active at low light times such as dusk, dawn and night (Zhao *et* al., 2009). Warburton and Yockney (2000) found that significantly more possums were caught when using a white backing board with a flour blaze rather than just a blaze. However, a flour blaze is not suited for a long-term attraction because it can be eaten by rodents or washed off by rain. Both Carey *et* al. (1997) and Hunter (2005) both found that photo luminescent pigments (also known as glow-in-the–dark) are highly attractive and can increase possum investigation rates to devices. Photo luminescent colours can absorb and reemit ambient light during darker periods, thereby attracting nocturnal animals.

Based on this literature, possums may find white, yellow and blue colours more attractive than the darker black, and based on the previous research, white could be the preferred 'lighter' colour by possums.

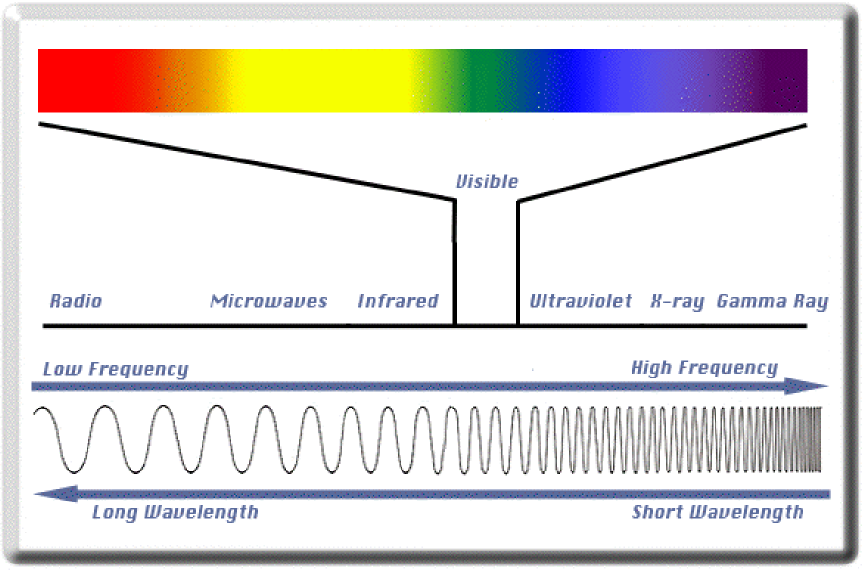

Figure 1.2: The visible light spectrum (source: www.techthefuture.com. October 2012)

1.5.3 **What materials are traps made from?**

In Britain, animal traps are made to look as natural as possible, with wood, drainpipes and logs often used to cover the traps, while "hazing" with sticks and stones to guide the animal through (King, 1973). Possum traps developed in New Zealand are often brightly coloured (for ease of location and to potentially increase possum interaction rates), and made from man-made products that are readily available and inexpensive, such as plastics or metal to keep the manufacturing costs down. Maxwell *et* al., (1997) found that stoat traps consisting of alternative material that reduce trap weight and improve trapper efficiency for stoat control included aluminium, mesh and corflute, but few past published literature has focused on possum behaviour to these materials .

Corflute is used for possum monitoring and as a cover for many kill traps that help guide possum into the jaws of tree-mounted traps (e.g. Sentinel and the set-n-forget traps) and doesn't appear to influence capture rates (Sweetapple *et* al., 2008; Sweetapple & Nugent, 2011). Metal strips are used to keep or prevent possums from climbing onto power-lines, protected trees or buildings; however, the attractiveness of metal compared with other materials is unknown. Metal possum traps on the market include the all leg-hold models and the Warrior.

Plastic material (polypropylene) forms the shell of some commercially available possum traps, this includes the long-serving Timms trap and the recent Henry trap.

Wood is not a common possum trap material, mainly due to its weight and low longevity in high rainfall areas. Wooden tunnels are; however, used to protect stoat traps from 'inquisitive possums' suggesting that wood is found attractive by some possums (Brown, 2001). Dilks *et* al., (1996) found that for the catching of stoats, placing traps on wooden bases rather than the ground significantly increased capture rates in the Hawdon and Eglington valleys (South Island, New Zealand); however, Murphy (1992) found that partially camouflaged traps were no more effective than visible traps for stoats. It is unknown what effect either wooden bases or camouflaging traps would have to possum interaction rates or whether natural products are less attractive than other man-made materials.

1.5.4 **Trap entrance design – big or small?**

The question about what trap entrance size or shape is the most attractive to possums has also not been fully answered in the literature despite many studies recognising that improvement in trap designs and tunnels can influence capture rates (Alterio *et* al., 1999; Hamilton, 2004; Domigan & Hughey, 2008). Entrance size and shape are traditionally based on the need to exclude non-target animals from interacting with the killing mechanism (Domigan & Hughey, 2008), while the trap size itself has multiple factors that must be considered while designing a new control device; this includes its cost, bulk, weight and the numbers one can carry in a pack, the killing mechanism humanness and the amount of material required to cover the whole trap at manufacturing.

A well-designed trap should encourage a possum to investigate the control device and not provide any opportunity to avoid the trap once it has been entered. The effectiveness of any trap can be reduced if the animal is allowed to move too much within the trap, both before (potentially setting off the trigger pre-maturely), and after the killing mechanism has been triggered (causing the killing mechanism to miss its targeted area).

Trap-hole entrances are built to guide the animals to the trigger. The three commercial trap designs investigated in this thesis each had their triggers at different depths in which the animal must enter the device. For instance: the Timms trap trigger is set 110 mm away from the entrance hole, while the Warrior's trigger is set at 130 mm with the Henry set at the shorter 100 mm. Domigan, (2011) recognised the importance of traps entrances and the need for traps to appear 'open' to encourage possum interaction. Domigan (2011) also reported through personal communications with an experienced pest contractor (Dave Hunter, Excel Biosecurity, personal communication, 15th January 2012) that the first electronic multi-kill possum traps failed to kill possums until the tight shell was removed and replaced with a more open, mesh wire covering, after which the device started to achieve possum kills. Dave Hunter believed that the reason for this was that possums did not like putting their heads into tightly enclosed boxes, and Domigan (2011) thought this could potentially account for why the Timms trap, with its large open entrance, had been so successful at capturing possums. Domigan (2011) also found the optimum strike distance for blocking the carotids within a possums neck (effectively chocking the animal to death) was 130-150 mm, and while designing the Bulldog trap (now known as the Warrior), entry width and trap opening of 100 mm was successful for catching possums. Domigan (2011) reported that if a trigger distance is too great, individuals will reach for the bait with their forelimbs, potentially setting the trap off on their forelimbs.

While comparing the entrance shape of the Timms trap to the square shaped LDL101 and 160 Conibear traps, Warburton *et* al., (2000) found no indication that the 'pear-shaped' external hole of the Timms trap added any benefit over and above the straight or offset jaws of other traps. Although the 'pear-shaped' Timms did not reduce the time to loss of palpebral reflexes, Warburton *et* al. (2000) reported the tighter, top loop of the 'pear-shape' opening was an important restraining mechanism while the animal was being rendered insensible. In the field, possums have been found with their necks rotated in the Timms trap, and others have had their forelimb's caught between the striking bar and neck, potentially not being able to produce a 'humane' kill or enabling escape. Warburton *et* al. (2000) summarized that the target animal must be vertically aligned, with no limbs obstructing the striking bar for consistently effective kills.

Trap entrance design should also consider the bait position, this needs to provide shelter so that the lure does not biodegrade or become damaged (King, 1973), while also remaining open for the possum to investigate (either by olfactory or visual clues). Trap size can also increase the life of the bait by protecting it from the elements and restricting access to all except those species able to enter. Most trap-hole sizes have been based around the size of the killing mechanism, with the finished entrance hole size being determined by the overall trap size. Research in New Zealand has demonstrated that the introduced possum is evolving to their new environment by increasing their skull size in order to adapt to the colder air temperatures at more southern latitudes (Yom-Tov et al., 1986; Kerle, 2001). In some populations this has occurred in only 30 generations (Kerle, 2001) and North Island possums are significantly lighter than South Island possums, thus their skull size is also different (Yom-Tov et al., 1986) as seen in Table 1.9.

Table 1.9: Possum bodyweight and head length at different locations in New Zealand (adapted from King 1973)

Location	Bodyweight (kg) *mean*	*maximum*	Head Length (mm; M: male, F:female)	*Reference*
North Island				
Silverdale	2.39	3.3	M=89, F=88	Triggs, 1982
Wanganui	2.32	3.95	-	Cowan, n.d
Orongorongo Valley	2.4	3.7	M=92 ± 3, F=90 ± 3	Crawley, 1973
South Island				
Mt Misery	3.16	4.45	M=96 ± 5, F=95 ± 4	Clout, n.d
Copland Valley	3.47	6.3	-	Fraser, 1979
Banks Peninsula	3.53	5.14	-	Gilmore, 1966

There has been no previous research looking at the effects of current trap dimensions on the entry behaviour of possums or any investigation of their reactions to devices with alternative dimensions (i.e. larger or smaller tunnels). There is also no information available on the effect of trap entrance shape. If new kill traps are to be developed, information is required to assist in designing a trap that maximising the number of animals that will encounter and interact with the device. Evidence suggests that dominate (heavier) possums must be removed before subordinate individuals will interact with a control device (Jolly, 1976; Cowan, 1982), therefore it is important to determine preferences for larger animals so that these individuals can be effectively removed.

1.5.5 **Trap orientation – horizontal or vertical?**

Domigan & Hughey, (2010) commented that the style of the trap ultimately determines the traps physical dimensions, and that the type and shape of the entry point is based on which non-target animals need to be excluded. For example, both the Warrior and Henry traps are positioned off the ground to reduce bird interactions from kiwi (*Apteryx sp.*) or weka (*Gallirallus australis*). These different requirements can make it challenging to create a single trap that is capable of excluding all non-target species, especially when the animals are highly intelligent and inquisitive like weka or kea (*Nestor notabilis*). Therefore, trap orientation is an important consideration.

Trap orientation also has the ability to influence both target animal behavioural responses and could lead to a decrease in interaction rates if the targeted animal doesn’t feel confident in putting their head into the device. The orientation of traps also has an important role in preventing non-target animals from triggering the killing mechanism. For example; if a possum trap is positioned in such a way that the bait is visually attractive and presented, and a passing inquisitive weka is able to peak at the bait, the subsequent non-target bird may become injured or killed.

Trap triggers must also remain free of debris, the commonly used Timms trap has a higher chance of being ineffective due to debris such as vegetation (i.e. sticks or other foliage) becoming lodged with the trap opening, potentially reducing the humaneness of the trap if the killing mechanism is slowed. For example; instead of a metal swing bar reducing the trapped possums unconscious within 30 seconds, the swing bar may be blocked by a branch slowing the velocity of the swing bar. This issue could be resolved if the trap orientation was such that debris never impeded the trap entrance opening.

Domigan (2011) found that while developing possum traps, most possums often placed their paw on the trap entrance, sometimes setting off a trap without a capturing the animal. He put this down to the possum investigating the ‘new thing’ in their environment with no further explanation given.

1.5.6 **Trap confidence – open or closed devices?**

It is presumed that the faster the approach, the more confidence the animal has towards that device. The speed at which interaction occurs was investigated to firstly confirm the sample preference and secondly, to quantify whether possums express confidence when investigating specific novel devices. For example, a device design that is 'open' or of larger size, could potentially allow an animal to quickly assess potential dangers. If a device is 'closed', meaning that an animal must spend time investigating or visually inspecting a device for the opening or bait access, then the animal could than lose interest and fail to interact.

It is widely thought that the majority of possums will eventually interact with a control device given enough time. During bait palatability trials held on Banks Peninsula 2011, several possums were videoed having difficulty retrieving the bait from mini Philproof bait-stations (Connovation Ltd) and in two recordings, different possums took over ten minutes before they successfully managed to remove baits because the size openings were too small (Sjoberg, unpublished report, 2011). Kavernmann (personal communication, Lincoln University Phd candidate, 2012) also found possums climbing all over Sentinel traps for up to 45 minutes trying to access the bait, with one possum leaving before triggering the device. By researching animal approach behaviours, confidence, body angles at possum/device approach and at hypothetical 'triggering' time, this understanding and knowledge could help future possum kill-trap designers to incorporate positive animal behaviour into control devices, allowing possums to more easily assess the potential risks and thereby increase trap interactions.

1.5.7 **Lessons from the literature**

As detailed above, little quantitative evidence has been published regarding how trap orientation and other design features might affect an animal's behavioural response to the presented traps. There is also scant knowledge on which trap design is preferred or which trap component is the most critical to a successful possum capture. Considering the large amount of money spent on possum control, it is surprising that the most widely controlled pest in New Zealand has had such little investigation concerning design improvements for trapping.

It is commonly thought that possums are inquisitive and will interact with any trap when found within their environment or home-range. This is somewhat correct, but many thousands of traps placed in high density possum areas do not always remove survivors from previous control campaigns. This basic knowledge in possum preferences concerning kill traps is lacking and therefore research into trap design and componentry is essential for increasing possum interaction rates and subsequently increasing native biodiversity through predator control or reducing the occurrence of

TB transmission in cattle and deer herds in New Zealand and is the focus of this Masters thesis. The above literature review has identified five possum/control device issues that warrant investigation, these include colour preferences, entrance geometry and entrance size preferences, material attractiveness and trap landscape orientation preferences. In the following chapters, both captive and free-ranging possum experiment results will be published.

Objectives

Given the aims of researching possum behavioural preferences towards novel control devices the five key research objectives include:

1. Testing possum attractiveness towards the colours Black, White, Blue and Yellow (Chapter 3.1).

2. Entrance geometry preferences between the shapes Square, Triangle, Key and Diamond (Chapter 3.2).

3. Trap size entrance opening preferences of 70, 80, 100 and 120 mm holes (Chapter 3.3).

4. Trap material attractiveness among Metal, Wood, Plastic and Corflute (Chapter 3.4).

5. Trap orientation preferences derived from current control devices of the Timms, Warrior and the Henry trap, compared with the control orientation of an open box facing upwards (Chapter 3.5).

Chapter 2
Methods

2.1 Possum Capture and Handling

Thirty-eight possums were captured from the wild from three different locations during 2012 (Orton Bradley Park, Banks Peninsula; Rotherham, North Canterbury and Lake Taylor Station, North Canterbury). Twenty-seven possums were caught by Clem Small (Rotheram, North Canterbury) between 20th - 24th February. Between April (12th – 13th) and August (20th – 22nd), the last 11 captures were untaken by the author at Orton Bradley Park on the author. This provided a turn-over of new possums into the trials to minimise any effect of multiple testing on the same individuals, while also allowing a random selection from available possums. For example, the colour preference experiment trialled 30 different possums, of which 23 came from possum batch one (February), four from batch two (April) and five from possums which arrived at August.

The possums were handled as little as possible to minimise stress. The average weight of the possums was 2.57 kg (± SE 0.09), with males averaging 2.58 (± SE 0.13) and females 2.57 (± SE 0.12). The sex ratio was 21 male: 17 female with only mixed aged adults being used (Table 2.1). Juveniles were excluded from laboratory experiments due to Lincoln Universities Animal Ethics Committee's policy only approving the use of adult wild animals for captive studies only.

Table 2.1: Numbers and average weights of the possum used during the experiments

	Number	Average Weight (kg)	Standard Error
Male	21	2.58	0.13
Female	17	2.57	0.12
Total	**38**	**2.57**	**0.09**

Each possum was held in captivity at the animal husbandry facility located at Lincoln University, Lincoln, New Zealand. Animals had been captured from the wild around farmlands using the Havahart® live capture traps (spring loaded door) baited with a slice (quarter) apple with a cinnamon-based 'flour blaze' also being used to attract the animals.

All animals were cared for by the Lincoln University animal staff and were held in captivity for five days prior to conducting trials, giving them time to acclimatise and following the Lincoln University standard operating procedure for possums (SOP #86). All animals were provided with a range of food and water *ad lib*. Cereal pellets (Western Milling Stockfeed, Rangiora, New Zealand) formed the maintenance feed while a selection of fruit and vegetables (bananas, tomatoes e.t.c) were used to supplement dry cereal pellets. Each adult possum undertook periodic health checks to ensure fitness and welfare of animals held in captivity, these checks involved weighing and recording animal weight and condition of fur as well as monitoring daily food consumption.

Possums were housed individually within a 2.2 by 1.15 m enclosure constructed from timber and wire netting with corrugated iron covering half the roof (to provide a dark corner), the other half being constructed of wire netting and shade-cloth to allow the entry of fresh air and sunshine. Each possum had a large hessian sack hanging under the corrugated iron roofing at the far end wall that formed its "drey" or den, the wall closest to the entrance door was clear for enrichment devices such as branches that were placed and periodically re-positioned and/or replaced. The one-ended sack allowed the researcher to enter the pen, set up an experiment and leave without the possum being aware of the proceeding trial.

All experiments were non-harm and had approval from the Lincoln University Animal Ethics Committee (approval # 451) under the title "Quantifying possum (*Trichosurus vulpecula*) behavioural responses and interactions to foreign devices (kill traps) in their environment" at Lincoln University.

2.2 Experimental Procedures

The trials consisted of a series of five preference experiments, each experiment comparing the responses of 30 possums to four different choices on offer. The responses measured included: the time till first investigation; which device was investigated from first to last; the time spent at each device as well as the approach angle and body positions when interacting and removing presented baits. An interaction was classified as once the animal had pushed its ears past the entrance hole or bit a Waxtag®, representing that the animal was likely to have set off a trap. There were occasions when possums licked, bit and smelt the side of the boxes without putting their head into the boxes, these observations were recorded, but not considered a interaction. Whereas an encounter referred to an event between an animal and a device.

Possums were tested individually within their enclosures (2.2 by 1.15 m). Animals were lured to investigate devices through the use of a food lure. Each trial was baited with a different food lures to increase novelty and investigation period with each separate trial (Table 2.2). Only proven food-based attractants were used and no new baits or materials were introduced to keep all trials consistent. Although subjects were enticed to the devices by food lures, possums were unable to visually identify the bait due to their placement within the boxes. Therefore, animals had to use olfactory clues to find the devices before possum preference or device attractiveness determined the selection progress.

Table 2.2: Food based lures were used to attract possums to investigate shape, size, material and landscape orientation preferences, while Resene paint was used for colour testing and painted on Waxtag® backings

	Lure used	Quantity given/trial	Supplier of lure
Colour	Colour paint and wax block	Waxtag® plastic backing (60 x 90 mm)	Pest Control Research (Waxtag®), Resene Paints (paint)
Shape	Apple	Quarter apple	New World, Lincoln
Size	Carrot	Quarter Carrot	New World, Lincoln
Material	Prefeed striker	4.5 g	Connovation Ltd
Landscape	FeraFeed 'Smooth in a Tube'	4 grams)	Connovation Ltd

No negative control was introduced (i.e. every box was baited with the same lure) during the choice experiments because these trials did intend to measure olfactory attractiveness, but rather preference testing of kill trap components such as colour, shape, size, materials and landscape orientation and position.

The experimental procedure involved the placement of baited, novel devices and materials in a randomised order (left to right) within the possum enclosure in the late afternoon or early evening, randomisation was achieved through the use of the RAND function in Microsoft Excel 2010. All pens were searched for stray pieces of bait the next morning (that could potentially affect a following trial and removed). All device material was thoroughly cleaned by scrubbing, rinsing in fresh water and dried between trials to remove bait odour and because animals sometimes scent-mark food sources.

All devices were placed into individual possum enclosures roughly one hour before sundown. This timing was seen as the most effective time for placement as the subjects were still inactive within their hessian sacks, making device placement easier for the operator. Also, the smell of the baits within each enclosure is limited to just a few hours rather than all day which could have made possums investigate food based lures out of their normal hours of activity.

2.2.1 Experiment one: Testing possum attractiveness towards difference colours

All Waxtags® were manufactured in Christchurch by Pest Control Research Ltd and were used in this trial because they are industry standard for monitoring possums (NPCA, 2010). They also provided ease in quantifying which coloured Waxtag® was interacted from first to last.

All Waxtags® were painted (all paint acquired from Resene Paints, Hornby, Christchurch) their allocated colour one day before trials took place and were dry before placement into possum pens to reduce any colour-specific odour. The colours tested were Yellow (Resene colour code 'gorse G90-195-091'), Black, White and Blue ('Lochmara B55-104-244'), and all of which came from same paint type (Resene total colour) to keep the ingredients, volatile organic compounds and application consistent.

None of the possum subjects had previous experience or interactions with Waxtags® at Lincoln, and it is unlikely that possums had previously interacted with any Waxtags® before being caught, mainly due to the private land where the animals were sourced having had no previous Waxtag® surveillance monitoring in the past (Clem Small, Possum contractor, personal communication, February 25th 1012).

Randomly positioned (the randomisation was done using the "RAND" function in Microsoft Excel™) painted Waxtags® were evenly spaced along a 12 mm thick marine ply board measuring 100 cm long by 20 cm wide. 15 cm Spacing between Waxtags® were used to ensure that each colour was independent, and not confounded by the location of other tags.

Waxtags® were held in place by 12 mm screws through the Waxtags® plastic backing and into the wooden marine ply board. Waxtags® were screwed at a height of 20 cm off the ground in the attempt to make the interacting possum stand on its back legs and bite the wax block (Figure 2.1). Each marine ply board was screwed into the wooden structural support beam within individual possum pen enclosures at the far end of the pen to create the maximum distance between the animals nest box (or sack) and the Waxtag® boards.

Figure 2.1: Colour preference testing was conducted by painting the plastic backing of Waxtags® and evenly spacing them along a wooden board.

2.2.2 **Experiment two: Entrance geometry preference**

Wooden boxes measuring 8000 cm^3 (width 20 x length 20 x height 20 cm box) with different entrance geometries were built from 1.2 cm marine ply to test possum shape preference. The shapes tested were Pear, Square, Triangle and Diamond and were made by cutting through a wooden side at roughly 10 cm^2 sizing. Although each shape was cut from the same width hole, some shapes became smaller (like the Key and the Diamond) than others but the shaped entrance hole size (10 cm^2) was thought to be a suitable size for all possums to easily access the presented baits inside the box.

Each 8000 cm^3 cubed box was randomly placed along a 100 cm by 30 cm, 1.2 cm marine ply sheet with holes drilled through the sheets at even spacing's (Figure 2.2), every box had a hole drilled into itself that allowed a bolt and nut to pass between the box and ply sheet making it easy for the operator to change the shape formation depending on the randomised design datasheet. Bait consisting of a quarter of an apple was placed at the front lip, but inside the shaped box in a fashion that allowed the animal to view each bait only when at close proximity.

Figure 2.2: Entrance geometry preference testing involved four shapes, this included (from left to right) a Triangle, Pear, Square and Diamond shapes in the form of wooden boxes.

2.2.3 **Experiment three: Trap size entrance openings**

A rectangular wooden box (100 x 20 cm broken into four 8000 cm^3 compartments) was used to determine whether possums have a preference concerning trap entrance opening sizing (Figure 2.3). This box was designed to allow operators to easily move the different sized opening holes by removing two 1.2 cm screws holding the size plate to the main rectangular structure, switching the size plates to the desired position, and then screwing all into place without them coming loose. The larger rectangular box had dividers between the different size plates to prevent animals entering into the box and moving along inside the rectangular box.

Figure 2.3: Testing entrance opening size preferences was undertaken by cutting circular holes within wooden plates that could easily be moved around depending on the randomised design layout.

Four different sizes were chosen to be tested, these were 70, 80, 100 and 120 mm diameter circular holes cut into the 2400 cm^2 wooden surface. These sizes were chosen because they range from tight around a possums head to loose around the neck area. Circular holes were used to test entrance size because round holes were not tested during the geometry preference trials, thereby making circular holes a novel object due to not being previously having been trialled.

Carrot pieces replaced apples as the lure because this was seen as a new trial, involving new baits to create another novel, independent experiment. Each quarter-sized, carrot piece was placed within each different size segment and all positioned at the same depth within the boxes for consistency (placed ~ 4 cm from the opening exposed to the animal).

2.2.4 **Experiment four: Trap material attractiveness**

Like the size design, a rectangular wooden box (100 x 20 cm) built from 1.2 cm marine ply sheets was used as the housing mechanism that tested for material preference (Figure 2.4). Plastic, metal, wood and corflute sheets were then cut into 20 cm^2 squares that fitted tightly over the longer rectangular box and could be moved around depending on randomisation.

Tested materials were sourced from a variety of places. The corflute was cut from old real estate signs (Ray White, Hornby), the metal sheets were recycled from an old washing machine (because of the ingrained white colouring it did not need painting), thereby all materials tested are not recently painted. The wood was sourced from the Lincoln University, Johnson Memorial Laboratory. A Timms trap was taken to Award Plastics and Displays (Christchurch) and analysed for exact plastic composite, with a sheet of white plastic purchased after this analysis to represent the traps made of plastic.

Each different parent material had a 100 cm^2 square shape cut through the centre to allow animals to access the presented baits (4.5 gram pre-fed “striker”, Connovation Ltd), while also getting the animal’s head close, if not touching the different material presented.

Figure 2.4: Material testing was conducted through the use of different materials cut into squares that covered a compartment that held a food bait.

2.2.5 **Experiment five: Trap landscape position preference**

In the final experiment, smaller wooden boxes (8000 cm^3) with an opening at one end were built from 1.2 cm marine ply and attached to a larger ply wood backing (100 x 40 cm). The open end acted as the access front for interacting animals to investigate and remove the presented baits. A small drop (4 gm) of possum lure ‘Smooth in a tube’ (Connovation, Auckland) was smeared on the far inside side of the box so that animals removing the baits would have to physically reach inside the box, with their head fully enclosed (Figure 2.5).

The tested angles included:

1. 10 cm off the ground, facing sideways (replicating a Timms trap design)
2. 30 cm above ground on angle (replicating a Warrior trap)
3. 30 cm above ground, facing down (replicating a Henry trap)
4. 10 cm off the ground, facing upwards (called a ‘box’)

Figure 2.5: Possums were lured into the wooden boxes by a few grams (pea sized droplet) of sweet smelling possum lure "Smooth in a tube" (Connovation Ltd, Auckland).

Each open box was screwed into the larger wooden backing in a randomised design. The backing was then screwed into place so that the test subject was able to access all open boxes equally. The larger backing rested on the ground to give the structure more strength as possums are known to climb, sit and bite most objects they come into contact with.

2.3 Experimental methods

Each experimental device was offered to individual possums over a one night period. Boards with the different devices were placed in pens at the same time of the day (roughly an hour before sunset) and removed from each pen at 0800 the following morning.

Thirty out of the thirty-eight possums were subjected to each different experiment. Individuals were only given each experiment test once, and each animal had a varying number of nights between experiments (between 1 to 12 nights between trials). Ideally, new possums would interact with each new experiment device, but this was unfeasible given the large number of animals required and other logistical constraints. Although some trials were similar in appearance, or the material between the trials was consistent (i.e all devices had a wooden, 1.2 cm marine ply backing), subtle differences were incorporated in each of the five experiments. For example, the food based lures were different in each experiment. Wood was used in the material experiment, but each material was coloured white to hide the natural colour of wood and to give all material types an equal opportunity to be selected.

Possum preferences were measured in a series of cafeteria, four –way choice test experiments (Appendix A). Preference was assessed by rating in order from first to last which device the animal interacted with in what order when investigating and removing baits in an arbitrary scale of preference (1-4). The bait was also simply recorded as consumed or not. The preference scores were:

1 = interacted first

2 = second

3 = third

4 = fourth

No = No interaction

An interaction was classified as positive only if the animal had its ears pushed passed the entrance hole, whereas a negative interaction was recorded when the animal did not enter a device past its ears. A negative interaction can incorporate a possible preparatory investigation that in subsequent visitations resulted in a positive interaction. There were occasions when possums licked, bit and smelt the side of the boxes without putting its head into the boxes. These were recorded but not considered a positive interaction because the animal failed to enter the boxes past its ears (see example below in Figure 2.6).

Figure 2.6: An example of a interaction (left) with the animals ears inside the box and no interaction (right) where the animal has yet to enter its head into the device.

Four different approach behaviours (or the speed in which an interaction takes place) were also recorded at the animal's first interaction for all of the experiments. These behaviours were recorded and analysed from a distance of 50 cm away from the devices and are described below (Table 2.3). Only the individual's first interaction was analysed, because after their first interaction, the novelty of the devices do not have the same strength and behaviour could change as the experiment continues.

Not all animals actually interacted with the devices, hence I also analysed animal confidence around the devices below (Table 2.3).

Table 2.3: Possum approach behaviours when interacting with novel devices

Approach behaviour	Description
N/A	No interaction with device
Slow	Two or more pauses before confirmed interaction
Steady	One pause before interaction
Fast	No pausing before animal entered the device

The animal's confidence within the tested devices was also assessed; to examine whether possums are confident around novel devices. These behaviours were classified and described as in Table 2.4. Although this analyses resembles the likeness of the approach behaviour, this approach confidence information reveals information about whether possums pause before entering a novel device rather that the speed at which interactions take place.

