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# Testing and improving baiting technologies for the management of mice (*Mus musculus*)

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A dissertation

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Abstract of a dissertation submitted in partial fulfilment of the

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# Testing and improving baiting technologies for the management of mice (*Mus musculus*)


## By K. Hopkins



In New Zealand, mice are a pest of conservation and economic importance. The work presented here was aimed at testing and improving baiting technologies for the management of mice. The objectives undertaken were: (1) to determine whether cellophane wrapped baits have an increased attractiveness to mice, (2) to measure the palatability of baits containing an antifungal compound against baits without the antifungal compound, (3) to measure the palatability of FF213 paste bait, and (4) to determine whether bait palatability differs between domestic and wild mice.

To test the attractiveness of cellophane-wrapped bait one mouse was allowed to feed on a wrapped bait while four wild mice in separate surrounding enclosures where observed for an hour. Results were collected using two methods; firstly time interacting with the bait as a percentage of the total, where time in the inner section of the surrounding enclosures was taken as a percentage of time when the middle mouse was interacting with the bait. Secondly, fifteen second counts, where observations of the mouse's location were taken every 15 seconds over one hour. Percentage data found all mice in all trials spent a higher proportion of time near the central mouse when the central mouse was presented cellophane-wrapped bait, compared with when it was presented unwrapped bait. However overall results where not statistically significant ($F_{1,111}$= 0.72; P = 0.399). While 15 second count data found mice spent a statistically higher proportion of time in the inner section when the bait was unwrapped ($X^2_{1,23}$ = 5,26; P = 0.022). The results of this study reject the notion that wrapping baits in cellophane increases it attractiveness to other wild mice.

Two-choice palatability trials showed that multi-species bait Ferafeed 213 had a significantly lower palatability than an EPA (experimental control )bait when tested on wild mice (trial 2: P=0.01, trial 3: P=0.002), though there was no significant difference for

domestic mice. A significant difference (P=0.004) was also found between the palatability for wild and domestic mice, with wild mice being less accepting of baits compared to domestic-raised mice. Two-choice trials on the multi-species Erayz antifungal bait found no statistically significant difference in palatability for wild or domestic mice when compared to Erayz bait without the antifungal compound. There were also no statistically significant differences in palatability between domestic mice than wild mice and all individuals consumed some test bait.

In conclusion the study found the cellophane type tested did not significantly alter the attractiveness of baits to wild-caught mice. Palatability trials found FF213 bait less palatable to wild-caught mice than the EPA standard, while domestic mice appear to be less discerning of baits. The results of this study also concluded that the addition of the antifungal compound did not alter the palatability of Erayz baits to wild-caught or domestic mice. While rodent control techniques in New Zealand have been developed primarily with rats as the target species, this study provides species-specific information focusing on wild caught mice, improving baiting technology for the future management of mice in New Zealand.

**Key Words:** House mouse, *Mus musculus*, bait palatability, attractiveness, cellophane, wrapped, control, antifungal bait

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# Chapter 1 Introduction

House mice (*Mus musculus*) have a major impact on food production world wide, damaging field crops and storage materials, while creating problems for exporting countries by distributing droppings and hairs resulting in the rejection of entire loads (Lund 1996). In New Zealand mice are also known as pests due to their predation of native arthropods, birds and their eggs, lizards (Redhead et al 1985, Badan 1986, Miller & Miller 1995, Hook & Todd 1992, Brignall-Theyer 1998). The house mouse is considered the most difficult pest to control or eradicate in New Zealand, and mice are considered to be the greatest threat to offshore islands because they are the most likely species to reinvade (O'Connor & Booth 2001). Dilks et al. (2003) describe mice as a problem in New Zealand due to their ability to support populations of larger predators including stoats.

Mice are therefore an important conservation and primary production pest in New Zealand, and there is a need for research on technologies that can be used to manage the negative impacts of this species. In this dissertation I address three areas of research that are pertinent to the current mice management scene in New Zealand: (1) enhancing the attractiveness of baits, (2) comparing bait preferences between domestic-raised and wild-caught mice, and (3) enhancing the palatability to mice of new commercial baits.

Rodent control techniques used in New Zealand have been developed primarily with rats as the target species (Clapperton 2006). While significant research has gone into the control of rats and possums, mice have received less attention.

One currently under-developed method that shows promise for increasing attractiveness of baits to mice, is that of cellophane-wrapped baits. Little research has been conducted in this area, and as such, the research conducted here explores the possibility that cellophane-wrapped baits create an increased attractiveness to nearby mice, an idea first discussed by Henderson & Frampton (2007b).

The benefits derived from the use of the laboratory mouse as a research tool is often offset by the continued success of wild mice (Festing & Lovell 1981). Whether palatability of domestic and wild mice differs is a topic of limited research. In this study, both domestic and wild house mice were used to establish whether wild mice should be used in trials instead of their more domestic relatives. Two commercial baits, including one with an antifungal compound additive were tested in order to establish two things: (1) whether the palatability of the test baits were higher than the controls used, and (2) whether domestic and wild mouse palatability scores showed a significant difference.

Commercial baits tested in the palatability trial included Ferafeed 213 (FF213), a multi-species paste bait, and Erayz antifungal treated bait (with the idea that a bait with antifungal properties will have an increased field life). Both of these baits have proven to be palatable to rats and possums, while this study focussed on their palatability for mice.

# Chapter 2 Literature review

## 2.1 Mice as a pest

Meehan (1984) gives three reasons why mice can be considered pests: (1) they cause monetary loss by destroying foodstuffs and materials, (2) they spread disease and (3) they are abhorred by most people. Smith & Buckle (1996) discuss the issue further by describing mice as pests because: (1) they have similar requirements to humans and domestic stock, (2) they have the potential at both the individual and the population level to respond rapidly to favourable circumstances and (3) they have the physiological and behavioural abilities to withstand unfavourable circumstances, including attempts to control them.

The present world distribution of the house mouse (*Mus musculus*) is probably more extensive than that of any other mammal apart from *Homo sapiens* (Rowe 1981). House mice, as well as some other rodent species, are known as commensal rodents, meaning that they are usually found in association with people, 'sharing the table'. However, since the word commensal implies no danger to the host these rodents might more precisely be termed kleptoparasitic (parasitism by theft - a form of feeding where one animal takes prey from another that has caught, killed, or otherwise prepared).

The impact of mice world wide is difficult to assess primarily because so many different resources can be affected by mice, and they have the ability to invade almost any type of structure. In certain parts of the world damage can occur to field crops as is the situation with the house mouse in Australia's wheat-growing areas. In industrially-developed countries with an overproduction in crops and adequate storage facilities commensal rodents like the house mouse are controlled primarily for hygienic and public health reasons, and only secondarily because of the damage inflicted on crops, stored crops or other food and materials. In many countries of subtropical or tropical regions the opposite is often observed. Starvation is often a

reoccurring threat to human populations and the damage caused by mice and other rodents to stored or field crops can be the difference between life and death. Hair and droppings in food can create huge problems for exporting countries so that entire loads are rejected by the authorities in the importing country. While in food stores mice can create problems, not only by consuming or soiling a substantial part of the food, but also because they destroy sacks, boxes, bags and other packaging materials (Lund, 1996).

House mice have also been implicated in extirpations and/or extinctions of indigenous species in ecosystems they have invaded and colonised that are outside their natural range. They are host to a range of diseases and parasites infectious to humans, the most serious being bubonic plague (*Yersinia pestis*) and salmonella (*Salmonella* spp.). However, mice are considered relatively unimportant as vectors of these diseases for their transmission to humans (Global Invasive Species Database 2008).

Although it was thought that the house mouse poses little direct predation risk to adult sea birds, recent international research and video evidence from Gough Island in the South Atlantic Ocean (Cuthbert & Hilton 2004, Wanless et al 2007) has shown conclusively that mice are responsible for widespread breeding failures and that predation of chicks by mice occurs at levels that are probably driving population decreases (Global Invasive Species Database 2008).

Studies conducted in New Zealand by O'Connor & Booth (2001) state that Department of Conservation staff identified the house mouse as the species they have greatest difficulty controlling or eradicating, shown by such failed attempts as on Mokoia Island (Cleghorn & Griffiths 2002). Mice are considered to be the greatest threat to offshore islands because they are the most likely species to reinvade. An additional problem is that in situations where mainland eradication of mammalian pests has been attempted, failure to remove mice often occurs (Saunders 2000, Gillies ed 2003).

Studies by Murphy & Dowding (1995), Alterio & Moller (1997) and Dilks et al. (2003) also describe mice as a problem in New Zealand due to their ability to support populations of larger predators. Among the best known examples of this are the population eruptions of mice that follow a heavy beech mast and support a much larger than usual cohort of stoats the following summer.

## 2.2 The House mouse in New Zealand

In New Zealand, house mice are distributed throughout the North and South Islands as well as many offshore islands, mainly through accidental transport by humans (Taylor 1984). On some islands mice have failed to establish, or live as commensals only. An example of this is Campbell Island where mice have been observed around buildings in the past, but died out after the island was abandoned in 1931 (Taylor 1978). It is thought that mice have been prevented from dispersing on these islands, including Stewart, Kapiti, and Raoul Island, by the presence of high numbers of Norway rats, as it has been found that islands without Norway rats are more likely to have mice. Mice have been eradicated from 14 islands (Appendix 1) since 1983, although many other attempts have been unsuccessful, as mice have proven to be far more difficult to eradicate than rats (King ed 2005).

### 2.2.1 Behaviour

Laboratory studies have shown that house mice are not neophobic (a fear of new things or experiences), but they are sporadic and peripatetic feeders. Meehan (1984) describes mice as 'inquisitive' and found they will readily accept new food. This means that they can feed at 20-30 different sites each night, even favouring new food sources over old ones (Meehan 1984) and might therefore be considered neophilic (a love of novel and new things). Foraging mice continually sniff the substrate, and occasionally rear up to sample airborne information (Mackintosh 1981).

The practical effect of this type of feeding behaviour is that mice, like rats, will tend to ingest only a small amount of poison bait from a new bait point, and are susceptible

to developing bait shyness if the toxicant is an acute poison (MacDonald & Fenn 1996).

### 2.2.2 Habitat

The house mouse is usually thought of as typical of urban habitats, but in New Zealand it is also found in native and exotic temperate forests, pasture, croplands, and subalpine tussock (Taylor 1978). Mice are intermittently common in beech and podocarp-hardwood forest (Murphy 1992, Fitzgerald et al. 1996, O'Donnell & Phillipson 1996, Choquenot & Ruscoe 2000, Ruscoe et al. 2003, Ruscoe et al. 2004), road edges, cut-over forest, and exotic plantations (Clout 1980, King 1996), on sand dunes (Miller 1999), in kanuka (*Kunzea ericoides*) scrub and gorse (*Ulex europaeus*) stands (Williams & Karl 2002), and in rank grass (Alterio 1994, Blackwell et al. 1998, Ratz 2000). In general, mice reach higher population densities in areas with dense ground cover. Mice also inhabit more traditional places such as houses, stores, and factories (especially those dealing with food products), rubbish tips and farm buildings. The habitat choices of individuals are a trade-off between access to food and safety from predation (Ylönen et al. 2002).

### 2.2.3 Home range

Animals move for four main reasons: (a) to find food, (b) water, (c) shelter, and (d) to find and protect breeding partners and young.

Normally rats and mice do not move great distances. These limits are referred to as a home range. This is different from a territory in that the whole of the home range is not necessarily defended, whereas a territory (a small part of the home range) usually is (Meehan 1984). Both individual and group territories may be found in wild mice in New Zealand, because territoriality and home range size are probably functions of per-capita resource availability and behavioural/social factors rather than a species characteristic. In a low-density population in the Orongorongo Valley, both males and

females maintained individual territories. Individual mice had minimum home ranges averaging 0.6ha (Murphy 1989). On sand dunes near Dunedin, mean range length was 57.6 ± 10.3 m, with a distance between successive captures usually 0-15 m (Miller 1999).

