Response of kiwi to a range of baits and lures used for pest control in New Zealand.

Tamsin Elizabeth Ward-Smith

1998

A thesis presented in partial fulfilment of the requirements for the Degree of Master of Science in Ecology at Massey University

"Seagull"

Acknowledgements

I have travelled just about over the whole of North Island during this thesis and have met so many people along the way who have helped me!

Firstly though, funding was provided by the **Department of Conservation**, and the **Massey University** Graduate Research Fund. All the work in this study was made possible by the use of time-lapse infra-red video equipment, kindly lent by **Chris Eckroyd** and the New Zealand Lottery Board. Also, without **Barry Springrice** the stuff would never have gone in the first place, or after the numerous times it broke down. I am very thankful that he knew so much!. **Hugh Robertson** also assisted with setting this project up , and with **Rogan Colbourne** introduced me to Northland kiwi.

At Massey I am very grateful to **Murray Potter** for putting up with me and this thesis for so long, especially for getting me hooked on kiwi in the first place, for never sending me away to come back later, and for always being positive! **Robin Fordham** has also been very supportive, and has given lots of helpful editing hints. **Alastair Robertson** was patient with all my stats questions, but more importantly lent his house so we could write in peace, you can't imagine what a luxury that was. **Bruce** and **Fiona** also lent their house for a month and thanks also to them. **Erica Reid** is just one realy helpful secretary and has made my life a lot easier!

For my time at Waikaremoana I thank **John McLennan** for his kiwi inspiration, for helping to get things going, and always happy times at the lake (I just want to get back there), **Jonathan Miles** for ferrying me around and help with setting up cameras, and **Grant, Sid, Ray** and **Frank** for leaping (most of the time) to carry batteries up and down the hills (Ray especially for organising to charge them, and for always going out of his way to help, it made a real difference!). In Northland I am especially grateful to **Pat Millar** for jacking up the accommodation, making me welcome up there and for skillfully identifying suitable nests, **Ray Pierce** for providing a caravan, and the **Lovells** for awesome meals, desperately needed showers, their help, and somewhere to relax (other than the caravan!). I am also grateful to **Ray** and **Barbara Walter** on Tiritiri Matangi Island, for welcoming me to work there and providing support, **Karori Reserve**

for letting me work with the weka, and **Dick Veitch** for his help with permit applications.

During the work with captive kiwi I have also met, and want to thank numerous people who made the work fun and run as smoothly as possible: **Eric Fox** and the **Otorohanga Kiwi House**, and **Tony Billing** for allowing me to work with kiwi in their establishments (Tony Billing and Bronwyn in particular for their kindness, good food and wine), **June** and **John Holt** for somewhere to stay in luxury, and do field work, and **Pat** and **Arthur Cowan** for time with them at their amazing home, yummy food and good vibes.

I also want to thank **Dave Morgan** who has helped me so much with getting to grips with baits, answering many questions and with planning work for Chapter five. **Carter Observatory**, Wellington also kindly provided sunset and sunrise times used in the behaviour chapter.

Heaps of thanks to all my friends and flat-mates; in particular **Penny Aspin** for being such a cool person and never failing to find us a distraction, **Brent Stephenson** for his wizzey skills at map drawing and computer stuff (ugg!!), and endless cups of coffee, **Don Ravine** who's just Don, always helpful, patient, full of positive boosts to my confidence (when I needed it) and a great proof reader, **Karen** who is just a great friend to me and who has suffered this thesis almost as much (and has still hung in to read drafts), **Janine** for her positivity and motivation for life, and **Zane** for putting up with lots of stress and lending his car to jet up and down the country. Lastly, thanks heaps to my **mum**, my **dad** and **John** for always being there (to lug batteries when all the other muscles had run out), and if not, then for sending me positive stuff in letters. You guys are just great!

Abstract

The primary aim of this thesis was to assess the palatability to North Island brown kiwi (*Apteryx australis mantelli*) of a range of non-toxic baits and flavours used to lure baits. During the wild bait trials incubation patterns of nesting male kiwi, chick behaviour and the presence of predators at the nesting burrow were recorded. A new 'improved' ground laid 1080 paste was also tested on a range of non-target bird species. All ten captive kiwi fed at least once on at least one bait type (i.e. carrot, No.7, RS5, apple pulp, and paste) but did not prefer any to their usual artificial diet. Wild kiwi did not feed on any bait type placed outside the nest entrance, but may have ingested apple pulp, or paste when they probed these baits. Results indicate that cereal-based baits are the safest bait type to sow aerially in kiwi habitat, while apple pulp baits are highly acceptable to kiwi. Cinnamon, aniseed, orange and clove flavours did not significantly attract or deter captive kiwi from feeding on portions of their usual diet. Insufficient flavoured cereal No.7 baits were eaten to determine whether any bait and flavour combination affected kiwi response to these baits. No wild kiwi fed on any cinnamon or orange flavoured No.7 cereal baits placed outside the nesting burrow, but kiwi did probe these baits. Incubating male kiwi left the nest once each night, except for two kiwi which sometimes left the nest twice in a night. One of these sometimes made three trips from the nest in a night. The active period of kiwi did not appear to be influenced by the number of times they emerged in a night. Male kiwi tended to spend less time away from the nest when chicks were due to hatch, following which they increased the time spent away. Possums, rats and mice regularly visited kiwi nests, but did not deter males from incubating, or harm kiwi eggs or chicks. Five species - robin, saddleback, blackbird, pukeko and weka, fed on a non-toxic cinnamon-lured form of 1080 paste. Species other than those mentioned rarely landed on the ground and therefore encountered paste infrequently. Captive weka found the paste highly palatable, while 24% of robins and possibly half of a pukeko family fed on the paste. All bird visits to the paste baits declined after the first day of exposure. Recommendations are made on the safe laying of paste baits in areas where robin, saddleback, weka or pukeko are present.

Table of contents

Acknowledgements.....iii
Abstract.....v
Table of contents.....vi
List of figures.....x
List of tables.....xi

Chapter one: A review of 1080: its use, and effects on non-target species, with specific reference to kiwi..... 1

INTRODUCTION 1
PART ONE 1
Background to pests in New Zealand and methods for their control 1
Compound 1080 - use and effects on vertebrate animals 3
Impacts of 1080-poison operations on non-target species 4
Background to New Zealand 1080 operations 5
Subsequent bait modifications 5
Monitoring of common and rare bird species 6
Types of 1080 baits used in New Zealand 7
PART TWO 8
Study animal - Kiwi 8
The Kiwi Recovery Plan 10
Risk of poisoning to kiwi 11
Difficulties with monitoring kiwi during poisoning operations 12
Outputs from the Kiwi Recovery Plan 13
Thesis aims and layout 16
REFERENCES 17

Chapter two: The response of captive and wild kiwi to a range of non-toxic baits used for pest control in New Zealand. 32

ABSTRACT 32
INTRODUCTION 32

Chapter two

MATERIALS AND METHODS 35
Kiwi used 35
Baits used 37
Captive kiwi trials 42
Wild kiwi trials 44
RESULTS 45
Captive kiwi trials 45
Wild Kiwi Trials 54
DISCUSSION 61
Captive kiwi trials 61
Wild kiwi trials 64
Captive verses wild kiwi 66
Conclusions 67
Main points arising from the study 68
RECOMMENDATIONS 69
REFERENCES 69
APPENDIX 1 76
APPENDIX 2 77
APPENDIX 3 78

Chapter three: Response of captive and wild kiwi to a range of flavours added to baits used for pest control in New Zealand. 79