Table 2.4: Assessment of possum confidence with novel devices was investigated using the follow criteria

Confidence behaviour	Description
No confidence	Possum investigated by sniffing or visually inspected the device, but left without interacting with any device after two minutes
Lost confidence	Half-entered device, then pulled away with no further initial interaction, but interacted with other device over two minutes later
Gained lost confidence	Re-entered a previously 'lost confidence' device within two minutes
Confident	Positive interaction without delay

Possum body position at time of first positive interaction was recorded and analysed. This is seen as important information for trap designers to understand body positions and behaviours when developing kill traps. This research investigated whether possums preferred to have their forelimbs close to their head when interacting or feeding from novel devices. The behaviours expressed were classed as:

NA = No interaction

Head only = confirmed interaction with the head entering through opening

Head plus limb = head in, plus the front paws positioned near the head, e.g. resting paws on device opening lip or shelf while heads inside searching for bait

Possum approach angle and bait recovering techniques were also qualified. Approach angles were recorded as accessing the baits from the top, bottom, left, right or straight into the devices, while the bait recovery techniques investigated whether possums solely use their teeth retrieving baits, or whether possums also use their forelimbs to gather the baits closer towards their mouths (teeth or teeth with forelimbs).

Animal latency was recorded between interactions as was the frequency of interactions within a defined two hour time period (i.e. the number of times an individual entered or bit a device).

All Camera footage was analysed the following day with the relevant media files saved for future analysis. After the first positive interaction, footage was analysed for an additional two hour period only. The actual time possums spent sniffing and chewing baits could not be distinguished because their lack of movement meant that the cameras were not always triggered, so investigation concerning the order of which the baits were taken was the main focus, as well as the total time investigating before a positive interaction was recorded. All observations were recorded by specific cameras used randomly throughout the trials while one person was responsible for all video analysis. Cameras were randomly allocated to the different pens each experiment and the majority of the trials had one camera present while some of the earlier trials had two cameras set up to view the same area as a comparison between the two camera models. No differences were found between the two cameras models as both sets of video footage were analysed by a single person with minimal discrepancy found between the two, therefore the remaining trials employed using one camera per experiment.

Infra-red, motion sensor cameras were used to record all animal interactions with devices. These were positioned at a high angle and situated behind the advancing animals to capture approaches towards the devices. Camera were situated in the same location within the pens for all trials. The majority of cameras were positioned to shoot and record within a 100 cm radius around the tested device to allow behaviour to be monitored (Figure 2.7).

Figure 2.7: Cameras were positioned at a high angle to record possum approach behaviour while also giving a clear field of vision of interactions with each device. Above is an example picture capturing a possum removing bait from the 'Timms' design during landscape position testing on the night of the 28th August, 2012.

The type of cameras used were a mix of the Acorn LA series (Viewtech Ltd, Christchurch, New Zealand) and the Bushnell 'Trophy Cam HD Max' (Trailcampro, Springfield, Missouri, United States). All Cameras were held in place by string and plastic cable ties (Figure 2.8). All cameras were set to record 30 seconds of video footage with 1 second time lapses between recordings if any additional motion was detected by the cameras sensors.

Figure 2.8: The Acorn LA series camera (Viewtech ltd) inside a metal security case (to prevent animal damage) positioned on the possum enclosure wire roof to capture animal's interactions and behaviour towards devices.

2.4 Analyses

Once the video footage was viewed, the raw results were transferred onto a Microsoft Excel™ 2010 spreadsheet. On completion of all the trials, the data was imported into R version 2.14.1 for specific data analysis (see below). Video footage was used and analysed for several reasons. Firstly, cameras were programmed to provide the exact time when behaviours was recorded, and behaviours recorded related to real time (in seconds). Secondly, reviewing the footage several times allowed the researcher to identify similarities and any odd behaviours across all experiments, helping to form a larger picture of possum behaviour. Thirdly, when no possum activity was taking place, the motion sensors were not activated, therefore there was no footage to review saving research time without comprising the risk of not recording any behaviour around a device.

Statistical analysis aimed to quantify possum preferences with a cafeteria test (Rozin, 1976) an individual choice test comparing the attractiveness of one thing over another of four choices. Comparisons between variables such as first choice, second choice, sex and weight was investigated with calculations being made from within the two hour study period per possum.

When comparing models with different covariates, the Akaike Information Criterion (AIC) was used to identify the “simplest” best fitting model from a set of competing models. The chosen model is the one that minimizes the kullback-leibler distance between the model and the data’s truth, indicating the model of best fit (Burnham & Anderson, 2001); however, model complexity is penalised for extra parameters (Burnham & Anderson, 2002). As a rule of thumb, models with a change of less than two have substantial empirical support (or positive evidence) for the model. Models with a change of 4-7 indicate considerably less support, and models with a change (ΔAIC) of greater than 10 have essentially no support are very unlikely model candidates (Burnham & Anderson, 2002). Akaike weights also provide another measure of the strength of evidence for each model, in effect, the Akaike weights present the candidate models on a scale of 1, thus allowing readers to interpret a straightforward set of models that indicates the probability of best model fit. For example; an Akaike weight of 0.80 for a model, indicates that given the whole data set, that model has a 80% chance of being the model with best fit compared with the other candidate models. In addition, one can compare the Akaike weights of all the competing models to determine to what extent which candidate model is better than another (Anderson, 2001). The ‘theoretic-information’ data analyses approach was adopted in this research over the more traditional ‘frequentist’, P-value analyses, because it is flexibility in interrupting animal behaviours and its ability to supply a biologically significant result, rather than the tradition ‘P-value’ analyses that although is more statistically robust, can often be detached from biologically significant behaviours relating to applied science research.

AIC tables have the advantage over other statistical analyses methods because it is easy to compare completing models (both the ΔAIC and Akaike weights), and calculations remain the same regardless of whether the AIC or AIC_c is used (Anderson *et* al., 2001). In contrast to conventional model selection, the AIC focuses on the strength of evidence (ΔAIC and Akaike weight) giving a measure of uncertainty for each model (Burnham & Anderson, 2002). However the AIC is not a traditional hypothesis testing procedure and does not have an alpha valve giving readers a notion of statistical significance (Burnham & Anderson, 2001).

To analyse the choice test data we employed a multinomial log-linear model using the "nnet" package in R version 2.14.1. This package also assesses the influence of categorical and continuous variables and we also included the sex (gender) and bodyweight of the individual subjects. Where the AIC tables indicated that these explanatory variables were important the data was presented as a percentage bar graph providing a visual interpretation of the results.

In addition to the choice data analysis we also analysed the number of times possums interacted with the colours, as most possums chewed multiple Waxtags®. Additionally, we also investigated the possum second colour choice to confirm whether colour choices were consistent. The number of times each colour Waxtag® was bitten was analysed with a Generalised Linear Mixed Model using the package "lme4" in R version 2.14.1. For this analysis we used a "poisson" error distribution with each individual listed as a random effect. Again the fixed effects were the sex and bodyweight of the individual subjects.

2.5 Field trials

The field trials were undertaken at two South Island study sites, Station Creek (Springs Junction, Lewis Pass, represented as a red "S" pin on the map below) and the Taipo Valley (Westland, seen as the red "T" pin on Figure 2.9) between the 10th - 23th July (11 nights) and the 26th July – 6th August (10 nights) respectively. Field trials approved under Lincoln Universities Animal Ethics Committee (# 451) and the Department of Conservation (National Permit Number: WC-34320-FAU). Field trials are seen as necessary to compare preference behaviours between wild caught and wild animals as animals behaviours can be altered within captivity (Veasey, Waran & Young, 1996; Kunzi *et* al., 2003).

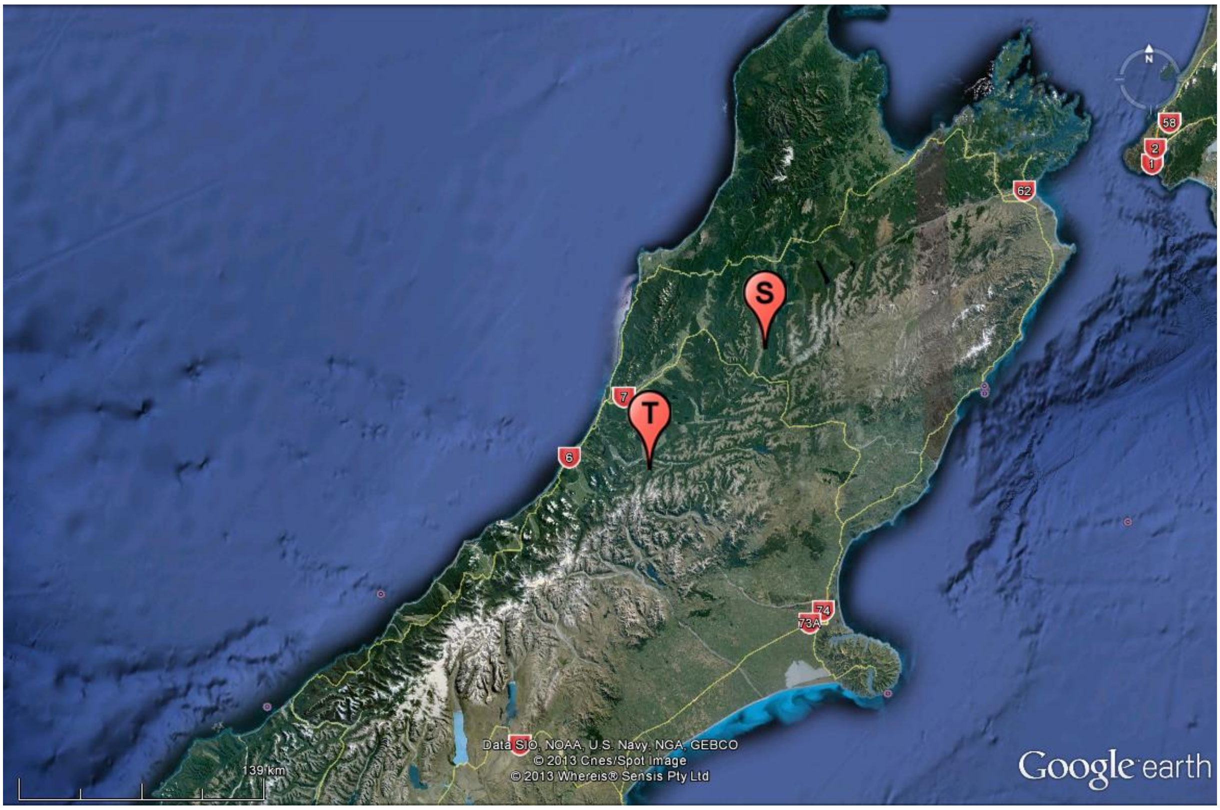

Figure 2.9: Map of New Zealand's South Island and the location of both field study sites, the red "S" pin represents Station Creek (Lewis Pass) while the red "T" pin is of the Taipo River, Westland. Maps courtesy of Google earth. Scale bar on the bottom left corner is 139 km.

Preference testing as per the captive study detailed above (i.e. colour, shape, size, material and landscape orientation) was conducted along four wheel drive service tracks at Station Creek (Figure 2.10) and along the Taipo River valley at the second field site (Figure 2.11). Two of each preference tests were undertaken each night to increase sample size and utilise time while in the field. Like the pen trials, each device design was randomly selected each night, and device placement design was also random (Appendix A). Different study locations were selected each night to ensure a constant supply of naïve possums interacting with each preference test.

Each experiment had a minimal spacing of 50 m apart, which gave the nightly trial length of 500 m (which was then replicated over another 500 m transect) (Figure 2.11). Distances were located and stored in a handheld GPS (Garmin 60CSx). Jolly (1976) and Ward (1984) both reported that possums will forage on seasonally available foods over 200 m away from their den sites, therefore the distance of 50 m was chosen between devices in an attempt to maximise possum encounter rates along a given transect, without permitting a single individual to investigate all experiments in normal night of foraging.

Each experiment was baited with the same lure as used in the pen trials and replaced with fresh baits each day (as seen above in Table 2.2) and positioned on a suitable tree. A tree was considered 'suitable' for experiments when they reached the desired distance away from the previous trial (by using the GPS), hidden from view to prevent public interference and also a support tree was within the nearby vicinity. This 'support tree' was needed to position the camera to record animal interactions with the preference tests. The devices were held tight onto their supporting trees by way of metal wire loops to prevent movement when interacted with (screwing devices to the trees was not permitted by the DOC permit).

Each device was removed from the previous night's position, cleaned/wiped down with a soft brush and transferred to another site 50 meters away from the end of the previous night's trial via four wheel drive or quad bike. Devices were removed each morning and moved to a new site during the afternoon of the same day. While removing the devices from their overnight positions, the observer recorded whether any baits were removed and searched for evidence of animal sign (such as animal faecal matter).

In keeping with the pen trials, a mixture of the Acorn LA series and Bushnell 'black flash' infra-red, motion sensor cameras was used to record all interactions with the same settings as detailed above. Unlike pen testing, the interacting possum's sex or weight could not be determined (unless there was sufficient video evidence to show genitalia). However, video footage comparing the animal's relative size (adult versus juvenile) and fur colour could be used to distinguish between individual possums interacting with devices.

2.5.1 **Lewis Pass**

Station Creek is located north of Springs Junction on State highway 65 (Figure 2.10) and is dominated by red and mountain Beech (*Nothofagus fusca* and *solandri*) forests. Beech forests are not particularly known for their high possum numbers compared with mixed podocarp forests (Coleman *et* al., 1980; Clout & Gaze, 1984); however, beech forests are still able to maintain high possum densities in some areas and years (Coleman *et* al., 1980). Station Creek was chosen as a study site because of its good four wheel drive access, the time period between the last control operation (three years), and the access and close proximity to accommodation (both private huts and DOC house within Springs Junction).

The last 1080 (sodium fluoroacetate) operation at this site was undertaken during the spring of 2009, and it was thought that the possum numbers were increasing sufficiently enough to warrant a study site for this research. Station creek was also selectively logged by the old New Zealand Forest Service until the early 1990's (Gavin Collis, Department of Conservation, personal commutations. 5th June

2012), during which time many four wheel drive tracks were installed throughout the valley system. Most of these tracks are still serviceable and were utilised throughout this study.

The weather was fine 10/13 days with intermitted frosts and overcast nights, however during the weekend of the 14th – 15th July, 156 mm of heavy rain fell, making rivers un-crossable, bringing large trees down and causing bodies of water to pool in low laying areas for the period between the 14th – 18th July.

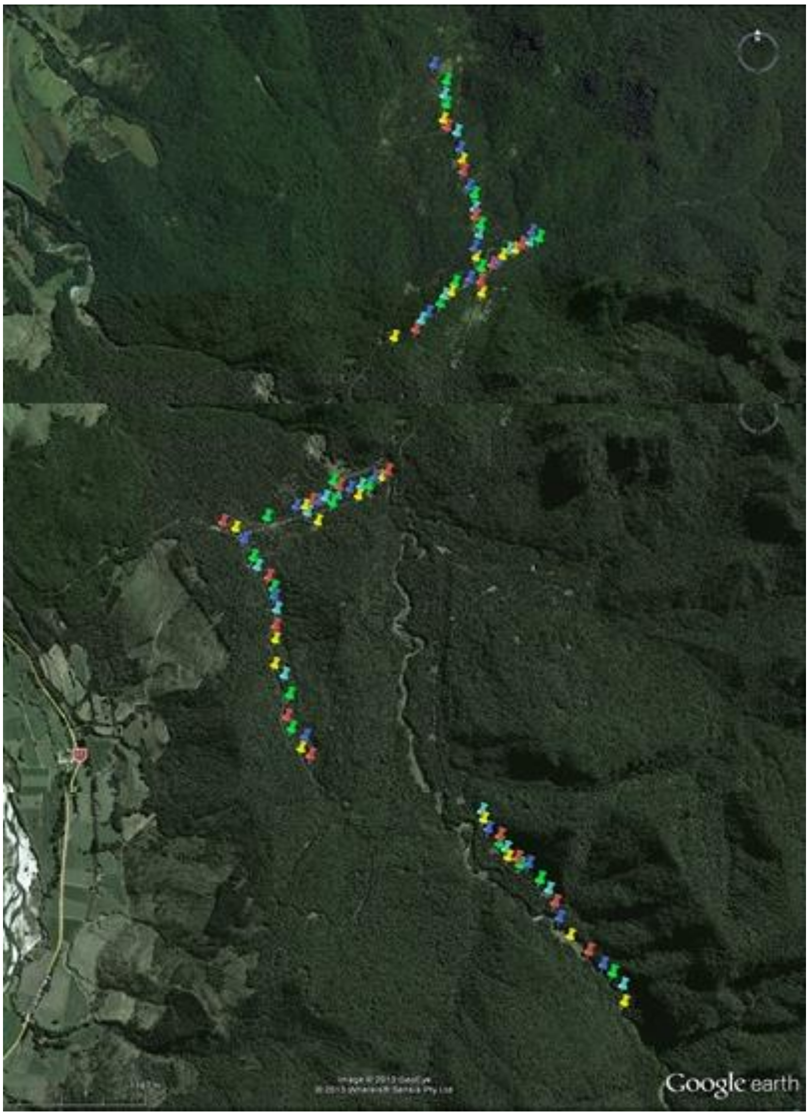

Figure 2.10: Station Creek, located off State Highway 65, Southeast of Maruia township. Coloured pins indicate locations of overnight device placement (red = Colour, green = shape, light blue = size, dark blue = material and yellow = landscape position). Weather and flooded rivers prevented a continuous strip of overlapping locations being employed, instead, accessible tracks determined nightly design placement. Maps courtesy of Google earth. Scale bar on the bottom left corner is 1182 m

2.5.2 **Westland**

The Taipo River is a large river that flows westwards from the main divide into the Taramakau River, entering just south of the Bald Range (Figure 2.11). Wide river terraces with regenerating mixed podocarpus (*Podocacarpus totara, Prumnopitys ferruginea, Dacryduim cupressium*) forest comprised the majority of the vegetation, although smaller patches of mature Kanuka (*Kunzea ericoides*) stands dotted the river flats.

Figure 2.11: The Taipo River study site is indicated by the coloured pins on the map above, squeezed between the Bald, Kelly and the Campbell ranges are productive river flats were the devices were positioned. State Highway 73 connects the east and west coasts together through Canterbury and Westland. Maps courtesy of Google earth, scale bar on the bottom left corner is 9.81 km.

Historically, high possum populations have been recorded within the Taipo River and there is no evidence to doubt that possum densities have decreased to low levels (DOC pesticide summary 2012; Animal Health Board - TB disease control area map 2012-2013). The weather during the study period was generally clear with little rainfall and few heavy frosts. There were gale force winds for three consecutive nights (30th July – 3rd August) which could have potentially impacted on possum foraging behaviour.

Like the previous research conducted at Station Creek, each experiment was positioned 50 meters apart and the lines of devices moved daily. Device position placement started from the top of the valley, working down the river flats. The placement of all devices was determined by the support trees available for both device and camera placement, this was normally on or just within the forest edge margin (as seen below in Figure 2.12). Colour trials (seen below as red pins) were stopped after one night as the coloured Waxtags® were not deemed as attractive as the food-based trials.

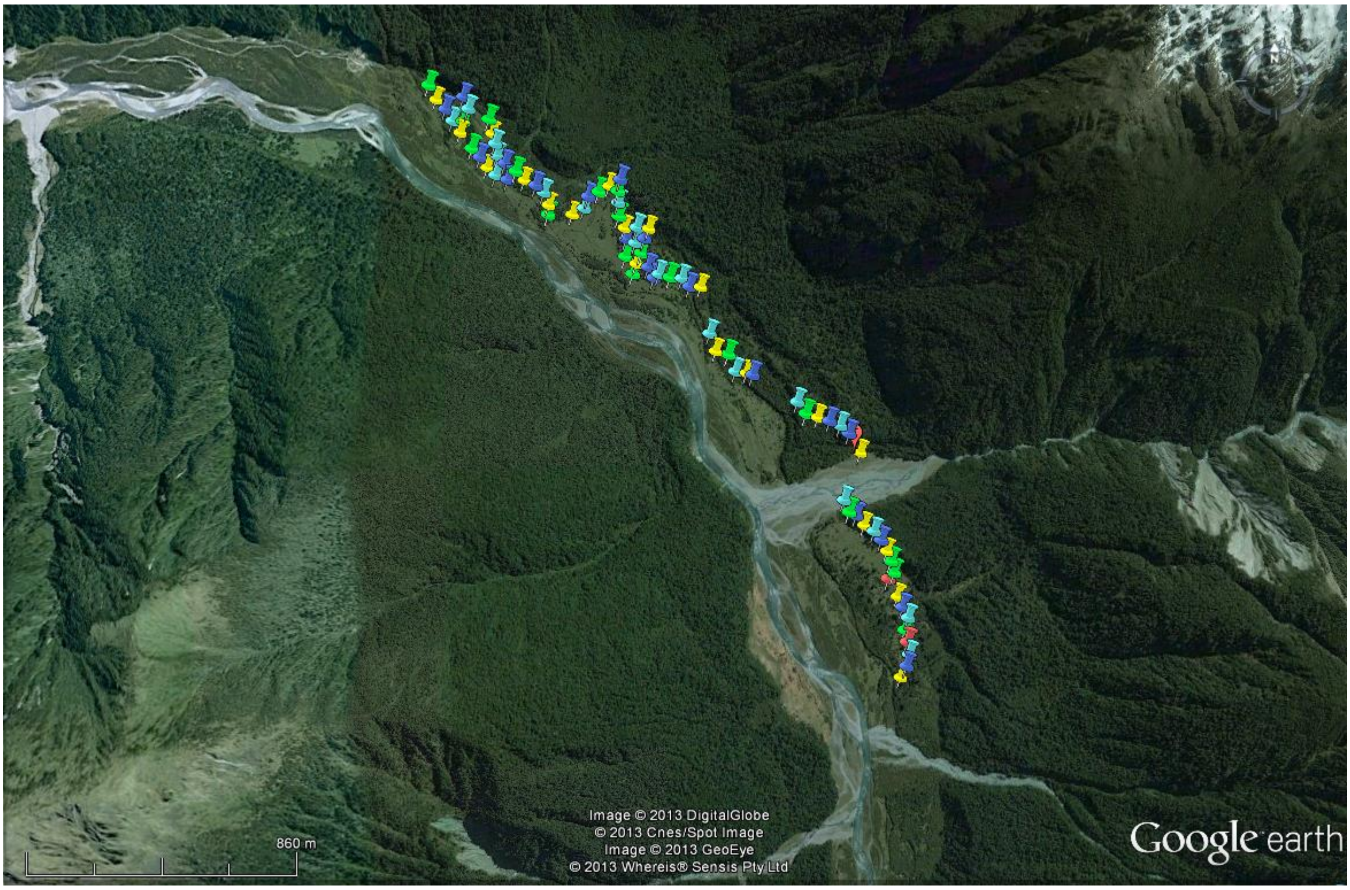

Figure 2.12: Device locations down the Taipo River flats, each pin represent the position of an overnight experiment while the colours are which type of test was undertaking at that specific site (red = colour, green = shape, light blue = size, dark blue = material and yellow = landscape position). Maps courtesy of Google earth, scale bar on the bottom left corner is 860 m.

2.5.3 **Analyses of field research**

Due to the high non-target bait removal and very low possum interactions recorded throughout both study sites, the resulting possum preference data collected during field research was not formally analysed; however, non-target interactions and possum behaviour around devices were recorded and kept for observation purposes and is commented on in Chapter Six.

Chapter 3

Possum preference testing

3.1 Colour attractiveness results

Twenty eight of the thirty possums interacted with the coloured WaxTags®. Of these animals, 50% (14 individuals) interacted with Black Waxtags® first (Figure 3.1). Of the remaining 14 possums, one individual did not investigate any further Waxtags® and was subsequently removed from the data set for consistency. For the other 13 possums their second choice preference was analysed, providing more weight that their first test choice was indeed an expressed preference. For the second choice, Black was still the most preferred, with eight (62%) choosing Black as their second preference. Only three (23%) interacted with White, two (15%) Blue, and no possums interacted with the Yellow Waxtags® for their second preference choice.

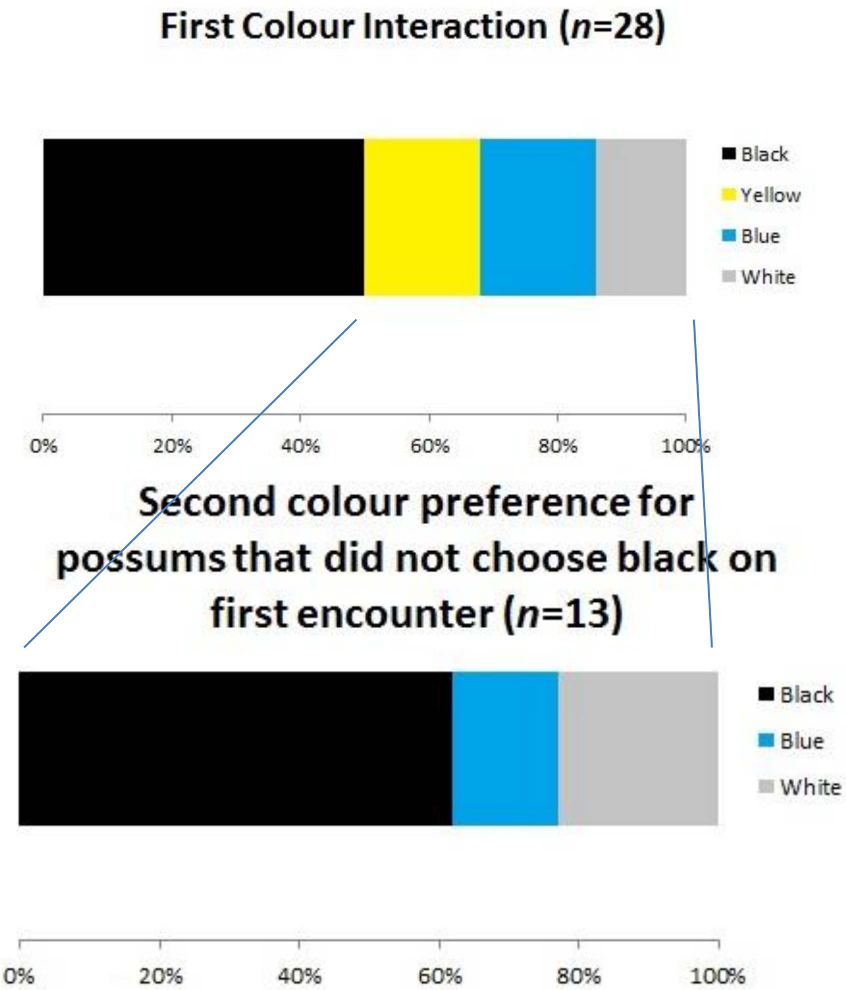

Figure 3.1: Possum first and second choice preferences towards coloured WaxTags®. *Note*: sample size changes as possums that chose black at first preference were then removed from the second graph.

The statistical model with the highest weighting was the null (colour) model with an Akaike weighting of 82% (Table 3.1). However, there is also some weighting (although much reduced) for the models including the main effects of Bodyweight (BW) and Gender (Sex). The effects of these two variables are seen in Figure 4.3 below.

Note: in Table 3.1 and following Tables, Bodyweight is referred to as BW, **+** equals combination of factors, **:** equals an interaction between the variables. AICc = Akaike Information Criterion corrected for small samples. *N*= number of parameters in the model and the Akaike Weight (Burnham and Anderson 1998) of a model is exp(-1/2 * Delta QAICc) divided by the sum of this quantity for all models.

Table 3.1. Akaike's first order information criterion (AIC_c) of a set of candidate models used to estimate the effect (magnitude) of the given variables and their precision towards possum preference towards colour (n=28)

Model	AIC_C	ΔAIC_C	Akaike weight	*N*	Deviance
Colour	73.3	0	82%	4	67.3
Colour + BW	77.8	4.5	9%	7	65.8
Colour + Sex	77.9	4.6	8%	7	65.9
Colour + Sex : BW	82.4	9.2	1%	10	64.6
Colour + Sex + BW	82.6	9.4	1%	10	64.4
Colour + Sex + BW + Sex : BW	87.2	13.9	0%	13	63.2

Both sexes expressed the same selections preferences over the four colour choices offered (Figure 3.2), with the colour Black the preferred colour for both sexes (male *n*=8/16 and female *n*=6/12). Blue and Yellow was chosen at relatively the same numbers between them, although their attractiveness was much less when compared to the colour black. White was the least attractive with only 4/28 possums interacting with white WaxTags® at their first interaction.