### 2.2.4 Diet

A study by Mutze et al. (1991) on food consumption rates in wild mice indicated the mice need to eat the equivalent of 17% of their body mass each day to maintain that mass, while Meehan (1984) states that mice eat up to 20%, with young animals tending to eat proportionally more than adults. However, many external factors, such as the water content, calorie content and food quality will influence the amount eaten. In general, mice only eat what is necessary to maintain health. When offered the constituent parts of a diet individually, Meehan (1984) states they will only eat enough of each dietary component to ensure good health, with this phenomenon known as 'dietary self selection'. As stated earlier, mice are considered to be light and intermittent feeders, especially when compared with rats (Crowcroft & Jeffers 1961). Mice are semi-crepuscular, they have two main feeding periods, at dusk and dawn (Rowe 1981), but continue to feed less intensively throughout the night and day (Crowcroft 1966).

In contrast to rat species that cannot survive more than a few days without access to water, the house mouse can survive without drinking by exploiting the water created by metabolism and by concentrating their urine considerably (Lund 1996).

The diet of mice exhibits remarkable flexibility, and includes both small invertebrate and plant material, helping to explain their worldwide colonising success. In New Zealand, caterpillars (Lepidoptera) are generally the most common invertebrate food group eaten followed by spiders (Araneae), beetles (Coleoptera), and weta (Orthoptera). Minor dietary items include leaves, fungal spores, annelids, arthropods, cockroaches, centipedes, earwigs, amphipods, lizards, and birds (Redhead et al. 1985, Badan 1986, Miller & Miller 1995, Brignall-Theyer 1998). Most invertebrates eaten by mice are 3-12 mm long (Craddock 1997). Mice have been found to eat a range of

seed species in feeding trials (Williams et al. 2000), including hard beech (*Northofagus trunata*), mountain beech (*N. solandri var. cliffortioides*), and rimu (*Dacrydium cupressinum*), though not miro (*Prumnopitys ferruginea*) seeds, which have a very hard husk (Ruscoe et al. 2004). In the Orongorongo Valley, slightly more plant material was found in May/August samples, and arthropods in spring/summer (Fitzgerald et al. 1996); consumption of major items of the diet may (Badan 1979, Badan 1986) or may not (Craddock 1997) directly reflect their relative availability in the habitat.

## 2.3 Mouse control in New Zealand

Rodent control techniques used in New Zealand have been developed primarily with rats as the target species (Clapperton 2006). The need for mouse-specific control techniques is best summarised by Pursley (1989) who said: "Establishing controls for either mice or rats is as different as comparing apples and oranges". Few island rodent eradication programmes (and even fewer mainland eradication programmes) have been principally aimed at mice (Cleghorn & Griffiths 2002). Mice do not often represent a direct threat to wildlife and are usually only by-kill in 1080 operations against possums or ship rats (Miller & Miller 1995). However, mice were specifically targeted in a successful eradication programme operation to protect the Cook Strait giant weta (*Deinacrida rugosa*), McGregor's skink (*Cyclodina macgregori*) and the goldstripe gecko (*Hoplodactylus chrysosireticus*) on Mana Island (Hook & Todd 1992). The Enderby Island eradication was initially intended for rabbits (*Oryctolagus cuniculis cuniculis*) and the majority of the other campaigns have focused on exterminating rat species (*Rattus rattus, R. norvegicus* and *R. exulans*). Consequently, little research has been carried out on the most effective bait types and toxins for mice (Cleghorn & Griffiths 2002).

While Clapperton (2006) acknowledges that New Zealand is a world leader in rat eradication techniques, particularly on islands, he states that only 61% of mouse eradication attempts in New Zealand from 1980 to the 1990s were successful. Most of the baits and delivery systems currently used for controlling rodents have not been

comprehensively evaluated to assess attractiveness for those animals that reside in areas with an abundance of food (Clapperton 2006).

Most control operations against infestations of house mice involve the application of rodenticides, whether as solid bait, dust, or water. Rodenticides are chemical substances used for killing rodent pests (generally through ingestion). Johnson & Prescott (1996) state that the most important feature of a rodenticide that contributes to its performance are its toxicity and palatability, both of which are largely assessed in the laboratory.

While the benefits of non-chemical methods of rodent control are increasingly recognised, lethal chemical agents, such as rodenticides, are at present the backbone of all practical rodent control programmes in both agricultural and urban environments, and this looks to continue into the future until viable alternatives become available (Buckle 1996). The fact that there is often no cost-effective alternative to poisons in rodent control raises many fears about the impacts on non-target species, secondary poisoning and the general hazards associated with highly toxic materials (MacDonald & Fenn 1996).

Not surprisingly therefore, considerable attention has been focused on rodenticides, their efficacy, best mode of application and related problems. While the occurrence of mouse population resistance to anticoagulant poisons has stimulated genetic and biochemical research, less of an advance has been made into the understanding of the physiological mechanisms involved in the development of "poison bait shyness". The occurrence of this phenomenon in rodents, the outcome of the ingestion of a sub-lethal dose of an acute poison and subsequent bait shyness, was clearly demonstrated in experimental studies conducted over 50 years ago by Rzoska (1953).

With acute poisons, inadequate control can occur as a result of a sub-lethal dose of poison. Improved success using acute poisons against mice can be achieved by the laying of non-toxic bait for two or three days before the poison is included but this "pre-baiting" technique (Southern 1954) is not always adopted for economic or other reasons (Rowe 1981). Attempts have been made to increase mice acceptance of

poison bait, including delaying the onset of poisoning symptoms by the use of microencapsulation techniques (Greaves et al. 1968, Cornwell 1970, Henderson & Frampton 2007c).

## 2.4 Domestic and laboratory mice versus wild-caught mice

The house mouse has been domesticated for several thousand years, and used scientifically since at least 1664 (Berry 1984). The domesticated house mouse, is now the most widely used experimental animal, and tests carried out on them have contributions in many fields of research, especially biomedical science. Modern strains were developed from pet mice, and to some degree also from wild mice, around 1908 (Berry 1984). Wild mice have been investigated as a source of inherited genetic material, and it has become increasingly clear that wild and laboratory mice differ in many ways. Some of these differences may be due to a founder effect, and some may be due to selection. Festing & Lovell (1981) state it is obvious that the behaviour of wild mice is very different from that of laboratory mice, presumably as a result of countless generations of selection of the latter for domestication by man, combined with natural selection for the ability to reproduce and survive under laboratory conditions. The degree of difference between the two depends to a large extent on the trait studied.

The benefit derived from the use of the laboratory mouse as a research tool is often offset be the various problems posed to mankind as the result of the continued success of the wild animal (Festing & Lovell 1981). The conversion of the mouse from pest to pet to productive element of the scientific community took place slowly (Staats1966). Due to their high dispersal and importance in medical and experimental psychological research, knowledge of rodent biology is heavily biased by an overwhelming emphasis on commensal rodents, including house mice. There is an significant bias towards data obtained from laboratory studies: one survey of the science citation index between 1986 and 1988 revealed 23,700 publications on rats, but less than a

dozen on wild rats and only a few of these were studies in the wild (MacDonald & Fenn 1996). The same bias is true for mouse studies.

The impact of domestication on behaviour appears to be less for mice (MacKintosh 1981), but Klimstra (1972) warns that much of the data on behaviour of albino mice has little application in the field. Bronson (1979) suggested that commensal and feral populations of mice differ in many characteristics including social organisation. While mice are generally neophilic (Barnett 1988), Kronenberger & Médioni (1985) argue that wild mice may have rapidly evolved neophobia because of man's fight against rodents. Therefore, for management of wild mouse populations in New Zealand, it is important that any baits or other control technologies that have been developed through research on laboratory-raised mice, are also tested for efficacy on wild mice.

# Chapter 3 This study

Efforts by managers to eradicate rodents using poison baits are often complicated by the lack of species-specific information available. Vertebrate pest managers have long recognised that the success of control programmes depends directly on an understanding of the animal's biology in any given situation, such as, the importance of feeding (Berdoy & MacDonald 1991) and social behaviour (MacDonald et al. 1999) have been emphasised. Anecdotal evidence suggests that each species of rodent may exhibit different feeding preferences for the various commercial rodent baits, but no controlled studies to verify species preferences have been conducted (O'Connor & Eason 2000).

Several elements of behaviour such as neophobia and conditional or unconditional aversion to the bait base or rodenticide can help rodents to avoid eating a fatal dose of a rodenticide and may explain treatment failures that cannot be accounted for by physiological resistance. Enhancement of such elements constitutes a novel defence mechanism, termed 'behavioural resistance' by Humphries et al. (1992) citing evidence that house mice from a hard-to-control population in the English Midlands exhibit strong avoidance of certain types of baits, bait boxes and traps. Similarly, Brunton et al. (1993) cite enhanced neophobia in the Norway rat as an example of behavioural resistance.

Henderson & Frampton's (2007a) study states that it was apparent from observed behaviour that the noise made by rodents interfering with cellophane bags promoted increased feeding activity in nearby mice. However, observations indicated that despite an aroused interest by mice at the cellophane bag noise, the material used was too durable to allow ready access by rodents to the contents of bags. This study aims to determine whether the use of cellophane wrapped baits (Cellophane FF213) increases the attractiveness the mouse bait (Table 3.1). Essentially a lure, the cellophane could possibly increase the sphere of influence of bait and may also increase consumption of baits (O'Connor & Eason 2000).

While the conclusions of Henderson & Frampton (2007a) were drawn from observations made using domestic mice, this experiment will focus on wild-caught mice with the aim of making the baits more applicable to real field use.

**Table 3.1** Description of baits tested.

| Name of bait | Name referred to in text | Bait type | Description |
|---|---|---|---|
| Cellophane FF213 | Cellophane wrapped bait | Paste | Connovation Ltd standard possum and rat feed paste wrapped in standard florist cellophane with a thickness of 30 mu |
| Ferafeed 213 | Unwrapped FF213 | Paste | Connovation Ltd standard possum and rat feed paste |
| Erayz Multi-species bait- with FF213 antifungal | Erayz antifungal | Paste | Multi-species development bait |
| Erayz Multi-species bait- without antifungal | Erayz non-antifungal | Paste | Multi-species development bait |
| Striker Prefeed containing Multi-species Ferafeed 213 | Ferafeed 213 or FF213 prefeed | Paste | For the first trial the bait was contained in the potato starch Striker. For following trials the bait was removed. |
| EPA 'challenge' diet | EPA | Loose mix cereal | Provided by Connovation Ltd. Used as standard control. |

Although the innate feeding behaviour of mice (i.e., nibbling throughout the day) cannot be changed, their response to novel foods can be changed by increasing the palatability of bait (Henderson & Frampton 2007b).Therefore this study aims to test the palatability of two commercial baits, Erayz antifungal treated bait, and FF213 prefeed (Table 3.1). The development of an antifungal treated bait stems from the need to prolong the life and palatability of the bait when used in the field. Any mould

that grows on the bait could affect palatability (O'Connor & Eason 2000), therefore the development of bait which has antifungal properties could increase their effectiveness by increasing their longevity, but the addition of antifungal agents must not have a negative impact on bait palatability to mice.

This study aims to help address the shortage of mouse specific data in New Zealand by comparing the palatability of the two commercial products (Table 3.1) using both domestic and wild house mouse.

## 3.1 Research objectives

1. To determine whether wrapping baits in cellophane increases bait attractiveness to mice (Experiment 1).
2. To measure the palatability of Ferafeed 213 prefeed (FF213) paste bait (Experiment 2)
3. To measure the palatability of baits containing an antifungal compound against baits without antifungal compounds (Experiment 3).
4. Determine whether bait palatability differs between domestic and wild-caught mice (Experiments 2&3).

# Chapter 4 Experiment 1. Attractiveness of cellophane-wrapped baits

## 4.1 Introduction

Results of a study by Ehert & Dreyer (1984) found that house mice can localise a sound source and can do so with considerable accuracy in the high ultrasonic range. The animals depended on acoustic cues in the localisation tests, when other cues, for example olfactory and visual ones, were not available for them. Mice have well-developed hearing, and are able to hear noises from ca. 10kHz to ultrasounds over 100kHz (Gourevitch & Hack 1966, Ehret 1974). Mice in the Ehert & Dreyer (1984) study needed repetitive sound stimulation during their approach, and this obviously allowed them to correct their course and to keep their movement goal directed.