ABSTRACT 79
INTRODUCTION 79
Flavours added to baits in New Zealand 80
Testing flavours on non-target bird species 80
MATERIALS AND METHODS 82
Materials 82
Captive kiwi trials 82
Wild kiwi trials 85
RESULTS 86
Captive kiwi trials 86
Wild kiwi trials 94

Chapter three

DISCUSSION 97
Captive kiwi flavour trials 97
Wild kiwi flavoured bait trials 99
Conclusions 101
Main points arising from the study: 101
RECOMMENDATIONS 102
REFERENCES 102

Chapter four: Behaviour of incubating kiwi and predators at nesting burrows 106

ABSTRACT 106
INTRODUCTION 106
Kiwi breeding behaviour 106
Kiwi and predators 107
Study areas 108
Introduced mammals 108
METHODS 109
Data collection and analysis 109
RESULTS 110
Video monitoring of kiwi 110
Video monitoring of predators at the nest 121
DISCUSSION 122
Video monitoring of kiwi 122
Predator visits to the nest 124
REFERENCES 126

Chapter five: Testing the response of native birds to a new formulation of 1080 apple paste..... 129

ABSTRACT 129
INTRODUCTION 129
Background 129
Non-target species testing 130
Objective 131
METHODS 131
Bait used 132
General forest birds 132
Robins 134
Kereru 134
Weka 135
Pukeko 135
RESULTS 136
General forest birds 136
Robins 138
Kereru 139
Weka 139
Pukeko 141
DISCUSSION 143
Forest birds 143
Robins 144
Kereru 145
Weka 146
Pukeko 146
General comments 146
RECOMMENDATIONS 147
Management 147
Research 147
REFERENCES 148
APPENDIX 1 151

List of figures

Figure		Page
1.1	A North Island brown kiwi.	9
2.1	Location of wild kiwi study sites.	38
2.2	View across Lake Waikaremoana, Te Urewera National Park.	39
2.3	Looking towards a video recorded kiwi nest.	39
2.4	View of bush patches containing kiwi in Northland.	40
2.5	Position of the five bait types outside a kiwi nest in Northland.	40
2.6	The proportion of captive kiwi which fed on baits at least once, and more than once.	47
2.7	Mean duration spent feeding by captive kiwi on their usual food and each bait type.	50
2.8	Total duration spent feeding each night by captive kiwi on all bait types.	52
2.9	Mean number of probes per minute by wild kiwi on baits and presented invertebrates.	60
3.1	Mean duration spent feeding by captive kiwi on flavoured food portions in the first two hours of the night.	89
3.2	Total duration spent feeding by captive kiwi on flavoured food portions throughout the whole night.	90
3.3	Mean duration spent feeding by each captive kiwi on flavoured food portions in the first two hours of the night, and throughout the whole night.	91/92
4.1	Mean time of emergence after sunset for incubating wild kiwi.	112
4.2	Mean duration spent away from the nest for incubating wild kiwi.	113
4.3	Mean duration that wild kiwi spent away from the nest with increasing stage of incubation.	114
4.4	Wild kiwi emerging from its nest.	116
4.5	Possum at the entrance of a wild kiwi nest, and with its head inside the nest.	117
5.1	Location of video recorded sites on Tiritiri Matangi Island in the Hauraki Gulf.	133

List of tables

Table		Page
2.1	Number of captive kiwi which fed on each bait type on nights one to five.	48
2.2	Total number of each bait type eaten by captive male and female kiwi.	48
2.3	Repeated Measures ANOVA investigating the duration that captive kiwi fed on each bait type and their usual food.	51
2.4	Repeated Measures ANOVA investigating the duration that captive kiwi fed on each bait type on nights one to five.	51
2.5	Kruskal-Wallis values for one-way ANOVA between sex and the rank assigned to each bait type for individual captive kiwi.	53
2.6	Kruskal-Wallis values for one-way ANOVA between sex and the ranks assigned within bait types according to the numbers of baits eaten by individual captive kiwi.	54
2.7	Number of small and large pellet baits eaten by captive kiwi.	54
2.8	Number of observations of wild kiwi feeding on presented food and other invertebrates outside the nest.	55
2.9	Number and duration of wild kiwi encounters with each bait type, and worms and cicada nymphs.	57
2.10	Total number of times wild kiwi probed each bait type, or worms or cicada nymphs.	59
3.1	Repeated Measures ANOVA investigating the duration captive kiwi fed on flavoured food portions in the first two hours of the night.	87
3.2	Repeated Measures ANOVA investigating the total duration captive kiwi fed on flavoured food portions.	88
3.3	Total number of flavoured baits eaten by captive kiwi.	94
3.4	Total number and duration of wild kiwi encounters with cinnamon-flavoured cereal baits.	96
3.5	Total number and duration of wild kiwi encounters with orange-flavoured cereal baits.	96
4.1	Percentage of times wild kiwi emerged and covered their nest.	118
5.1	Number and mean duration of bird visits to paste bait.	136
5.2	Number and mean duration of visits to paste bait made by all species.	137

Table **Page**

5.3 Number and mean duration of feeding visits to paste bait by all species. 138

5.4 Number and duration of feeding visits made to the paste by male and female robins. 140

5.5 Number and duration of visits to paste by species other than robin. 141

5.6 Number and duration of visits and feeding visits to paste by pukeko. 142

A review of 1080: its use, and effects on non-target species, with specific reference to kiwi.

INTRODUCTION

PART ONE

Background to pests in New Zealand and methods for their control

Until approximately 2000 years ago New Zealand's fauna had been evolving in the absence of herbivorous and predatory land mammals (Wodzicki 1950) with the exception of bats. However, with the arrival of Polynesians to New Zealand (Holdaway 1996) and later, with European colonisers, came a suite of companion animals, some by accident and others intentionally. Many of the 'new' species including rabbits (*Oryctolagus cuniculus cuniculus*), feral goats (*Capra hircus*), cats (*Felis catus*), stoats (*Mustela erminea*), ferrets (*Mustela furo*) and the brushtail possum (*Trichosurus vulpecula*) adapted well to the climate and vegetation, and as a result now flourish at the expense of agricultural and/or conservation values (Cowan 1990; Fitzgerald 1990; Gibb and Williams 1990; King 1990; Rudge 1990).

Methods to control these pest species include shooting, trapping (Spurr 1991), and the use of poisons such as cyanide (Reid 1986) and 1080 (sodium monofluoroacetate)(Batcheler 1978; Rammell and Fleming 1978). Pest control operations are considered to be beneficial to non-target wildlife since they improve the habitat and reduce competition for food (Spurr 1991; Fraser 1995). However, these operations may also detrimentally affect non-target species (Harrison 1978a; Spurr 1991; Spurr 1994a). In particular, concerns over the effects of 1080 possum control operations on native birds have been expressed since this poison was first used in New Zealand (Fraser et al. 1995). Birds have been reduced in numbers and found dead following 1080 operations (Forest Research Institute 1981; Warren 1984; Calder and Deuss 1985; Powlesland, pers. comm.) and as a result it has been necessary to monitor

populations to determine whether the risks of using 1080 are acceptable in the long term to these species.