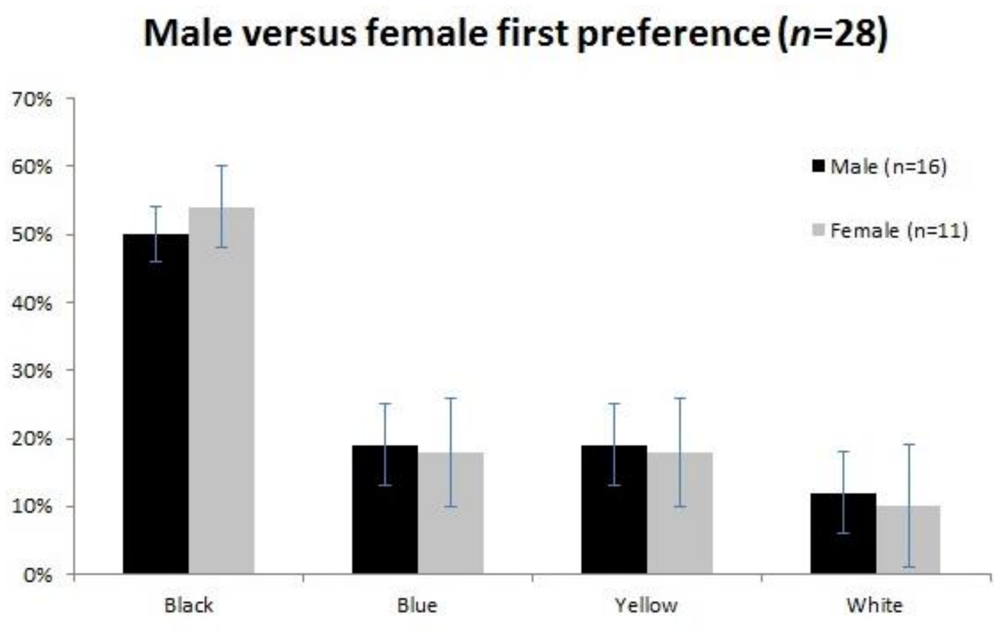

Figure 3.2: Colour preference in percentage of first interactions ± SEM, with black the most preferred colour for both sexes (*n*=28).

Bodyweight was not a factor in the colour Black becoming the preferred first choice. Both light weight (< 2.49 kg) and heavy (>2.5 kg) male and female possums interacted with black at higher percentages than any other colour. Lighter weight females (<2.49 kg) did not show a major preference between Black, Blue or Yellow (Figure 3.3).

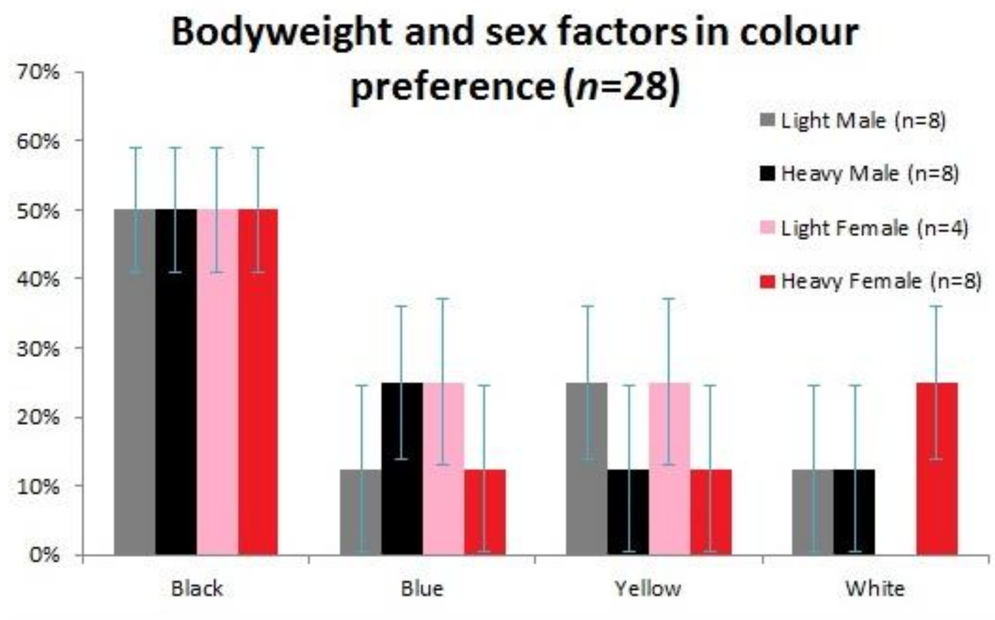

Figure 3.3: Bodyweight and sex as factors colour preference (n=28) ± SEM. Heavy individuals < 2.5 kg while light individuals are > 2.49 kg.

3.1.1 **Colour attractiveness discussion**

This experiment suggests that possums expressed a colour preference towards the Black Waxtag® (50%, *n*=28). This result is surprising considering the vast majority of previous literature suggests that 'lighter' colours, such as White, are the preferred choice for possums (Carey *et* al., 1997; Warburton and Yockney, 2000). The reasons behind the previous results and this thesis is unknown, but could possibly be related to 'lighter' colours being more easily found in the field compared to an outdoor enclosure colour choice test. Possible explanations could also include that some possums have previously been exposed to White control devices in the form of bait stations and may have received a sub-lethal dose of a toxin, thus making the colour White unattractive. It has been widely publicised that possums that received a sub-lethal dose of toxin, can become 'bait-shy', correlating subsequent illness with the ingested bait or station in which the bait was found (Ross *et* al., 1997). However, this explanation is unlikely to be relevant in this research due to all the possums being caught in areas where toxins had not been are not applied for many years, if at all (Clem Small, Clem Small Contracting, personal communication, 2012). Another theory behind Black being the most attractive colour could be related to the contrast specific colours had on the wooden experimental backing board, for example; Black might have stood out against the wood over the other colours or white wax of the Waxtag® potentially increasing the first off encounter rate.

In conclusion, both sexes interacted with the Black coloured WaxTags® at higher percentages than any other colour. It was found male possums found the Black Waxtags® more attractive irrespective of weight, followed by Blue for heavy males and Yellow for lighter weighted males. Female possums also preferred Black over the other colours. Heavy females interacted with White as their second choice and light-weighted females interacted with Blue and Yellow after the preferred Black.

3.2 Entrance geometry preference results

Again 28 of 30 individually-penned possums interacted with the experimental shape devices. Twenty six were animals previously used in the colour trials, while four animals had not been exposed to any previous experiments. It was not considered likely that the colour preference trial would create any bias in the shape preference trial. For these 28 animals, 50% choose the Square shape as their first preference, followed by the Key shape (25%), Diamond (15%) and the Triangle shape (10%) (Figure 3.4).

For the 14 possums that didn't initially interact with the Square shape their second choice preference was Square (*n*=5), Key (*n*=4), the Triangle (n=3) with only one possum interacting with the Diamond shaped device. The remaining individual did not interact with any of the devices.

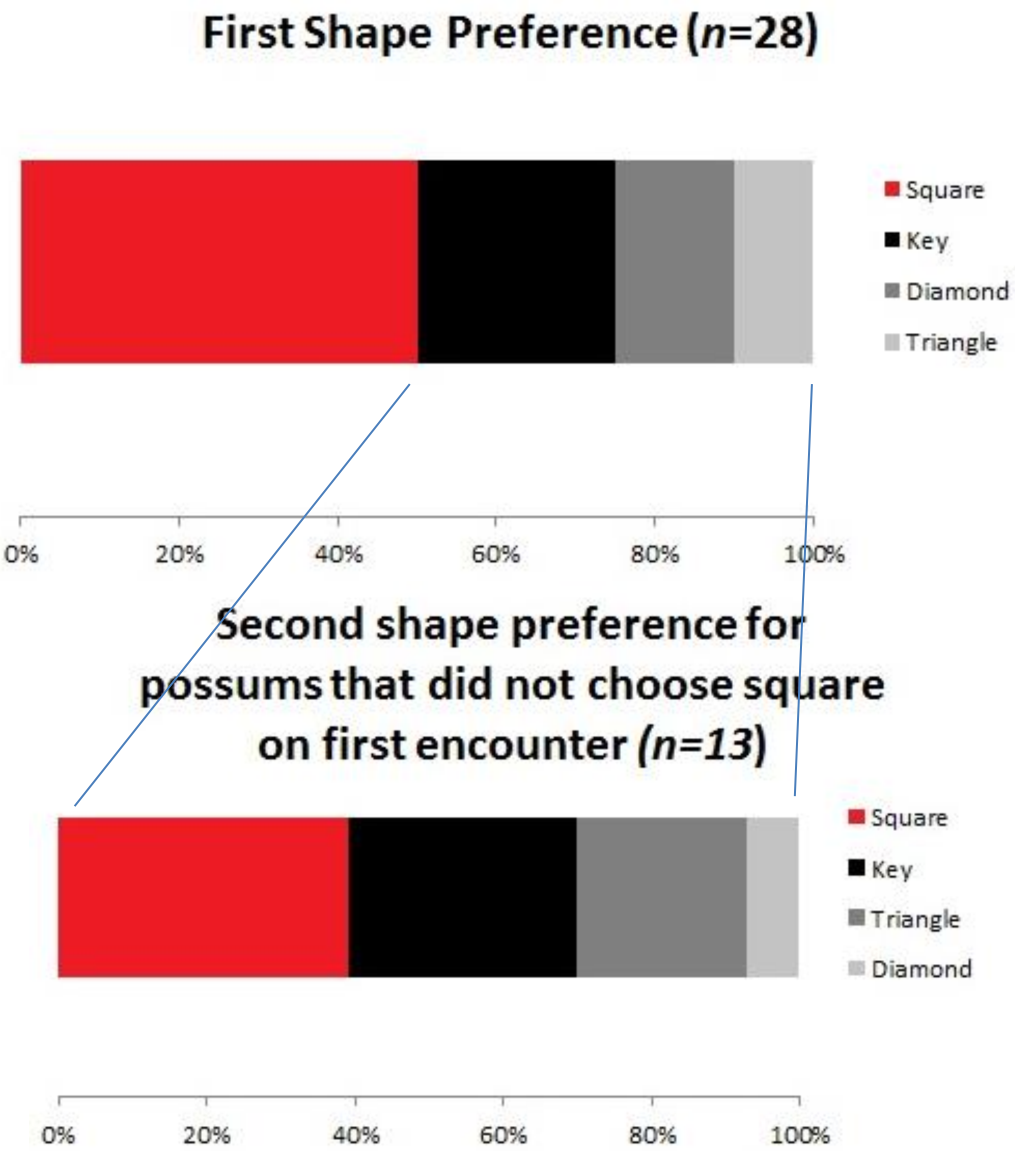

Figure 3.4: Possum first and second choice preferences towards novel shapes. *Note*: sample size changes as possums that chose square at first preference were then removed from the second graph.

The AIC results in Table 3.2 indicate that the entrance shape is the best statistical model given the complete set of six candidate models with an Akaike weighting of 53%. However, Shape + Sex, which includes the additional variable for bodyweight, also ranks high. Indeed, Shape + Sex has a ΔAIC_C of only 1.2 and an Akaike weight of 29%. This result indicates a relatively high amount of uncertainty regarding the best model as both models are likely (although not equal) candidates. The other models in the set of candidates are very unlikely (i.e ΔAIC_C <4). This reveals a common problem; when no single model is clearly the best and one cannot base all predications on the model ranked in first place.

Table 3.2: Akaike's first order information criterion (AIC_c) of candidate models used to estimate possum preference towards shape within a four way cafeteria test. A total of 28 observations were analysed.

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Shape	73.3	0	53%	4	67.8
Shape + Sex	74.5	1.2	29%	7	62.5
Shape + BW	77.8	4.5	6%	7	66.6
Shape + Sex + BW	78.7	4.9	5%	10	60.7
Shape + Sex : BW	77.9	4.1	7%	10	59.9
Shape + Sex + BW + Sex : BW	80.7	9.9	0%	13	56.7

The influence of gender is demonstrated in Figure 3.5, with the females more like to interact with the Square shape and the males more likely to interact with the Key Shape.

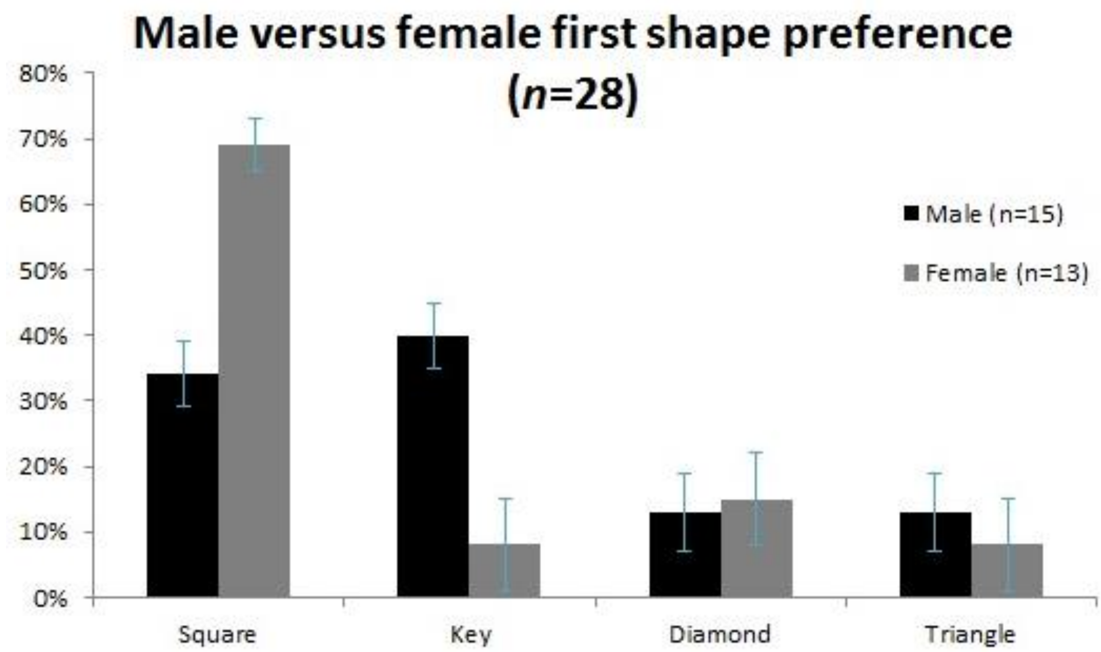

Figure 3.5: Sex preferences towards novel shapes (*n*=28); ± SEM.

When incorporating bodyweight (Figure 3.6), heavier possums and lighter females showing a slight preference for the Square design (40% and 60% respectively). Lighter males displayed a preference (60%) for Key shape over all other designs.

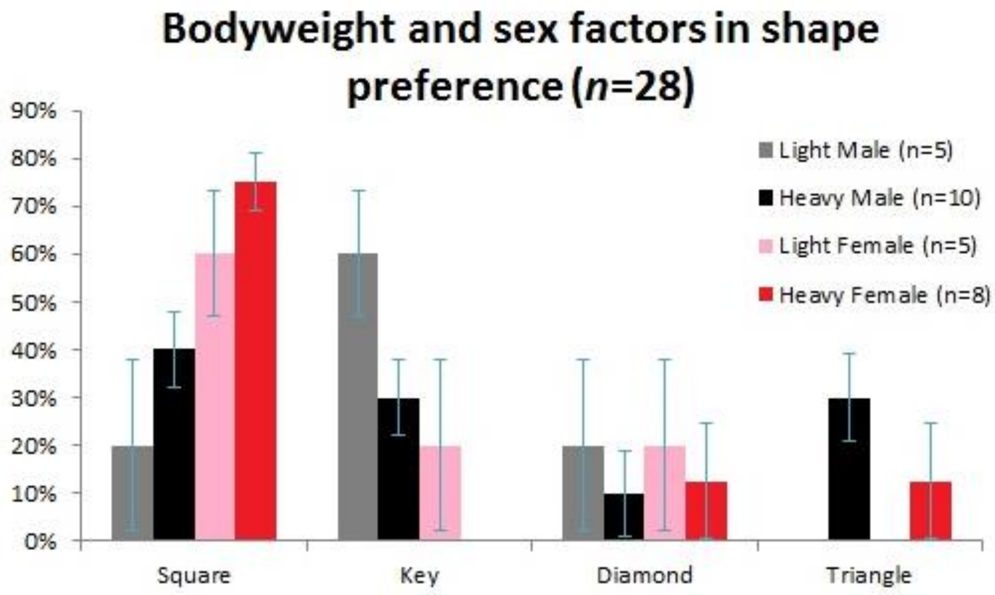

Figure 3.6: Bodyweight and sex as factors in shape preference (n=28); ± SEM, ironically the graph also denotes preference towards larger sized openings with the larger entranceways going from left to right.

3.2.1 Entrance geometry preference discussion

The results indicate that possums had a strong preference for devices with a Square entrance, with 50% of all first-off interactions (*n*=28) selecting the Square shape, followed by the Key shape (25%). Both of these shapes have a more ‘open’ design, allowing possums to place their front limbs on the edge of the shape openings. Females (both heavy and light) interacted with the Square design at much higher frequencies than any other shape, while males were spilt between the Square and Key shapes.

During this research, it was observed that possums that could position their forelimbs in close proximity to their heads while investigating and removing baits (like resting on the entrance lip of the Square shape), expressed shorter investigation times over the other shapes of Triangle or Key, designs in which individuals steadied their heads with forelimbs on the outside of devices. This behaviour could be related to the confidence the possum perceives it gains because of their ability to quickly push themselves out of the device with their forelimbs if in danger, or if the possum experiences a sudden loss of confidence while investigating the device. Possums are arboreal animals that rely on their forelimb strength to climb trees for resource gathering (Clout & Ericksen, 2000), to utilise this behaviour and perceived possum strength, a trap that incorporates a platform or walls for possums to rest or grip their forelimbs close to their head while they investigate a device, could have positive effects such as increasing confidence/stability and ease of access.

The Diamond and Triangle shapes were less preferred designs (however, this could also be from the smaller entranceways of these two shapes compared with the wider Square and Key shapes), maybe due to the potential restricted space inside the devices and it was found that in many cases, the possums head was, or did, touch the sides of those shapes. It could have been that after the individuals' first or second interaction with an 'open' device, their confidence grew and individuals were unconcerned whether their heads or necks touched the sides of novel devices that were tighter around the head area. It seems unwise for any animal to position its head in a novel device that has its vital body parts (i.e. head and neck) exposed. Therefore, it is hypothesised that a more open device like the Square shape, may well result in increased possum investigation.

3.3 Trap size entrance opening results

All of the individually-penned possums (*n*=30) interacted with entrance openings which had been baited with food. Twenty four possums were exposed to previous colour or shape trials while six were naïve animals. It was not considered likely that the two previous trials would create any bias in the size preference trial. The Large (120 mm diameter circular hole) was the most chosen opening size with 15 possums (50%) entering, followed by Medium (100 mm) with six (20%) possums. The two smaller diameter holes (Small and Tight, 80 & 70 mm respectively) had only 16% and 13% interaction rates (Figure 3.7).

Of the 15 possums that did not interact with the Large-sized diameter on first encounter, 47% then showed a preference towards the Large-sized entrance openings in their second choice, while the Medium and Small sizes both attracted 20% of the secondary preference choices, and the Tight size only had two interactions (13%).

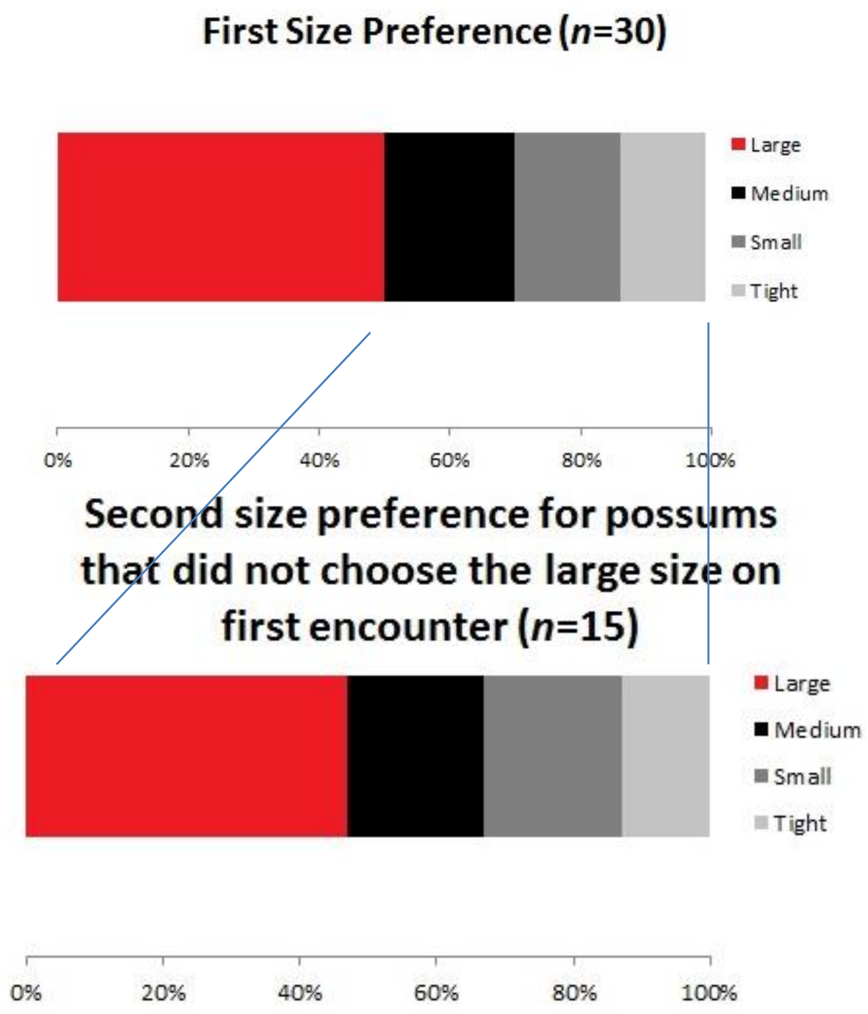

Figure 3.7: First and second possum preference for various sized entrance openings ranging from 70 – 120 mm baited with quarter carrot (*n*=30). Note: sample size changes as possums chose Large at first preference were then removed from the second graph.

The best statistical model had both entrance Size and Bodyweight as explanatory variables, with an Akaike weighting 62%, compared with the next model (Null Size model) at 18% (Table 3.3). Bodyweight was a factor in three out of four top models, even with the reducing ΔAIC_c results.

Table 3.3: Set of candidate models (AIC_c) used to estimate possum preference towards size in a four way cafeteria test, 30 observations were analysed.

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Size + BW	77.7	0	62%	7	65.7
Size	80.1	2.4	18%	4	74.1
Size + Sex : BW	81.6	3.9	9%	10	63.6
Size + Sex + BW	81.8	4.1	8%	10	63.8
Size + Sex	84.2	6.4	2%	7	72.2
Size + Sex + BW + Sex : BW	87.0	9.3	1%	13	63.0

There was little gender variation between the preference choices (Figure 3.8). Both male and female possums interacted with the large entrances at higher frequencies than any other entranceway size. A female and male aversion (or more likely distrust or lack of confidence entering) to smaller entranceways is clearly indicated by their frequency of interactions at the different sizes (Figure 3.8).

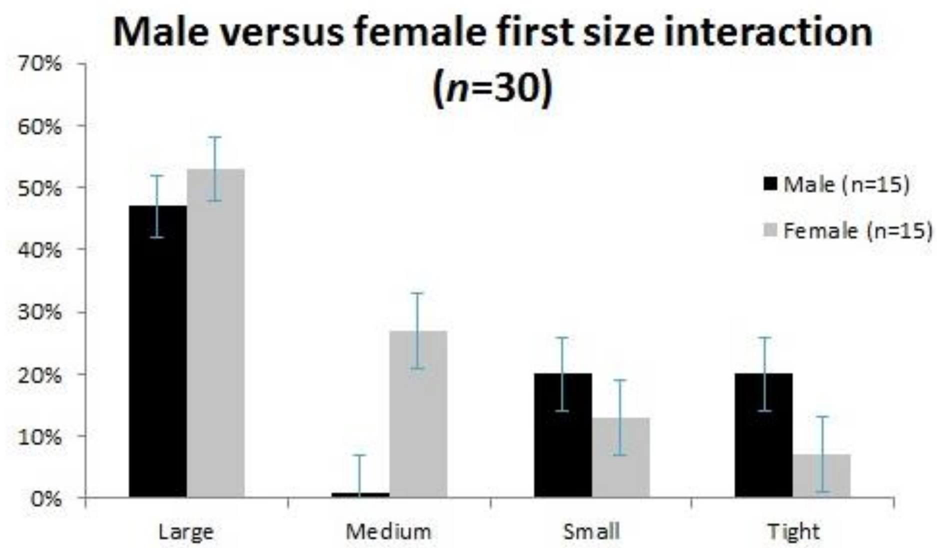

Figure 3.8: Sex preferences towards entrance way sizes (*n*=30); ± SEM.

There was certainly a correlation between an individual's bodyweight and entrance size preference (Figure 3.9), Heavier-weighted possums (>2.5 kg) interacted with the large sized entrances at higher frequencies than any other devices. The small sample sizes of the lighter possums makes it harder to depict the true meaning of lighter (<2.49 kg) animals.

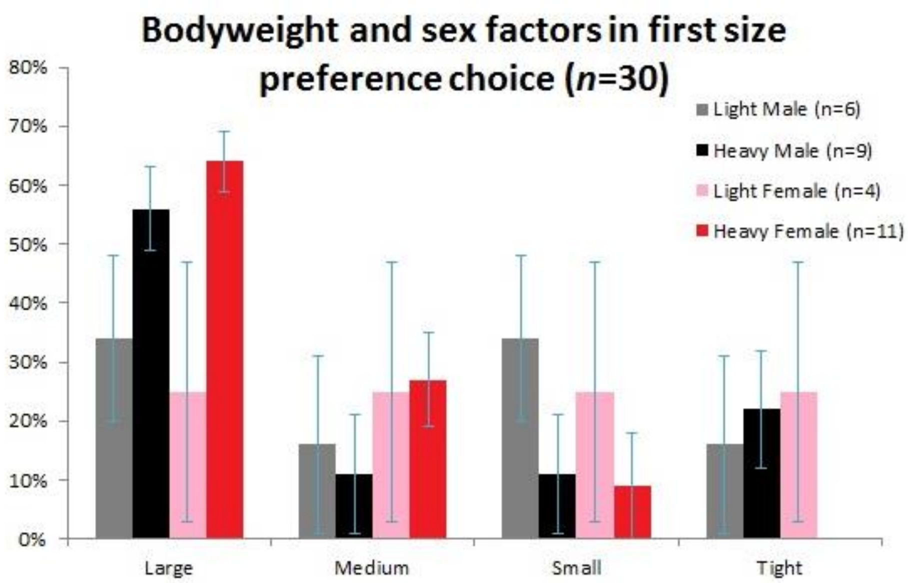

Figure 3.9: Bodyweight and sex were variables in entrance size selection (n=30); ± SEM

3.3.1 **Trap size entrance opening Discussion**

Overall, possums expressed a strong desire to interact with Large-sized entrance opening (120mm) the smaller holes (100, 80 or 70mm), with 50% of the first interactions (*n*=30) recorded for the Large opening. These results confirms the shape hypothesis (see Chapter 1.5.4) which stated that possums would have more confidence with open, larger device entranceways. By incorporating these preferred behaviours into future kill traps, this information could potentially lead to increased interactions between possums and control devices and potentially reduce non-target trap interactions, thus reducing the number of devices needed per hectare (maintenance control) or increase harvest rates (in both eradiation or rapid-knockdown operations).

Both the first and second choice preferences showed a strong preference for the larger entranceway opening. The AIC values (Akaike weight 62%) from the set of candidate models indicated a major influence of bodyweight and this is depicted in Figure 4.10. As possums increased in weight, the chances of them interacting with smaller holes decreased (Table 3.3). Although the small sized device (80 mm diameter) had a highest percentage of interaction probability for possums weighting < 1.5 kg, the attractiveness quickly reduced and was only 13% for animals weighting 2 - 2.5 kg. As previously mentioned in the introduction (Table 1.9), possum mean bodyweight and head length increases with as the latitude moves south. Triggs (1982) found possums caught and measured at Silverdale (30 km north of Auckland) had a male mean head length of 89 mm, whereas Clout (n.d) reported male mean head length of 96 mm at Mt Misery (Nelson Lakes National Park). Therefore, if control devices are to be manufactured and deployed throughout New Zealand for pest operations, a larger entrance size of between 110 – 120 mm diameter is recommended.

Female possums interacted with the Large-sized holes at higher frequencies than with smaller holes. Surprisingly, not all male possums demonstrated this trend (Figure 3.9), with two_heavier male possums (2.57 and 2.65 kg respectively) investigating the smallest hole. It is unknown why this occurred as the hypotheses predicted that the larger the possums the more inclined to investigate larger holes in order to fit their bigger heads. It is assumed that possums weighing ~2.5 kg (as these two individuals were), might not have development a fully grown skull as larger possums (> 3 kg) struggled to retrieve baits inside the smallest (70 mm) hole. The results also confirm that some possums, no matter how large, will investigate even the smallest holes for food and this has implications concerning high possum densities and native hole nesting birds. Possums are widely known to predate on native hole nesting birds like kaka (*Nestor meridoinalis*) and are responsible for failed nesting attempts. (Brown, Innes & Shorten, 1993; Brown, Moller & Innes, 1996; Brent Barrett, Centre Wildlife Management and Conservation Lincoln University, personal communications, 2012).