Research by Reed & Yoshino (2001) state that stimuli such as light and tones have been found variously to both increase and decrease the rate of instrumental behaviour when they are made dependent upon a response (e.g., Reed et al. 1996). Previous investigations of the effects of presenting a response-dependent tone have produced a mixed pattern of results. Some studies have demonstrated a suppressive effect of a tone (e.g., McAdie et al. 1993; McAdie et al. 1996; Reed et al. 1995; Reed et al., 1996), whereas other experiments have shown either response facilitation or no effect of such a tone (Andronico & Forgays 1962; Symmes & Leaton 1962).

As stated previously Henderson & Frampton's (2007a) study observed behaviour that indicated the noise made by rodents interfering with cellophane bags promoted increased feeding activity of nearby mice. However, observations suggest that despite an aroused interest by mice in response to the cellophane bag noise, the type of cellophane they used was too durable to allow ready access by rodents to the contents of the bags. While Henderson & Frampton's (2007a) conclusions were drawn through observations made using domestic mice, the present experiment will focus on wild mice to assess the potential application of cellophane-wrapped baits to enhance control of wild mice. This study aims to determine whether the use of cellophane

wrapped baits increases mice attraction to bait. Essentially a lure, the cellophane could possibly increase the sphere of influence of bait and may also increase consumption of baits (O'Connor & Eason 2000).

## 4.2 Materials and methods

*Mouse collection and field work*

All experimental work conducted on mice hereafter in this dissertation was approved by the Animal Ethics Committee of Lincoln University.

Domestic mice were provided by Pest Control Research Limited in Christchurch, with the original source being Otago University, Dunedin, New Zealand. Mice were housed individually in commercial mouse trays containing wood shavings and a drinking bottle. Domestic-raised mice were allowed to acclimatise for at least two weeks prior to bait palatability testing. Mice were fed *ad libitum* on possum pellets supplied by Western Animal Nutrition, Rangiora.

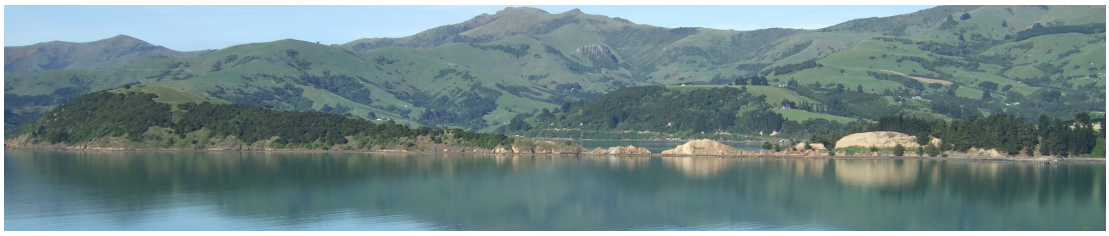

**Figure 4.1** View of north east side of Onawe Peninsula where wild mice were sourced.

Wild mice were captured from Onawe Peninsula on Banks Peninsula (43º45'48.19S, 172º55'34.39E), using the "Trapper 24/7 Multicatch" supplied by Pest Management Services Ltd, Paraparaumu, Kapati Coast. Peanut butter ("No frill" brand) was used as bait in the traps. After individuals were captured they were transported to Pest Control Research Limited facilities and housed in commercial mouse trays in similar

conditions to the domestic mice, with wood shavings, a drinking bottle, and feed *ad libitum.*

Mice were allowed a minimum of 9 days acclimatisation prior to Experiment 1. Mice were sexed using instructions sourced from various websites (Government of South Australia 2007, Nash 2007) (Appendix 2). Individuals were sexed to ensure an even sex ratio for the experiments. Mice were exposed to natural lighting and minimum noise disturbance.

*Experimental procedure*

To compare the attractiveness of unwrapped baits with cellophane wrapped baits five randomly selected wild mice (3 male and 2 female) were housed in blue 30 cm x 33.5 cm x 40 cm deep plastic sterile storage containers (enclosures) as in Anderson et al. (2003). These were closed with a fine aluminium mesh lid to prevent mice escaping. Mouse behaviour was filmed using a Sony Video 8 Handycam.

Enclosures were arranged in a cross formation, with one enclosure in the centre and the four remaining placed on each side of the central container (Fig. 5.2). Each enclosure had its base lined with a thick white plastic in order to increase the visibility of mouse movement to the video camera. Two lines were drawn on the white bases in each of the four outer containers, to divide the area into three even sections. The lines were drawn parallel to the edge of the central container. This was done using black marker pen to ensure visibility of the divisions through the video camera. The three sections were labelled 1, 2 & 3 with 1 being furthest from the centre container and 3 closest.

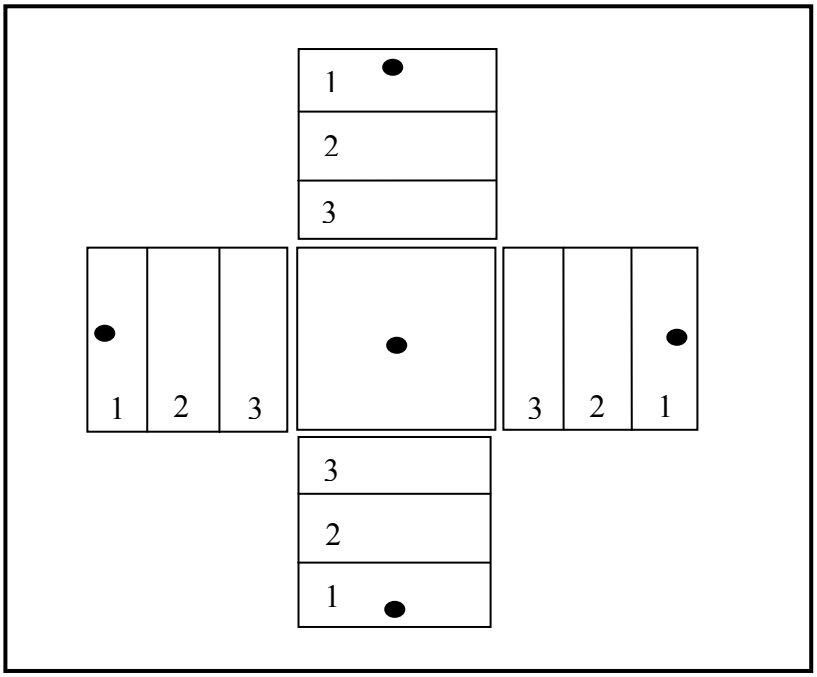


**Figure 4.2** Layout design of the five enclosures, including position of food and water (•) and individual storage container sections (labelled 1-3).

During the two-day acclimatisation period, food (unwrapped FF213 prefeed) and water were provided *ad libitum* within the experimental arenas (storage containers). These were situated in section 1 for the outer mice, and situated in the middle of the arena for the central mouse. The position of the food and water remained constant in these locations throughout the experiment.

The Camcorder was positioned for a 'birds-eye' view of the five storage containers including acclimatisation time. Twenty two hours prior to commencing filming, all food was removed from the enclosures. This was continued over the six days of the experiment resulting in the mice only having access to food for two hours the camcorder was running.

To test if the cellophane wrapping caused mice to be attracted to the bait, individual cellophane-wrapped bait was presented to the mouse in the central enclosure, and the position of each of the outer four mice was recorded while the central mouse fed on the bait (Appendix 3). The position of all mice at 15 second intervals was also recorded (Appendix 3). Preliminary work had indicated that the mice were having

trouble accessing the FF213 prefeed bait within the cellophane bag. Therefore holes were made through the cellophane to promote increased interaction to the mouse (Figure 4.3). Mice were allowed to feed for two hours with food then being removed from all enclosures for another twenty two hour period.

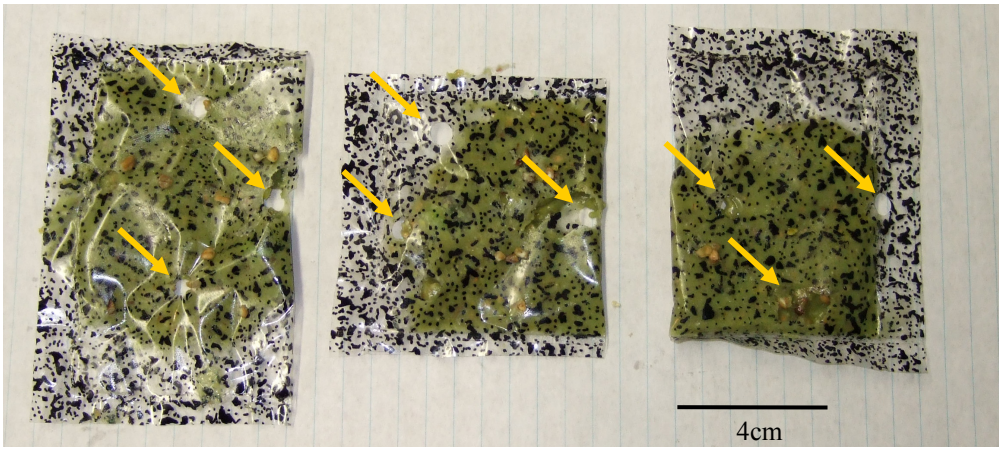


**Figure 4.3** Cellophane wrapped FF213 bait used in experiment showing three holes in each cellophane bag aimed at increasing interaction between the mouse and bait. Yellow arrows indicate holes.

*Data analysis*

Results were analysed in two ways:

1. Time interacting with the bait as a percentage of total, where time in the inner section (section 3) was taken as a percentage of time when the middle mouse was interacting with the bait. This was analysed using a generalised linear model weighting (with the dependent variable being the number of times the middle mouse spent on the bait).
2. Fifteen second counts, where over one hour observations of the mouse's location were taken every 15 seconds. This was analysed using a generalised linear model with a binomial link function where the total possible count was 240 over the one hour.

## 4.3 Results

Figure 4.4 shows that in all trials ($n$=12) the mice spent a higher proportion of time in section 3 (nearest the central mouse) when the central mouse was directly interacting with cellophane-wrapped bait, compared with when it was interacting with unwrapped bait. Whilst this response was consistent for all mice, the overall difference was not statistically significant ($F_{1,111}$= 0.72; P = 0.399).

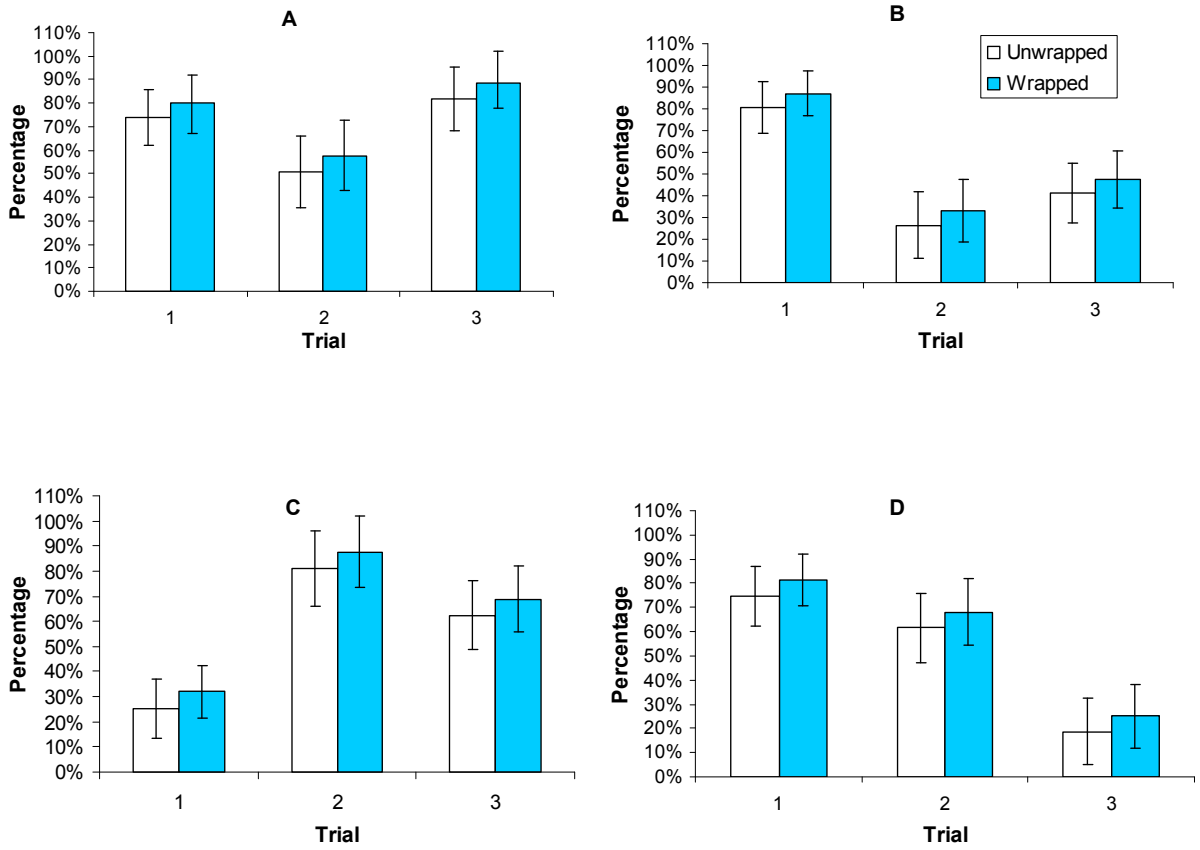


**Figure 4.4** Mean proportion of total time each mouse spent (± SEM) in section 3 (nearest central mouse) when central mouse is interacting with the bait. Figure (a) Female 1, (b) Female 2, (c) Male 1, (d) Male 2. SEM's are "approximated" by the GenStat GLM root (ErrorMeanSquare/number of reps in the group).