Possums

Among New Zealand's mammal pests, the brushtail possum has become one of the most serious (King 1990), and ubiquitous. Possums were first liberated into New Zealand from Eastern Australia around 1837 to establish a fur trade (Pracy 1974). Since then they have spread rapidly and numbers are now estimated to be around 70 million (Livingstone and Nelson 1993). At least $58 million is spent annually on control and research (Peterson et al. 1994). Possums have a damaging effect on native forests (Kean and Pracy 1949; Fitzgerald and Wardle 1979; Batcheler 1983; Cowan 1990) and may be influencing forest dieback (Batcheler 1983; McBreen 1997), while in places some mistletoes (*Peraxilla* spp) have been selectively browsed almost to local extinction (Wilson 1984; Livingstone and Nelson 1993). Since 1967 possums have also been identified as vectors of bovine tuberculosis (Tb) and are involved with promoting the spread of the disease to farm stock, subsequently jeopardizing exports of beef, dairy produce and venison (Cowan 1990). Possums also impact on native fauna indirectly through competition for food resources, and directly by disturbing nesting birds and preying on eggs and chicks of species such as kiwi, kokako and kereru (Leathwick et al. 1983; McLennan 1988; Brown et al. 1993; Innes 1994).

The first official possum control campaigns relied on trapping, shooting and poisoning with cyanide, arsenic and phosphorous (Peterson et al. 1994). Since 1948 compound 1080 has been used extensively in New Zealand initially for rabbit control (Caithness and Williams 1971) and now principally for the control of possums (Rammell and Fleming 1978). Aerial distribution of 1080 in carrier baits such as carrot or cereal pellets has become a major control technique, which is effective over large and/or inaccessible tracts of forest (Spurr 1994a). In areas where greater sowing precision is required 1080 pastes are also hand-laid in bait stations, directly onto the ground, or on leaves (Rammell and Fleming 1978; Morgan and Goodwin 1995).

As the need to control possums has increased so has the use of 1080 in aerial and ground-based operations (Harrison 1978a; Morgan and Goodwin 1995). Alternative

techniques (e.g. trapping and shooting) and toxins (e.g. cyanide, brodifacoum, pindone, cholecalciferol, Batcheler 1978; Eason et al. 1993; Jolly et al. 1995; Eason et al. 1996; Haydock and Eason 1997) for possum control exist. However, in New Zealand 1080 is used over more area than all other poisons combined (Peterson et al. 1994), primarily because it is effective as a mammal poison and kills relatively humanely (Eisler 1995), has not been found to contaminate water-ways (Eason et al. 1992), and is cost effective over large areas (Spurr 1994a). At least until acceptable biological controls become available, 1080 is likely to remain the toxin of choice for large-scale wild mammal control (Eason et al. 1992).

Compound 1080 - use and effects on vertebrate animals

1080

Compound 1080 is a broad spectrum poison (Batcheler 1978), that is synthesised for commercial use, but occurs naturally as fluoroacetate compounds in some poisonous plants of Australia (*Gastrolobium* and *Oxylobium* spp), Brazil, and Africa (Eisler 1995). The toxic properties of 1080 work by blocking the Krebs cycle (TCA cycle) which is the major energy-producing pathway in most organisms. Death by 1080 is considered to be one of the most humane methods of killing pests, since the brain is usually affected first and animals are generally semi-comatose before they enter terminal seizures (Eisler 1995). There is no known effective antidote (Atzert 1971).

Although a number of countries register 1080 (e.g. Australia, Canada, United States), it is not in widespread use (Livingstone and Nelson 1994). New Zealand is now the largest user of 1080 world-wide (cited in Peterson et al. 1994). In the United States 1080 was banned in 1972 following concerns over the adverse effects on non-target species and restricted only to use in livestock protection collars (Palmateer 1990). Australia, the second largest 1080 user, has used 1080 since the 1950s - initially for rabbit control *(Oryctolagus cuniculus)* and later for the control of other mammal pests (McIlroy 1981a; McIlroy 1981b; McIlroy 1984; Calver et al. 1989a; Calver et al. 1989b).

Sensitivity of terrestrial vertebrates to 1080 poison

Animals differ widely in their sensitivity to 1080 (Eisler 1995). Amphibians and reptiles are amongst the most resistant to 1080 of all vertebrates (Atzert 1971), with LD_{50}'s (the dose required in mg per kg body weight to kill 50% of the population) ranging from 44 mg kg^{-1} to 2000 mg kg^{-1} (cited in Eisler 1995). In contrast, most mammals are highly sensitive to 1080 (Eisler 1995) and consequently, it is a particularly effective poison for use against possums. LD_{50}'s of 1080 for possums from areas lacking fluoroacetate vegetation (i.e. those that have not developed a natural resistance to 1080) are as low as 0.39 - 0.92 mg kg^{-1} body weight (McIlroy 1983). New Zealand's absence of native non-target terrestrial mammals (except for two species of bat) may explain the widespread use that 1080 has received in this country.

The sensitivity of birds to 1080 lies generally between that of mammals, and reptiles and amphibians (Rammell and Fleming 1978; McIlroy 1986), although within birds there is also wide variation. LD_{50}'s of 1080 lie in the range of <1 mg kg^{-1} to >10 mg kg^{-1}, but may be as high as 102-278 mg kg^{-1} for emu (McIlroy 1984; Twigg et al. 1988; McIlroy 1994).

Impacts of 1080-poison operations on non-target species

Individuals from a wide range of native species have been found dead after wild mammal control operations using 1080 (Spurr 1979; McIlroy 1982; Hegdal et al. 1986; Koenig and Reynolds 1987; McIlroy 1992; Spurr 1993; Spurr 1994a). However, despite the past extensive use of 1080 in New Zealand, U.S.A., Canada and Australia there are relatively few instances where the effects of 1080 on non-target populations have been monitored (Hegdal et al. 1986; Calver et al. 1989a). In California, 1080 control operations for ground squirrels were reported to have killed a number of non-target wildlife including rodents, rabbits, seed-eating and insectivorous birds, yellow-billed magpies, raptors, mammalian predators, and a domestic dog and cat (Hegdal et al. 1986; Koenig and Reynolds 1987). Most monitored operations in Australia however, found that populations of non-target birds and mammals were not detrimentally affected, despite a high number known to be susceptible to 1080 (McIlroy et al. 1986; McIlroy and Gifford 1991).

Background to New Zealand 1080 operations

In New Zealand the effects of early 1080 operations on non-target species received little attention and were poorly documented (Harrison 1978a). Few non-target species' deaths were reported and those were considered to be within acceptable limits and of little long-term consequence to populations of native species (Batcheler 1978; Harrison 1978a). Poisoning was avoided in areas known to contain rare bird species. However, the first 1080 control operations that were comprehensively monitored in the central North Island (1976-1977) found high mortality of native and introduced bird species (Harrison 1978a; Harrison 1978b), particularly after operations using un-dyed baits and/or baits lured with raspberry. The Wildlife Service promptly conducted trials to improve bait safety for non-target species. They found that bird mortality was highest in 1080 trials using unscreened carrot bait, or bait which still contained 'chaff' (particles <16 mm in diameter) (Forest Research Institute 1981). Removal of these small carrot fragments reduced mortality by 50% to one dead native bird per 12 ha, and when cereal pellets were used mortality was reduced further to one dead native bird per 35 ha (Harrison 1978a).