However, perhaps if control devices with larger entrances were left near hole-nesting bird nest sites then possums would be more likely to interact with the control device rather than the nest site.

The fact that most females (especially heavier or dominate females) chose devices with the larger entrance opening for investigation is useful. This information could be important for kill trap designers to understand, because to rapidly reduce or even eradicate possums from an isolated area (such as islands or bush fragments), removing the females from a population will limit and prevent the production of offspring (Cowan, 2000). Although the lighter females showed no clear preference, the sample size comparing light to heavy females is uneven (4 and 11 respectively) and as such has a low power.

3.4 Material attractiveness results

All individually-penned possums (*n*=30) interacted with the material design devices. Twenty nine possums had encountered previous colour, shape and size trials as a combination or singularity, while only one possum was naïve. It was not considered likely that the colour, shape or size preference trial would create any bias in the material preference trial as new food baits were used. The metal devices had the highest frequency of interactions with nine (30%) interacting possums, followed closely behind by Corflute and Wood with 8 possums each (27%). Plastic had the least number of interactions with sixteen percent (Figure 3.10).

Removing the possums that interacted with metal at first encounter, the remaining 21 possums still showed a preference for Metal with 48% (10 possums) removing bait from the metal devices on second interaction. This was then followed by Wood and Plastic both with four possums (19%) and then Corflute with three possum interactions (14%).

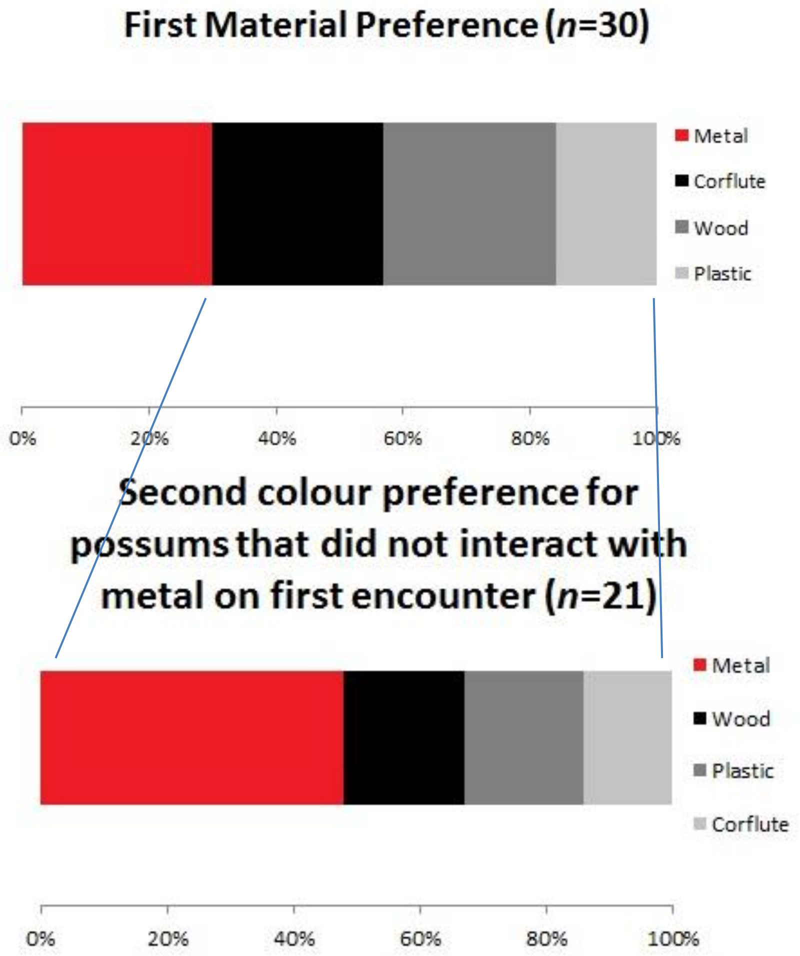

Figure 3.10: First and second possum preference towards various (*n*=30). *Note*: sample size changes as possums chose Metal at first preference were then removed from the second graph.

The Material (Null) statistical model had the strongest support with an Akaike weighting of 76%, with the remaining models reducing considerably in support. As indicated with the ΔAIC_C values, there is little correlation with animal bodyweight; however, the model with gender dose have some support with a weighting of 16% (Table 3.4).

Table 3.4: Akaike's first order information criterion (AIC_c) of the regression models of possum preference towards material. A total of 30 observations were analysed.

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Material	87.9	0	76%	4	81.9
Material + Sex	91.0	3.1	16%	7	79.0
Material + BW	93.0	5.1	6%	7	81.0
Material + Sex + BW	96.2	8.3	1%	10	78.2
Material + Sex : BW	97.1	9.2	1%	10	79.1
Material + Sex + BW + Sex : BW	99.4	11.5	0%	13	75.4

The influence of gender is displayed in Figure 3.11. With females more likely to interact with metal devices than males, whereas males interacted with Corflute devices more than females.

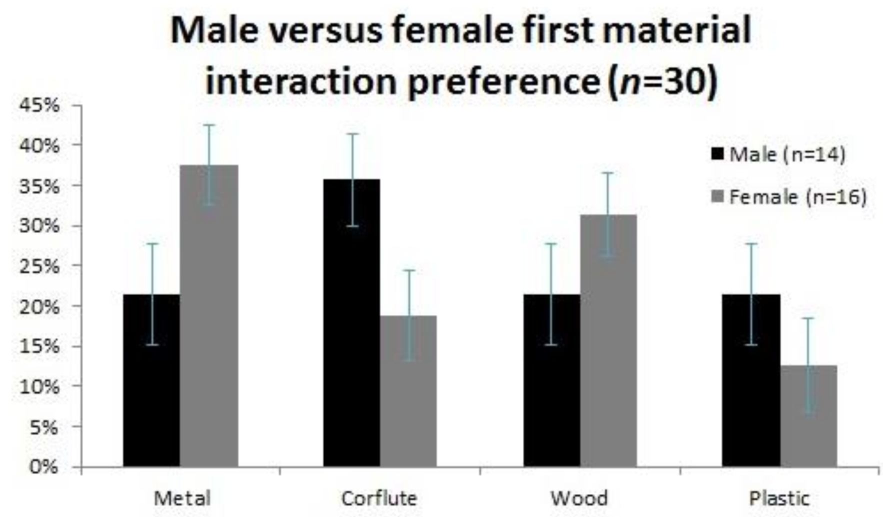

Figure 3.11: Sex preferences towards material preferences (*n*=30); ± SEM.

Looking at bodyweight, lighter males (<2.49 kg) interacted with Corflute material at higher percentages than any other possum group. Light females also showed a weak trend towards Metal devices while heavy male and females (>2.5 kg) showed no obvious preference trend between the device materials (Figure 3.12).

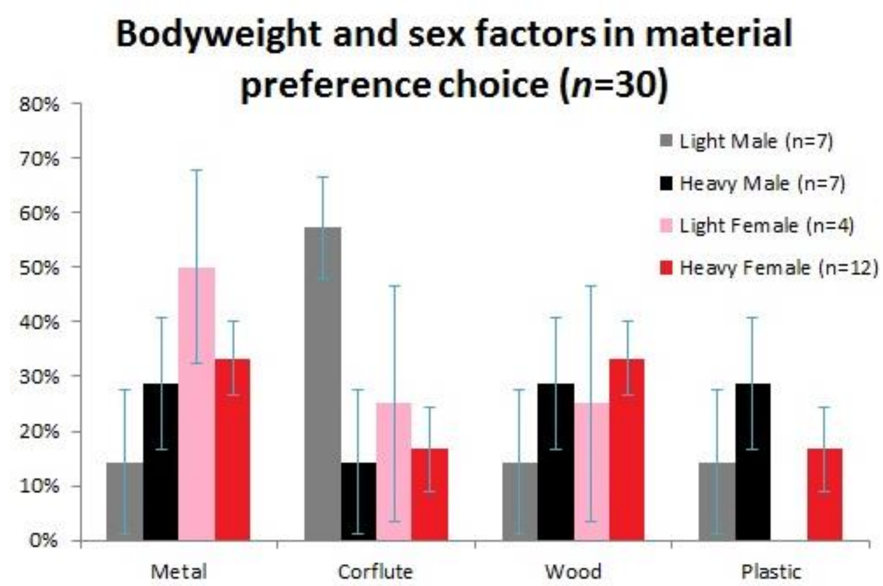

Figure 3.12: Bodyweight and sex as material choice variables (n=30); ± SEM.

3.4.1 **Material attractiveness discussion**

Possums showed a no usable preferences towards different material devices; however, this was the most challenging preference to decipher both biologically and statistically for a number of reasons. Firstly, all possums had been caught in metal live-capture traps and most likely held over a short period of time within the traps before translocation. In addition, possums would have been gassed unconscious with halophane for health check and removal of pouch young. This traumatic experience may well have caused neophobia within the study animals, as found with toxin shyness (Morgan et al., 2001; Thomas, 2005). However, no neophobia behaviour was shown by the test animals towards Metal suggesting that the traumatic experience of capture wasn't influential on subsequent behaviour.

Secondly, high acceptance of wood also raises questions regarding potential experimental bias. For example; all possums lived within an outdoors wooden enclosure while in captivity, and all the devices, not just the material cafeteria test were built from wood (because it was the easiest, cheapest and most convenient material to work with).

Thirdly, the plastic results could also have been compromised as possums daily food pellets are delivered from plastic bait stations, therefore possums are conditioned to removing bait from plastic devices. However, this potential bias was thought to be overcome by using a novel food lure.

In conclusion, it is believed that the base material for a possum trap is not a major factor when an animal is weighting up investigation or not, with possums being caught in metal leg hold traps since the 1920's (Warburton & Orchard, 1996), while plastic Timms and Henry traps are also both known to successfully killed possums (Warburton, Gregory & Morriss, 2000; Steve Hix, Connovation, personal communication, 2012). Possums have also been observed interacting with wooden DOC200 boxes (pers obs) and are known to interact with Corflute chew cards. These results confirm a lack of a clear selection preference for trap construction materials.

3.5 Landscape orientation preference results

Nearly all of the individually-penned treatment possums (*n*=29 out of 30) interacted with the baited landscape device designs. All 30 animals had been previously used in one or a combination of preference trials; however, it was thought that the length of time and new, novel food baits used would not bias the experiments. The landscape orientation design called 'Timms' was interacted with at significantly higher percentages than any other design (63 %). The 'Warrior' design followed with twenty percent, with the 'Box' and 'Henry' designs only receiving ten and three percent respectively (Figure 3.13).

As with previous trials, individuals that had interacted with the Timms design were removed, and the remaining possums were analysed for their second preference choice. This time the Timms and Box designs both had four possum percentages, the Warrior had another two animal interactions, with the Henry design only having one interaction.

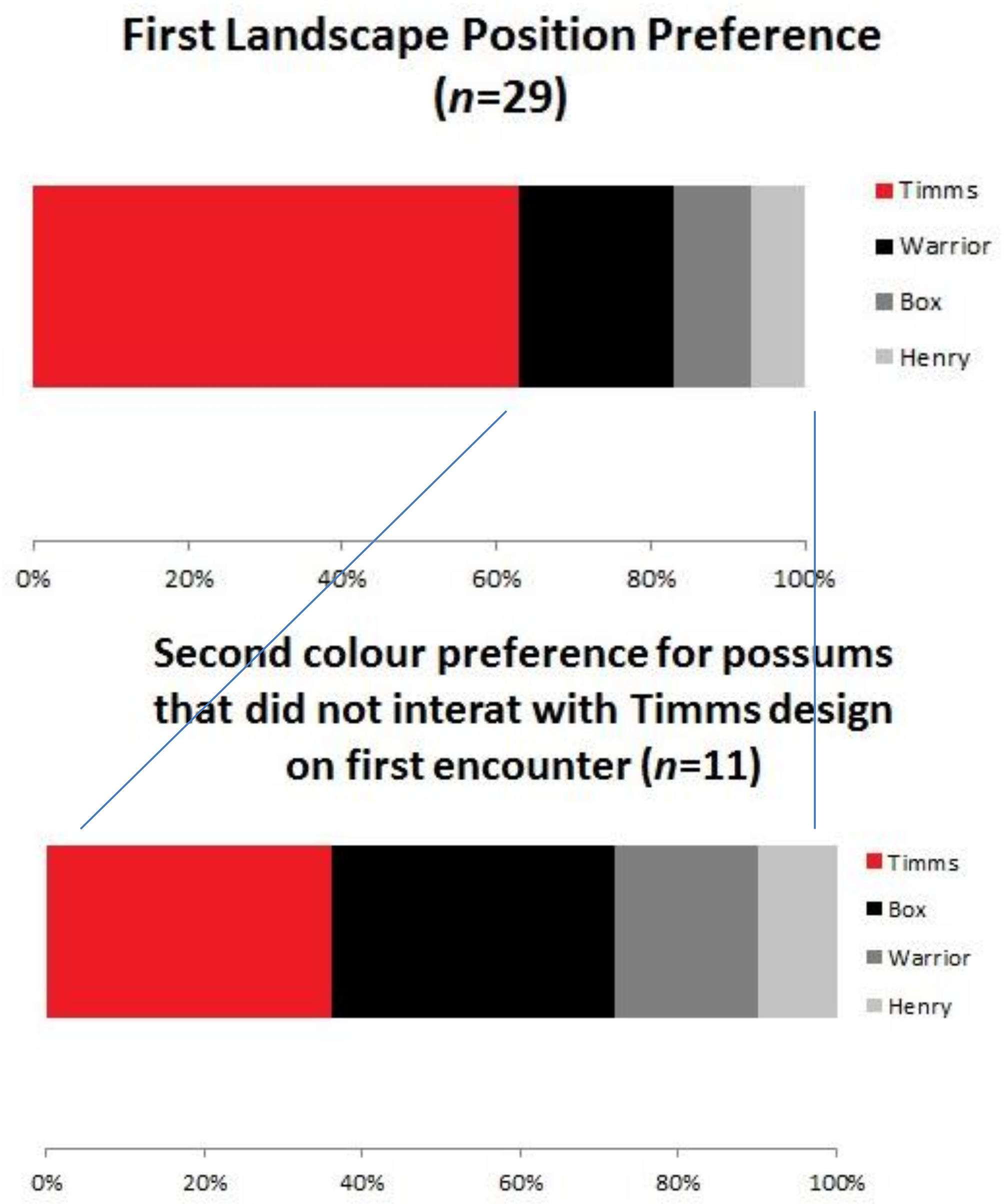

Figure 3.13: First and second preference choice of possums towards trap orientation (*n*=30). *Note*: sample size changes as possums chose Timms at first preference were then removed from the second graph (as seen in Appendix A)

Considerable support is given to the landscape(null) statistical model with a Akaike weighting of 60%. The variable 'Sex' having some support with a Akaike weighting of 27% (Table 3.5). Bodyweight did not seem to be an important factor and the models incorporating bodyweight had little support.

Table 3.5: Set of candidate models (AIC_c) analysed to estimate possum preference towards trap orientation within the landscape in a four way cafeteria test, 30 observations were analysed.

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Landscape	66.4	0	60%	4	60.4
Landscape + Sex	68.0	1.6	27%	7	56.0
Landscape + BW	70.8	4.4	7%	7	58.8
Landscape + Sex : BW	71.9	5.5	4%	10	53.9
Landscape + Sex + BW	72.5	6.1	3%	10	54.5
Landscape + Sex + BW + Sex : BW	75.9	9.5	1%	13	51.9

Both possum sexes showed a strong preference towards to the Timms landscape position (Figure 3.14), with significantly more interactions occurring; however, slightly more females interacted with the Warrior and Box designs.

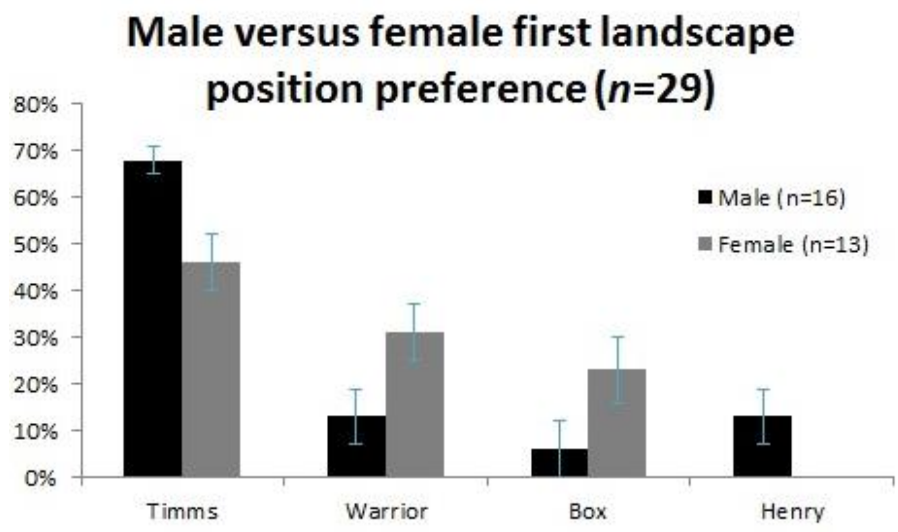

Figure 3.14: Sex preferences towards novel shapes (*n*=28); ± SEM.

There were little obvious patterns for bodyweight with the heavy female possums (> 2.5 kg) interacted with the Timms design at higher rates than any other, followed closely by the Warrior and Box devices (Figure 3.15).

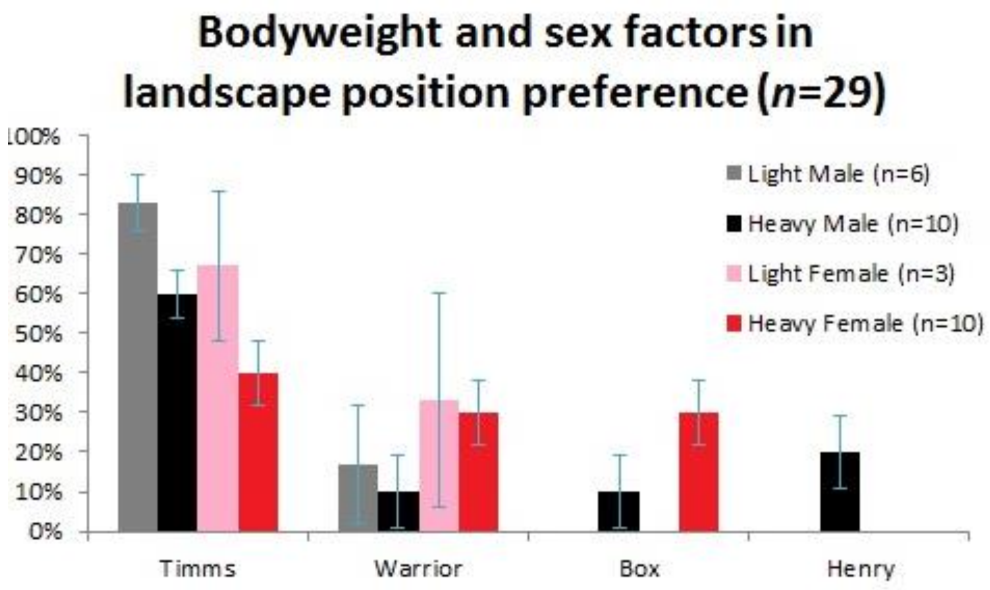

Figure 3.15: Bodyweight and sex as factors in control device landscape orientation design (n=29); ± SEM.

3.5.1 Landscape orientation preference discussion

To improve possum control in New Zealand it is important to understand how possums to interact with control devices. These results show that possums interacted with the Timms landscape device design at significanlty higher percentages than any other design. Eighteen out of the possible 29 possums interacted with the Timms design (63%), followed by the Warrior design with six (20%) possums. Both of these designs are 'open', meaning they require little effort to investigate as the bait can be visually observed from outside of the control device, compared with the remaining designs (Box and Henry) that require more effort to reach the baits. This 'open' orientation design with a wide front facing opening is used in bait stations and the Timms trap (KLB, Palmerston North), both with good success.

The Henry design result was interesting (now known as the A12 trap by GoodNature Ltd, Wellington) with the lowest level of interactions. Its prerequisite mode of investigation of making possums lift their head into the kill chamber, while the body remains stationary on the ground did not appear attractive. Just two males (2.85 and 2.75 kg respectively) removed the bait from the Henry trap design on first encounter (7%).

As mentioned in the introduction, this thesis is not a quality control report comparing one trap to another trap. The concept of 'set and forget' traps is that control devices continue to work over extended time periods with multiple kills, and one could argue that over subsequent encounters an individual would eventually interact with a device (before the lure becomes unattractive). However, given the recent published reports commenting on possum 'walk bys' (Ball *et* al., 2005; Brown & Warburton, 2012; Sam *et* al., 2012) suggest that it can take up to 60 days to ensure a 95% chance of individual possum capture within its home range. With this evidence in mind, a simply theory concentrating on simple applied practices must be employed, that is, the animals first interaction with a control device must be its last. To achieve this, control devices need to incorporate behavioural preferences to reduce lost capture opportunities.

It is speculated that the more 'open' designs (Timms and Warrior) encourage possum investigation in three ways (Ian Domigan, Lincoln University, personal communication, 2012). Firstly, the ease of investigation and ability to undertake a quick visual assessment of the novel device and the perceived risk of removing a visible bait (i.e., the perceived risk is lower than positive food/nutrition gain). Secondly, being able to identify the exact location of the bait without extensive searching and repeatedly moving their heads side to side, and thirdly, having an open device design that a possum can maintain stability on while investigating. This could be on the ground or an object like a tree, or part of the trap, to secure itself on.

Possums are essentially opportunistic feeders that will often continue on with their feeding routine or 'walk by' a control device on their way to a favourite browsing tree or feeding site (Kerle, 2001). As such, the control devices need to be attractive and encourage interaction. Open designs that entice visual assessment are needed. Once investigating, possums then need to feel confident about interacting with the device before a capture occurs. The longer a possum investigates a baited trap, the higher the chance of that individual becoming less interested, and subsequently leaving the device, returning to their normal nightly routine.

Chapter 4

Encounter frequencies

4.1 Encounter frequency results

The average number of encounter frequencies (Figure 4.1) differed between the trials, meaning that the overall interaction rates were varied amongst the five trials. Both the size and landscape experiments had higher levels of possum participation when it came to interacting with the devices over multiple visits within a two hour period (with animals interacting with devices 8.5 - 9 times on average). This was somewhat surprising, because after their first initial investigation and interaction, the bait was removed giving the animal no further food-driven curiosity behaviour. For example, the third most interacted with device were the Waxtags® which didn't have any food-based lure to entice animal participation, the possums were simply chewing on unpalatable wax.

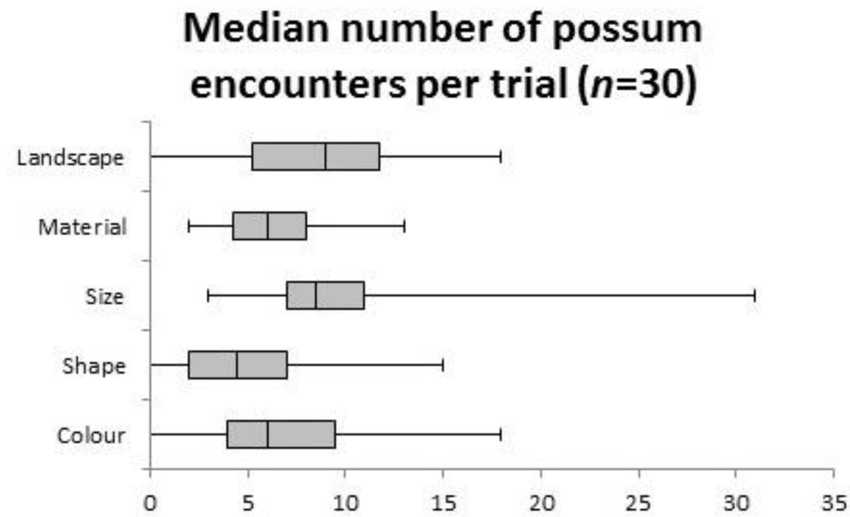

Figure 4.1: Median number of encounter frequencies for each trial (*n*=30).

4.2 Colour attractiveness encounter frequency results

The frequency of encounters within the two hour observational period for the Waxtags® were also recorded and analysed. The time started with the first interaction with the first Waxtag® (each tag bite was considered an interaction). Yellow was the colour least interacted with by possums, thereby achieving the highest proportion of animals that did not interact with the colour, while Black was the opposite, high interaction rates that related to very few 'no interactions' (i.e. no biting of Waxtags®) (Figure 4.2). A small sample (7%) of possums chewed both White and Black Waxtags® over five times within the two hour period. For transparency, the raw data are presented in the Appendix A. Black was preferred colour in the preference trials (see Chapter 3.1).

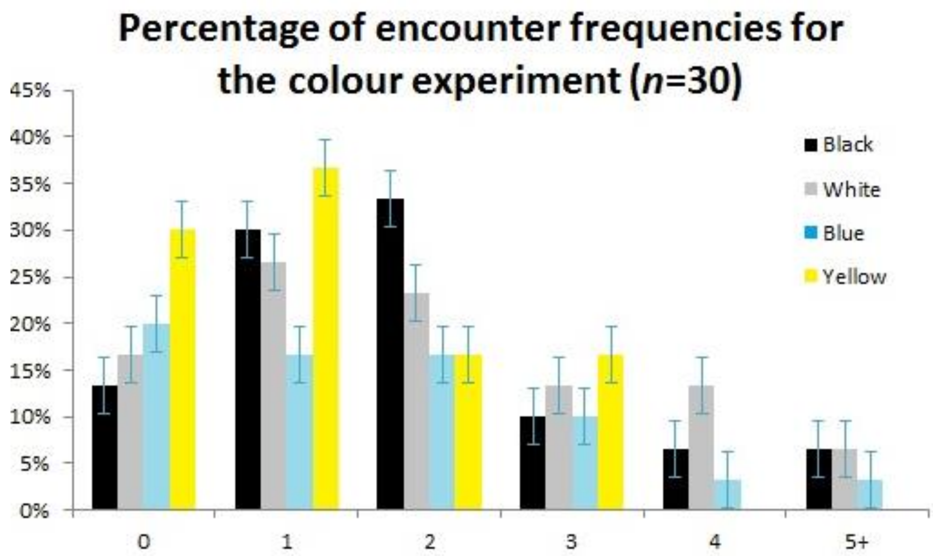

Figure 4.2: Encounter rate (in %) of the number of times possums frequented a coloured Waxtag® (*n*=30); ± SEM.

The statistical model with the highest Akaike weighting was colour plus gender at 25% weight, followed by both the Null and Colour model on 17% (Table 4.1). Colour was found as a variable in four of the top five models with bodyweight as an explanatory variable having less support. However, a relatively high amount of uncertainty regarding the best model candidate is indicated by the ΔAIC_C only amounting to 3.1. Again revealing a statistical dilemma that not one single model has greater weight that another, reducing the strength of the highest ranked model predications. The effects of the model "Colour + Sex" was not investigated further because of the relative closeness all other models indicated.

Table 4.1: Akaike's first order information criterion (AIC_c) of candidate models used to estimate possum preference towards colour within a four way cafeteria test. A total of 28 observations were analysed.

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Colour + Sex	110.3	0	25%	8	104.3
Null	111.1	0.8	17%	4	107.1
Colour	111.1	0.8	17%	4	107.1
Colour + Sex : BW	111.4	1.1	15%	12	103.4
Colour + Sex + BW	111.7	1.4	13%	12	103.7
Colour + BW	112.5	2.2	8%	8	106.5
Colour + Sex + BW + Sex : BW	113.4	3.1	6%	16	103.4

4.2.1 **Colour attractiveness encounter frequency discussion**

Black-coloured Waxtags® had the lowest percentage of zero interactions (13%), meaning that the remaining 87% of possums chewed a Black Waxtag® at least once, providing extra weight that possums do show a preference towards the colour Black. Yellow was the least attractive colour with 30% of all possums not interacting with Yellow Waxtags®, and no possums interacted with a Yellow device more than three times over the two hours.

Possums appeared to express continued favouritism for the colours of Black and White, with each of these colours being interacted with by possums four and five times (within the two hour period) at much higher rates than the other colours. For instance; 20% of individuals interacted with White Waxtags® more than 4 times and 14% of individuals that interacted with Black Waxtags® more than 4 times. Possums treated Blue with a somewhat consistent encounter rate, and although 7% of individual possums interacted with a Blue-coloured Waxtag® more than 4 times, 17% of individuals did not find blue attractive enough to even bite once. Weser and Ross (2012) found that kea (*Nestor notabilis*) preferred yellow cake cubes (over brown, red and green), as yellow was found to be the least attractive for possums yet highly attractive to kea, yellow coloured kill traps are not suitable in areas where kea are found.