Figure 4.5 shows that in 7 out of 12 trials the mice spent a higher proportion of time in the inner section (when recorded every 15 sec) when the bait was unwrapped, and this difference was statistically significant ($X^2_{1,23} = 5{,}26$; P = 0.022).

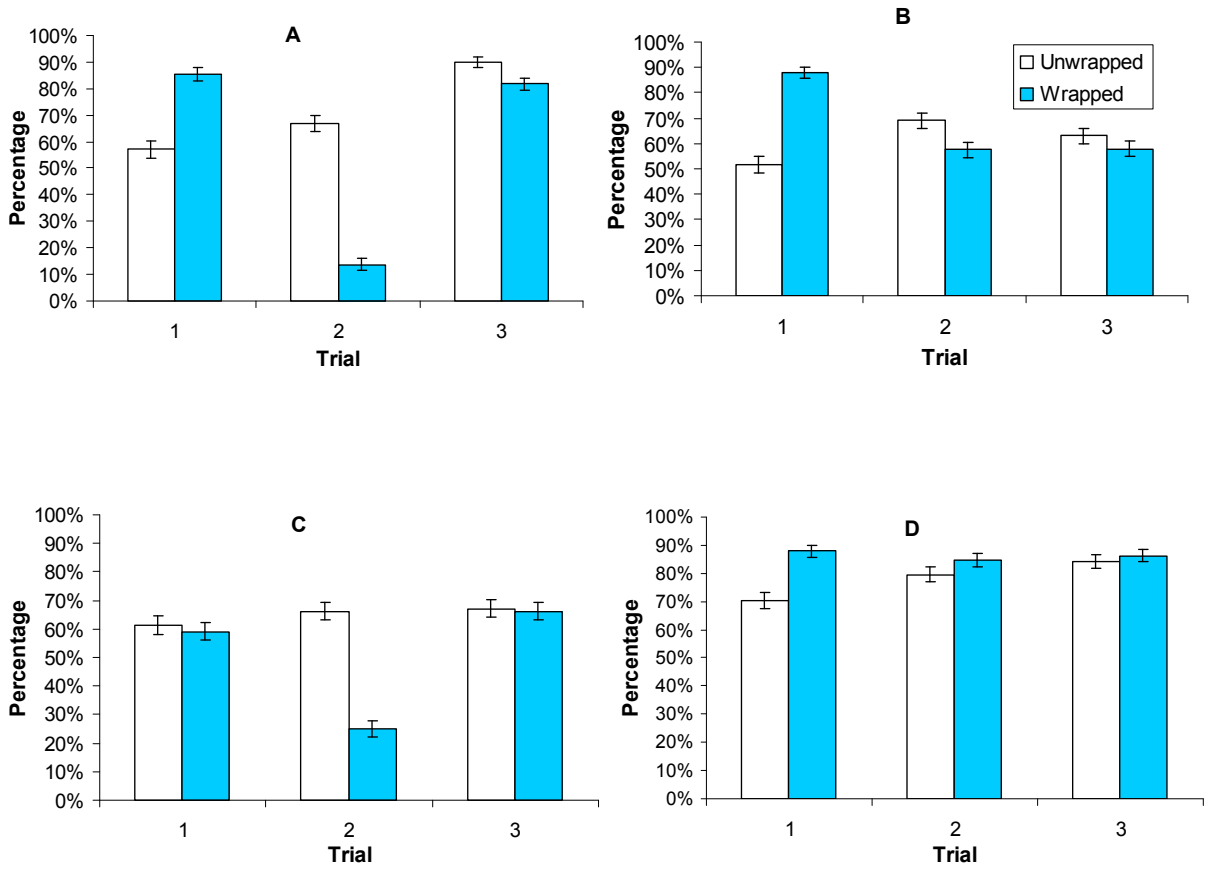


**Figure 4.5** Mean proportion (± SEM) of time spent in section 3 (nearest middle mouse) derived from 15-second count data over one hour. Figure (a) Female 1, (b) Female 2, (c) Male 1, (d) Male 2. SEM's are "approximated" by the GenStat GLM root (ErrorMeanSquare/number of reps in the group).

In this experiment there was high variability between individuals, with graph C (Male 1) spending a higher proportion of time in the inner section when the central mouse's bait was unwrapped, while graph D (Male 2) shows the opposite. Both female mice (graphs A and B) vary between trials as to whether they spend more time in the middle section when an unwrapped or wrapped bait is presented to the central mouse.

## 4.4 Discussion

Although the results of first trial (Figure 4.4), when the central mouse was directly interacting with the bait, show no statistically significant difference the graphs do indicate that all individuals in all trials spent a higher percentage of time in section 3 when the central mouse was interacting with a cellophane-wrapped bait. This result suggests that the cellophane may be having a small effect and increasing the sample size of test individuals and/or undertaking a larger number of trials may indicate a significant effect. Also, the result could be more positive if techniques were found to improve the attractiveness of the cellophane-wrapped bait. For example, the type of cellophane used in this study was a standard wrapping cellophane obtained from a florist (S. Hix  pers. comm.). Further research investigating different strengths and thicknesses of cellophane may make the bait more attractive. The cellophane used in this experiment needed holes to increase interaction. Accordingly, I speculate that more brittle cellophane (that is broken open easily) may be more effective.

Interestingly, the 15-second count data (Figure 4.5) shows that the unwrapped bait was more attractive than wrapped bait. Whilst this difference was statistically significant, there was considerable variation within and between individuals. For example, Female 1 spent over 80% of her time in section three during trial compared to less than 20% in trial two. Contrastingly, Male 1 spent over 65% of his time in section three in all of the trials, regardless of whether the middle mouse's bait was wrapped or unwrapped. These observations may indicate that the mice had an overall general preference for section 3, which may have been influenced by other factors. For example, it may have contained the darkest area in the enclosure. This trend was observed for all mice with only 2 out of 12 trials having an individual mouse spending less than 50% of their time in section 3.

Based on the results of this research I conclude that wrapping baits with cellophane (at least for the type of cellophane I used) is unlikely to enhance bait attractiveness for wild mice. These conclusions are in contrast to the previous results of Henderson & Frampton (2007a); however, there are many factors which may have generated the

different results. First, the Henderson & Frampton (2007a) research used domestic-raised mice, whereas in the present experiment wild mice were sourced from Onawe Peninsula. The wild mice are unlikely to have had any prior experience with the baits or the cellophane, which may have induced a neophobic response unlike that of the commensal domestic mice used in the Henderson & Frampton (2007a) study. This hypothesis is supported by studies conducted by Brown (1993) and Airey & O'Connor (2003) who found that wrapping bait in tinfoil or in ziplock plastic bags reduced its palatability and efficacy to wild-caught mice. Second, it should be considered whether it was the sound of the cellophane that promoted feeding activity in the Henderson & Frampton (2007a) study or the influence of social and feeding behaviour. While mice were housed individually during this study, mice were paired together during the Henderson & Frampton (2007a) study. It is possible that other cues (e.g. urine or smell) increased bait attractiveness, not the sound of the cellophane which was the factor directly tested in this study. Finally, the mice in Henderson & Frampton (2007a) were allowed access to the cellophane wrapped bait. Accordingly, the bait itself may have enhanced attractiveness.

Given that most mouse control in New Zealand is undertaken on wild mice on islands and forest or bush areas as opposed to commensal mice, I recommend further testing into whether there is any difference in the attractiveness of cellophane wrapped bait between domestic and wild mice. If further research proves that cellophane wrapped baits are attractive to domestic mice (as in the Henderson & Frampton 2007a study) and not wild mice it could still be developed for urban areas when mice are exposed to wrapped food on a regular basis.

## 4.5 Future research and recommendations

- Undertake trials on both wild and domestic mice to determine any variation between the two.
- Test different types of cellophane (increase noise, alter permeability, colour, texture, or brittleness).
- Increase sample size to reduce variation between individuals effecting overall results.
- Increase filming duration to determine if the cellophane takes a longer time to have an effect on attractiveness.
- Test the palatability of cellophane wrapped bait as interaction with the bait directly affects its attractiveness to other individuals, this could be a major issue in the wild where there are alternative food sources.
- Determine how close other mice must be for cellophane noise to have an effect, for example where home ranges are large other mice may not be in a position to hear the cellophane and be attracted.
- Length of time the cellophane noise needs to be occurring (interaction time with the wrapped bait) to result in a response from nearby mice should be researched. This could be achieved by simulating the sound of cellophane movement instead of relying on the central mouse to interact with the wrapped bait.
- The experiment could be repeated under red light which has been shown (McClearn 1960) to increase activity.

# Chapter 5 Experiments 2 & 3. Bait palatability to domestic and wild-caught mice

## 5.1 Introduction

Efforts by managers to eradicate rodents using poisoned baits are often complicated by the lack of information available on bait palatability for any particular species. Although the innate feeding behaviour of mice (i.e., nibbling throughout the day) cannot be changed, their response to novel foods can be influenced by increasing the palatability of bait (Henderson & Frampton 2007b).

The development of an antifungal treated bait stems from the need to prolong the life and palatability of the bait when used in the field. Any mould that grows on the bait could affect palatability (O'Connor & Eason 2000). Therefore the development of bait which has antifungal properties could increase the effectiveness by increasing bait longevity. Wax coatings are the usual method of lengthening a particular bait type's field life (O'Connor & Eason 2000); however this often interferes with the palatability of the bait.

This study aims to test the palatability of two commercial baits, Erayz antifungal treated bait and FF213 prefeed on both domestic and wild mice. It also aims to determine whether a commercial bait treated with an antifungal compound will decrease its palatability to mice.

## 5.2 Materials and methods

*Mouse collection and field work*

Domestic mice were provided by Pest Control Research Limited, Christchurch. Mice were housed individually in commercial mouse trays containing wood shavings and

drinking bottle for two weeks prior to bait palatability testing. Mice were fed *ad libitum* on possum pellets supplied by Western Animal Nutrition, Rangiora.

Wild mice were collected from Onawe Peninsula on Banks Beninsula, using the "Trapper 24/7 Multicatch" supplied by Pest Management Services Ltd. In Fitzgerald & Cong's (1989) study on Mana Island, a bait mixture of peanut butter and rolled oats was used to lure mice. Here, peanut butter ("No frill" brand) was used to attract individuals. After individuals were captured they were transported to Pest Control Research Limited facilities and housed in commercial mouse trays in similar conditions to the domestic mice, containing wood shavings and drinking bottle, and fed *ad libitum.*

Mice were allowed a minimum of two weeks acclimatisation prior to palatability trials, with the exact duration dependant on which day the wild mice were captured. Mice were sexed using instructions sourced from various websites (Government of South Australia 2007, Nash 2007) (Appendix 2). Individuals were sexed in order to obtain an even sex ratio for the experiments. Mice were exposed to natural lighting and minimum noise disturbance.