Subsequent bait modifications

Since these early trials, baits and sowing techniques have been modified to increase non-target species safety, and to comply with quality specifications (Haydock and Eason 1997). Since 1978 fragments of carrot 'chaff' containing lethal concentrations of 1080 for small passerines have been sieved out through a 16 mm grid (Harrison 1978a). Green dye within the colour range 221 (brilliant green) to 267 (deep chrome green) of the New Zealand Standards Specifications (Section 23, Standards Act, 1965) is added to baits after this colour was found to be least attractive to a variety of bird species (Kalmbach and Welch 1946; Caithness and Williams 1971; Pank 1976; Udy and Pracy 1981; Brunner and Coman 1983; Bryant et al. 1984). The green colour also enables users to identify toxic baits. Since 1983, cinnamon or other approved oils have been added to attract possums and mask the smell and taste of 1080, whilst repelling some bird species (Udy and Pracy 1981; Morgan et al. 1986; Morgan 1990; Spurr 1994a). Other lures which were found to be attractive to kiwi (e.g. raspberry, juniper, rose, banana and wintergreen) and which resulted in high mortality during early operations

have been banned (Udy and Pracy 1981). Baits are also aerially sown at reduced densities. Cereal-based baits are now distributed at around 5-10 kg/ha (Speed et al. 1988; Walker 1997) compared with 10-20 kg/ha, while carrot is distributed at 12 kg/ha compared with 30 kg/ha (Morgan 1994). Lowering sowing rates further to 1-2 kg/ha is being investigated (cited in Landcare Research 1996) with the aim of reducing bird-bait encounters, costs, and the amount of poison in the environment.

Monitoring of common and rare bird species

Despite bait improvements a number of native bird species are known or suspected to consume 1080 poisoned baits (Spurr 1979; Spurr 1991; Spurr 1994a). However, monitoring has found little evidence that 1080 operations since 1978 have been detrimental to populations of common native (e.g. bellbird, fantail, brown creeper), or introduced (e.g. blackbird, chaffinch) bird species (Warren 1984; Spurr 1991; Millar and Anderson 1992; Robertson et al. 1993; Spurr 1994a; R. Powlesland, pers. comm) in the long term. For example, a population of North Island robins which was reduced by 54% during an aerial 1080 operation to control possums had recovered within one year to higher numbers than previously recorded. This was largely a result of high productivity following a marked reduction in possum and rat numbers (R. Powlesland, pers. comm.). Recently though, it has been brought to attention that the standard techniques used to monitor most common birds (e.g. 5 minute counts) have not been validated (Spurr, E.B. and Powlesland, R. 1997) and therefore may not acurately detect significant changes in bird numbers. Also the haste at which some control operations have been scheduled has meant that little time was available to build up a sufficient base-line of monitoring data prior to the operations (Forest Research Institute 1981; Millar and Anderson 1992). It is essential that further monitoring of some common species such as tomtits and whiteheads (which have been found dead after exposure to aerial 1080 possum control) is conducted using methods that have been validated for monitoring bird population numbers.

In contrast to common birds, up until 1993 most rarer bird species (e.g. kiwi, fernbird, kokako and kaka) had received only limited monitoring throughout poisoning operations (Spurr and Powlesland 1997). This was partly a consequence of these species being

undetectable using standard bird monitoring techniques (Warren 1984; Lloyd and Hackwell 1993). In the last three years however, the use of radio-telemetry equipment has aided the monitoring of species such as kiwi (Pierce and Montgomery 1992; H. Robertson, pers. comm.), kokako (Innes and Williams 1990), kaka and blue duck (Greene 1995), weka and morepork (Walker 1997). Consequently, there is now a clearer understanding of the risk that rarer birds face from 1080 operations. Some species however, have still been inadequately monitored throughout all types of operations (e.g. weka, kaka, kereru) and others for which further monitoring throughout operations using particular bait types (e.g. kiwi and carrot bait) would be beneficial (Spurr and Powlesland 1997).

Types of 1080 baits used in New Zealand

In New Zealand there are three main bait types used as carriers of the poison 1080. These are carrot, cereal-based pellets, and apple paste.

Carrot Bait

Carrot bait is prepared in the field using Reliance cutting machines (those which produce less chaff) which chop fresh carrot into chunks between 4 and 6 g mean weight. The weight stipulation ensures that baits are large enough to contain sufficient poison to kill a possum. This reduces sub-lethal feeding and the potential for subsequent bait shyness (Harrison 1978a). Baits are surface coated with 1080 (0.08 - 0.15% wt:wt), dyed green and lured (0.1% vol:wt) with an approved essential oil (Haydock and Eason 1997) before loading into a fixed wing aircraft or helicopter for distribution.

Pellet Baits

Two main types of cereal-based baits are produced in New Zealand: No.7 and RS5. Type No.7 pellets are a wheat-based bait used primarily in the North Island, while in the South Island an RS5 pellet consisting of barley and maize is produced for use in aerial pest control and in bait stations. Baits are produced in small and large sizes. Large baits are required to have a mean weight of 5 g and are impregnated with 1080 within the range of 0.08-0.2 % wt:wt. Small baits weigh approximately 1 g and are also impregnated with 1080 at 0.08 % wt:wt. Green dye is incorporated into the bait and

food grade cinnamon essence added at 0.1% v/wt (Haydock and Eason 1997). Pellets are then distributed aerially or hand-laid in bait stations.

Paste Baits

When greater bait laying precision is required, and where stock and humans can be excluded, 1080 apple based pastes may be used (Rammell and Fleming 1978). Traditional 1080 pastes were similar to domestic jams with a fruit base and added sugar. This was later replaced in the 1970s with an apple base, after the jam seeds were found to be attractive to some birds (Livingstone 1994) and the high sugar content of the bait attractive to bees (McIntosh et al. 1964). Pastes are manufactured by Animal Control Products Ltd. and supplied in 25 kg pails or 500 g tubes. Baits are dyed green and lured with cinnamon oil at 0.1% v/wt. 1080 is incorporated throughout the bait at 0.08% wt:wt. Operations generally involve pre-feeding with a non-toxic, un-dyed paste for three days which is then replaced with toxic paste. The bait is laid as walnut-sized portions (approximately 5 g) on turned earth or 'spits' dug every 3-5 m on lines 5-10 m apart, or around forest edges. 'Spits' are then turned over at the end of the operation to cover any remaining bait (Morgan et al. 1997).

PART TWO

Study animal - Kiwi

Kiwi are members of the ratites, a small group of flightless birds which include ostriches, rhea, emu, cassowaries and extinct forms such as moa. Current taxonomy recognises three species of kiwi within the genus *Apteryx:* brown kiwi (*Apteryx australis*); great spotted kiwi (*Apteryx haastii*); and little spotted kiwi (*Apteryx owenii*) (Mathews 1931; Heather and Robertson 1996). Recent work, however, suggests that there are four species of kiwi (Baker et al. 1995), with brown kiwi comprising two genetically distinct species: Northern brown kiwi (*Apteryx mantelli*) now including kiwi in the North Island and at Okarito in the South Island, and Southern brown kiwi (*Apteryx australis*) including Stewart Island kiwi and those from the southern most South Island. This study deals primarily with North Island brown kiwi (*Apteryx australis mantelli*) (Figure 1.1).

Figure 1.1 A North Island brown kiwi (photo by Christine Zeiler).

Kiwi are endemic to New Zealand. Main populations of brown kiwi are now found in the upper two thirds of the North Island, in Northland, Coromandel Peninsula, Taranaki, Tongariro, Wanganui, and in parts of Te Urewera National Park, while in the South Island brown kiwi are found on Stewart Island, Fiordland, Okarito, and Haast. Little spotted kiwi are now probably restricted to the off-shore islands: Kapiti, Red Mercury and Hen Island, while great spotted kiwi are found only in the South Island, mainly from Northwest Nelson to the Southern tip of the Paparoa Ranges (Butler and McLennan 1991)

Kiwi are generally nocturnal, secretive birds and consequently have been heard by few, and seen by even fewer New Zealanders. Despite this, kiwi play an important role in New Zealand culture and their obscure and highly distinctive characteristics have gained them significance on a national level. Among birds kiwi are unusual. Their breastbone lacks a keel and they possess only tiny vestiges of wings. They have a long bill with nostrils near the tip, paired functional ovaries, and lower blood temperatures thought to be more typical of mammals than birds (Farner et al. 1956; Kinsky 1971; Calder and Dawson 1978). Female kiwi hold the record for laying the largest egg proportionate to

body size of any bird of similar weight, and which contains more energy than eggs from other species of similar size (Reid 1971a; Reid 1971b; Calder 1978; Calder 1979). Incubation may take between 77-92 days (Potter 1990a) and in some taxa is performed solely by the male (McLennan 1988), with females assisting in other taxa (McLennan and McCann 1989). Kiwi are omnivorous and feed on a range of invertebrates, vegetable matter, seeds, fruits and possibly small vertebrates (Gurr 1952; Bull 1959; Reid et al. 1982; Colbourne and Powlesland 1988; Colbourne et al. 1990; Miles 1995).