Apart from this colour trial, all other experiments have food-baited devices, and one would expect that after the bait is removed, interactions would reduce. However, possums have been known to repeatedly chew the wax completely off the tags, leaving only the plastic backing (personal observation). It is thought that the behaviour that produces this continued chewing of coloured Waxtags® is more likely to be a response to boredom rather than a preference towards the wax itself (wax is not overly palatable). Although the continued interaction with a device can be seen as a boredom response, the first interaction is still clearly a subconscious choice between a four choice cafeteria test.

4.3 Entrance geometry encounter frequency results

Both the Square and Key shapes had the lowest numbers of zero interactions; this is consistent with the previous results suggesting that these two shapes are the most preferred, although it must be acknowledged that the shape size may play a role in these results . Diamond, Triangle and Square shaped designs all had a small percentage of 5+ device encounters, and it is thought that both the Diamond and Triangle designs gained this result due to the difficulty some recorded animals had still attempting to retrieve the baits (Figure 4.3). Most device encounters occurred only once, suggesting that once the food bait is removed, the devices lost their attractiveness and animals tended not to interact with devices further.

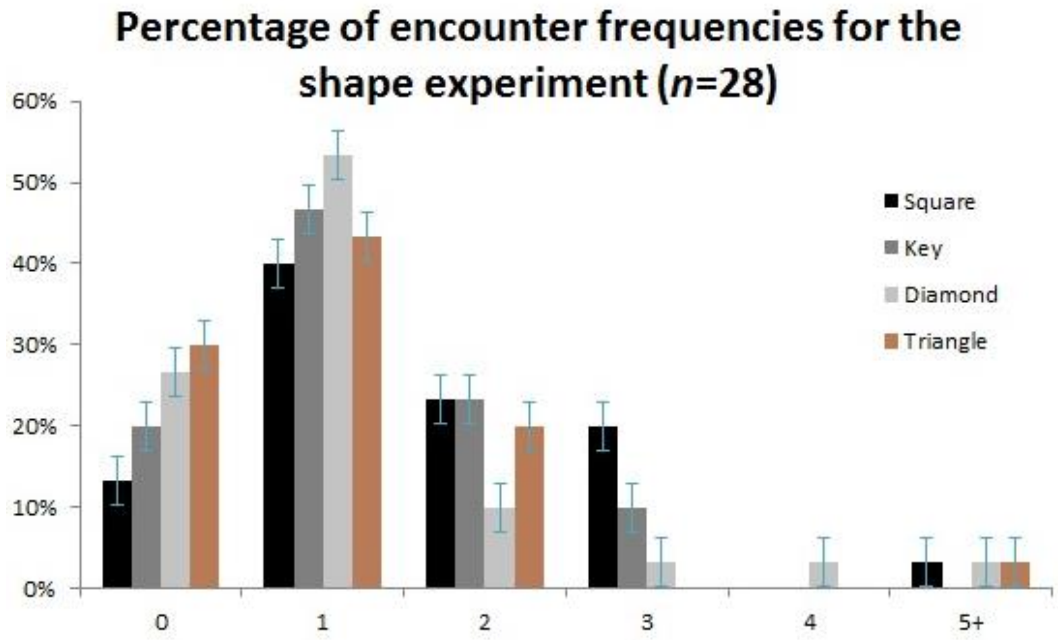

Figure 4.3: Percentage of encounter frequencies towards the different shape designs. (*n*=28); ± SEM.

The statistical model with the highest Akaike weighting included both shape and bodyweight with an Akaike weighting of 30%, with three out of the top four models also including bodyweight as an explanatory variable (Table 4.2).

Table 4.2: Akaike's first order information criterion (AIC_c) of a set of candidate models used to estimate the effect (magnitude) of the given variables and their precision towards possum preference towards shape (n=28)

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Shape + BW	132.0	0	30%	8	126.0
Null	132.5	0.5	23%	4	128.5
Shape + Sex + BW	133.8	1.8	12%	12	125.8
Shape + Sex : BW	134.0	2.0	11%	12	126.0
Shape + Sex + BW + Sex : BW	134.2	2.2	10%	16	124.2
Shape + Sex	134.4	2.4	9%	8	128.4
Shape	135.3	3.3	6%	16	125.3

Possums (both light and heavy weights) were less inclined to interact with the Triangle shape as seen by the high percentage (35%) of possums with no interactions. Heavy possums were also not interested in the Diamond shape design (35%) while lighter weight animals interacted with this shape more than their heavier counterparts. This trend reversed for the Key shape with lighter possums showing less interest than heavier animals, while few possums avoided the Square shape (Figure 4.4).

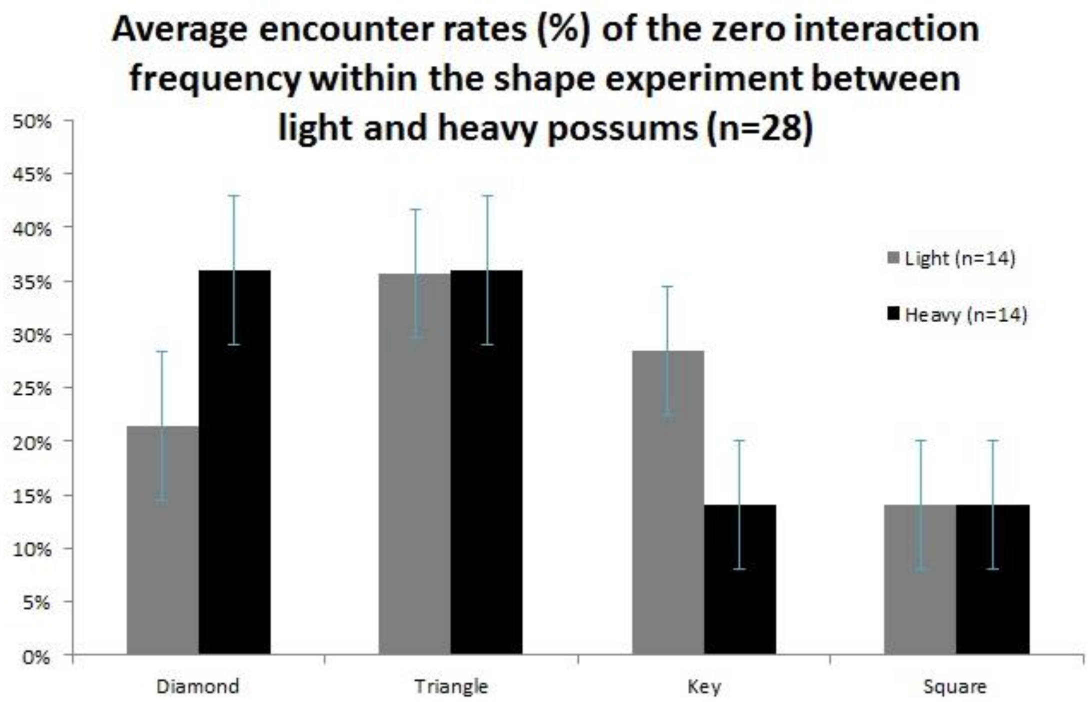

Figure 4.4: Different weighted possums and the numbers of **zero** encounters (in %), ± SEM**.**

4.3.1 **Entrance geometry encounter frequency discussion**

As was expected, the two preferred shape designs (Square and Key) had the lowest percentage of zero interactions (13% for the Square design and 20% for the Key shape), whereas the Triangle shape had 30% zero interactions, closely followed by the Diamond shape with 27%.

Shape designs that are unattractive to possums will not obtain or maintain animal interest, potentially limiting the success of a control device, producing a possum 'walk by' and thereby reducing control effectiveness. If shape designs are attractive to possums, then animals will continue to interact with the device even after the bait has been removed. For example; up to 46% of individual possums repeatedly interacted with the Square shape more than twice, followed by the Key shape with 33% possums repeating their visitations more than twice, while Diamond and Triangle shapes were not seen as attractive designs to investigate after the bait was removed (19% and 23% repetitively for encounters greater than twice).

Statistical models with bodyweight were ranked high with three out of the top four models having bodyweight as an explanatory variable. Analyses was therefore undertaken to determine whether heavy (>2.5 kg ,or dominate) possums had a choice preference that is different from light (<2.49 kg or light sub-ordinate) possums. Again the Square shape was found to be the most attractive to both heavy and light weighted possums with over 87% of the animals interacting with a Square-shaped device and had the lowest number of zero interactions. The Key design was also found to be attractive to heavy possums with 87% of individual possums interacting with it, while encounter rates are reduced by 71% for light-weight possums. The Diamond shape also provides substantial support that bodyweight as a factor in determining shape preferences, with 71% of the light-possums interacting with a Diamond-shape design, whilst only 64% of the heavy possums interacted with the same shape design.

4.4 Trap size entrance opening encounter frequency results

Almost all the possums interacted with the different size designs in this experiment (as seen with the low zero percentage in Figure 4.5); however, most of the Tight, Small and Medium designs were only interacted with once or twice compared to the Larger diameter entrance hole (120 mm) that constantly achieved multiple visits.

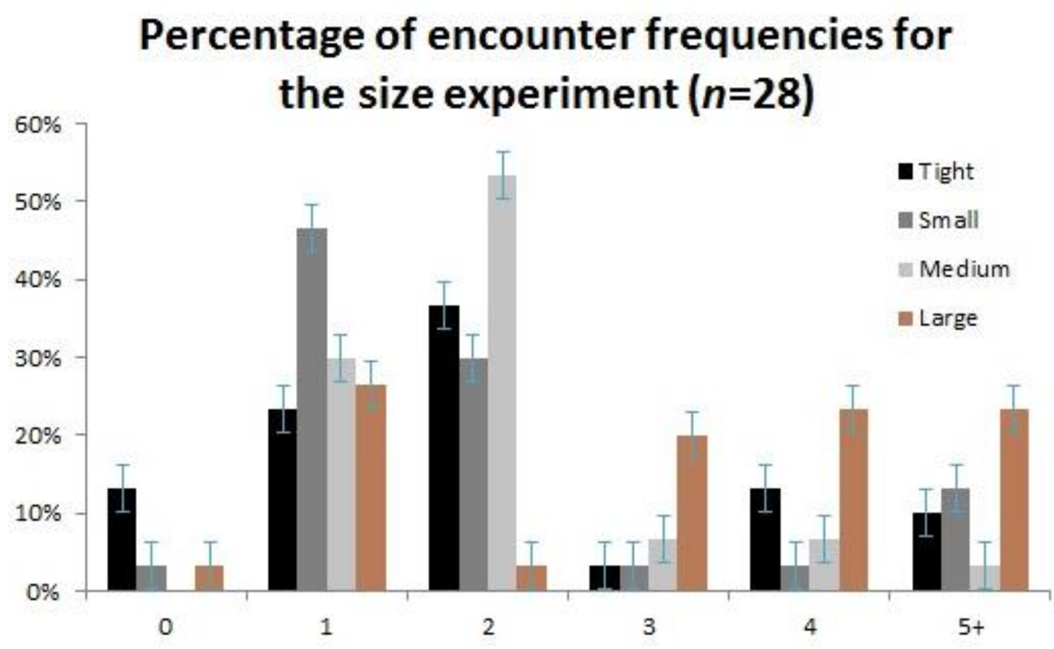

Figure 4.5: Encounter rate (in %) of the number of times possums frequented a device design (*n*=28), ± SEM.

The statistical model with the highest Akaike weighting was the null and size models (both with 31% weighting) suggesting that there is little power for the other explanatory variables. However, gender and bodyweight have some support (14% and 11% Aklaike weighting respectively). (see Table 4.3).

Table 4.3: Set of candidate models (AIC_c) analysed to estimate possum preference towards size preference in a four way cafeteria test, 30 observations were analysed.

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Null	143.5	0	31%	4	139.5
Size	143.5	0	31%	4	139.5
Size + Sex	145.1	1.6	14%	8	139.1
Size + BW	145.5	2.0	11%	8	139.5
Size + Sex : BW	147.1	3.6	5%	12	139.1
Size + Sex + BW	147.1	3.6	5%	12	139.1
Size + Sex + BW + Sex : BW	149.1	5.6	2%	16	139.1

4.4.1 Trap size entrance opening encounter frequency discussion

Larger entrance openings received the highest percentage of multiple encounters suggesting that the larger the entrance hole the more attractive the device could become for possums to put their heads in. Over 65% of the possums interacted with the Large (120 mm) diameter entrance holes over 3 times, compared to the Tight (26%), Small (19%) and Medium (17%) entrance holes.

From an animal's perspective, it may be unwise to investigate novel devices that press against an animal's head and neck, and not surprisingly, the larger entranceway holes were again expressed as the preferred devices to investigate. However, some possums continued to investigate and interact with Tight, Small and Medium-sized holes, and the behavioural rationality behind such responses are unclear (although most likely encouraged by the food lure reward, a topic which is covered later in this thesis).

4.5 Material attractiveness encounter frequency results

Nearly all of the possums interacted with each material choice; however, most designs lost their attractiveness quickly after the first possum/material interaction, in particular the Corflute. After the initial interaction with the Corflute device, animals quickly dropped off investigating Corflute devices multiple times, unlike Metal or Wood objects which possums showed considerably higher interest towards. For instance; metal and wooden device designs were investigated three times more within the two hour period by 20% and 18% of the possums respectively (Figure 4.6).

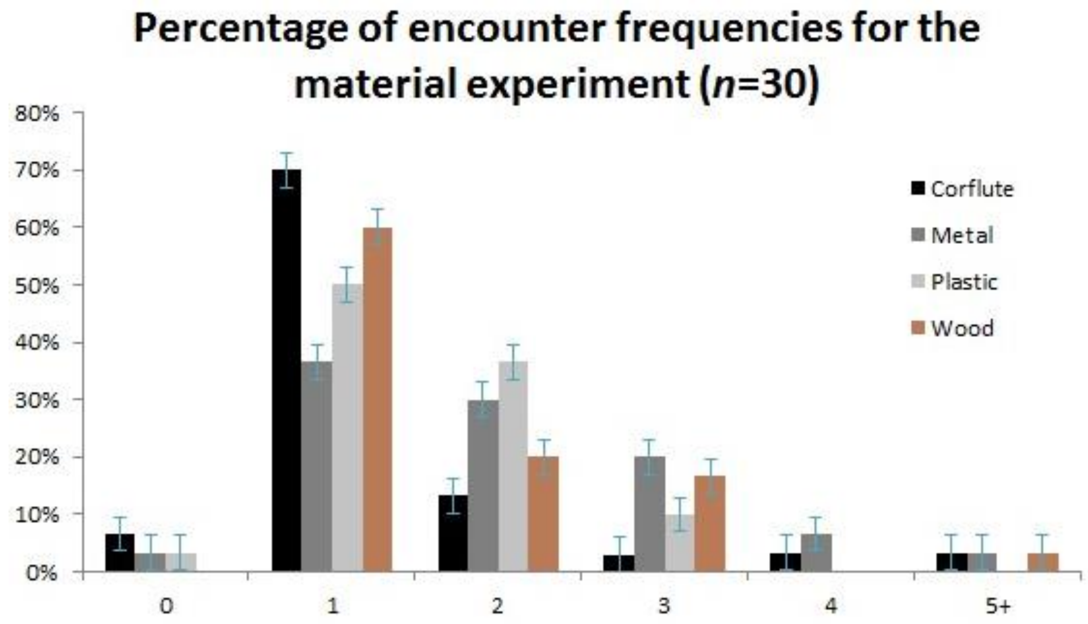

Figure 4.6: Percentage of encounter frequencies towards material devices, each shape bar adds up to 100% of all interactions for that specific material (*n*=30); ± SEM.

The statistical model with the highest Akaike weighting was the null model with an Akaike weighting of 39% suggesting that there is little support for any of the explanatory variables. Despite this material is still included in three of the top four models and the variation in the encounter frequencies is shown above (Table 4.4).

Table 4.4: Akaike's first order information criterion (AIC_c) of the regression models of possums preference towards material. A total of 30 observations were analysed.

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Null	77.29	0	39%	4	73.29
Material	78.57	1.3	20%	16	68.57
Material + BW	79.29	2.0	14%	8	73.29
Material + Sex	79.29	2.0	14%	8	73.29
Material + Sex : BW	81.29	4.0	5%	12	73.29
Material + Sex + BW	81.29	4.0	5%	12	73.29
Material + Sex + BW + Sex : BW	83.28	6.0	2%	16	73.28

4.5.1 Material attractiveness encounter frequency discussion

Almost all of the possums interacted with all the different materials with Corflute having the lowest numbers of interactions. Corflute was also the material that was most likely to only be encountered once at a value of 70% its overall interactions, this was followed by Wood on 60%, Plastic on 50% and Metal on 37%. All tested materials lose their attraction, this is shown by the animal interaction tailing off; however, some materials drop slower than others. For example; Metal tended to have a gradual decline in interactions with 37% of possums interacting once, 30% interacting twice and the remaining 30% of the possums interacted more than 3 times. While other materials failed to consistently attract the same individual to re-visit within the two-hour period.

It is not unusual to witness a tailing off in possum interest as a trial is continued (Lee Shapiro, Connovation Ltd, personal communications, 2012 James Ross, Lincoln University, personal communications, 2012). Once the bait has been removed (and the bait was removed in almost all of the possum device encounters at first interaction), there becomes little incentive for possums to further investigate; therefore, a device which has its food-based lure removed, but still remains attractive enough that possums continue to interact with, could potentially have advantages in the field. Metal is one such material that seems to receive consistent encounters without a food reward (as did Wood and Plastic, but to a much lesser extent).

As mentioned earlier, Corflute was not found to be as attractive as other material in this experiment; however, Corflute is currently being used as a non-intrusive monitoring tool for possums called 'chew-track-cards'. Chew-cards provide a cheap alternative to map very low density possum sites and also have an advantage over Waxtags® because of their higher sensitivity in detecting rodents. From these results, Corflute appears to be a suitable material for a possum monitoring tool as most animals interacted with it at high levels. Although possums did not continue to interact with Corflute devices more than once, one time is all that is needed in monitoring to confirm the present or absence of an animal.

4.6 Landscape orientation preference frequency encounter results

Both the least preferred landscape designs (Box and Henry) were only investigated once by 45% of the possums, providing further evidence that these two designs are unattractive to possums, whereas both the Timms and Warrior type designs were interacted with multiple times. For example; the Timms design was revisited four times (within the two hour period) by 23% of possums and a total of 17% of these possums interacted with this design more than five times (Figure 4.7).

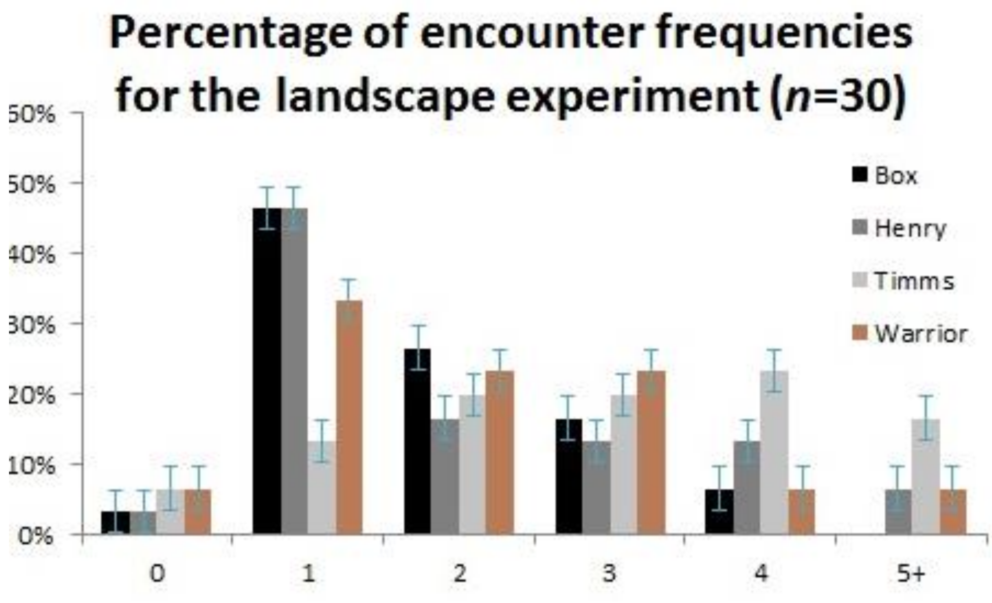

Figure 4.7: Encounter rate (in %) of the number of times possums frequented a device design (*n*=30); ± SEM.

The statistical model with the highest Akaike weighting was the Landscape model, all other Akaike weights are below 10%, giving empirical support that Landscape is the most important explanatory variable (Table 4.5). The effects of Landscape design are displayed and explained by the above Figure.

Table 4.5: Set of candidate models (AIC_c) analysed to estimate possum preference towards trap orientation within the landscape in a four way cafeteria test, 30 observations were analysed.

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Landscape	106.4	0	68%	16	96.36
Landscape + Sex	110.3	3.9	7%	8	104.3
Null	111.1	4.7	6%	4	107.1
Landscape + Sex : BW	111.4	5.0	6%	12	103.4
Landscape + Sex + BW	111.7	5.3	5%	12	103.7
Landscape + BW	112.5	6.1	3%	8	106.5
Landscape + Sex + BW + Sex : BW	113.4	7.0	2%	16	103.4

4.6.1 **Landscape orientation preference frequency encounter discussion**

All device designs had low percentages for zero encounters suggesting that either all designs are readily assessable or that the bait lure used was highly attractive. Both the Box and Henry designs had 47% of their encounters occurring only once, their reduced ability to retain animal interest is also noted with the very low percentages for multiple encounters. In contrast, the Timms design was successful at drawing back 40% of the possums to re-investigate and interact with the device more than four times within the two-hour period.

I believe the openness of the Timms design contributed to its attractiveness in the trial, as possums were able to view inside the device with the smallest effort, and animals could also place their forelimbs close to their heads in a position that gives them confidence that if something occurred (i.e the hole collapses while investigating), they are in a position to pull themselves out of harm's way.

The Warrior design is somewhat similar to the Timms design, although did not appear as attractive as the Timms. The Warrior design still had more repeat visitations than the Box or Henry designs. Again, the attractiveness could potentially be attributed to its openness, ease of investigation and the ability of possum to interact with the device when their forelimbs are close to their heads. Many possums investigating the Warrior stood on their hind legs, steadied themselves with their forelimbs on the outside of the Warrior design and investigated by sticking their heads inside the device. Unlike the Henry design which saw animals awkwardly move around the outside of the device before stretching out their hind-legs and removing the bait (Figure 4.8).

Figure 4.8: The effort and awkwardness to remove bait was different for each landscape design, left Timms, right Henry.

The lure used in the landscape experiments was the 'smooth in a tube' gel type bait from Connovation Ltd (Auckland). Possums found this bait so highly attractive that camera footage revealed possums returning and licking the empty devices for up to 6 hours after they had previously removed the bait. It is due to this highly palatable lure that each landscape design was encountered several times, and I believe if the lure was not as attractive as it was, the Box and Henry designs would not have had any multiple encounters at all.

Chapter 5

Possum approach speed, confidence and body position behaviours towards novel devices

5.1 Introduction

Approach behaviours were investigated, recorded and analysed to determine whether possums expressed confidence towards novel designs and whether sex or bodyweight was a variable in an animal's approach. A total of 37 possums were used, with only their first positive approach and interaction towards a novel device analysed. Although these same 37 animals were used throughout the five different preference trials, it was thought that that first encounter with a novel device was a true representative of their behaviour, rather than after animals had become accustomed to approaching novel devices in further captive experiments.

5.2 Possum approach speed results

It is presumed that the faster the approach, the more confidence the animal has towards that specific device (this assumption was made because all individuals were well fed, therefore hunger was not a driving variable). Three different approach behaviours (or the speed in which an interaction took place) was recorded at the animal's first interaction with all of the experimental devices. These behaviours were recorded and analysed from a distance of 50 centimetres away from the devices).

Half of the trialled possums paused once before entering or interacting with a device, potentially indicating an animal's thought process, possibly weighting up the danger involved with such interaction by showing a reluctance to fully commit. Forty-four percent of females interacted with a novel device without pausing, while males tended to be wearier with only 24% rapidly removing a bait or interacting with a coloured Waxtag® (Figure 5.1). There was little gender effect found between animals that interacted with devices after two or more pauses (called a 'slow' approach).

The statistical model with the highest Akaike weighting was the speed model at 65% weighting (Table 6.1). However, there is also some weighting (although much reduced) for the model including gender, and the effects of this are shown in the below Table 5.1.

Table 5.1: **Akaike's first order information criterion (AIC_c) of the regression models of possums speed towards first interaction with a novel device. A total of 37 observations were analysed.**

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Speed	78.2	0	65%	2	74.2
Speed + Sex	80.5	2.3	20%	4	72.5
Speed + BW	82.1	3.9	9%	4	74.1
Speed + Sex + BW	84.5	6.3	3%	6	72.5
Speed + Sex : BW	85.1	6.9	2%	6	73.1
Speed + Sex + BW + Sex : BW	86.6	8.4	1%	8	70.6

The effects of speed and gender can be seen below with males having a higher percentage tendency to approach novel devices slower (either as a slow or steady approach) that female possums.

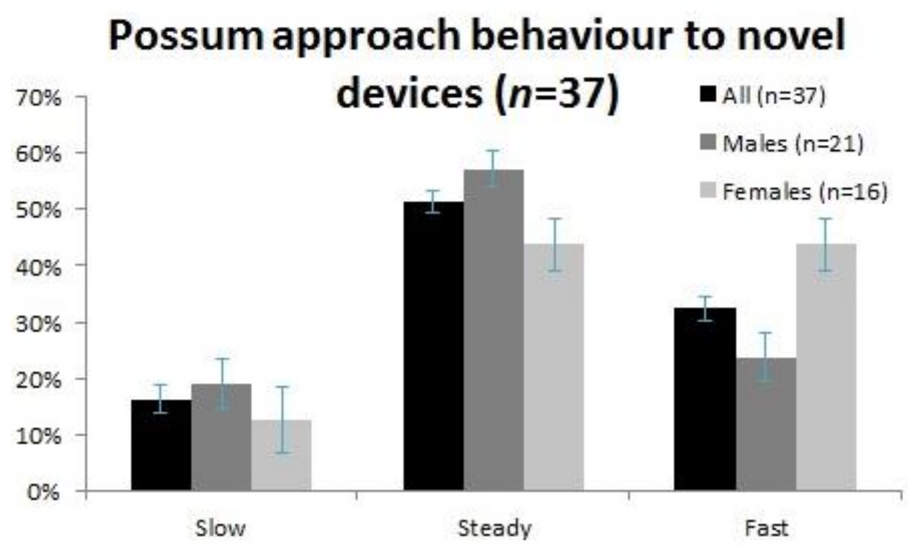

Figure 5.1: Possum approach behaviours at first device encounter (n=37); ± SEM.

Some differences between heavy (>2.5 kg) and light (<2.49 kg) possums were observed in the trials (Figure 5.2). Thirty-nine percentage of the heavier, more dominant possums interacted the device without pausing to investigate, while only 21% of the lighter possums showed such self-assertive behaviour. Lighter possums were also more wary of devices with 64% of light possums pausing once before entering, compared to the 43% for the heavier possums.

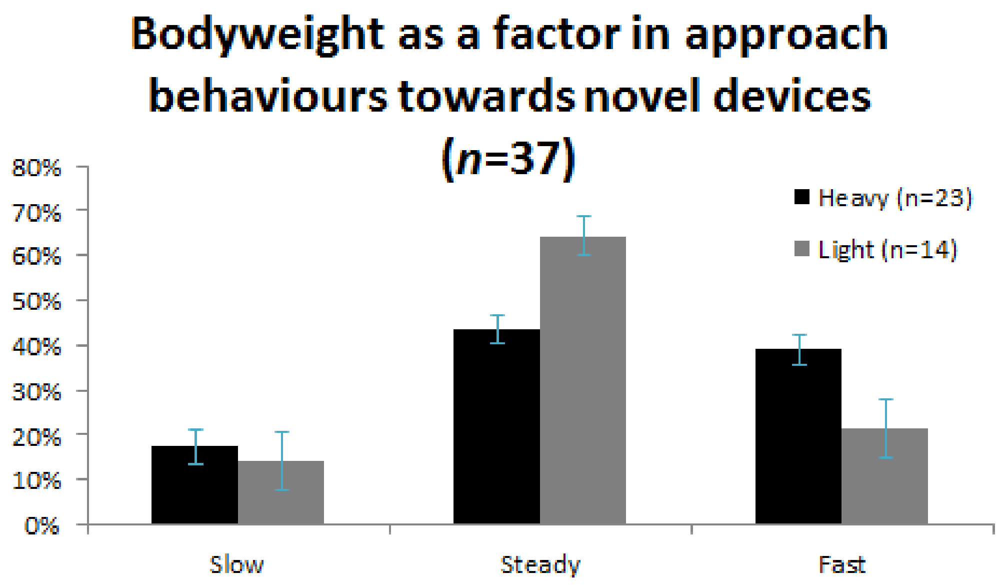

Figure 5.2: Comparison of possum bodyweights to approach behaviours (n=37); ± SEM.