Manufactured bait was supplied by Connovation Ltd (Auckland) (Table 5.1). FF213 prefeed bait was supplied in a "striker" container (Figure 5.3) made of potato starch with a cardboard base. Bait was extracted from these containers after the first trial due to domestic mice eating the container.

*Experimental procedure*

As in Henderson & Frampton (2007b) mice were presented paired trays containing 20 g of test bait and 20 g of control bait. There was no recognised paste or solid bait to use as an "industry standard", so the EPA cereal loose mix was used as a control throughout the trials which did not involve the antifungal treated bait. The two treatments as well as the two controls presented to each individual are summarised in table 5.1.

**Table 5.1** Baits presented to wild and domestic house mice for a 22 hour period.

| Code | Treatment |
|---|---|
| Control 1 | EPA (industry standard) (Figure 5.2) |
| Test bait | FF213 prefeed (Figure 5.2) |
| Control 2 | Erayz (Non-antifungal treated bait) (Figure 5.1) |
| Test bait | Erayz (Antifungal treated bait) (Figure 5.1) |

EPA 'challenge' diet comprises of 65% finely ground maize, 25% rolled oats, 5% sugar (95% purity), and 5% corn oil (95% purity) (Johnson & Prescott 1996) and was used as the control bait.

**Figure 5.1** Erayz antifungal treated bait (pink ceramic dish) and Erayz non-treated bait/control (blue ceramic dish). ~20 g each as presented to mice. Ceramic tray dimensions: 65 mm diameter, 25 mm deep.

**Figure 5.2** FF213 prefeed bait (pink ceramic dish) and EPA control (blue ceramic dish). ~20 g each as presented to mice. Ceramic tray dimensions: 65 mm diameter, 25 mm deep.

Each day one of the 2 test baits (+ control) were weighed and placed in feeding trays inside the mouse's cage. Control 1 (EPA industry standard) was used against the 'Striker FF213 prefeed' bait (Figure 5.1), while Control 2 (Erayz: Non-antifungal treated bait) was used against the Erayz (Antifungal treated) bait (Figure 5.2). Each mouse (ten mice presented to each of the two test baits) was left for approximately 22 hours to feed on the bait before the remains of the 'test' and 'control' baits were weighed in order to determine how much had been eaten. Due to spillage from the bait holding containers a best attempt was made at collecting any bait found within each individual's cage and returning it to the correct container. This was unable to be undertaken after Erayz trial nights due to both the test and control baits having extremely similar physical properties.

The weight eaten of each bait was recorded (Appendix 4). New test and control baits were then weighed and presented to each of the twenty mice. After the first trial night using Striker FF213 prefeed bait, the method was altered. FF213 prefeed bait was removed from the pre-packaged "Striker" containers and presented in identical containers as the control bait. This was done as some of the domestic mice ate more of the "Striker" container than the test bait, making it difficult to determine the palatability of the test bait.

(A) (B)

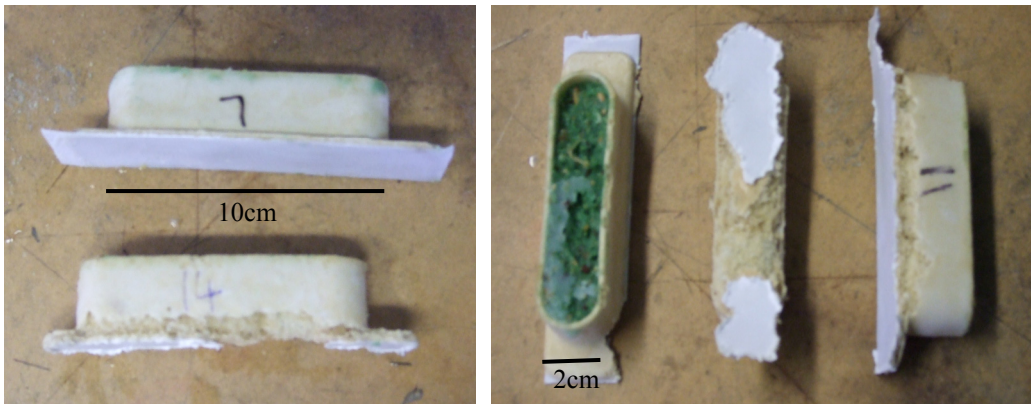


**Figure 5.3** Example of FF213 prefeed bait presented in Striker containers on first trial night, showing consumption of striker. (A) Top striker presented to wild mouse, bottom to domestic mouse, (B) All three presented to domestic mice.

*Testing order*

Individuals were presented with the FF213 prefeed bait over three trial nights, while the Erayz antifungal bait was tested over two nights due to a limited supply of the test bait and time constraints. All individuals were presented with the FF213 prefeed and control bait on the first night of testing, while the following night they were presented the antifungal bait and its control. This cycle was continued over consecutive nights until the 5 trial nights were completed. The baits were presented on alternate nights with the first, third and firth night being FF213 prefeed and the second and forth night being Erayz (repeated twice due to limited resources).

*Data analysis*

For each individual the daily palatability or 'bait acceptance' of the 'test' bait was calculated as the percentage of test bait eaten in relation to total bait consumption (Figure 5.4).

$$\text{Palatability (\%)} = \frac{\text{Total weight (g) of test bait eaten (T)}}{\text{Total weight (g) of control bait (C) + test bait (T) eaten}} \times 100$$

**Figure 5.4** Palatability calculation (Johnson & Prescott 1996, O'Connor & Booth 2001, Henderson & Frampton 2007)

The palatability of the two test baits was calculated for each individual and then used to determine the overall palatability of the test bait for wild and domestic mice. Standard deviation and standard error of the mean were also calculated for the wild and domestic mice. A two-sample t-test assuming equal variances was calculated to determine whether there was a significant difference between the test bait and the control bait. A paired two sample t-test for means was also calculated to determine whether there was any significant difference between individuals palatability of test v control bait.

## 5.3 Results

In four of the five feeding trials the test bait (FF213 prefeed) had a lower mean palatability than the EPA control (Table 5.2). In feeding trials 2 and 3 the palatability of the test bait was higher for domestic mice than wild mice, and this difference was significant in the third feeding trial. In all trials, wild mice consumed significantly less test bait than the control; however, differences in palatability for domestic mice were not significant. Table 5.2 also shows that test bait was always consumed by domestic mice; whereas, in feeding trial 3 only 60% of wild mice consumed any test bait, which must also be considered when assessing test bait palatability.

**Table 5.2** Palatability results of FF213 prefeed paste bait tested against standard EPA control. (* Figures unable to be calculated due to mice consuming both FF213 bait and Striker container bait was provided in). Any significant values (P<0.05) are highlighted in bold.

| **Contrast** | **Trial** | **Mean palatability (%) ± SEM** | | **Percentage of mice that consumed test bait** | | ***t*-test two-sample (Wild v Domestic)** | ***t*-test paired (Test bait vs EPA)** | |
|---|---|---|---|---|---|---|---|---|
| | | Wild | Domestic | Wild | Domestic | | Wild | Domestic |
| FF213 vs EPA | 1 | 17.55 ± 4.21 | * | 100% | 100% | * | **P=0.001** | * |
| FF213 vs EPA | 2 | 31.39 ± 6.07 | 42.67 ± 3.83 | 100% | 100% | P=0.13 | **P=0.01** | P=0.09 |
| FF213 vs EPA | 3 | 19.83 ± 6.75 | 52.06 ± 7.47 | 60% | 100% | **P=0.004** | **P=0.002** | P=0.79 |

The results presented in Table 5.3 indicate the test bait had higher palatability in only one of four feeding trials. However, these differences were not statistically significant in the palatability of the test bait versus the control bait for either wild or domestic mice. In contrast to Table 5.2, there was also no differences in palatability of the test bait between domestic mice than wild mice with all individuals consuming some test bait.

**Table 5.3** Palatability results of Erayz antifungal bait tested against Erayz non-antifungal control.

| **Contrast** | **Trial** | **Mean palatability (%) ± SEM** | | **Percentage of mice that consumed test bait** | | ***t*-test two-sample (Wild v Domestic)** | ***t*-test paired (Test bait vs EPA)** | |
|---|---|---|---|---|---|---|---|---|
| | | Wild | Domestic | Wild | Domestic | | Wild | Domestic |
| Erayz antifungal vs non-antifungal | 1 | 47.57 ± 6.31 | 47.03 ± 6.33 | 100% | 100% | P=0.95 | P=0.71 | P=0.65 |
| Erayz antifungal vs non-antifungal | 2 | 58.28 ± 9.53 | 42.37 ± 6.30 | 100% | 100% | P=0.18 | P=0.41 | P=0.26 |

## 5.4 Discussion

*Experiment 2: FF213 palatability*

The results of this study have shown that the multi-species test bait FF213 prefeed had a lower mean palatability than the EPA control diet in four of the five palatability trials undertaken. Certainly, the domestic mice found the test bait more palatable than did wild mice in all comparable trials and this difference in palatability was statistically significant in the third trial.

The potato starch "striker" containers in which the FF213 bait was supplied were removed as they were found to be palatable to the wild mice but not the domestic mice. Figure 5.3 demonstrates how some of the wild mice ate more of the striker container than the FF213 bait it contained. This is of relevance as bait in the field is often presented in these wax coated "striker" containers. If the palatability of the storage unit is higher than that of the bait it holds the target animal may not receive a lethal dose of the poison.

Whilst there was no statistically significant difference between the palatability of the test (FF213 prefeed) and control (EPA) for domestic mice, there was some variation between trials with trial two showing the control (EPA) with a higher palatability and trial three showing the opposite with the test bait (FF213 prefeed) having a higher palatability. For the wild mice, however, the test bait (FF213 prefeed) always had a significantly lower palatability than the control (EPA). This supports the conclusion that the differences between domestic and wild mice are important when it comes to pest control research, and that research must also be conducted on wild mice if the bait is expected to show similar results in the field.

When determining why there is a difference in bait preferences of wild and domestic mice, it could be assumed the difference is due to the differences in diets experienced earlier in their lifetime. Meehan (1984), however, states that the claim of rodents preferring to eat food which they have experienced as infants is not necessarily true and high bait palatability may over-ride any previous experiences. Although studies by Leon et al. (1977) do not support this, Meehan (1984) found that rats weaned and reared on commercially available rodent diets show no preference for these in later life when offered a choice of foodstuffs. There are, however, a number of factors to be taken into account when considering this hypothesis such as sexual differences, the use of domesticated strains, the time factor, the nutritional properties of the test foods and the place where experiments are conducted (Meehan 1984).

When considering the reason for a significant difference in the palatability of the test and control baits, the type of bait must be investigated as the test bait (FF213 prefeed) was a paste and the control (EPA) a cereal loose mix. A pairwise comparison by Frampton & Henderson (2007b) found that domestic mice given paste baits found it to be significantly more palatable (mean palatability= 75.2%) than all other treatments including loose cereal mix (mean palatability= 61.0%) and solid cereal bait (mean palatability= 54.3%). Accordingly, the Frampton & Henderson (2007b) results contrast to the results of this study in which the cereal loose mix (EPA) was statistically more palatable than the paste bait (FF213 prefeed) for wild mice. This suggests that the bait type (cereal loose mix, paste, and solid cereal bait) that has the

highest palatability for wild mice needs to be further explored to increase the acceptance of the bait presented.

The palatability of the FF213 prefeed test bait must be questioned due to the fact that only 60% of wild mice sampled the test bait in the third trial, although all domestic mice consumed some test bait. The FF213 prefeed bait has been developed as a multi-species bait, so palatability may not be as high as would be expected of a species-specific bait. Anecdotal evidence suggests that each species of rodent may exhibit different feeding preferences for the various commercial rodent baits, but no controlled studies to verify preferences have been conducted (O'Connor & Eason 2000).