In recent years knowledge of kiwi ecology has increased through research which has investigated kiwi habitat requirements, pair bonding, spacing behaviour, breeding and reproductive biology (McLennan 1988; Jolly 1989; Potter 1989; McLennan and McCann 1991; McLennan 1996). These studies have helped guide management decisions and above all, have highlighted the plight of kiwi. It is now well recognised that kiwi populations have declined markedly in range and abundance throughout mainland New Zealand (McLennan and Potter 1992; McLennan et al. 1996). Habitat loss and fragmentation largely through burning and roller-crushing of scrub habitat (Potter 1990b; Millar and Pierce 1995), predation by dogs (Taborsky 1988), cats and mustelids (McLennan and Potter 1992; McLennan and Potter 1993; McLennan et al. 1996), and the accidental killing of birds with poisons and traps intended for predators (Reid 1986; McLennan 1987), have all been identified as contributing factors. In particular, a recent collaborative study has shown that extremely low recruitment rates due to high juvenile predation is paramount in this decline (McLennan et al. 1996), and largely responsible for the adult-biased population structure of kiwi on mainland New Zealand (McLennan and Potter 1993).

The Kiwi Recovery Plan

In 1991 a Kiwi Recovery Plan (Butler and McLennan 1991) was written following growing concern over the fate of kiwi. The plan provided a framework for the following five years of kiwi research and management, and had the long term goal of:

"maintaining and, where possible, enhancing the current abundance, distribution and genetic diversity of kiwi".

The first aim of the plan was to identify threats to kiwi populations and current population trends. This included investigating the effects of 1080 operations on kiwi. Previous surveys and anecdotal reports showed that high numbers of kiwi were being affected by control operations using cyanide poisoning and trapping (Reid 1986; Spurr 1991). Although no kiwi had been found dead following 1080 poisoning operations, aerial applications of toxic baits and other ground based 1080 operations presented a potential risk to populations. Objectives 4 and 7 of the Kiwi Recovery Plan outlined specifically the need for research into the effects of such possum control operations on kiwi, and the need to develop 1080 and cyanide baits that are unattractive to kiwi (Butler and McLennan 1991). Since the start of this thesis the Kiwi Recovery Group has amended the original objective (which related only to possum control operations) to cover all 'pest' control operations, and this includes the effects of rat eradication programmes on island populations of kiwi. Although pest control operations other than those for possums will be mentioned below, the focus of this thesis is primarily on the effects on kiwi of possum operations using baits containing 1080.

Risk of poisoning to kiwi

Being ground foraging and omnivorous (Gurr 1952; Bull 1959; Reid et al. 1982; Colbourne and Powlesland 1988; Colbourne et al. 1990; Kleinpaste 1990), kiwi are at risk from poisoning through the ingestion of toxic baits (primary poisoning) and contaminated invertebrates (secondary poisoning) (Spurr 1979).

While the potential for kiwi to feed directly on toxic baits is recognised, less is known about the risks of secondary poisoning. A wide range of invertebrates feed on 1080 baits (Notman 1989; Goodwin and Ten Houten 1991; Eason et al. 1993; Spurr 1994b) but little is known about the consequences for insectivorous species feeding on invertebrates containing 1080 residues. In the United States it was suggested that 1080 poisoned ants were responsible for the secondary poisoning of insectivorous birds such as acorn woodpeckers, white-breasted nuthatches, and ash-throated flycatchers (Hegdal et al. 1986), while in New Zealand insectivorous birds found dead after 1080 operations may have fed either on toxic baits or insects containing poison (Spurr 1979). The potential for secondary poisoning of kiwi is a valid concern. However, there are no

LD_{50}'s for 1080 for any species of kiwi, and so determining the quantity of poisoned invertebrates or bait required for a lethal dose is impossible.

Kiwi have been classified in a high risk category of non-recovery if reduced in numbers as a result of 1080 poisoning, based upon their low densities, restricted distribution, low reproductive rates, and poor ability to disperse (Spurr 1979). This suggests that in addition to being at risk of poisoning during control operations for wild mammals, kiwi may also have a low chance of recovery if significantly reduced in numbers by such operations.

Difficulties with monitoring kiwi during poisoning operations

Rarer and nocturnal species such as kiwi require species-specific monitoring and the additional effort required has often meant that they have inadvertently been excluded from standard monitoring operations that focused primarily on conspicuous diurnally active species (Harrison 1978a).

Deaths of common non-target bird species by 1080 poisoning have been measured by five minute call counts, territory mapping and roll calling of birds, banding birds, searching for dead birds, and radio-tagging (Atkinson et al. 1995). These techniques have limitations and have not been adequately validated even for monitoring common bird species (Spurr and Powlesland 1997). With the exception of radio-tagging none of the methods is appropriate for monitoring the survival of individual kiwi.

For example, five minute call counts are one of the standard techniques used to count bird populations (Dawson and Bull 1975) and have been used extensively to identify changes in bird population numbers following poisoning operations (Spurr 1981; Warren 1984; Millar and Anderson 1992). However, they provide only a relative index of bird conspicuousness (Dawson and Bull 1975) and are really only appropriate for detecting substantial changes in numbers of common species, not individuals of rare and/or nocturnal species (Warren 1984).

Despite this, call counts (calls hour $^{-1}$) have been used to index populations of nocturnal species (Keyes and Rasch 1985; McLennan 1992) and in some cases, to detect changes in kiwi population numbers following 1080 operations (Pierce and Montgomery 1992). One drawback is that a measurement using call rates is only sensitive to those kiwi which call and may not detect individuals which call infrequently, or have yet to reach calling maturity (Colbourne and Kleinpaste 1984). Furthermore, studies have also found that kiwi call rates show seasonal and nightly variation (Colbourne and Kleinpaste 1984; McLennan and McCann 1991), and may also be affected by other environmental factors (Miles 1995). Therefore, while providing a relative index of numbers, call rates are inappropriate for tracking the survival of individuals (particularly juveniles) within populations, unless the population is monitored regularly and individuals can be identified. Territory mapping and roll calling techniques have similar disadvantages for kiwi since they also rely on identifying individuals.

Unlike common bird species, kiwi are also likely to go undetected during searches for dead birds (Atkinson et al. 1995). Kiwi exist at low densities (ranging from 1 bird per 2.5 hectares (Potter 1990b) to 1 bird per 55 hectares (McLennan et al. 1987)) in comparison to some other forest birds. They are therefore unlikely to be found dead, particularly since searches generally cover only a small part of the treated area (Warren 1984), which may be restricted to accessible areas such as tracks (Millar and Anderson 1992). Previous reports which noted high numbers of kiwi deaths following cyanide or trapping control operations (Reid 1986) may have been biased towards locating dead animals close to regularly serviced lines.