5.2.1 **Possum approach speed discussion**

Female possums interacted with novel devices without pausing at higher rate than males (39% and 21% respectively). Jolly (1976) and Cowan (1982) both reported that female possums were generally dominant over males, therefore the speed of the approach behaviour could potentially be related to dominance and supremacy amongst other possums, potentially through aggressive vocal or body language behaviour. Although little difference was found between sexes interacting with the slow approach, males tended to investigate novel devices with a pause before fully committing in either removing the bait or chewing the wax rather than the females had a 'no nonsense' attitude of not pausing before interacting.

Bodyweight was also seen as having some influence in possum approach behaviour. Lighter weighted possums (<2.49 kg) investigated objects at a slower pace than heavier (>2.5 kg) possums, while heavy possums showed little concern when interacting with novel devices. This is seen with over 35% of heavy possums not pausing before interacting with novel devices, compared to the lighter possums where only 21% interacted without pausing.

5.3 Possum confidence towards novel device results

The animal's confidence within the tested devices was also assessed; this trial focused on analysing possum behaviour while interacting with novel devices for the first time, with the aim of producing information regarding whether possums are confident interacting with novel devices. Device confidence interactions will achieve information in the knowledge gaps relating to possum behaviour around investigating devices. These behaviours are classified and fully described within the Methods Chapter, Table 2.4.

The model with the highest Akaike weighting was the null model at 58% Akaike weight; however, there is some support for the model with gender as an explanatory variable. All other models had much reduced Akaike weightings (Table 5.2).

Table 5.2: Set of candidate models (AIC_c) used to estimate animals confidence when approaching novel devices, 37 observations were analysed.

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Confidence	90.6	0	58%	3	84.6
Confidence + Sex	92.1	1.4	28%	6	80.0
Confidence + BW	95.1	4.4	6%	6	83.1
Confidence + Sex + BW	96.3	5.6	3%	9	78.3
Confidence + Sex : BW	96.5	5.8	3%	9	78.5
Confidence + Sex + BW + Sex : BW	98.7	8.0	1%	12	74.7

It was found that nearly all possums eventually interacted with novel devices. Fourteen percent of all animals (that undertook all of the above experiments) took over two minutes to interact with a device and this was shared evenly between the sexes; however, the majority of possums (86%) interacted with a device within two minutes of first approach. Both sexes interacted with novel devices without conducting an initial investigation at about the same rate (~50%) as seen below in Figure 5.3.

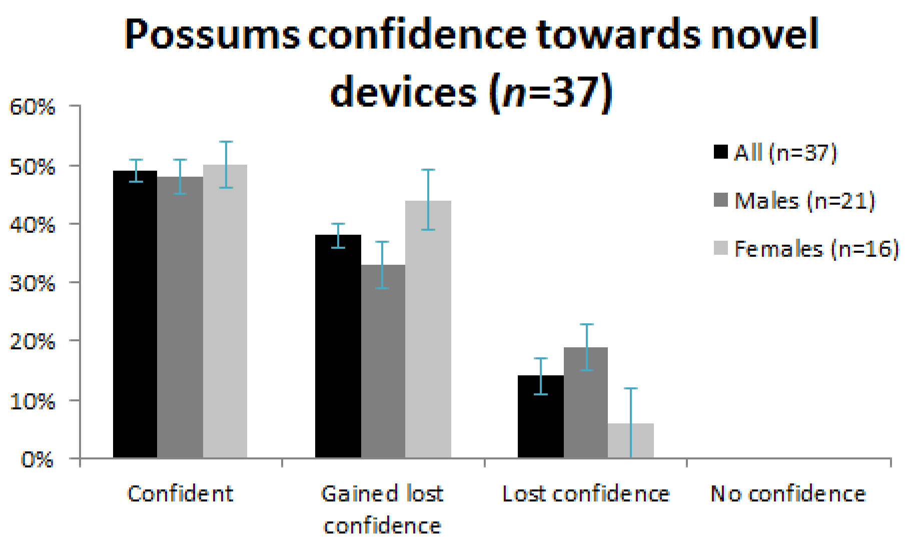

Figure 5.3: Possums investigative confidence towards novel devices (*n*=37); ± SEM.

Bodyweight was seen as a factor determining an individual's approach confidence towards a novel device (Figure 5.4). Heavier possums (>2.5 kg) were more likely to interact with a device without stopping to pause than light individuals (57% compared to 36%), while 21% the lighter weighted possums (<2.49 kg) took over two minutes to remove a bait compared to a heavier, more dominate possum of which only 9% took over two minutes to remove a bait. Again the lighter possums were more weary of novel devices with 43% taking within two minutes to interact with a device, while heavy possums 'gained lost confidence' with 35% interacting within two minutes. Although this analyses resembles the likeness of the approach behaviour, this approach confidence information reveals information about whether possums pause before entering a novel device rather that the speed at which interactions take place.

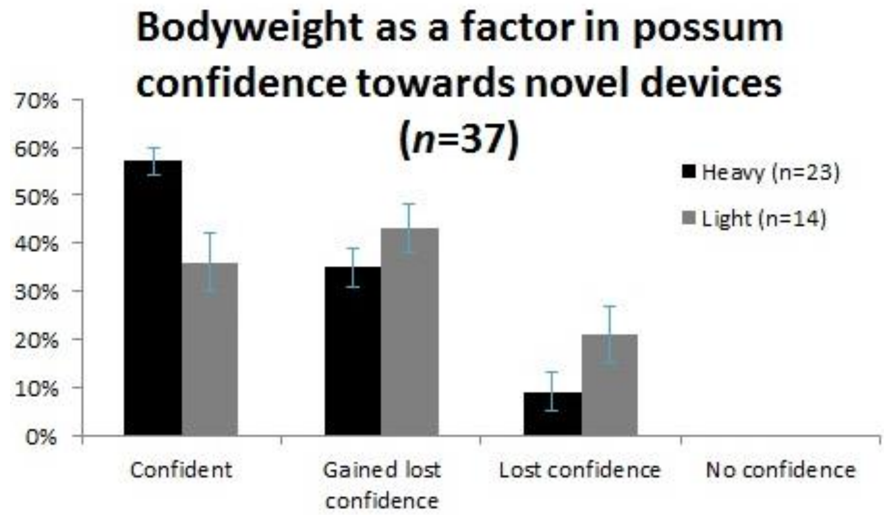

Figure 5.4: Bodyweight as a variable influencing possums confidence towards novel devices (*n*=37); ± SEM.

5.3.1 Possum confidence towards novel device discussion

Boxes sexes interacted with novel devices within equal timeframes. Thirteen percent of all animals took over two minutes to interact with a device (called the 'lost confidence' group), this behaviour manly consistent of animals first approaching the device wearily, sniffing or licking the outside of the device, pulling away to sit ~30 cm away from devices often to groom themselves or look around (as if watching for other approaching possums), some individuals would then interact and remove the baits, while most would half enter their heads into the device, suddenly lose confidence and back out to repeat the behaviour or grooming and looking around before finally interacting with a device, often several minutes after their first approach.

Of these 'lost confidence' animals, the majority were individuals weighting less the 2.5 kg. This is consistent with Spurr and Jolly's (1999) report suggesting that subordinate possums will only approach feeding troughs once the dominant possums were absent. Although test possums were housed individually, the wire mesh netting between the pens still allowed possums to view others on either side of their enclosures while investigating devices, potentially still imprinting a sense of subordinate behaviour onto the low weight individuals.

Forty-seven percent of all possum interactions occurred in the ‘gain lost confidence’ category, suggesting that most possums are cautious when entering new objects. Males were the largest component of this group (50% rather than females with 44%), as were lighter weighing individuals (53% over the heavy animals 44%), advocating that males and smaller possums are more tentative than large females; however, these results were not pronounced as clearly as hoped, presumably due to sample size. These findings are further expressed by the behaviours of ‘confident’ (no delay in interacting with devices) individuals, of which 41% of females compared to 30% of males expressed this behaviour. As with the previous results, heavy possums again interacted with novel devices at higher percentages of ‘confident’ interactions than light-weight possums (42% over 24% respectively).

5.4 Possum body position and angle at time of ‘triggering’ results

For possum kill traps to be developed and designed so that they become more efficient and humane, natural animal behaviours must be investiagted to determine possum body positions and approach angles at time of device triggering. Although these trials consisted of non-harm devices, ‘hypothetical’ triggering was presumed at bait removal or first chew of a Waxtag®, notwithstanding previous knowledge that ‘presumption is the mother of all stuff-ups’, most kill traps rely on possums biting a bait held on a ‘trip wire’ to release the tension, thus activating the killing mechanism. With this in mind, bait removal or a bite, although not a ‘trigger’, can be used as a reference to the exact time of ‘hypothetical triggering’, allowing the camera footage to be reviewed and body positions and angles recorded. The behaviours analysed were classed as; “NA”, “head” or “head plus limb” (fully described in Methods Chapter 2.3, experimental methods.

Considerable support is given to the Position model with an Akaike weighting of 57%; however, the variable gender and position also had an Akaike weighting of 25%. Bodyweight does not seem to be an important explanatory variable (Table 5.3).

Table 5.3: Set of candidate models (AIC_c) analysed to estimate possum body position at time of triggering , 37 observations were analysed.

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Position	22.3	0	57%	2	18.0
Position + Sex	24.0	1.6	25%	4	16.0
Position + BW	26.0	3.6	9%	4	16.0
Position + Sex : BW	27.6	5.3	4%	6	15.6
Position + Sex + BW	27.7	5.3	4%	6	15.7
Position + Sex + BW + Sex : BW	31.6	9.3	1%	8	15.6

An overwhelming 95% of all possums interacted with a novel device using their forelimbs to help guide, anchor or steady themselves. Five percent of possums interacted with devices without the help of their forelimbs (called 'head only') and all were males (Figure 5.5).

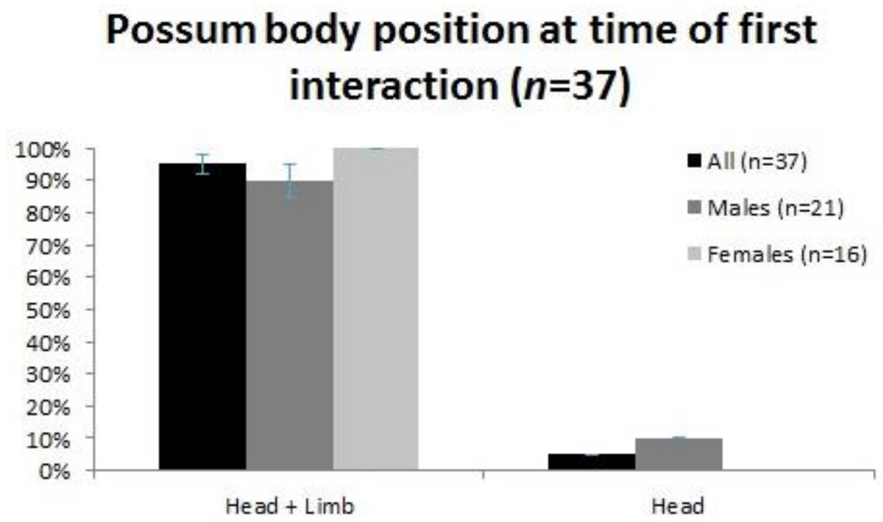

Figure 5.5: Percentage of possum body positions at time of triggering (*n*=37); ± SEM.

Bodyweight was not seen as a major variable in body position due to the vast majority of individuals interacting with novel devices with their forelimbs in assistance (91% for the heavy possums and 100% in the lighter individuals). Two heavy possums were the only individuals that interacted with their heads only (Figure 5.6).

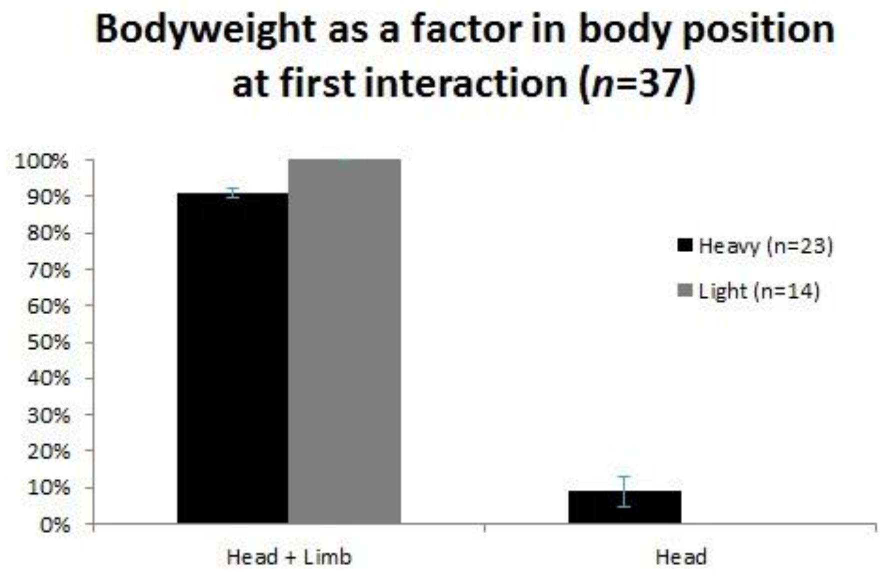

Figure 5.6: Bodyweight as a variable in possum body position at time of triggering (*n*=37); ± SEM. *Note*: Gender is not included due to lack of head body position data.

Understanding an animal approach angle towards a control device could also answer questions about which position a particular trap component is best suited for enticing possum interactions, while minimising triggering by non-targets. For example, if possums are found to approach a device in a particular fashion, designing a trap that encompasses this preferred angle could increase possums/trap interaction rates and reduce the number possum 'walk byes'.

Heavy support is given to the Angle model as the Akaike weight is 82%, however, there is some support for the model with both angle and gender as explanatory variables with a weighting of 12% (Table 5.4).

Table 5.4: Akaike's first order information criterion (AIC_c) of a set of candidate models used to estimate the effect (magnitude) of the given variables and their precision towards possum body position angles at novel device triggering time (n=37).

Model	AIC_C	ΔAIC_C	Akaike weight	*n*	Deviance
Angle	85.6	0	82%	3	79.6
Angle + Sex	89.3	3.8	12%	6	77.3
Angle + BW	91.4	5.8	4%	6	79.4
Angle + Sex + BW	95.2	9.6	1%	9	77.1
Angle + Sex : BW	95.4	9.8	1%	9	77.4
Angle + Sex + BW + Sex : BW	98.7	13.1	0%	12	74.7

Fifty-one percent of the trialled possums approached the novel devices from straight ahead, followed by the left side (32%), the right side (14%), and one individual (3%) made its approach from crawling underneath the devices before interacting with them (called the 'bottom' approach). No possums were observed sitting on top of any devices before interacting with them (Figure 5.7).

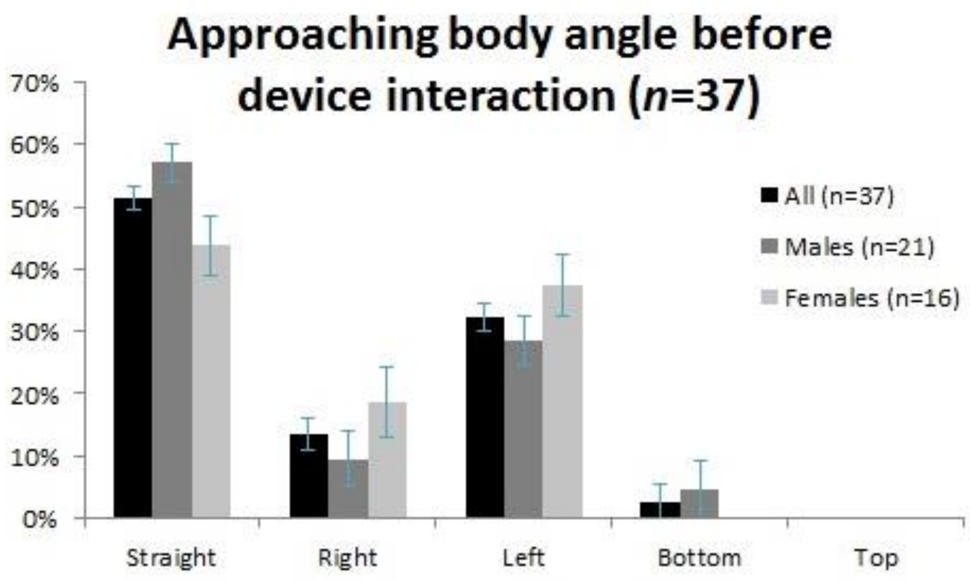

Figure 5.7: Possums body angle when approaching novel device (*n*=37); ± SEM.

Bodyweight was seen as having low influence in determining individual approach angles (Figure 5.8). Heavy possums showed a preference to approach a novel device from straight ahead (61%), then from the left side (26%) followed by the right and bottom (9% and 4% respectively). Light possums preferred an approach angle from the left (43%), followed by straight (36%) and lastly, to the right (21%) but it is difficult to establish clear trends.

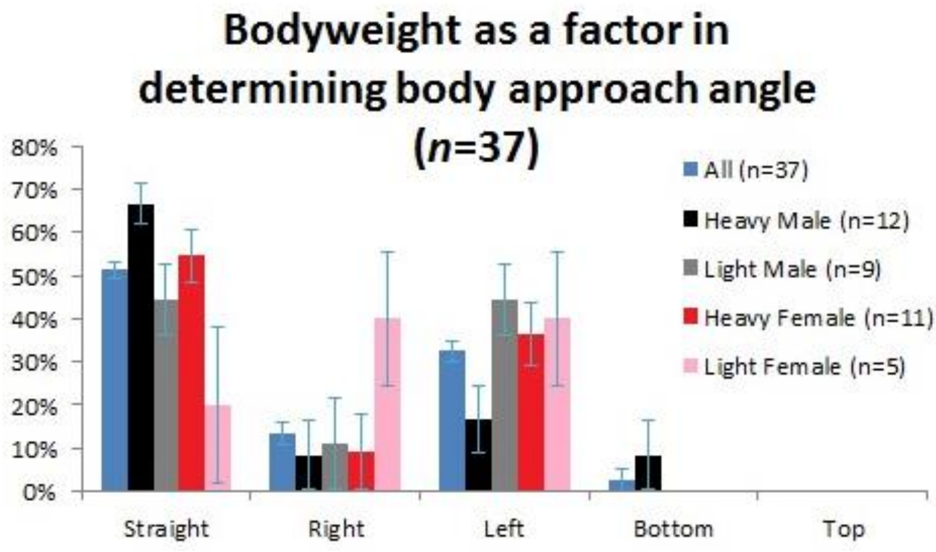

Figure 5.8: Bodyweight as variables in possum body approach angle at time of triggering (*n*=37); ± SEM. *Note*: Gender sample size

5.4.1 **Possum body position and angle at time of 'triggering' discussion**

The vast majority of possums (95%) interacted with novel devices only once they had their forelimbs securely imbedded around the device entranceway. Possums used their forelimbs to help guide, anchor or steady themselves when removing the bait. Animals either positioned their forelimbs on the outside of the devices or just within the device opening to support and steady the weight of their heads as they fully entered a device to remove a bait. Although possums have been reportedly caught with only their arms in traps of several popular possum trap models (Steve Hix, Connovation Ltd, personal communication, 2012), no possum in this experiment was observed removing a bait with their forelimbs. Domigan (2011) found that possums were more likely to interact with a control device if their forelimbs were within close proximity to their heads and these results support this hypothesis.

Possums approached novel devices from predominately straight on (51%) before interaction, followed by the left side (32%), the right side (14%) and from below the device (3%). Because every cafeteria test device (1 x 0.4 m ply wood board) was placed within the possum enclosure pens directly facing the animals den sack or box because of the size restrictions of the pens (1.15 m wide enclosures), therefore no possums were able to approach the devices from behind.

Males favoured the straight approach more than females (57% and 44% respectively), while female possums were more open to different approach angles such as from the left (38% compare to males 32%) or right (19% over the males 10%), the reasons for these results are unclear but do indicate some gender differences.

Chapter 6

Field results – Non-target interference

6.1 Introduction

Possum numbers have been significantly reduced in many regions of New Zealand, predominantly from aerial 1080 poison operations. However, recent research has indicated unexpected consequences of possum control. For example, evidence has shown rat numbers can double in two years after possum control compared with non-control sites (Sweetapple & Nugent, 2007), and reports from possum contractors suggest that these high rat numbers make ground-based possum maintenance control more difficult and expensive (Martin Bergstrum, Central Districts Pest Control Ltd, 2012). Although these field trials were conducted to gather further evidence to quantify possum preferences to novel devices, camera traps enabled both possum and non-target bait take detection, supplying information on bait loss frequency to non-targets, which species were the first to interact with the devices and allowed an estimate on possum 'walk byes' to be taken, and whether this was a common occurrence.

6.2 Field results

Field trials were undertaken at two South Island study sites, Station Creek (Springs Junction, Lewis Pass) and the Taipo Valley (Westland) both combining to form 21 nights of observations (11 nights Station Creek, 10 nights Taipo River). Preference testing (colour, shape, size, material and landscape orientation) was conducted along service four wheel drive tracks at Thompsons flat in Station Creek and along the Taipo River valley flats as described in the Methods Chapter.

It was thought that if the preference stations were to remain within one location, devices would have lost their novelty after a single possum/device interaction had occurred, meaning that re-visits in subsequent nights could not be considered novel and this was the reason why devices were moved to new locations each night. The main factor for the unusable field data in possum preferences was the interactions and bait take of non-target species, particularly ship rats (Table 6.1). After analysing the camera footage after the field trials, significant non-target bait interference was deemed to the major contributor to low numbers of possum encounters.

Table 6.1: **Summary of preference station activities at both field sites. *Note*: encounter rates includes all animals caught on camera not necessarily resulting in a 'walk by'.**

	Walk By	Bait Removal
Possum	20	7
Rat	60	41
Weka	18	17
Other non-targets	11	1
Total	**109**	**66**

Twenty possums were recorded encountering devices with the majority (65%) walking past (called a 'walk by') the novel devices with only seven of these individuals actually removing baits. Ship rats removed 62% of the presented baits from the preference stations, followed by the inquisitive native ground dwelling bird the weka (*Gallirallus australis*) removing 25% of baits, while the targeted possum removed much lower 10% of the bait.

At Station Creek (*n*=143 device observation nights), ship rats (*Rattus rattus*) removed 78% of the bait while possums removed just 18%. Five occasions were recorded were rats removed baits before a possum investigated preference stations; at this point the un-baited devices were unattractive and not investigated further by any possums (Figure 6.1). The smell of fresh rat scent around the devices and/or the lack of a food based lure likely repelled or prohibited possum investigation.

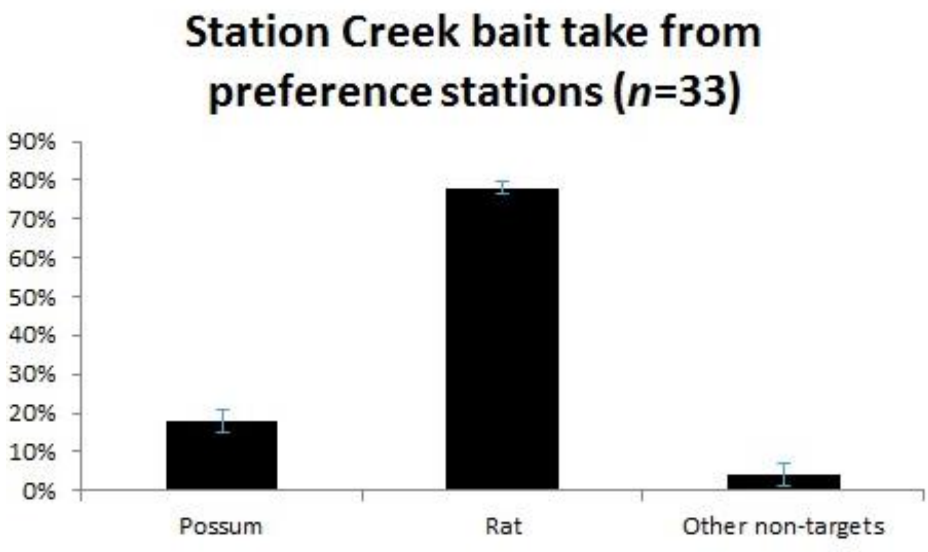

Figure 6.1: Bait take from Station Creek study site (*n*=33); ± SEM.

Much like Station Creek, the Taipo River study site (n=100 device observation nights) also provided evidence of high non-target device interaction. Only one possum was recorded removing bait from preference stations while 97% of all bait removal was undertaken by non-target species. Unlike

Station Creek where ship rats were responsible for the all of non-target interactions, weka played a major role in bait removal (52%) along with ship rats (45%) at the Taipo River study site (Figure 6.2).

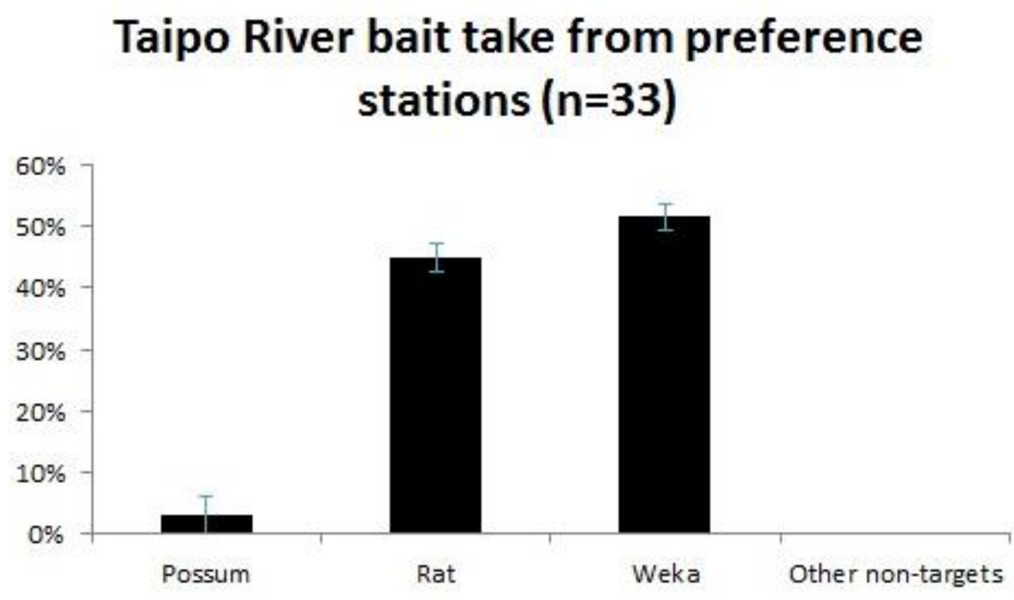

Figure 6.2: Bait take from the Taipo River study site (*n*=33); ± SEM.

A list of all species recorded on camera footage is listed below in Table 6.2. Of these, the majority of interactions was undertaken by rats, weka and possums; however, weka (*Gallirallus australis*) and the South Island robin (*Petroica australis*) are native bird species and are therefore extremely undesirable species to have encountering any control device.

Table 6.2: Summary of all species that encountered a devices and a description of interaction

Species	Location	Type of interaction	Number
Possum	Station + Taipo	Bait take or investigated without bait take	22
Ship rat	Station + Taipo	Bait take or investigated without bait take	63
Weka	Taipo	Bait take or investigated without bait take	18
Mouse	Station + Taipo	Nibbled bait	5
South Island Robin	Station	Sat on device lip, periodically entering	3
Hare	Station	Walk by	1
Hunting dog	Station	Sniffed device	1
Stoat	Taipo	Sniffed device	1

6.2.1 **First interaction with devices**

On eight separate occasions (out of the 105 preference station nights in the field), cameras recorded non-target species removing bait from devices that possums later came to investigate on the same night (Table 6.3). On average, rats encountered baited devices 104 minutes before possums were recorded on cameras, all recorded possums then did not investigate and subsequently 'walked by' devices without an interaction occurring.

Table 6.3: Time differences between non-target device encounter and possum encounter on same device on the same day.