Because the control bait (EPA) was a loose cereal mix, it was distributed throughout cages by each mouse during feeding periods (Fig. 5.5). This may have generated a higher than actual control bait palatability as collecting all of the stray bait was difficult. Although a best attempt at gathering all loose bait was made, it is realised that a bias towards the control bait is possible.

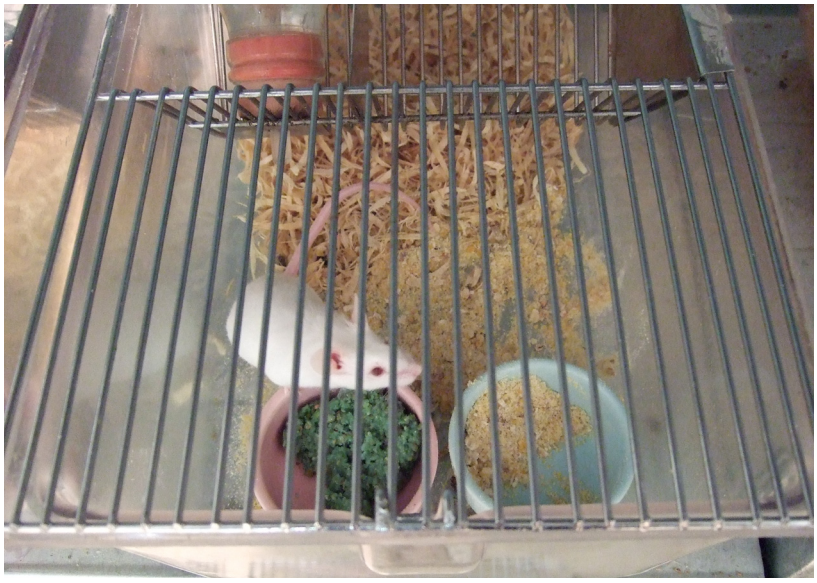

**Figure 5.5** Mouse presented with FF213 prefeed test bait and EPA control. Note the EPA bait spilt from ceramic bowl. Ceramic tray dimensions: 65 mm diameter, 25 mm deep.

As it is unknown how long the EPA had been stored for, we can only assume the palatability remained constant. The same batch of EPA was used for all trials and due to the short duration of the trial period no significant decrease in palatability is likely. At the University of Reading, Johnson & Prestcott (1996) found that batches of standard meal prepared according to EPA guidelines did not have a consistent and stable palatability. Although care was exercised to ensure adherence to EPA methods of preparation, a marked decline in palatability was observed over the initial ten-week storage period. Liberation of a pleasant aroma following grinding to produce the required particle size specifications is thought to be responsible for an initial short-term enhancement in palatability of the challenge diet (Johnson & Prescott 1996). Johnson & Prescott (1996) state that research has found EPA palatability decreases over time. As ready made EPA was provided the exact palatability was unknown. It is therefore suggested that future research on EPA palatability over time should be conducted in New Zealand to ensure new baits are tested against an accurate standard control.

*Experiment 3: Erayz antifungal palatability*

The results of the Erayz antifungal bait palatability trial found that there was no statistically significant difference in palatability between the antifungal test bait and the control (Erayz non-antifungal) for both domestic and wild mice. This result is encouraging as this indicates that antifungal compounds could be used in bait to increase field life without decreasing its palatability for mice. Although some studies have been undertaken, (e.g. Morris et al. 2008) there is little published research on the palatability or durability of commercial bait products under different environmental conditions. Little information exists on the relative palatability of the current commercially available long-life baits and whether their palatability requires improvement. Bait palatable to all four rodent species, kiore (*Rattus exulans*), norway rat (*Rattus norvegicus*), ship rat (*Rattus rattus*) and house mouse (*Mus musculus*) is required, so that a lethal dose is consumed on first exposure. The bait must not break down over six months in a warm and humid environment, nor be eaten in large quantities by non target species (O'Connor & Eason 2000). Often a wax coating is used to protect the bait and limit moisture uptake, lengthening its field life by a few weeks (Thomas 1998). As the wax coating or any mould on the baits may degrade the

palatability of the baits the Erayz antifungal treated bait could prove to be a valuable bait development as other research indicates that wrapping bait in tinfoil or in ziplock plastic bags reduces its palatability and efficacy for mice (Brown 1993).

Finally, as the Erayz bait is also a multi-species bait, the palatability of the antifungal treated bait must also be tested on the other target species to ensure the antifungal compound does not have a detrimental impact on palatability for these other species.

*General Discussion on Experiments 2 & 3*

The Erayz antifungal bait now needs to be tested against alternative baits with known palatabilities (for example the EPA used in the previous palatability trial). Erayz antifungal and FF213 must next be tested in the field as a laboratory measurement of palatability and bait acceptance only gives an indication of the likely performance of a formulation in the field, with the results requiring careful interpretation. Unfortunately, there is a lack of published information comparing laboratory-generated data with actual field performance (Johnson & Prescott 1996). It is therefore hard to compare between studies that have been undertaken in laboratory conditions with those that are undertaken in the field.

Most of the baits and delivery systems currently used for controlling rodents have not been comprehensively evaluated to see how attractive they are to those animals that reside in areas with an abundance of food (Clapperton 2006). In a field situation there will be alternative food available and hence the baits need to be at least as palatable as the alternative food sources. Comparative trials should be undertaken which include access to a normal diet. Quy et al. (1996) found that the availability of alternative food and where baits were placed had the greatest influence on baiting effectiveness with farm populations of Norway rat. This highlights the need for two types of testing: (i) the relative palatability of the current products to determine the best bait (which was undertaken in this study), and (ii) bait consumption when plenty of natural foods are available to ensure consumption of a lethal dose on first exposure (O'Connor & Eason 2000). I recommend that should a bait show promise in palatability trials it also needs to be tested with plenty of natural food available.

In addition to palatability there are other factors that may influence bait acceptance in the field. Two aspects of rodent biology are particularly helpful in understanding and improving bait acceptance: social behaviour and feeding behaviour (O'Connor & Eason 2000). One major factor that should be explored is the impact of social interactions on bait consumption. Social interaction or peer influence may well be important in the eradication of rodent populations, as individuals in some species will actively choose to eat the same food as their peers (this has been observed with Norway rats; Taylor & Thomas 1989). A study by Valsecchi et al. (1996) also found that mice learn their food preferences from observing other mice feeding, while a study by Rowe (1973) found subordinate mice fed when the dominant animals were inactive. Similarly, Drickamer & Springer (1998) found that while there were no significant differences in nocturnal activity patterns by age or sex, subordinate male mice were active early in the night and dominant males were active later. The impact of social interactions and feeding behaviour were largely ignored in the present study as all mice where housed individually. However, future areas of research should be aimed at the influence of social interactions and feeding behaviour, to achieve the highest possible bait palatability, and better understand the importance of these interactions in mouse control. I recommend incorporating these influences into further bait palatability trials to gain more field-specific results. These would include observing field trials in order to determine what social and feeding behaviours can be used to increase current bait palatability.

Finally, several elements of behaviour such as neophobia, and conditioned or unconditioned bait aversion can help rodents to avoid eating a fatal dose of a poison bait. This may explain treatment failures that cannot be accounted for by physiological resistance (Johnson & Prescott 1996). Enhancement of such elements constitutes a novel defence mechanism, termed 'behavioural resistance' by Humphries et al. (1992) citing evidence that house mice in a 'hard-to-control' population in the English Midlands exhibit strong avoidance of certain types of baits, bait boxes and traps (Johnson & Prescott 1996). This could be considered a possible reason for the low consumption by the wild mice, as of which future research into alternative bait types and bait delivery systems should be conducted.

## 5.5 Future research and recommendations

- Field trials must be undertaken on both FF213 prefeed and Erayz antifungal bait.
- Palatability of the potato starch Striker container should be undertaken in order to establish whether use is recommended.
- It is recommended that any future studies are presented in the same coloured containers. Meehan (1984) stated that 'rats and mice are almost certainly colour blind', though there was limited research on the difference of colour preferences between laboratory mice and wild mice. This is perhaps a future area of study due to the fact that the FF213 and EPA are very different in colour, and would even appear very different to mice if they are indeed colour blind.
- Bait consumption should be tested when plenty of natural foods are available to ensure high palatability in natural environments, if consumption of the bait is low the individual will not consume a lethal dose on first exposure and may become bait shy.
- Further developments into accurately measuring consumption after a test night should be made. This research experienced problems with bait becoming distributed throughout the individuals' cage resulting in errors when the bait was re-weighed. Due to the cereal loose mix (EPA) being spilt out of feeding trays more than the paste baits, the EPA results have a higher error factor.
- Further research on the influence of social and feeding behaviour should be undertaken to increase palatability of already developed baits.
- Develop a better understanding of mice preference when it comes to bait types (cereal, loose, paste) and delivery systems.
- Greater resources must be directed into research areas aimed at improving the effectiveness of currently used rodenticide baits. A more forward-looking approach needs to be adopted by the pest-control industry since it is now recognising that inefficient control measures can often seriously exacerbate an already problematic situation.

# Chapter 6 Conclusions

The three experiments of this study were carried out in order to test and improve baiting technologies for the management of mice.

*Experiment 1: Attractiveness of cellophane-wrapped baits*

The cellophane type tested did not significantly alter the attractiveness of baits to wild-caught mice.

*Experiment 2: FF213 prefeed palatability*

FF213 prefeed bait is less palatable to wild-caught mice than the EPA standard. Domestic mice appear to be less discerning of baits.

*Experiment 3: Erayz antifungal palatability*

The addition of the antifungal compound does not alter the palatability of Erayz baits to wild-caught or domestic mice.

*Experiment 2 & 3: Palatability difference between domestic and wild-caught mice*

Experiment 2 found a difference in bait palatability between domestic and wild-caught mice while Experiment 3 found no significant difference in bait palatability. Due to the conflicting results of both experiments it is difficult to conclude whether there is a significant palatability difference between domestic and wild-caught mice.

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# Chapter 8 Appendices

## 8.1 Appendix 1: Distribution of mice on New Zealand islands (>1ha), with dates of eradication operations

| Region | Island name | Area (ha) | Eradication started | Reference |
|---|---|---|---|---|
| **Northland and Bay of Islands** | | | | |
| Bay of Islands | Harakeke | 12 | - | |
| | Kohangatara | 1 | - | |
| | Moturoa | 143 | 1993 | |
| | Poroporo | 8 | - | |
| | Rimariki | 22 | 1989 | (Veitch & Bell 1990) |
| Cavalli group | Motutapere | 6 | - | |
| Whangarei harbour | Limestone | 38 | - | |
| Whangaroa | Stephenson | 123 | - | |
| **Hauraki Gulf** | | | | |
| | Arid (Rakitu) | 350 | - | |
| | Browns | 58 | 1995 | (Veitch 2002a) |
| | Great Barrier | 28 510 | - | |
| | Kawau | 2257 | - | |
| | Motuihe | 195 | 1997 | (Veitch 2002b) |
| | Moturekareka | 19 | - | |
| | Motutapu | 1509 | - | |
| | Motutara | 5 | - | |
| | Rangitoto | 2333 | - | |
| | Te Haupa | 9 | - | |
| | Waiheke | 9459 | - | |
| **Eastern and central N.I.** | | | | |

| | | | | |
|---|---|---|---|---|
| Bay of Plenty | Hauturu | 10 | 1992 | (Thomson, unpubl.) |
| | Whenuakura | 3 | 1883 | (Veitch & Bell 1990) |
| Central | Mana | 217 | 1989 | (Hook & Todd 1992) |
| | Somes | 23 | 1990 | |
| Coromandel | Motutapere | 50 | 1994 | (Thomson, unpubl.) |
| Hawke's Bay | Portland | 150 | - | |
| Kaipara | Moturemu | 5 | 1992 | (McFadden, unpubl.) |
| Lake Rotorua | Mokoia | 135 | *2001 | |
| **Nelson-Marlborough** | | | | |
| Nelson | Adele | 88 | - | |
| | D'Urville | 16 782 | - | |
| | Haulashore | 6 | 1991 | |
| Marlborough | Allports | 16 | 1989 | (Brown 1993) |
| | Arapawa | 7785 | - | |
| | Blumine | 377 | - | |
| | Forsyth | 775 | - | |
| | Mabel | 1 | - | |
| | Motutapu | 2 | 1989 | (Brown 1993) |
| | Pickersgill | 103 | - | |
| | Tarakaipa | 35 | - | |
| **Southern South I.** | | | | |
| Dusky Sound | Fixed Head | 36 | - | |
| | Long | 1960 | - | |
| Preservation Sound | Coal | 1622 | - | |
| Stewart I. group | Ruapuke | 1525 | - | |
| Lake Wanaka | Mou Waho | 140 | 1995 | (McKinlay 1999) |
| **Outlying islands** | | | | |
| Chathams | Chatham | 90 650 | - | |

| | | | | |
|---|---|---|---|---|
| | Pitt | 6203 | - | |
| Subantarctic | Auckland | 45 975 | - | |
| | Antipodes | 2025 | - | |
| | Enderby | 710 | 1993 | (Torr 2002) |
| | Masked | 5 | - | |

- still present

* second eradication attempt

Adapted from King (2005)

## 8.2 Appendix 2: Sexing Mice & Rats

To determine the sex of mice and rats, examine the distance between the anus and the urinary/genital opening. This distance is longer in males than in females. In addition, females have nipples that are usually noticeable by 10 days of age. Males do not have nipples. In older females, the nipples are covered with fur, so a careful examination must be made, or a female could erroneously be called a male. Finally, in adult males, the testicles can be felt at the base of the tail (Nash 2007).