Outputs from the Kiwi Recovery Plan

Not surprisingly therefore, it is only as a result of the recovery plan and relatively recent advances in techniques such as radio-tagging that studies have been able to monitor the survival of kiwi throughout a variety of poisoning operations using different bait types.

Brown kiwi

The first study to follow the survival of kiwi throughout a 1080 poison operation was in 1990, in Waipoua Forest. Radio transmitters were fitted to seven North Island brown kiwi prior to an operation which used Wanganui No.7 cereal baits (5 kg/ha, 0.08%

1080). All radio-tagged birds survived the operation (Pierce and Montgomery 1992). However, in a non-toxic bait experiment prior to the poison drop there was evidence indicating that some kiwi had fed on un-dyed, cinnamon flavoured cereal pellets. Two of 17 kiwi scats collected from the area contained rhodamine dye which had been impregnated into the baits (Pierce and Montgomery 1992). A large study in Northland (1995) also tracked the survival of kiwi through operations using Wanganui No.7 cereal-based baits (3 kg/ha, 0.15% 1080) and apple paste (0.15% 1080). Radio transmitters were fitted to 35 adult and 1 juvenile kiwi. Twenty-two of those birds (14 males and 8 females) were exposed to cereal-based baits and 12 (7 males, 4 females and one juvenile) were exposed to 1080 apple paste. Two males were exposed to both the pollard and 1080 paste treatments. With the exception of one juvenile lost to predation, all kiwi survived for at least 3 months (when monitoring ceased) following exposure to the 1080 poisoned baits (H. Robertson, pers. comm.). Two North Island brown kiwi were also exposed to an aerial application of screened 1080 carrot bait (10 kg/ha, 0.08%) in Tongariro Forest (June 1995). In August of the same year both radio-tagged birds were on nests confirming their survival and that of their mates (R. Martin, pers. comm.). No individuals of this species have been reported dead after any 1080-poisoning operation.

Great spotted kiwi

Great spotted kiwi have been monitored through two operations using 1080 poison. In North and South Karamea seven radio-tagged kiwi (3 males and 4 females) were exposed to RS5 cereal-based baits (5 kg/ha, 0.15% 1080) in the winter of 1994. All birds were found alive when monitoring ceased 80-159 days following the drop (Lyall 1995). In the same year radio transmitters were also fitted to five male and four female great spotted kiwi in the Saxon area, North-west Nelson, prior to a 1080 cereal drop. All of the monitored kiwi survived at least 15 days following the drop. However, transmitters fell off four birds so only five kiwi could be confirmed alive five months later (Walker 1997).

Little spotted kiwi

Since little spotted kiwi are restricted to off-shore islands they have been exposed only to toxic operations using cereal baits and brodifacoum poison. One death has been

confirmed from brodifacoum poisoning following two aerial applications of cereal-based talon 7-20 (20 ppm brodifacoum) for rodent control on Kapiti Island in 1996 (11 kg/ha and 6 kg/ha respectively) (R. Empson, pers. comm., in Spurr and Powlesland 1997). The baits were similar to those used in 1080-poisoning operations. Little spotted kiwi may therefore also be susceptible to similar operations using 1080. However, during an earlier poison drop using Talon 20P to control rats on the Mercury Islands off the north-east coast of the Coromandel, nine radio-tagged little spotted kiwi survived the operation (Robertson et al. 1993). Little spotted kiwi on Kapiti Island have also been exposed to an experimental drop of non-toxic carrot baits. None of the scats examined fluoresced with the dye pyranine which had been impregnated into the baits (Lloyd and Hackwell 1993).

In summary, a total of 82 kiwi from three species have been radio-tagged during exposure to aerial application of 1080 cereal bait, 1080 carrot and cereal talon (brodifacoum), and ground laid 1080 paste. North Island brown kiwi have been exposed to 1080 cereal bait, carrot, and paste; great spotted kiwi to 1080 cereal bait; and little spotted kiwi to talon (brodifacoum). Studies so far indicate that kiwi have not been affected detrimentally by these poison operations. Further monitoring of kiwi during operations using 1080-cereal bait operations are now classed as low priority. However, only two kiwi have been monitored, and are known to have survived operations using carrot bait. Tracking kiwi survival throughout operations using carrot therefore remains high priority (Spurr and Powlesland 1997).

To date, research on the effects of pest control operations on kiwi has focused largely on monitoring the survival of individuals throughout operations. No studies have directly observed the response of wild kiwi to any bait types, to determine whether kiwi are (1) feeding on baits and surviving, or (2) encountering baits and rejecting them. It is possible that kiwi which have survived monitored operations so far have not encountered baits. Particular bait types may also carry greater risk than others to kiwi, yet with the current monitoring techniques it has not been possible to determine this. Only one study has monitored the survival of a juvenile kiwi throughout a poisoning operation (H. Robertson, pers. comm.) and this is another area where greater research is

required. Poisoning operations may have greater effect on kiwi populations if juveniles, which are already the targets of intense predation, are attracted to novel items such as baits. Also, little emphasis has been placed on investigating whether the lures used to attract pest species to baits have a similar effect on kiwi.

Thesis aims and layout

This primary aims of this thesis are to (1) assess the palatability of a range of baits to captive kiwi in order to determine which bait types are of potentially greatest risk, (2) obtain direct bait encounters with wild kiwi, and (3) determine the response of captive and wild kiwi to a range of flavours added to pest control baits. Additionally a new paste bait used to kill possums is tested on a range of non-target bird species, with the aim of determining their response to this bait preparation prior to its widespread use in the field. The chapters are intended to be read as separate units and make recommendations where appropriate.

Chapter 2 investigates the response of captive and wild kiwi to a range of non-toxic unflavoured baits used commonly in New Zealand for pest control, particularly those used as carriers of 1080 poison. Bait types are placed in decreasing order of acceptance to captive kiwi to provide an indication of which types are most likely to be eaten. Bait encounters with wild kiwi and chicks are also obtained by placing baits outside the nesting burrow. These wild kiwi bait encounters are the first to be recorded, and enable comparison of the responses of wild and captive kiwi, and an assessment of how reliable captive birds are at predicting bait take by kiwi in the wild.

Chapter 3 investigates the response of captive kiwi to four flavours that are commonly added to baits to mask the smell and taste of the poison, and to lure the pest species. This is tested by examining the response of kiwi to flavours placed directly into their usual artificial diet and on No.7 cereal based baits. The response of wild kiwi to cinnamon and orange flavoured No.7 cereal baits is also investigated by recording kiwi encounters with baits placed outside nest entrances.

The response of wild kiwi to baits in Chapter one and Chapter two was determined by filming at nests using an infra-red video camera. This also enabled data to be collected on the behaviour of incubating male kiwi, chicks, and predators at nesting burrows. These data are presented in **Chapter 4**.

Chapter 5 investigates the response of a range of non-target bird species to a new formulation of 1080 apple paste used for possum control. The study appears in the thesis in the style of the report written for Landcare Research. This was later combined with work by Shirley McQueen and edited by Dave Morgan, (Landcare Research) into a report prepared for the Animal Health Board, the full reference of which is:

Morgan, D.; Ward-Smith, T. and McQueen, S. 1997. *Responses of Native Birds and Bats to "Bee-safe" Possum Paste*. Landcare Research Contract Report: LC9697/126. Prepared for Animal Health Board, Wellington. 20 pp.

REFERENCES

Atkinson, I.A.E.; Campbell, D.J.; Fitzgerald, B.M.; Flux, J.E.C. and Meads, M.J. 1995. *Possums and possum control; effects on lowland forest ecosystems. A literature review with specific reference to the use of 1080.* Department of Conservation. Science for Conservation No.1. Wellington. 32 pp.