Non-target before possum	Time of first non-target interaction (24 hour time)	Time of first possum interaction (24 hour time)	Time Difference (in minutes)
Rat	2200	2236	36
Rat	1821	1901	40
Rat	0126	0317	69
Rat	1755	2143	192
Rat	0131	0227	56
Rat	1806	2300	234
Rat	2006	2248	102
Weka	1718	2108	160

6.3 Field discussion

Non-target control device interference rates are important variables when controlling any pest species. Firstly, non-targets can make control operations less effective by removing intended bait from the targeted pest. Secondly; control operations are made more expensive by the extra bait and laboured needed. Thirdly; many non-target pest species are able to retrieve/destroy baits without harm (i.e rats destroying Feratox® bait bags while leaving cyanide pellets unattractive to possums); and lastly, non-target species can also be by-catch of a control tool (for example, 1080 poison and risks to birds)

In this study the use of novel devices in the form of coloured Waxtags® or baited boxes posed no risk to non-target species, thus it is unclear whether true kill devices would have been triggered by these non-targets. In the National Pest Control Agencies best practice trapping manual 2008, it is stated that any location where weka or other ground dwelling birds reside, traps must be raised on sets to prevent interaction occurring. Although non-target species are not intentionally lured to control devices, many baits act as a lure and some traps that are set along the ground can catch a wide range of non-targets (Veitch 2001; Auckland Regional Council Fact Sheet, 2010). However, most suppliers also manufacture trap covers/shields that are specifically designed to prevent non-target interactions occurring. As with any device that remains dry in the field, invertebrates will congregate, at these sites, non-target species (especially the smaller insect feeding passerines) will always be at risk and South Island robin by-catch has been reported in DOC 200 kill traps (Brent Barrett, Lincoln University, personal communications, 2012).

Rodents have long been known to remove baits from possum kill traps without setting them off (National Pest Control Agencies, 2008). These results do quantify levels of rat interference rates with control devices and reiterate the need for rat control, before and during possum control operations. This can be achieved by several means; however, poison usage seems the only viable option available given the lack of effective multiple kill, resetting rodent control devices, multi-species bait or rodent repellent currently on the market.

Twenty possums were recorded walking past the novel devices with only 35% of these individuals actually interacting and removing baits. The sample size was too small to allow the field data research to be compared to the laboratory results, therefore the data set was left out of the preference research leaving the field data to focus on the non-target and walk-by activities. These walk-by events are consistent with Brown & Warburton (2012) reported findings estimating that possum encounter rates with leg hold traps can be as low 22%. Much more research is needed to increase these interaction rates, and it is hoped that this thesis can added to the growing number of recent publications focused on attracting possums to interact with control devices (Hunter, 2005; Kavermann, 2012)

The time difference between non-target device interactions and possum device encounters will remain problematic due to the behavioural differences in foraging and activity timing. In high rodent density areas, some rats will be forced to forage for resources at earlier times than normal (Mitchell & Brown, 1990), this could also be true for high possum populations and this is believed to be the case with the high rat interference at Station Creek. In any case, rodent numbers must be controlled before more successful and efficient possum control can be achieved.

Chapter 7

General Discussion and Summary

7.1 Summary of the thesis

This thesis aimed to assess possum preferences towards control device components with the objective of coming up with an optimised trap design that not only increases possum encounter rates, but also install an animal's confidence so that possum/trap interaction rate is increased. Trap components investigated included: colour, geometry of entrance openings, size of the trap entrance, material of construction and trap orientation within the landscape.

These finding imply that possums do show behavioural towards certain aspects of a possum kill traps, and that by manipulating designs to incorporate animal curiosity, possum trap efficiency could be increased.

7.2 Main results

The information gathered from this study suggests that a control device with the components consisting of the preferred choices (Table 7.1) would create a highly desirable device that would have increased interaction rates over currently employed traps and bait stations.

Table 7.1: Combined possum preferences towards trap components, both first and second preferences as indicated from this research

	First Preference	Second Preference
Colour	Black	Yellow or Blue
Shape	Square	Key
Size	120 mm diameter	100 mm
Material	Metal	Corflute or Wood
Landscape	Timms	Warrior

By interpreting the information about possum preferences in this thesis, Black is the colour most highly preferred, followed by Yellow or Blue. The Henry trap (GoodNature Ltd, Wellington) combines a mixture of colours including white, black and orange. Although a combination of colours was not trialled in this research, it seems that a combination of possum preferred colours (like Black and bright colours that can easily been seen by operators) could potentially be beneficial at both attracting possums to investigate, but also for public safety and site identification.

Square-shaped trap entranceways were found to be more attractive than other shapes trialled; reasons behind these results are unclear, although correlations between possums interacting with the more 'open' designs can be made. The square-shaped design was open enough that an animal could investigate and remove baits with minimal physical touching of the entrance walls, while possums also indicated a larger size preference and again allowing possums to investigate and remove baits with the minimal physical touching of the surrounding trap walls.

The material preference testing did not show any obvious clear preferences one way or another. Suggestions for these weak results are mentioned below in the research limitations section; however, it seems fair to comment that possums in this study found no construction material preferable over any another material. As with the trap orientation, possums with their 'minimal input for greatest gains' behaviour found the Timms design the most attractive. This is not surprising because the Timms design is 'open', bait can be easily seen form outside the device with no real investigation needed, and baits can be removed in a natural position of sitting with the back-limbs on the ground while reaching in with their forelimbs close to their head to gather the bait or trigger the killing mechanism. This design appears superior over the Henry trap construction which forces possums to lift their heads vertically into the entranceway, poking their heads up into an awkward angle while remaining out-stretched and balanced on their back-limbs.

7.2.1 **The effects of gender**

For eradication operations, removing the females from a population prevents the reproductive ability and future viability of that population (Cromarty *et* al., 2002). It is therefore important to look at female preference trap designs and determine whether females have a different preferences. It was found that female possums had the same preferences in colour, shape, size, material and landscape position as males in three out of five experiments (as seen in Table 7.2). Therefore, devices with componentry made from these preferences would theoretically become more attractive to females than existing control devices that do not exhibit these preferred qualities; however, none of the AIC tables expressed any major gender differences throughout the preference experiments.

Table 7.2: Gender preference differences

	Male	Female
Colour	Black	Black
Shape	Key	Square
Size	Large	Large
Material	Corflute	Metal
Landscape	Timms	Timms

7.2.2 Dominate possum preferences

Dominate possums (i.e. > 2.5 kg) can affect the success of control operations as they have strong influence on animal/trap interactions (Jolly, 1976; Biggins & Overstreet, 1978; Oldham, 1986). For example, subordinate possums will often not interact with a feed stations if larger, more dominate possums are around or have scent marked a resource. Therefore, dominate possums should be removed first, opening up the social structure of possum hierarchies, allowing subordinate possums to then interact with control devices.

The table below (Table 7.3) indicates the preferences shown by dominate male and female possums. There is little overall difference between the sexes; however, males expressed no preference concerning device material while females domonstrated their preference for metal and wood devices by choosing to interact with these materials first.

Table 7.3: Dominate possums, both male and females and their preferences

	Male	**Female**
Colour	Black	Black
Shape	Square/Key	Square
Size	Large	Large
Material	No preference	Metal/Wood
Landscape	Timms	Timms/Warrior/Box

7.3 Research limitations

Before specific results are discussed, some possible study design limitations must be considered and mentioned. Behavioural research has long been touted by many scientists as lacking empirical, hard research data, or by simply interpreting one animals behaviour and giving it another animals quality's (often human like) and can cause great controversy. While this MSc research is certainly not perfect, every opportunity to discuss the methods or experimental design was taken, this included bouncing ideas around with many senior scientists from varied backgrounds. Each agreed that the key foundation of good behavioural science is consistency, therefore each experiment consistent of thirty possums, individually housed and trialled over separate nights with multiple nights 'rest' before another experiment was undertaken on that individual. Despite the fact possums were used multiple times (and several individuals were involved in all five experiments), financial and time constraints combined with unusable field data contributed to the necessity for re-using individuals multiple times, and these repeat subjects were exposed to quite different experiments. There was also little difference between the shape and size experiments, and it must be acknowledged that the size of the different shapes varied between each other although the width of the shape holes was consistent with one another. Using the same possum multiple times could lead to one-sided results; however, each experiment was constructed different and baited differently, creating novelty at each trial; however, it is impossible to know whether experimental biases occurred.

The difference between the individual experiments is seen as the key for preventing biases, for example: the colour experiments used un-baited Waxtags® with the only lure being their plastic backing painted, compared with the material construction devices had a mixture of different material that the possums were somewhat unfamiliar with, and using a highly attractive bait that animals had not been previously exposed too (Ferafeed striker, Connovation Ltd).

While the shape, size and material experiments required the animal to enter their heads into a 'box' type device, the landscape experiments required animals to investigate open-ended devices that they could easily enter/exit from, this was also baited with a different commercial possum attractant ('Smooth in a Tube', Connovation Ltd) and every device was baited exactly the same way.

The laboratory sample size of thirty possums per experiment was hoped to be supplemented by field research data and the comparison between captive animals and wild possum behaviour would have been fascinating; however, non-target animal interactions and low possum encounters meant that the field research was mostly unusable for the possum preference experiments. The field data collected did however, raise interesting findings about possum/device encounter rates and non-target/device interactions that will be mentioned later within this the discussion section.

A sample size of thirty for each experiment could be considered as lacking statistical power that can adversely affect the conclusion validity, and this is seen in some experiments with the relatively high amount of uncertainty regarding the best candidate models in the AIC tables. However, applied science research often lacks the significant statistical results that are common with other sciences, but it is the biologically significant results that are important in quantifying animal preferences. The thirty laboratory replications are not insignificant, and have helped to reduce the sampling error. Missing interactions (i.e. values) were left out of the data set reducing the sample size in some cases; however, when dealing with wild animals, one must expect that not all subjects will interact with the devices.

Habituation effects were observed during the trials, with unnatural possum behaviour such as feeding outside their normal feeding periods noted. It not uncommon for some wild-caught possums to become active during the day in captivity with the longer they remain in captivity (personal observation). However, these unnatural behaviours were limited to a few individuals and not did appear to have any effect on the subsequent trials in terms of interaction rates or different behavioural responses from the norm. Although some trials failed to gain 100% participation from the sample population, the subsequent 'tailing off' effect as the animals selected and moved through the four novel devices (i.e. animals may have stopped investigating with devices after interacting with three of them), can be put down to three factors. Firstly, all of the devices may not have been attractive for the individual, hence no interaction. Secondly, the animal may not have found all the lures appealing. For example, devices baited with apple might not have had the same appeal as a device baited with 'smooth in a tube' (Connovation Ltd) because the animal was often fed an apple as part of its captive diet. Thirdly, food was provided in conjunction with the baited devices and the animals may have already fed before investigation took place. Because the camera's field of view was focused on the devices, individuals may have consumed their nightly fill from the alternative captive food supply.

7.4 Comments on experimental design

For the reasons mentioned above, only the preferences from animals first and second choice were used for the main analysis, the thought being that it is hard to quantity whether individuals third or fourth choice is actually an expressed preference or a food-driven response. It can also be assumed that by the animals third choice the novelty factor has been eliminated and the animal would have gained enough confidence in the devices to investigate without the thought of pending danger. Additionally, only the possums initial approach speed, confidence, body position and head angle at time of first triggering was analysed.

To discount the issue of the device positioning contributing to the results, investigation into the influence the randomised design had on first or second preferences was also undertaken. For this I hypothesised that possums would investigate the outer edges of the cafeteria test at higher rates than devices in the centre of the device board, and that possums simply moved from one device to another along the broad or in a fashion showing selectivity. Because of the randomised design employed, possums had a 25% chance of interacting with any one device along the four choices and due to the devices themselves being randomly allocated between the different trials; the first choice selection should be in theory, divided equally along the cafeteria board. Below, Tables 8.4 and 8.5 both indicate that first and second preference choice was in fact that individual's preference chosen along a random assigned board. Although the devices within the middle of the cafeteria tests were selected at higher rates than outside edges, there is no correlation depicting that this 'edge effect' had any bearing on the reported results (Table 7.4).

Table 7.4: Location of first interaction and their position along the cafeteria test.

	Border left	Left middle	Right middle	Border right	*n*
Colour	11%	32%	32%	25%	*28*
Shape	21%	18%	21%	39%	*28*
Size	17%	30%	33%	20%	*30*
Material	13%	30%	43%	13%	*30*
Landscape	21%	34%	24%	21%	*29*
Average + SEM	**17% ± 0.1%**	**29% ± 0.2%**	**31% ± 0.2%**	**23% ± 0.2%**	

The issue concerning the second choice being a valid preference or whether the individual simply moved along the design board is also dispelled by Table 7.5. Here the second choice was compared to the position of the first choice and it was found that possums equally moved left, right or to a device in between their first and second choice. The position comparing the third and fourth chosen devices was not analysed as the devices were considered to have lost their novelty (see comments above).

Table 7.5: The movement of possums between first and second choice preferences and their direction

	Left	**Right**	**Device in between**	***n***
Colour	25%	46%	29%	*28*
Shape	32%	25%	43%	*28*
Size	30%	37%	33%	*30*
Material	20%	47%	33%	*30*
Landscape	31%	28%	41%	*29*
Average + SEM	**27.5% ± 0.2%**	**36.5% ± 0.3%**	**35.8% ± 0.2%**	

7.4.1 **Measuring animal behaviour**

Willingness to interact, preference and confidence can be seen as three separate issues concerning an animal's behaviour, but this research considers them interlinked. Willingness to interact with the presented devices, irrespective of whether the devices were considered novel or not, was enticed by a food lure to generate results in a timely manner. Whether the devices were baited or not and the subsequent behaviours associated with the results is not covered further; however, it is widely accepted that a baited device drives a food or resource exploratory behaviour rather than an un-baited device which may drive just a curiosity behaviour (Berlyne, 1950; Perelberg *et* al., 2010). Either way, it is uncommon for a control device to be operated in the field without a food-based lure to attract animal investigation.

Preference and confidence are likely be highly related, but this relationship is hard to quantify. An example of this linkage is that the larger-sized device entranceway was found to be the most preferred size design. Whether the larger sized openings allowed possums to investigate and enter/remove their heads without physically touching the device sides with their heads or necks is uncertain, but from the animals perspective it seems unwise to enter a novel object that restricts and confines such an important part of the body. I believe that the animal's preference in these experiments is closely related to their confidence and this can be further justified by the short, or more assertive investigation times, some animals took before entering devices.

7.5 Future control device designs

To date, control device research has generally focussed on making improvements to pre-existing baits and lures (Carey *et* al., 1997; Thomas & Maddigan, 2004). While Hunter (2005) found that luminescent Waxtags® attracted more possum bite marks than other coloured Waxtags®; other recent research using possum lures to attract target animals to interact with control devices has also been researched and quantified. For example, Kavermann (unpublished Phd thesis, 2013) has advanced knowledge of audio lures and this technology appears to have the potential to attract possums to control devices faster and more efficiently than the traditional olfactory-based baits. If future control devices are to achieve the highest encounter rates possible, all of this recent research should be incorporated in such a trap design.

Control devices also need to incorporate a more 'open' design to increase possum interaction rates while reducing non-target encounters. For example, the Warrior trap (Connovation Ltd., Auckland) has no sides apart from clamping bars on either side of the main jaws, the clamping bars are designed in such a way that possums can see through into the trap and bait (to increase investigation), but the clamping bars prevent individuals from reaching the bait from the sides, thereby guiding animals to enter the trap from the front. "Openness" is deemed as the ability of the trap to present an attractive bait in an open visual format, in which a possum can gain access to the bait and subsequently trigger the device, while spending the least amount of time and effort investigating. It appears that unless the bait can be seen and easily accessed (olfactory and visually), some possums will investigate devices for only a short time period, before continuing on with their routine feeding habitats without a positive interaction occurring.

The likes of the new multiple kill, self-setting GoodNature A12 possum kill traps is seen by many as the start of a new era in control device designs; however, this research suggests the landscape orientation of the Henry design would be less preferred compared to other trap orientations. The Henry trap could potentially have its attractiveness and subsequent capture rates increased by simply installing the device horizontally rather than the current recommended best practice of vertical orientation and warrants further research.

7.5.1 **Controlling non-target pests and limiting unfavourable by-catch**

Unfortunately, if New Zealand wants to maintain its biodiversity and have the agricultural economy remain open to overseas export markets, we must kill introduced pests, and although the introduction of animal welfare laws requires all animals, whether farmed or pests be treated in a humane manner, adverse effects to native non-target animals is sadly inevitable when attempting to control another species. The use of best practices can avoid the majority of native bird/device interactions that occurred during this study (Table 7.6), and is freely available to the public when undertaking trapping (National Pest Control Agencies website).

Table 7.6: Summary of undertaken field practices versus best practices as advocated by the NPCA

My field practices	Best Practice (under NPCA)
No pre-feeding	Pre-feed possum devices
No rodent control before operation	Control rodents if in high numbers before possum devices are place in field
Devices were set on the ground in areas of known ground-based native bird species	Use raised sets in areas where ground-based birds are found

This thesis also highlights the impact rodents can have on bait-take when possum control operations are undertaken. The need for rodent control in certain areas is essential to ensure a possums first interaction with a device is that individual’s end point. An effective, multiple kill or re-setting rodent control device is needed to maintain rodents to low levels (such as the Goodnature A24 multi-species trap); however, rodent home ranges and social behaviour makes them notoriously difficult to control and trapping alone has had mixed results (MacKay, Russell & Murphy, 2007; Bowie, Kavermann & Ross, 2011). Currently, research is investigating highly palatable, toxic, multi-species baits that could control a wide range of pest animals in one application (Smith, Eason & Sam 2011), although this comes with risk for birds. This thesis indicates how important rodent control is if successful possum control operations are to occur. Pre-feeding possum devices with rodenticide laced bait is another viable rodent control option before possum control is undertaken.

7.6 Future research

Improving possum control operations relies on increasing possum encounters and interactions with control devices. These encounters are encouraged using a variety of baits and lures that stimulate possum visual, olfactory or auditory senses and therefore draw possums towards a control device. Future research on possum control devices is limitless, although much restricted by the flow of capital investment. Multiple kill, self-setting traps that can be left in the field for extended periods of time are one such method that is greatly favoured as is long-life toxins that are non-target friendly, and humane.

Luring animals to a specific location in their environment, or into the realms of another possum's home-range to investigate and subsequently interact with a control device, is seen as the fundamental research question left to answer. New Zealand wildlife managers are world renowned for controlling large numbers of animals in control operations; however, it is the small number of individuals remaining after such control operations that are the most difficult to subsequently target and remove. Future research could expand Kavermann's (2013) success with audio lures, and Hunters' (2005) recommendations suggesting luminescent strips on control devices, with the finding of this research to further improve animal interaction around control devices.

Future investigation should also look into new olfactory lures, either food-based such as extremely palatable and highly desirable plant extracts or other essential oils (extended life in the field), which are known to be highly attractive to some populations of possums, while remaining unattractive to non-target species. Other olfactory lures could involve extracting and manufacturing synthetic dominant females smells. Visible lures should also be investigated, with any lure that can been seen over large distances and are attractive (i.e. flashing night lights) having a spatial advantage over olfactory lures, which generally only work over short distances (Figure 7.1).

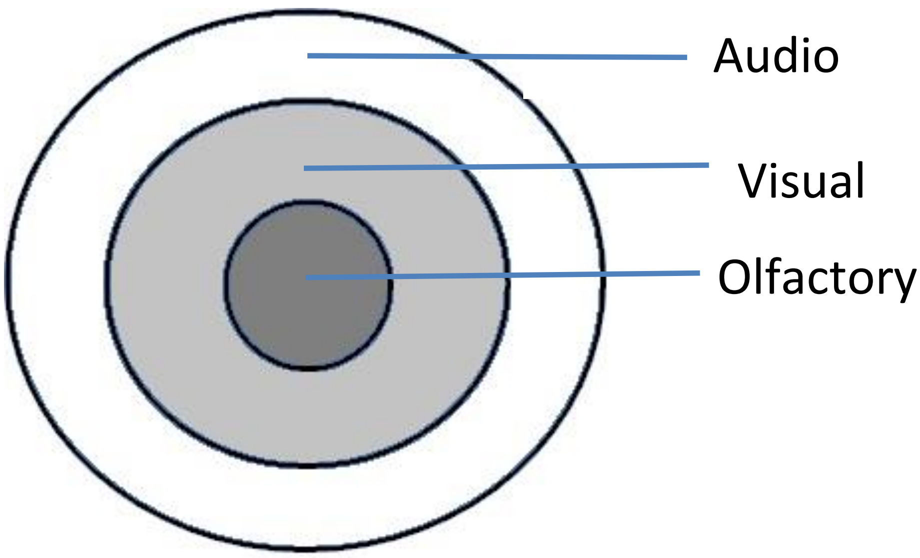

Figure 7.1: The proposed organization of audio, visual and olfactory lures within a spatial scale measured from a central lure station (adapted from Kavermann, 2013)

7.7 Thesis summary

As research continues into investigating new possum traps and toxins, control device designs need to develop to accommodate the requirements of new bait delivery systems or trap killing mechanism and ensure only target species are allowed access to the bait while remaining the most attractive as possible for possums. In conclusion, despite the low statistical sample size and lack of field data relating to possum preference, this thesis measured and presented several possum preferences for colour, entrance geometry, trap size openings, material attractiveness and landscape trap orientation.

Briefly, this research shows that possums are willing to interact with any construction material without seeming to deter possum encounter rates; however, possums appear to have clear preferences for the colour black, larger-sized entrance holes and a horizontal trap orientation. There was also weaker evidence for a square-shaped entrance hole. These preferred control device components should now be added to existing devices, with the ultimate aim of producing a control device that creates possum novelty at first glance and wills them to investigate. This will then install animal/device confidence so that every possum successfully interacts with a control device at first encounter.

Appendix A

Research data

The following tables are a summary of the raw data collected from the laboratory and field during reearch for this thesis. It is not all the material recorded but a summary to provide an overview of the data collected.

A.1 Laboratory colour preference test design layout

Experimental design layout of Laboratory trials, experimental positons were randomised by the “rand” function in Microsoft Excel™ (A1 – A5).

Test number	Date	Possum	Sex	Left			Right
1	19/03/2012	23	M	Yellow	White	Black	Blue
2	19/03/2012	24	F	Black	Yellow	Blue	White
3	19/03/2012	25	F	Black	Blue	White	Yellow
4	20/03/2012	26	F	Blue	Black	White	Yellow
5	20/03/2012	27	M	White	Blue	Black	Yellow
6	20/03/2012	28	F	White	Blue	Black	Yellow
7	26/03/2012	29	M	Blue	Black	Yellow	White
8	26/03/2012	30	M	White	Yellow	Black	Blue
9	26/03/2012	31	F	Blue	White	Yellow	Black
10	29/03/2012	32	M	Yellow	White	Black	Blue
11	29/03/2012	33	F	Blue	White	Black	Yellow
12	29/03/2012	22	F	Blue	White	Black	Yellow
13	21/04/2012	10	F	Black	Yellow	White	Blue
14	21/04/2012	15	M	Yellow	Black	White	Blue
15	21/04/2012	8	M	Black	Yellow	White	Blue
16	23/04/2012	222	M	Yellow	Black	Blue	White
17	23/04/2012	4	M	Black	Blue	White	Yellow
18	23/04/2012	16	F	White	Yellow	Blue	Black
19	24/04/2012	18	M	Yellow	Black	White	Blue
20	14/04/2012	3	F	Blue	Yellow	White	Black
21	25/04/2012	14	M	White	Blue	Black	Yellow
22	26/04/2012	2	M	Black	Yellow	White	Blue
23	26/04/2012	JB1	M	Blue	Yellow	Black	White
24	26/04/2012	21	M	Blue	Yellow	Black	White
25	27/04/2012	13	M	Yellow	Black	Blue	White
26	27/04/2012	H1	M	Yellow	Black	White	Blue
27	27/04/2012	H2	F	Black	Yellow	White	Blue
28	26/08/2012	7b	F	Black	Yellow	Blue	White
29	28/08/2012	5b	M	Blue	Yellow	Black	White
30	29/08/2012	2b	F	Yellow	Black	White	Blue

A.2 Laboratory shape preference test design layout

Test number	Date	Possum	Sex	Left			Right
1	5/04/2012	23	M	Diamond	Key	Triangle	Square
2	6/04/2012	25	F	Triangle	Key	Diamond	Square
3	6/04/2012	24	F	Square	Diamond	Key	Triangle
4	6/04/2012	26	F	Triangle	Square	Diamond	Key
5	21/04/2012	27	M	Diamond	Square	Key	Triangle
6	21/04/2012	28	F	Triangle	Key	Diamond	Square
7	21/04/2012	29	M	Key	Triangle	Diamond	Square
8	21/04/2012	31	F	Square	Triangle	Diamond	Key
9	22/04/2012	32	M	Triangle	Key	Square	Diamond
10	22/04/2012	222	M	Triangle	Diamond	Square	Key
11	23/04/2012	33	F	Triangle	Key	Square	Diamond
12	24/04/2012	18	M	Key	Square	Triangle	Diamond
13	24/04/2012	30	M	Diamond	Square	Key	Triangle
14	25/04/2012	12	M	Diamond	Square	Key	Triangle
15	26/04/2012	10	F	Square	Triangle	Key	Diamond
16	26/04/2012	16	F	Square	Triangle	Key	Diamond
17	27/04/2012	14	M	Key	Triangle	Square	Diamond
18	28/04/2012	H2	F	Square	Triangle	Key	Diamond
19	28/04/2012	JB1	M	Diamond	Triangle	Square	Key
20	29/04/2012	4	M	Trianlge	Square	Diamond	Key
21	29/04/2012	13	M	Diamond	Key	Triangle	Square
22	29/04/2012	21	M	Key	Diamond	Triangle	Square
23	30/04/2012	H1	M	Diamond	Key	Square	Triangle
24	8/05/2012	2	M	Key	Triangle	Diamond	Square
25	30/05/2012	3	F	Diamond	Triangle	Key	Square
26	30/05/2012	22	F	Square	Diamond	Key	Triangle
27	26/08/2012	8b	M	Key	Triangle	Diamond	Square
28	27/08/2012	2b	F	Key	Diamond	Triangle	Square
29	28/08/2012	4b	F	Diamond	Square	Key	Triangle
30	28/08/2012	10b	M	Diamond	Square	Triangle	Key

A.3 Laboratory size preference test design layout

Test number	Date	Possum	Sex	Left			Right
1	28/04/2012	25	F	Small	Medium	Large	Tight
2	28/04/2012	27	M	Tight	Medium	Small	Large
3	30/04/2012	26	F	Medium	Large	Tight	Small
4	30/04/2012	28	F	Tight	Small	Large	Medium
5	30/04/2012	29	M	Large	Small	Medium	Tight
6	30/04/2012	30	M	Small	Large	Tight	Medium
7	30/04/2012	31	F	Small	Large	Tight	Medium
8	1/05/2012	2	M	Medium	Large	Small	Tight
9	1/05/2012	18	M	Large	Medium	Small	Tight
10	1/05/2012	4	M	Medium	Tight	Large	Small
11	3/05/2012	3	F	Small	Large	Medium	Tight
12	3/05/2012	H2	F	Medium	Small	Large	Tight
13	3/05/2012	13	M	Small	Medium	Large	Tight
14	5/05/2012	14	M	Large	Medium	Tight	Small
15	5/05/2012	15	M	Large	Tight	Medium	Small
16	5/05/2012	16	F	Tight	Medium	Large	Small
17	7/05/2012	12	M	Tight	Small	Medium	Large
18	7/05/2012	22	F	Small	Large	Medium	Tight
19	8/05/2012	JB1	M	Small	Medium	Large	Tight
20	8/05/2012	32	M	Medium	Large	Tight	Small
21	8/05/2012	33	F	Tight	Large	Small	Medium
22	9/05/2012	JB2	F	Large	Medium	Tight	Small
23	9/05/2012	24	F	Small	Large	Tight	Medium
24	26/08/2012	4b	F	Small	Medium	Large	Tight
25	26/08/2012	5b	F	Large	Medium	Tight	Small
26	27/08/2012	3b	F	Tight	Small	Large	Medium
27	27/08/2012	6b	F	Small	Tight	Large	Medium
28	28/08/2012	9b	M	Large	Small	Tight	Medium
29	28/08/2012	2b	F	Medium	Tight	Large	Small
30	29/08/2012	8b	M	Tight	Small	Large	Medium