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**Sexing Mice**

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The easiest way to find out the sex of the mice is to look at the position of the genital organs. The distance between and anus and genital papilla is always shorter in the female (Government of South Australia 2007).

## 8.3 Appendix 3: Cellophane wrapped baits experiment raw results

### 8.3.1 Time in inner section (section 3) when central mouse was interacting with bait

| **Day 1- Wrapped Ferafeed bait** | | | | |
|---|---|---|---|---|
| Time on bait (seconds) | Time in section 3 (seconds) | | | |
| Middle Mouse | Female 1 | Female 2 | Male 1 | Male 2 |
| 19 | 19 | 19 | 0 | 19 |
| 53 | 53 | 22 | 0 | 53 |
| 3 | 3 | 3 | 0 | 0 |
| 24 | 0 | 24 | 0 | 24 |
| 28 | 28 | 28 | 7 | 28 |
| 186 | 186 | 186 | 160 | 186 |
| 3 | 3 | 3 | 3 | 3 |

| **Day 2- Wrapped Ferafeed bait** | | | | |
|---|---|---|---|---|
| Time on bait (seconds) | Time in section 3 (seconds) | | | |
| Middle Mouse | Female 1 | Female 2 | Male 1 | Male 2 |
| 47 | 47 | 0 | 47 | 47 |
| 82 | 82 | 16 | 82 | 57 |
| 25 | 7 | 0 | 25 | 0 |
| 136 | 0 | 101 | 136 | 25 |
| 112 | 95 | 71 | 112 | 105 |

| **Day 3- Wrapped Ferafeed bait** | | | | |
|---|---|---|---|---|
| Time on bait (seconds) | Time in section 3 (seconds) | | | |
| Middle Mouse | Female 1 | Female 2 | Male 1 | Male 2 |
| 85 | 85 | 78 | 60 | 0 |
| 117 | 84 | 0 | 7 | 0 |
| 202 | 202 | 58 | 71 | 10 |
| 9 | 9 | 6 | 9 | 9 |
| 204 | 204 | 81 | 188 | 199 |

| **Day 4- Unwrapped Ferafeed bait** | | | | |
|---|---|---|---|---|
| Time on bait (seconds) | Time in section 3 (seconds) | | | |
| Middle Mouse | Female 1 | Female 2 | Male 1 | Male 2 |
| 113 | 0 | 33 | 0 | 21 |
| 496 | 465 | 307 | 120 | 450 |
| 233 | 84 | 233 | 233 | 138 |
| 113 | 113 | 83 | 0 | 113 |

| **Day 5- Unwrapped Ferafeed bait** | | | | |
|---|---|---|---|---|
| Time on bait (seconds) | Time in section 3 (seconds) | | | |
| Middle Mouse | Female 1 | Female 2 | Male 1 | Male 2 |
| 385 | 60 | 22 | 142 | 177 |
| 397 | 105 | 206 | 121 | 361 |
| 426 | 281 | 154 | 309 | 401 |

| **Day 6- Unwrapped Ferafeed bait** | | | | |
|---|---|---|---|---|
| Time on bait (seconds) | Time in section 3 (seconds) | | | |
| Middle Mouse | Female 1 | Female 2 | Male 1 | Male 2 |
| 81 | 81 | 30 | 81 | 24 |
| 36 | 0 | 0 | 36 | 0 |
| 155 | 138 | 125 | 155 | 155 |
| 165 | 165 | 99 | 0 | 165 |

## 8.3.2 Mouse location 15-second count data over 1 hour

| | | **Day 1- Wrapped Ferafeed bait** | | | | | |
|---|---|---|---|---|---|---|---|
| | Section | Female 1 | Female 2 | Male 1 | Male 2 | | Middle mouse |
| (Outer) | 1 | 31 | 29 | 94 | 22 | Eating | 24 |
| (Middle) | 2 | 4 | 0 | 4 | 7 | Not Eating | 216 |
| (Inner) | 3 | 205 | 211 | 142 | 211 | | |

| | | **Day 2- Wrapped Ferafeed bait** | | | | | |
|---|---|---|---|---|---|---|---|
| | Section | Female 1 | Female 2 | Male 1 | Male 2 | | Middle mouse |
| (Outer) | 1 | 206 | 56 | 162 | 30 | Eating | 25 |
| (Middle) | 2 | 1 | 46 | 18 | 7 | Not Eating | 215 |
| (Inner) | 3 | 33 | 138 | 60 | 203 | | |

| | | **Day 3- Wrapped Ferafeed bait** | | | | | |
|---|---|---|---|---|---|---|---|
| | Section | Female 1 | Female 2 | | Male 2 | | Middle mouse |
| (Outer) | 1 | 41 | 84 | 65 | 29 | Eating | 37 |
| (Middle) | 2 | 3 | 17 | 16 | 4 | Not Eating | 203 |
| (Inner) | 3 | 196 | 139 | 159 | 207 | | |

| | | **Day 4- Unwrapped Ferafeed bait** | | | | | |
|---|---|---|---|---|---|---|---|
| | Section | Female 1 | Female 2 | Male 1 | Male 2 | | Middle mouse |
| (Outer) | 1 | 102 | 109 | 88 | 68 | Eating | 86 |
| (Middle) | 2 | 1 | 7 | 5 | 3 | Not Eating | 154 |
| (Inner) | 3 | 137 | 124 | 147 | 169 | | |

| | | **Day 5- Unwrapped Ferafeed bait** | | | | | |
|---|---|---|---|---|---|---|---|
| | Section | Female 1 | Female 2 | Male 1 | Male 2 | | Middle mouse |
| (Outer) | 1 | 76 | 54 | 68 | 46 | Eating | 75 |
| (Middle) | 2 | 4 | 20 | 13 | 3 | Not Eating | 165 |
| (Inner) | 3 | 160 | 166 | 159 | 191 | | |

| | | **Day 6- Unwrapped Ferafeed bait** | | | | | |
|---|---|---|---|---|---|---|---|
| | Section | Female 1 | Female 2 | Male 1 | Male 2 | | Middle mouse |
| (Outer) | 1 | 23 | 88 | 34 | 37 | Eating | 25 |
| (Middle) | 2 | 1 | 11 | 45 | 1 | Not Eating | 215 |
| (Inner) | 3 | 216 | 151 | 161 | 202 | | |

## 8.4 Appendix 4: Palatability experiment raw results

| | **EPA v Striker FF213 bait** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trial 1 | | | | | | | | | | | | |
| | | EPA | | | | Striker 213 bait | | | | | | | |
| | Animal no. | Pre Wt | Post Wt | Eaten | | Pre Wt | Post Wt | Eaten | Bait | Striker | | Total | Pal. of 213 bait |
| Wild | 1 | 85.25 | 78.95 | 6.30 | | 28.05 | 27.35 | 0.70 | | | | 7.00 | 0.1 |
| | 2 | 83.35 | 80.05 | 3.30 | | 27.30 | 26.90 | 0.40 | | | | 3.70 | 0.108108 |
| | 3 | 84.70 | 79.40 | 5.30 | | 29.05 | 29.05 | 0.00 | | | | 5.30 | 0 |
| | 4 | 87.10 | 82.15 | 4.95 | | 27.85 | 26.60 | 1.25 | | | | 6.20 | 0.201613 |
| | 5 | 87.85 | 84.25 | 3.60 | | 27.40 | 26.05 | 1.35 | | | | 4.95 | 0.272727 |
| | 6 | 87.30 | 82.30 | 5.00 | | 28.00 | 27.70 | 0.30 | | | | 5.30 | 0.056604 |
| | 7 | 85.00 | 80.20 | 4.80 | | 27.60 | 23.95 | 3.65 | | | | 8.45 | 0.431953 |
| | 8 | 83.50 | 74.85 | 8.65 | | 28.00 | 24.45 | 3.55 | | | | 12.20 | 0.290984 |
| | 9 | 84.20 | 79.10 | 5.10 | | 27.85 | 27.50 | 0.35 | | | | 5.45 | 0.06422 |
| | 10 | 86.65 | 81.60 | 5.05 | | 26.95 | 25.45 | 1.50 | | | | 6.55 | 0.229008 |
| Domestic | 11 | 87.90 | 81.00 | 6.90 | | 28.00 | 24.40 | 3.60 | 18.50 | 5.65 | | | |
| | 12 | 87.50 | 78.15 | 9.35 | | 27.80 | 22.00 | 5.80 | 18.35 | 3.60 | | | |
| | 13 | 83.25 | 78.95 | 4.30 | | 27.75 | 26.30 | 1.45 | 19.05 | 7.15 | | | |
| | 14 | 84.65 | 70.50 | 14.15 | | 28.10 | 25.05 | 3.05 | 20.10 | 4.95 | | | |
| | 15 | 86.95 | 77.75 | 9.20 | | 27.20 | 24.50 | 2.70 | 17.85 | 6.55 | | | |
| | 16 | 86.60 | 79.20 | 7.40 | | 27.80 | 23.05 | 4.75 | 16.50 | 6.55 | | | |
| | 17 | 84.70 | 78.75 | 5.95 | | 27.65 | 25.80 | 1.85 | 18.60 | 7.15 | | | |
| | 18 | 88.05 | 79.20 | 8.85 | | 27.45 | 23.50 | 3.95 | 16.35 | 7.10 | | | |
| | 19 | 86.55 | 84.55 | 2.00 | | 28.10 | 18.10 | 10.00 | 10.70 | 7.40 | | | |
| | 20 | 87.40 | 78.50 | 8.90 | | 28.15 | 24.60 | 3.55 | 17.80 | 6.80 | | | |
| | | | Total: | 129.05 | | | Total: | 53.75 | | | | | |
| | This first trial used the striker bait container, following trials did not include the striker container but the bait by itself. | | | | | | | | | | | | |