Atzert, S.P. 1971. *A review of sodium monofluoroacetate (compound 1080) its properties, toxicology, and use in predator and rodent control.* United States Department of the Interior Fish and Wildlife Services, Bureau of Sport Fisheries and Wildlife Special Scientific Report 146. Washington, D.C.

Baker, A.J.; Daugherty, C.H.; Colbourne, R. and McLennan, J.L. 1995. Flightless brown kiwi of New Zealand possess extremely sub-divided population structure and cryptic species like small mammals. *Proceedings of the National Academy of Science* 92: 8254-8258.

Batcheler, C.L. 1978. *Compound 1080, its properties, effectiveness, dangers and use.* New Zealand Forest Service, Wellington, New Zealand.

Batcheler, C.L. 1983. The possum and rata-kamahi dieback in New Zealand: A review. *Pacific Science* 37: 415-426.

Brown, K.; Innes, J. and Shorten, R. 1993. Evidence that possums prey on and scavenge birds' eggs, birds and mammals. *Notornis* 40: 169-177.

Brunner, H. and Coman, B.J. 1983. The ingestion of artificially coloured grain by birds, and its relevance to vertebrate pest control. *Australian Wildlife Research* 10: 303-10.

Bryant, H.; Hone, J. and Nicholls, P. 1984. The acceptance of dyed grain by feral pigs and birds. *Australian Wildlife Research* 11: 509-16.

Bull, P.C. 1959. Stomach contents of a North Island kiwi (*Apteryx australis mantelli*) from the Raetahi district. *Notornis* 8: 143-145.

Butler, D. and McLennan, J. 1991. *Kiwi Recovery Plan.* Department of Conservation. Threatened Species Recovery Plan Series No. 2. Wellington.

Caithness, T.A. and Williams, G.R. 1971. Protecting birds from poisoned baits. *New Zealand Journal of Agriculture* 122: 38-43.

Calder, B. and Deuss, F. 1985. *The effect of 1080 poisoning on bird populations in Motere, Pureora State Forest, Winter 1984.* New Zealand Forest Service (unpublished) Internal Report ODC 148.2:414.11. Auckland. 34 pp.

Calder, W.A.I. 1978. The kiwi. *Scientific American* 239: 102-110.

Calder, W.A.I. 1979. The kiwi and egg design: Evolution as a package deal. *BioScience* 29: 461-467.

Calder, W.A.I. and Dawson, T.J. 1978. Resting metabolic rates of ratite birds: The kiwi and the emu. *Comparative Biochemistry and Physiology* 60A: 479-481.

Calver, M.C.; King, D.R.; Bradley, J.S.; Gardner, J.L. and Martin, G. 1989a. An assessment of the potential target specificity of 1080 predator baiting in Western Australia. *Australian Wildlife Research* 16: 625-38.

Calver, M.C.; King, D.R.; Bradley, J.S.; Gardner, J.L. and Martin, G. 1989b. Assessment of an approximate lethal dose technique for determining the relative susceptibility of non-target species to 1080 toxin. *Australian Wildlife Research* 16: 33-40.

Colbourne, R.; Baird, K. and Jolly, J. 1990. Relationship between invertebrates eaten by little spotted kiwi, *Apteryx owenii*, and their availability on Kapiti Island, New Zealand. *New Zealand Journal of Zoology* 17: 533-542.

Colbourne, R. and Kleinpaste, R. 1984. North Island brown kiwi vocalisations and their use in censuring populations. *Notornis* 31: 191-201.

Colbourne, R. and Powlesland, R.G. 1988. Diet of the Stewart Island brown kiwi (*Apteryx australis lawryi*) at Scolay's flat, southern Stewart Island. *New Zealand Journal of Ecology* 11: 99-104.

Cowan, P.E. 1990. Brushtail possum. *In:* King, C.M. (Ed), *The Handbook of New Zealand Mammals*, pp 68-98. Oxford University Press, Auckland.

Dawson, D.G. and Bull, P.C. 1975. Counting birds in New Zealand forests. *Notornis* 22: 101-109.

Eason, C.T.; Gooneratne, R.; Wright, G.R.; Pierce, R. and Frampton, C.M. 1993. The fate of sodium monofluoroacetate (1080) in water, mammals, and invertebrates. *Proceedings 46th New Zealand Plant Protection Conference 1993.* pp 297-301.

Eason, C.T.; Frampton, C.M.; Henderson, R.; Thomas, M.D. and Morgan, D.R. 1993. Sodium monofluoroacetate and alternative toxins for possum control. *New Zealand Journal of Zoology* 20: 329-334.

Eason, C.T.; Wright, G.R. and Batchelor, D. 1996. Anticoagulant effects and the persistence of brodifacoum in possums (*Trichosurus vulpecula). New Zealand Journal of Agricultural Research* 39: 397-400.

Eason, C.T.; Wright, G.R. and Fitzgerald, H. 1992. Sodium monofluoroacetate (1080) water-residue analysis after large-scale possum control. *New Zealand Journal of Ecology* 16: 47-49.

Eisler, R. 1995. *Sodium monofluoroacetate (1080) hazards to fish, wildlife and invertebrates: A synoptic review*. Contaminant Hazard Reviews No.30.

Farner, D.S.; Chivers, N. and Rinez, T. 1956. The body temperature of the North Island kiwis. *Emu* 56: 199 - 206.

Fitzgerald, A.E. and Wardle, P. 1979. Diet of the Australian possum *Trichosurus vulpecula* (Kerr) in the Waiho Valley, South Westland. *New Zealand Journal of Zoology* 6: 339-345.

Fitzgerald, B.M. 1990. House cats. *In:* King, C.M. (Ed), *The Handbook of New Zealand Mammals*, pp 330-348. Oxford University Press, Auckland.

Forest Research Institute. 1981. The effects of 1080-poisoning operations on non-target bird populations. *What's New in Forest Research?* 94: 4 pp.

Fraser, K.W.; Spurr, E.B. and Eason, C.T. 1995. Non-target kills of deer and other animals from aerial 1080 operations. *Rod and Rifle* 16: 20-22.

Gibb, J.A. and Williams, J.M. 1990. European rabbit. *In:* King, C.M. (Ed), *The Handbook of New Zealand Mammals*, pp 138-160. Oxford University Press, Auckland.

Goodwin, R.M. and Ten Houten, A. 1991. Poisoning of honey bees (*Apis mellifera*) by sodium monofluoroacetate (1080) in baits. *New Zealand Journal of Zoology* 18: 45-51.

Greene, T. 1995. The effect of 1080 poison on kaka and blue duck populations - Pureora 1994. *Maniopoto Hunter's Newsletter* 5: 3-4.

Gurr, L. 1952. Some foods of the North Island kiwi (*Apteryx australis*). *Notornis* 4: 209-210.

Harrison, M. 1978a. The use of poisons and their effect on birdlife. *Seminar on the takahe and its habitat, 1978.* Te Anau. Prepared and Published by the Fiordland National Park Board, Invercargill, New Zealand. pp 203-221.

Harrison, M. 1978b. 1080. *Wildlife - a review* 9: 48-53.

Haydock, N. and Eason, C. 1997. *Vertebrate Pest Control Manual: Toxins and Poisons.* Department of Conservation, Wellington, 1997. 88 pp.

Heather, B. and Robertson, H. 1996. *The field guide to the birds of New Zealand*, Penguin Books (New Zealand) Ltd, cnr Rosedale and Airborne Roads, Albany, Auckland 1310, New Zealand.