A.4 Laboratory material preference test design layout

Test number	Date	Possum	Sex	Left			Right
1	10/05/2012	24	F	Plastic	Metal	Wood	Corflu
2	10/05/2012	26	F	Corflu	Wood	Plastic	Metal
3	10/05/2012	28	F	Wood	Metal	Corflu	Plastic
4	13/05/2012	25	F	Corflu	Metal	Wood	Plastic
5	13/05/2012	21	M	Plastic	Corflu	Wood	Metal
6	13/05/2012	27	M	Plastic	Corflu	Metal	Wood
7	14/05/2012	32	M	Corflu	Metal	Plastic	Wood
8	21/05/2012	33	F	Plastic	Wood	Metal	Corflu
9	22/05/2012	30	M	Corflu	Metal	Wood	Plastic
10	23/05/2012	29	M	Corflu	Plastic	Wood	Metal
11	23/05/2012	22	F	Corflu	Wood	Plastic	Metal
12	23/05/2012	31	F	Metal	Wood	Corflu	Plastic
13	24/05/2012	3	F	Plastic	Wood	Corflu	Metal
14	24/05/2002	18	M	Metal	Corflu	Plastic	Wood
15	24/05/2012	14	M	Wood	Corflu	Metal	Plastic
16	25/05/2012	4	M	Wood	Plastic	Metal	Corflu
17	25/05/2012	15	M	Wood	Plastic	Metal	Corflu
18	25/05/2012	16	F	Plastic	Corflu	Wood	Metal
19	28/05/2012	H2	F	Wood	Metal	Plastic	Corflu
20	28/05/2012	2	M	Corflu	Metal	Wood	Plastic
21	28/05/2012	JB1	M	Plastic	Wood	Metal	Corflu
22	26/08/2012	2b	F	Wood	Plastic	Metal	Corflu
23	26/08/2012	3b	F	Plastic	Corflu	Wood	Metal
24	27/08/2012	4b	F	Wood	Corflu	Metal	Plastic
25	27/08/2012	5b	F	Wood	Plastic	Metal	Corflu
26	28/08/2012	7b	F	Corflu	Plastic	Metal	Wood
27	28/08/2012	8b	M	Corflu	Plastic	Wood	Metal
28	29/08/2012	6b	F	Corflu	Wood	Plastic	Metal
29	29/05/2012	9b	M	Corflu	Metal	Wood	Plastic
30	30/08/2012	10b	M	Metal	Wood	Plastic	Corflu

A.5 Laboratory landscape position preference test design layout

Test number	Date	Possum	Sex	Left			Right
1	1/05/2012	24	F	Timm's	Henry	Warrior	Box
2	4/05/2012	2	M	Henry	Timm's	Box	Warrior
3	4/05/2012	3	F	Warrior	Henry	Box	Timm's
4	7/05/2012	25	F	Box	Timm's	Warrior	Henry
5	7/05/2012	31	F	Warrior	Timm's	Henry	Box
6	8/05/2012	32	M	Henry	Timm's	Box	Warrior
7	8/05/2012	16	F	Timm's	Box	Henry	Warrior
8	9/05/2012	13	M	Warrior	Timm's	Henry	Box
9	9/05/2012	222	M	Box	Henry	Warrior	Timm's
10	9/05/2012	H1	M	Box	Warrior	Timms	Henry
11	10/05/2012	JB1	M	Warrior	Box	Timms	Henry
12	13/05/2012	15	M	Box	Henry	Timms	Warrior
13	13/05/2012	14	M	Warrior	Henry	Box	Timm's
14	21/05/2012	21	M	Henry	Box	Warrior	Timm's
15	21/05/2012	H2	F	Box	Timm's	Warrior	Henry
16	22/05/2012	27	M	Warrior	Timm's	Henry	Box
17	22/05/2012	29	M	Timm's	Box	Warrior	Henry
18	22/05/2012	22	F	Box	Warrior	Timms	Henry
19	23/05/2012	28	F	Warrior	Timm's	Box	Henry
20	23/05/2012	30	M	Timm's	Henry	Box	Warrior
21	30/05/2012	4	F	Box	Warrior	Henry	Timm's
22	30/05/2012	26	F	Box	Warrior	Henry	Timm's
23	26/08/2012	10b	M	Henry	Box	Warrior	Timm's
24	26/08/2012	9b	M	Henry	Box	Warrior	Timm's
25	27/08/2012	7b	M	Timm's	Box	Henry	Warrior
26	27/08/2012	8b	M	Henry	Box	Warrior	Timm's
27	28/08/2012	2b	F	Warrior	Timm's	Henry	Box
28	28/08/2012	3b	F	Henry	Warrior	Box	Timm's
29	29/08/2012	5b	M	Henry	Box	Timms	Warrior
30	30/08/2012	6b	F	Timm's	Warrior	Box	Henry

Colour preference trial laboratory results

Trial #	Possum	Sex	Weight (KG)	Preference 1	Preference 2	Preference 3	Preference 4	Approach speed	Approach confidence	Body Position	Approach angle
1	23	M	2.45	White	Black	Blue	Yellow	Steady	Gained Lost conf	Head + Limb	Left
2	24	F	2.5	White	Blue	Black	Yellow	Steady	Confident	Head + Limb	Left
3	25	F	3.06	Yellow	Black	Blue	White	Steady	Gained Lost conf	Head + Limb	Straight
4	26	F	2.85	Black	Blue	White	Yellow	Fast	Confident	Head + Limb	Left
5	27	M	2.85	Blue	Black	White	Yellow	Steady	Gained Lost conf	Head	Straight
6	28	F	1.99	Black	White	Yellow	Blue	Steady	Gained Lost conf	Head + Limb	Right
7	29	M	3.57	Blue	Black	White	Yellow	Steady	Gained Lost conf	Head + Limb	Right
8	30	M	2.42	Black	Blue	White	Yellow	Steady	Gained Lost conf	Head + Limb	Left
9	31	F	1.5	Yellow	Black	White	Blue	Fast	Gained Lost conf	Head + Limb	Straight
10	32	M	1.77	Black	Blue	Yellow	NA	Slow	Lost confidence	Head + Limb	Straight
11	33	F	2.6	Black	Blue	White	Yellow	Steady	Gained Lost conf	Head + Limb	Straight
12	22	F	3.55	Black	Blue	White	Yellow	Steady	Confident	Head + Limb	Left
13	10	F	2.4	Blue	Black	White	Yellow	Steady	Gained Lost conf	Head + Limb	Right
14	15	M	2.38	Blue	White	Black	Yellow	Steady	Gained Lost conf	Head + Limb	Right
15	8	M	2.3	Yellow	White	Black	Blue	Steady	Lost confidence	Head + Limb	Left
16	222	M	2.85	Black	White	Yellow	Blue	Steady	Confident	Head + Limb	Straight
17	4	M	1.76	Yellow	White	Blue	Black	Steady	Confident	Head + Limb	Straight
18	16	F	2.46	Black	White	Yellow	Blue	Fast	Confident	Head + Limb	Left
19	18	M	1.2	Black	White	Blue	Yellow	Steady	Confident	Head + Limb	Left
20	3	F	2.77	Blue	NA	NA	NA	Slow	Lost confidence	Head + Limb	Straight
21	14	M	1.91	Black	Yellow	White	Blue	Steady	Confident	Head + Limb	Straight
22	2	M	2.57	Black	NA	NA	NA	Slow	Lost confidence	Head + Limb	Straight
23	JB1	M	3.29	Black	White	NA	NA	Slow	Gained Lost conf	Head + Limb	Straight
24	21	M	2.21	NA	NA	NA	NA	NA	NA	NA	NA
25	13	M	3.6	NA	NA	NA	NA	NA	NA	NA	NA
26	H1	M	3.3	Black	White	Yellow	Blue	Fast	Confident	Head + Limb	Left
27	H2	F	2.7	White	Blue	Yellow	Black	Fast	Confident	Head + Limb	Straight
28	7b	M	2.7	Yellow	Black	White	Blue	Steady	Gained Lost conf	Head	Straight
29	5b	M	2.65	White	Black	Yellow	Blue	Fast	Confident	Head + Limb	Left
30	2b	F	2.7	Black	White	Blue	NA	Fast	Confident	Head + Limb	Left

Entrance geometry preference trial laboratory results

Trial #	Possum	Sex	Weight (KG)	Preference 1	Preference 2	Preference 3	Preference 4	Approach speed	Approach confidence	Body Position	Approach angle
1	23	M	2.45	Key	Square	Triangle	Diamond	Steady	Gained lost conf	Head + Limb	Straight
2	25	F	3.06	Square	Triangle	Diamond	Key	Steady	Confident	Head + Limb	Straight
3	24	F	2.5	Square	Triangle	Key	NA	Steady	Gained lost conf	Head + Limb	Left
4	26	F	2.85	Square	Triangle	Key	NA	Fast	Confident	Head + Limb	Left
5	27	M	2.85	Diamond	Key	Square	Triangle	Steady	Gained lost conf	Head	Straight
6	28	F	1.99	Square	Key	Triangle	Diamond	Steady	Gained lost conf	Head + Limb	Right
7	29	M	3.57	Key	Square	Diamond	Triangle	Steady	Gained lost conf	Head + Limb	Straight
8	31	F	1.77	Key	Square	Diamond	NA	Steady	Gained lost conf	Head + Limb	Straight
9	32	M	1.77	Diamond	Triangle	Key	Square	Fast	Gained lost conf	Head + Limb	Left
10	222	M	2.85	Square	Key	NA	NA	Slow	Gained lost conf	Head + Limb	Straight
11	33	F	2.6	Square	Diamond	Key	Triangle	Steady	Gained lost conf	Head + Limb	Bottom
12	18	M	1.2	NA	NA	NA	NA	Steady	Gained lost conf	Head + Limb	NA
13	30	M	2.42	Key	Triangle	Square	Diamond	Steady	Confident	Head + Limb	Left
14	12	M	2.85	Triangle	Key	Square	Diamond	Steady	Gained lost conf	Head + Limb	Right
15	10	F	2.4	Diamond	Square	NA	NA	Steady	Gained lost conf	Head + Limb	Left
16	16	F	2.46	Square	Diamond	Key	Triangle	Steady	Gained lost conf	Head + Limb	Straight
17	14	M	1.91	Square	Diamond	NA	NA	Steady	Gained lost conf	Head + Limb	Bottom
18	H2	F	2.7	Diamond	Key	NA	NA	Fast	Confident	Head + Limb	Right
19	JB1	M	3.29	Square	Diamond	Key	Triangle	Steady	Confident	Head + Limb	Right
20	4	M	1.76	NA	NA	NA	NA	Slow	Lost confidence	Head + Limb	NA
21	13	M	3.6	Square	Triangle	NA	NA	Steady	Confident	Head + Limb	Straight
22	21	M	2.21	Key	NA	NA	NA	Slow	Lost confidence	Head + Limb	Straight
23	H1	M	2.7	Key	Diamond	NA	NA	Slow	Gained lost conf	Head + Limb	Straight
24	2	M	2.57	Square	NA	NA	NA	NA	NA	NA	Bottom
25	3	F	2.77	Square	Key	Diamond	Triangle	NA	NA	NA	Right
26	22	F	3.55	Square	Diamond	Key	Triangle	Fast	Confident	Head + Limb	Left
27	8b	M	2.65	Triangle	Key	Square	Diamond	Fast	Confident	Head + Limb	Bottom
28	2b	F	2.7	Triangle	Square	Key	Diamond	Steady	Gained lost conf	Head	Straight
29	4b	F	1.76	Square	Key	Triangle	Diamond	Fast	Confident	Head + Limb	Left
30	10b	M	2.75	Key	Triangle	Square	Diamond	Fast	Confident	Head + Limb	Straight

Trap size entrance trial laboratory results

Trial #	Possum	Sex	Weight (KG)	Preference 1	Preference 2	Preference 3	Preference 4	Approach speed	Approach confidence	Body Position	Approach angle
1	25	F	3.06	Medium	Large	Tight	Small	Fast	Confident	Head + Limb	Straight
2	27	M	2.85	Small	Tight	Medium	Large	Steady	Gained lost conf	Head + Limb	Right
3	26	F	2.85	Medium	Large	Tight	Small	Steady	Gained lost conf	Head + Limb	Straight
4	28	F	1.99	Tight	Small	Medium	Large	Slow	Gained lost conf	Head + Limb	Bottom
5	29	M	3.57	Large	Medium	Tight	Small	Steady	Confident	Head + Limb	Straight
6	30	M	2.42	Medium	Tight	Small	Large	Steady	Gained lost conf	Head + Limb	Straight
7	31	F	1.5	Small	Large	Medium	NA	Steady	Gained lost conf	Head + Limb	Left
8	2	M	2.57	Tight	Small	Large	Medium	Slow	Gained lost conf	Head + Limb	Bottom
9	18	M	1.2	Small	Medium	Tight	Large	Steady	Gained lost conf	Head + Limb	Left
10	4	M	1.76	Large	Medium	Small	Tight	Slow	Lost confidence	Head + Limb	Straight
11	3	F	2.77	Large	Tight	Medium	Small	Fast	Confident	Head + Limb	Left
12	H2	F	2.7	Large	Tight	Medium	Small	Steady	Gained lost conf	Head	Right
13	13	M	3.6	Medium	Small	Tight	Large	Steady	Gained lost conf	Head + Limb	Straight
14	14	M	1.91	Tight	Medium	Small	Large	Fast	Gained lost conf	Head + Limb	Straight
15	15	M	2.38	Large	Small	Tight	Medium	Steady	Gained lost conf	Head	Left
16	16	F	2.46	Large	Medium	NA	NA	Slow	Lost confidence	Head + Limb	Straight
17	12	M	2.85	Large	Small	Medium	Tight	Steady	Gained lost conf	Head + Limb	Straight
18	22	F	3.55	Large	Tight	Medium	Small	Fast	Confident	Head + Limb	Right
19	JB1	M	3.29	Large	Tight	Medium	Small	Fast	Gained lost conf	Head + Limb	Left
20	32	M	1.77	Small	Medium	NA	NA	Steady	Gained lost conf	Head + Limb	Straight
21	33	F	2.6	Large	Tight	Medium	Small	Fast	Confident	Head + Limb	Left
22	JB2	F	3.15	Medium	Large	Tight	Small	Fast	Gained lost conf	Head + Limb	Straight
23	24	F	2.5	Large	Medium	Tight	Small	Steady	Confident	Head + Limb	Right
24	4b	F	1.76	Medium	Large	Small	Tight	Slow	Lost confidence	Head + Limb	Straight
25	5b	M	2.65	Large	Medium	Tight	Small	Slow	Gained lost conf	Head + Limb	Left
26	3b	F	2.6	Large	Medium	Tight	Small	Steady	Confident	Head + Limb	Straight
27	6b	F	2.55	Large	Medium	Small	NA	Slow	Gained lost conf	Head + Limb	Right
28	9b	M	2.65	Tight	Large	Medium	Small	Fast	Confident	Head + Limb	Straight
29	2b	F	2.7	Small	Large	Medium	Tight	Slow	Lost confidence	Head + Limb	Bottom
30	8b	M	2.65	Large	Medium	Small	Tight	Slow	Confident	Head + Limb	Bottom

Material attractiveness trial laboratory results

Trial #	Possum	Sex	Weight (KG)	Preference 1	Preference 2	Preference 3	Preference 4	Approach speed	Approach confidence	Body Position	Approach angle
1	24	F	2.5	Metal	Wood	Corflu	Plastic	Fast	Confident	Head + Limb	Straight
2	26	F	2.85	Wood	Plastic	Metal	Corflu	Steady	Gained lost conf	Head + Limb	Left
3	28	F	1.99	Metal	Corflu	Plastic	Wood	Fast	Gained lost conf	Head + Limb	Right
4	25	F	3.06	Plastic	Wood	Metal	Corflu	Steady	Gained lost conf	Head + Limb	Straight
5	21	M	2.21	Wood	Plastic	Metal	Corflu	Steady	Gained lost conf	Head + Limb	Straight
6	27	M	2.85	Wood	Corflu	Plastic	Metal	Slow	Gained lost conf	Head + Limb	Bottom
7	32	M	1.77	Corflu	Metal	Wood	Plastic	Slow	Lost confident	Head + Limb	Bottom
8	33	F	2.6	Wood	Metal	Plastic	Corflu	Fast	Confident	Head + Limb	Left
9	30	M	2.42	Corflu	Metal	Plastic	Wood	Steady	Gained lost conf	Head + Limb	Left
10	29	M	3.57	Plastic	Metal	Wood	Corflu	Steady	Gained lost conf	Head + Limb	Straight
11	22	F	3.55	Corflu	Wood	Metal	Plastic	Steady	Lost confident	Head + Limb	Right
12	31	F	1.5	Corflu	Wood	NA	NA	Slow	Lost confident	Head + Limb	Bottom
13	3	F	2.77	Corflu	Plastic	Wood	Metal	Steady	Gained lost conf	Head + Limb	Straight
14	18	M	1.2	Plastic	Metal	Corflu	Wood	Steady	Confident	Head + Limb	Straight
15	14	M	1.91	Corflu	Metal	Plastic	Wood	Fast	Confident	Head + Limb	Straight
16	4	M	1.76	Metal	Corflu	Wood	Plastic	Fast	Confident	Head + Limb	Left
17	15	M	2.38	Corflu	Wood	Plastic	Metal	Steady	Gained lost conf	Head + Limb	Straight
18	16	F	2.46	Wood	Metal	Plastic	Corflu	Slow	Lost confident	Head + Limb	Bottom
19	H2	F	2.7	Metal	Wood	Plastic	Corflu	Fast	Gained lost conf	Head + Limb	Straight
20	2	M	2.57	Corflu	Metal	Plastic	Wood	Fast	Confident	Head + Limb	Straight
21	JB1	M	3.29	Metal	Wood	Corflu	Plastic	Steady	Gained lost conf	Head + Limb	Straight
22	2b	F	2.7	Metal	Wood	Corflu	Plastic	Slow	Lost confident	Head + Limb	Left
23	3b	F	2.6	Wood	Plastic	Metal	Corflu	Slow	Gained lost conf	Head + Limb	Straight
24	4b	F	1.76	Metal	Corflu	Wood	Plastic	Steady	Confident	Head + Limb	Bottom
25	5b	M	2.65	Metal	Corflu	Wood	Plastic	Steady	Gained lost conf	Head + Limb	Right
26	7b	F	2.7	Metal	Plastic	Wood	Corflu	Slow	No confidence	Head + Limb	Straight
27	8b	M	2.65	Wood	Metal	Corflu	Plastic	Steady	Gained lost conf	Head + Limb	Left
28	6b	F	2.55	Wood	Metal	Plastic	NA	Steady	Confident	Head + Limb	Straight
29	9b	M	2.85	Plastic	Corflu	Metal	Wood	Slow	Lost confident	Head + Limb	Bottom
30	10b	M	2.75	Plastic	Corflu	Metal	Wood	Fast	Confident	Head + Limb	Straight

Trap landscape position preference trial laboratory results

Trial #	Possum	Sex	Weight (KG)	Preference 1	Preference 2	Preference 3	Preference 4	Approach speed	Approach confidence	Body Position	Approach angle
1	24	F	2.5	Timms	Warrior	Henry	Box	Steady	Gained lost conf	Head + Limb	Straight
2	2	M	2.57	Warrior	Box	Timms	Henry	Steady	Gained lost conf	Head + Limb	Straight
3	3	F	2.77	Warrior	Henry	Timms	Box	Steady	Lost confident	Head + Limb	Straight
4	25	F	3.06	Timms	Henry	Warrior	Box	Fast	Gained lost conf	Head + Limb	Straight
5	31	F	1.5	Timms	Warrior	Box	Henry	Slow	Lost confident	Head + Limb	Straight
6	32	M	1.77	Timms	Warrior	Box	Henry	Steady	Gained lost conf	Head + Limb	Straight
7	16	F	2.46	Warrior	Timms	Box	Henry	Steady	Gained lost conf	Head + Limb	Straight
8	13	M	3.6	NA	NA	NA	NA	NA	NA	NA	NA
9	222	M	2.85	Timms	Henry	Box	Warrior	Fast	Confident	Head + Limb	Straight
10	H1	M	2.7	Timms	Henry	Warrior	Box	Steady	Gained lost conf	Head + Limb	Straight
11	JB1	M	3.29	Timms	Box	Henry	Warrior	Steady	Gained lost conf	Head + Limb	Straight
12	15	M	2.38	Timms	Henry	Warrior	Box	Steady	Lost confident	Head + Limb	Straight
13	14	M	1.91	Timms	Warrior	Henry	Box	Fast	Confident	Head + Limb	Straight
14	21	M	2.21	Warrior	Timms	Box	Henry	Steady	Gained lost conf	Head + Limb	Left
15	H2	F	2.7	Timms	Warrior	Henry	Box	Slow	Lost confident	Head + Limb	Straight
16	27	M	2.85	Henry	Box	Warrior	Timms	Fast	Confident	Head + Limb	Right
17	29	M	3.57	Timms	Box	Warrior	Henry	Steady	Gained lost conf	Head + Limb	Straight
18	22	F	3.55	Warrior	Box	Henry	Timms	Steady	Gained lost conf	Head + Limb	Left
19	28	F	1.99	Timms	Warrior	Box	Henry	Fast	Confident	Head + Limb	Straight
20	30	M	2.42	Timms	Box	Warrior	Henry	Steady	Gained lost conf	Head + Limb	Left
21	4	M	1.76	Timms	Box	Henry	Warrior	Fast	Confident	Head + Limb	Left
22	26	F	2.85	Warrior	Timms	Box	Henry	Fast	Confident	Head + Limb	Left
23	10b	M	2.75	Henry	Box	Timms	Warrior	Steady	Gained lost conf	Head	Right
24	9b	M	2.85	Timms	Henry	Box	Warrior	Steady	Confident	Head + Limb	Straight
25	7b	F	2.7	Box	Timms	Warrior	Henry	Fast	Confident	Head + Limb	Right
26	8b	M	2.65	Box	Warrior	Henry	Timms	Fast	Confident	Head + Limb	Right
27	2b	F	2.7	Timms	Box	Henry	Warrior	Fast	Confident	Head + Limb	Left
28	3b	F	2.6	Box	Warrior	Henry	Timms	Steady	Confident	Head + Limb	Left
29	5b	M	2.65	Timms	Box	Henry	NA	Steady	Confident	Head + Limb	Straight
30	6b	F	2.55	Timms	Box	Henry	Warrior	Fast	Confident	Head + Limb	Straight

Appendix B

STANDARD OPERATING PROCEDURES

Possum's acclimatisation and husbandry

1. Procurement

- Possums will be captured from the wild. All endeavours will be made to catch possums within a fifty kilometre radius of Lincoln Township.
- Possums will be caught using wire cage traps (minimum size: 0.6m x 0.3m x 0.3m) that will be checked within 3 hours of sunrise as possums are susceptible to heat exposure and dehydration.
- Traps will be baited with an apple and a lure of cinnamon oil, icing sugar and flour mix.
- Possums will be transferred into a thick sack for initial examination and transportation.

2. Arrival

- Upon arrival possums will be checked over under isoflurane anaesthetic using the CWMC Possum Arrival Check sheet, they will be sexed, weighed and ear tagged, given a full body inspection including glands, any capture injuries will be treated as deemed necessary. Animals with injuries that would impede conduct of the trial will be euthanised and any pouch young will be removed and euthanised via cervical dislocation.
- All animals are assigned to a Principal investigator/s with a work plan and AEC number – this information is all recorded onto the individual cage card.

3. Acclimatisation

- Possums generally adapt well to captivity; however some can be susceptible to initial weight loss (particularly females). Accordingly, all animals food consumption is monitored daily, animals are visually checked daily.
- After the 2-week acclimatisation period, all animals will be weighed again, and those with a stable body weight are then deemed suitable for experimentation.
- Animals not adapting to captivity can develop diarrhea, can become anorexic and/or dehydrated. Accordingly, any animals losing more than 20% of initial capture weight will be enthanised using a CO_2 bath.

4. Caging/Pens

- All possums are individually housed in the outdoor pens (3m x 1.5m x 2m). Pens have a rain and wind proof shelter, a nesting box at ground level, a hessian nesting sack and/or sack hammock and tree branches to allow climbing.
- During summer pens are designed for effective ventilation. Shade will be provided via shade cloth on the open roof area to protect against excessive heat.
- Animals may be transferred to the indoor housing for short periods (2-3 weeks). Indoor possums are individually housed in galvanized steel mesh cages (minimum size: 1m x 0.4m x 0.55m) with mesh floors.
- A detachable nest box (minimum size: 0.35m x 0.2m x 0.2m) will also be installed in the cage to provide seclusion.

5. Environment

Indoor

- Light cycle: 12 hours light/12 hours dark (exceptions are noted on the room sign)
- Humidity: 30%-70%
- Temperature: 20°C
- Any environmental problems in the room (i.e. room temperature variations, obvious ventilation changes) will be reported to Lab Manager Jenn Bothwell or Martin Ridgway. Phone numbers are posted next to the phone in the hallway.

Outdoor

- Temperature and weather will be recorded daily.

6. Water

- Water will be provided ad libitum in both the indoor and outdoor pens.

7. Feed

- Possums are fed grain-based possum pellets ad lib (unless otherwise indicated) via a hopper. Feed should be kept at a level equivalent to one week intake at all times. Hoppers are not to be transferred to another possum's cage.
- Possums are hind-gut fermenters and require a high fibre diet. Daily possums are also offered a muesli mix of cracked corn, split peas, oats, wheat, barley, linseed pellets and extruded lupins, this mix works well for any fussy eaters.
- Possums will be fed daily seasonal fruit and/or greens such as carrots, apples and other fruits and vegetables, eucalyptus and other leafy browse will be provided for food and enrichment; they will also be given Vitamin B12 powder on their muesli mix or fruit, to assist to stimulate appetite for the first two weeks from arrival.
- Products will high levels of calcium will be avoided as possums are susceptible to calcinosis.
- If testing bait palatability it may be important to have a varied diet so that the possums do not become habituated to any feed type prior to the study.

8. Bedding

- Bedding for indoor nest boxes is not required and each outdoor pen is supplied with a Hessian nesting sack.

9. Cage and Outdoor Pen Cleaning

- Any food scraps left over will be removed daily, possums faeces will be removed weekly. Outdoor pens have a bark floor, the bark is removed after each possum, dwangs and walls are scrubbed down, and finally the whole pen is sprayed down with F10 veterinary disinfectant. The hessian sack will also be replaced for new possums.
- Trays under indoor cages will have any waste food removed daily; they are hosed clean of any faeces.
- Inside nest boxes will be cleaned fortnightly, more often for some individuals if required.

10. Room Sanitation

- Cleaning implements (brooms, bins, racks etc) will be cleaned every 6 months. – see Room Sanitation SOP) or more often during species changes in rooms or end of trials.

11. Paperwork

- Records of general health, bodyweight and water and food consumption will be entered into the husbandry ledger.
- Indoor paperwork including AEC's for current trials, animal numbers and results will be kept on the clipboard in each room. Do not remove the clipboard from its associated

room. Copies of current AECs and other paperwork is held by the Animal Lab Manager (Jenn Bothwell) will also be kept in the dry lab office.

12. Animal Health

- Observe rats for health status, adequate feed and water every day.
- Signs of illness may include, inactive (other than normal day time sleeping behavior) sitting out in the open in the outside pens, labored breathing, ocular or nasal discharge, excessive salivation, hair loss (Previous research with captive possums has indicated mortality due to blockages in the gut, mainly induced by excessive fur ingestion. Accordingly, during visual inspection signs of fur loss and excessive grooming will be monitored) weight loss or diarrhea.
- Any animal in severe distress will be promptly euthanised using a CO_2 bath (see below).
- Report health problems straightaway to the laboratory manager (Jenn Bothwell), PI or facilities manager (Martin Ridgway). Detail animal and problems on whiteboard and in daily activity log book.
- If you find a dead animal, place the carcass in a yellow biohazard bag. Record the cage and/or animal number on the whiteboard in both the possum shed/room and the daily log book. Also fill in the relevant details on any monitoring sheets. Place the animal in the freezer and notify the lab manager or PI immediately.

13. Daily Activity Log

- Record all animal husbandry and room/pen activities in the Daily Activity Log book in the possum shed or room. Please mark with your initials.
- Special instructions can be written on the whiteboard in the room/possum shed.

14. Housekeeping and Room Maintenance for indoors

- Animal room floors should be cleaned daily including sweeping and wiping down hard surfaces.
- Clean and disinfect the animal room floor using F10 sanitiser provided in the cleaning room every fortnight.
- Empty cages are cleaned in the room; nest boxes are cleaned and sanitised in the cleaning room, and stored to dry in the cleaning room.

15. Euthanasia

- Euthanasia of possums will be undertaken by placing the possum in its nest box within a sealed 20 litre box and administering CO_2 until the animal expires.
- Without pre-charging the chamber, we will introduce 100% carbon dioxide at the rate of 20% of the chamber volume per minute so as to optimise reduction in distress (i.e. 1-2 litres per minute).
- After the animal becomes unconscious, the flow rate will be increased to minimise the time to death. Possums will be left in the container until clinical death has been ensured; cessation of breathing has been established. This procedure will only be performed by staff with appropriate training.

Do NOT:

- Use animal rooms as storage areas
- Leave unneeded equipment, boxes etc. in rooms – rooms should not be cluttered. Cupboard space is available for smaller items to be stored

Do:

- Avoid making loud noises within the animal facility and moving animals unnecessarily
- Clean up after yourself; leave rooms/pens tidy as you have found them. Report any concerns to the lab manager.
- Be familiar with and refer to the "Code of Ethical Conduct for the Use of Animals" (a hardcopy copy of which can be found in the dry lab)

Prepared by James Ross December, 2011.
Updated 10/10/12 J.Bothwell

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