| | **EPA v FF213 bait** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trial 2 | | | | | | | | | | |
| | | EPA | | | | Striker 213 bait | | | | | |
| | Animal no. | Pre Wt | Post Wt | Eaten | | Pre Wt | Post Wt | Eaten | | Total | Pal of 213 bait |
| Wild | 1 | 88.60 | 82.10 | 6.50 | | 82.90 | 82.15 | 0.75 | | 7.25 | 0.103448 |
| | 2 | 83.65 | 82.30 | 1.35 | | 82.15 | 81.20 | 0.95 | | 2.30 | 0.413043 |
| | 3 | 89.95 | 85.30 | 4.65 | | 84.70 | 84.60 | 0.10 | | 4.75 | 0.021053 |
| | 4 | 83.85 | 82.45 | 1.40 | | 87.85 | 86.00 | 1.85 | | 3.25 | 0.569231 |
| | 5 | 86.25 | 83.55 | 2.70 | | 88.65 | 86.80 | 1.85 | | 4.55 | 0.406593 |
| | 6 | 82.55 | 80.35 | 2.20 | | 84.20 | 82.50 | 1.70 | | 3.90 | 0.435897 |
| | 7 | 86.20 | 82.30 | 3.90 | | 88.65 | 87.70 | 0.95 | | 4.85 | 0.195876 |
| | 8 | 82.80 | 79.85 | 2.95 | | 91.90 | 89.15 | 2.75 | | 5.70 | 0.482456 |
| | 9 | 81.35 | 76.90 | 4.45 | | 89.60 | 89.15 | 0.45 | | 4.90 | 0.091837 |
| | 10 | 83.00 | 81.45 | 1.55 | | 93.05 | 91.93 | 1.12 | | 2.67 | 0.419476 |
| Domestic | 11 | 82.70 | 77.40 | 5.30 | | 80.50 | 76.60 | 3.90 | | 9.20 | 0.423913 |
| | 12 | 80.95 | 77.90 | 3.05 | | 88.30 | 85.40 | 2.90 | | 5.95 | 0.487395 |
| | 13 | 79.40 | 75.20 | 4.20 | | 87.50 | 84.85 | 2.65 | | 6.85 | 0.386861 |
| | 14 | 84.75 | 81.20 | 3.55 | | 82.35 | 80.90 | 1.45 | | 5.00 | 0.29 |
| | 15 | 85.45 | 77.40 | 8.05 | | 91.80 | 87.65 | 4.15 | | 12.20 | 0.340164 |
| | 16 | 82.00 | 74.40 | 7.60 | | 84.00 | 79.60 | 4.40 | | 12.00 | 0.366667 |
| | 17 | 81.95 | 77.00 | 4.95 | | 89.25 | 86.85 | 2.40 | | 7.35 | 0.326531 |
| | 18 | 82.75 | 80.45 | 2.30 | | 88.35 | 84.10 | 4.25 | | 6.55 | 0.648855 |
| | 19 | 83.40 | 79.70 | 3.70 | | 83.35 | 77.45 | 5.90 | | 9.60 | 0.614583 |
| | 20 | 82.25 | 75.30 | 6.95 | | 84.65 | 80.35 | 4.30 | | 11.25 | 0.382222 |
| | | | Total: | 81.30 | | | Total: | 48.77 | | | |

| | **EPA v FF213 bait** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trial 3 | | | | | | | | | | |
| | | EPA | | | | Striker 213 bait | | | | | |
| | Animal no. | Pre Wt | Post Wt | Eaten | | Pre Wt | Post Wt | Eaten | | Total | Palatability |
| Wild | 1 | 89.40 | 87.10 | 2.30 | | 88.35 | 87.35 | 1.00 | | 3.30 | 0.30303 |
| | 2 | 88.15 | 87.00 | 1.15 | | 89.40 | 87.95 | 1.45 | | 2.60 | 0.557692 |
| | 3 | 88.45 | 85.10 | 3.35 | | 89.40 | 89.40 | 0.00 | | 3.35 | 0 |
| | 4 | 87.95 | 85.75 | 2.20 | | 92.60 | 92.05 | 0.55 | | 2.75 | 0.2 |
| | 5 | 87.95 | 83.45 | 4.50 | | 94.45 | 94.45 | 0.00 | | 4.50 | 0 |
| | 6 | 83.25 | 78.25 | 5.00 | | 97.45 | 97.45 | 0.00 | | 5.00 | 0 |
| | 7 | 86.70 | 82.10 | 4.60 | | 94.50 | 94.10 | 0.40 | | 5.00 | 0.08 |
| | 8 | 86.25 | 83.10 | 3.15 | | 89.90 | 87.55 | 2.35 | | 5.50 | 0.427273 |
| | 9 | 83.85 | 80.85 | 3.00 | | 91.40 | 91.40 | 0.00 | | 3.00 | 0 |
| | 10 | 84.45 | 82.05 | 2.40 | | 94.80 | 93.10 | 1.70 | | 4.10 | 0.414634 |
| Domestic | 11 | 89.40 | 84.60 | 4.80 | | 92.45 | 89.00 | 3.45 | | 8.25 | 0.418182 |
| | 12 | 82.65 | 77.65 | 5.00 | | 86.55 | 84.20 | 2.35 | | 7.35 | 0.319728 |
| | 13 | 81.55 | 80.10 | 1.45 | | 91.50 | 87.60 | 3.90 | | 5.35 | 0.728972 |
| | 14 | 85.70 | 77.05 | 8.65 | | 86.60 | 84.10 | 2.50 | | 11.15 | 0.224215 |
| | 15 | 86.85 | 81.90 | 4.95 | | 94.90 | 90.35 | 4.55 | | 9.50 | 0.478947 |
| | 16 | 85.65 | 80.85 | 4.80 | | 91.40 | 85.20 | 6.20 | | 11.00 | 0.563636 |
| | 17 | 82.30 | 77.55 | 4.75 | | 86.95 | 85.20 | 1.75 | | 6.50 | 0.269231 |
| | 18 | 87.30 | 83.10 | 4.20 | | 94.55 | 89.85 | 4.70 | | 8.90 | 0.52809 |
| | 19 | 88.15 | 88.15 | 0.00 | | 88.55 | 83.85 | 4.70 | | 4.70 | 1 |
| | 20 | 83.90 | 80.75 | 3.15 | | 94.55 | 88.00 | 6.55 | | 9.70 | 0.675258 |
| | | | Total: | 73.40 | | | Total: | 48.10 | | | |

| | **Antifungal v Non Antifungal treated Erayz bait** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trial 1 | | | | | | | | | | |
| | | Control | | | | Antifungal bait | | | | | |
| | Animal no. | Pre Wt | Post Wt | Eaten | | Pre Wt | Post Wt | Eaten | | Total | Pal of antifungal | |
| Wild | 1 | 80.00 | 68.40 | 11.60 | | 76.05 | 75.15 | 0.90 | | 12.50 | 0.072 | |
| | 2 | 77.25 | 75.45 | 1.80 | | 80.70 | 79.45 | 1.25 | | 3.05 | 0.409836 | |
| | 3 | 82.30 | 78.30 | 4.00 | | 80.80 | 78.10 | 2.70 | | 6.70 | 0.402985 | |
| | 4 | 77.85 | 75.55 | 2.30 | | 75.20 | 73.50 | 1.70 | | 4.00 | 0.425 | |
| | 5 | 78.40 | 76.50 | 1.90 | | 81.35 | 80.00 | 1.35 | | 3.25 | 0.415385 | |
| | 6 | 77.50 | 76.80 | 0.70 | | 76.50 | 74.15 | 2.35 | | 3.05 | 0.770492 | |
| | 7 | 79.60 | 73.00 | 6.60 | | 82.75 | 69.45 | 13.30 | | 19.90 | 0.668342 | |
| | 8 | 76.25 | 66.20 | 10.05 | | 79.65 | 67.55 | 12.10 | | 22.15 | 0.546275 | |
| | 9 | 73.80 | 67.45 | 6.35 | | 75.00 | 71.25 | 3.75 | | 10.10 | 0.371287 | |
| | 10 | 74.85 | 71.80 | 3.05 | | 74.45 | 68.10 | 6.35 | | 9.40 | 0.675532 | |
| Domestic | 11 | 80.65 | 73.45 | 7.20 | | 79.55 | 76.75 | 2.80 | | 10.00 | 0.28 | |
| | 12 | 74.80 | 65.40 | 9.40 | | 76.60 | 72.70 | 3.90 | | 13.30 | 0.293233 | |
| | 13 | 75.50 | 73.75 | 1.75 | | 77.40 | 74.50 | 2.90 | | 4.65 | 0.623656 | |
| | 14 | 78.95 | 73.75 | 5.20 | | 77.90 | 75.95 | 1.95 | | 7.15 | 0.272727 | |
| | 15 | 77.60 | 76.20 | 1.40 | | 80.15 | 73.85 | 6.30 | | 7.70 | 0.818182 | |
| | 16 | 78.90 | 71.70 | 7.20 | | 78.15 | 72.40 | 5.75 | | 12.95 | 0.444015 | |
| | 17 | 77.10 | 75.35 | 1.75 | | 79.15 | 74.85 | 4.30 | | 6.05 | 0.710744 | |
| | 18 | 77.10 | 70.90 | 6.20 | | 78.70 | 74.75 | 3.95 | | 10.15 | 0.389163 | |
| | 19 | 76.90 | 71.25 | 5.65 | | 74.90 | 67.05 | 7.85 | | 13.50 | 0.581481 | |
| | 20 | 78.10 | 70.90 | 7.20 | | 78.90 | 75.95 | 2.95 | | 10.15 | 0.29064 | |
| | | | Total: | 101.30 | | | Total: | 88.40 | | | | |

| | **Antifungal v Non Antifungal treated Erayz bait** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trial 2 | | | | | | | | | | |
| | | Control | | | | Antifungal bait | | | | | |
| | Animal no. | Pre Wt | Post Wt | Eaten | | Pre Wt | Post Wt | Eaten | | Total | Pal. of antifungal |
| Wild | 1 | 83.90 | 74.10 | 9.80 | | 80.35 | 77.05 | 3.30 | | 13.10 | 0.251908 |
| | 2 | 81.10 | 80.10 | 1.00 | | 80.55 | 78.30 | 2.25 | | 3.25 | 0.692308 |
| | 3 | 90.70 | 89.15 | 1.55 | | 81.20 | 75.75 | 5.45 | | 7.00 | 0.778571 |
| | 4 | 82.42 | 80.15 | 2.27 | | 91.65 | 90.90 | 0.75 | | 3.02 | 0.248344 |
| | 5 | 84.40 | 81.85 | 2.55 | | 81.60 | 80.35 | 1.25 | | 3.80 | 0.328947 |
| | 6 | 83.05 | 82.85 | 0.20 | | 87.00 | 82.05 | 4.95 | | 5.15 | 0.961165 |
| | 7 | 85.65 | 83.35 | 2.30 | | 79.55 | 73.30 | 6.25 | | 8.55 | 0.730994 |
| | 8 | 81.05 | 80.40 | 0.65 | | 88.50 | 78.40 | 10.10 | | 10.75 | 0.939535 |
| | 9 | 78.90 | 75.60 | 3.30 | | 80.90 | 72.25 | 8.65 | | 11.95 | 0.723849 |
| | 10 | 77.10 | 72.55 | 4.55 | | 83.15 | 82.20 | 0.95 | | 5.50 | 0.172727 |
| Domestic | 11 | 90.55 | 83.75 | 6.80 | | 79.60 | 72.45 | 7.15 | | 13.95 | 0.512545 |
| | 12 | 80.20 | 76.90 | 3.30 | | 81.20 | 80.60 | 0.60 | | 3.90 | 0.153846 |
| | 13 | 77.20 | 75.50 | 1.70 | | 88.80 | 85.55 | 3.25 | | 4.95 | 0.656566 |
| | 14 | 81.35 | 75.05 | 6.30 | | 81.25 | 80.55 | 0.70 | | 7.00 | 0.1 |
| | 15 | 84.30 | 80.20 | 4.10 | | 82.85 | 79.45 | 3.40 | | 7.50 | 0.453333 |
| | 16 | 79.50 | 73.25 | 6.25 | | 84.30 | 80.95 | 3.35 | | 9.60 | 0.348958 |
| | 17 | 82.50 | 79.90 | 2.60 | | 81.20 | 76.75 | 4.45 | | 7.05 | 0.631206 |
| | 18 | 82.05 | 77.25 | 4.80 | | 90.75 | 88.00 | 2.75 | | 7.55 | 0.364238 |
| | 19 | 80.55 | 72.55 | 8.00 | | 85.15 | 69.20 | 15.95 | | 23.95 | 0.665971 |
| | 20 | 78.20 | 73.85 | 4.35 | | 82.80 | 80.45 | 2.35 | | 6.70 | 0.350746 |
| | | | Total: | 76.37 | | | Total: | 87.85 | | | |