Hegdal, P.L.; Fagerstone, K.A.; Gatz, T.A.; Glahn, J.F. and Matschke, G.H. 1986. Hazards to wildlife associated with 1080 baiting for California ground squirrels. *Wildlife Society Bulletin* 14: 11-21.

Holdaway, R.N. 1996. Arrival of rats in New Zealand. *Nature* 384: 225-226.

Innes, J. 1994. The impacts of possums on native fauna. *Proceedings of a workshop on possums as conservation pests, possum and bovine Tb control NSS committee.* Christchurch. pp 11-15.

Innes, J. and Williams, D. 1990. *Do large-scale possum control operations using 1080, gin traps, or cyanide kill North Island kokako?* Northern Wildlands, Forest and Wildlands Ecosystem Division, Forest Research Institute. Contract report FWE 90/26. Rotorua.

Jolly, J.N. 1989. A field study of the breeding biology of the little spotted kiwi (*Apteryx owenii*) with emphasis on the causes of nest failure. *Journal of the Royal Society of New Zealand* 19(4): 433-448.

Jolly, S.E.; Henderson, R.J.; Frampton, C. and Eason, C.T. 1995. Cholecalciferol Toxicity and its Enhancement by Calcium Carbonate in the Common Brushtail Possum. *Wildlife Research* 22: 579-583.

Kalmbach, E.R. and Welch, J.H. 1946. Coloured rodent baits and their value in safe guarding birds. *Journal of Wildlife Management* 10: 353-360.

Kean, R.I. and Pracy, L.T. 1949. Effects of the Australian opossum (*Trichosurus vulpecula* Kerr) on indigenous vegetation in New Zealand. *Proceedings of the 7th Pacific Science Congress. IV Zoology.* pp 696-705.

Keyes, P. and Rasch, G. 1985. *The second survey of the brown kiwi in Waitangi State Forest.* New Zealand Forest Service (Unpublished).

King, C.M. 1990. *The Handbook of New Zealand Mammals*. 1995. King, C.M. Oxford University Press, Auckland. 600 pp.

King, C.M. 1990. The stoat. *In:* King, C.M. (Ed), *The Handbook of New Zealand Mammals*, pp 288-312. Oxford University Press, Auckland.

Kinsky, F.C. 1971. The consistent presence of paired ovaries in the kiwi *Apteryx* with some discussion of this condition in other birds. *Journal für Ornithologie* 112:334-357.

Kleinpaste, R. 1990. Kiwis in a pine forest habitat. *In:* Fuller, E. (Ed), *Kiwis*, pp 97-138. Swanhill Press, Shewsbury, England.

Koenig, W.D. and Reynolds, M.D. 1987. Potential poisoning of yellow billed magpies by compound 1080. *Wildlife Society Bulletin* 15: 274-276.

Leathwick, J.R.; Hay, J.R. and Fitzgerald, A.E. 1983. The influence of browsing by introduced mammals on the decline of the North Island kokako. *New Zealand Journal of Ecology* 6: 55-70.

Livingstone, P. and Nelson, P. 1993. *Controlling possums in New Zealand: the 1080 issue*. Animal Heath Board Report.

Livingstone, P.G. 1994. The use of 1080 in New Zealand. *In:* Seawright, A.A. & Eason, C.T. (Eds), *Proceedings of the Science Workshop on 1080*. The Royal Society of New Zealand. pp 1-9. Miscellaneous Series No. 28, Christchurch, New Zealand.

Livingstone, P.G. and Nelson, P.C. 1994. *Possum control and the use of 1080 in New Zealand*. Department of Conservation, Wellington, New Zealand.

Lloyd, B. and Hackwell, K. 1993. *A trial to determine whether kaka consume carrot baits, Kapiti Island, May 1993.* Department of Conservation Science and Research Internal Report No.62. 14 pp.

Lyall, J. 1995. *Great spotted kiwi monitoring in Karamea following a 1080 possum control programme.* Department of Conservation, Report to the Animal Health Board. 12 pp.

Landcare Research - *Manaaki Whenua.* 1996. *Aerial sowing and buckets- a new tool for the job.* Possum Research News - *He Korero Paihama* 5: 1-2

Mathews, G.M. 1931. *A list of the birds of the Australasia (including New Zealand, Lord Howe and Norfolk Island and the Australasian Antarctic Quadrant).* Taylor and Francis. London.

McBreen, K. 1997. *(Unpublished). "Kamahi decline in Tongariro National Park".* MSc. Thesis, Massey University, Palmerston North. 140 pp.

McIlroy, J.C. 1981a. The sensitivity of Australian mammals to 1080 poison. I. Intraspecific variation and factors affecting acute toxicity. *Australian Wildlife Research* 8: 369-383.

McIlroy, J.C. 1981b. The sensitivity of Australian animals to 1080 poison. II. Marsupial and eutherian carnivores. *Australian Wildlife Research* 8: 385-399.

McIlroy, J.C. 1982. The sensitivity of Australian animals to 1080 poison. III. Marsupial and eutherian herbivores. *Australian Wildlife Research* 9: 487-503.

McIlroy, J.C. 1983. The sensitivity of the brushtail possum (*Trichosurus vulpecula*) to 1080 poison. *New Zealand Journal of Ecology* 6: 125-131.

McIlroy, J.C. 1984. The sensitivity of Australian animals to 1080 poison. VII. Native and introduced birds. *Australian Wildlife Research* 10: 507-12.

McIlroy, J.C. 1986. The sensitivity of Australian animals to 1080 poison IX. Comparisons between the major groups of animals, and the potential danger non-target species face from 1080-poisoning campaigns. *Australian Wildlife Research* 12: 113-18.

McIlroy, J.C. 1994. Susceptibility of target and non-target animals to 1080. *In:* Seawright, A.A. & Eason, C.T. (Eds), *Proceedings of the Science Workshop on 1080*, pp 90-96. The Royal Society of New Zealand, Miscellaneous Series No.28, Christchurch, New Zealand.

McIlroy, J.C. and Gifford, E.J. 1991. Effects on non-target animal populations of a rabbit trail-baiting campaign with 1080 poison. *Australian Wildlife Research* 18: 315-325.

McIlroy, J.C.; Gifford, E.J. and Cooper, R.J. 1986. Effects on non-target animal populations of wild dog trail-baiting campaigns with 1080 poison. *Australian Wildlife Research* 13: 447-453.

McIlroy, M.C. 1992. The effects on Australian animals of 1080 poisoning campaigns. *Proceedings of the fifteenth vertebrate pest conference.* California, University of California, Davis.

McIntosh, I.G.; Palmer-Jones, T. and Staples, E.L.J. 1964. 1080 poison baits for animal pests: Wallaceville shows that proper use will not endanger bees or affect honey. *New Zealand Journal of Agriculture* 108: 141-143.

McLennan, J. 1987. Opossum hunting and kiwi - a reply to Brian Reid's article. *Fur Facts* 8 (29): 22-23.

McLennan, J. and McCann, T. 1989. Incubation by female great spotted kiwis. *Notornis* 36: 325-326.

McLennan, J.A. 1988. Breeding of North Island brown kiwi, *Apteryx australis mantelli*, in Hawke's Bay, New Zealand. *New Zealand Journal of Ecology* 11: 89-97.

McLennan, J.A. 1992. *Nationwide monitoring of kiwi populations.* DSIR Land Resources Contract Report No.92/21 for Department of Conservation, Wellington.

McLennan, J.A. 1996. *Ecology of brown kiwi and causes of population decline in the catchment of Lake Waikaremoana, Te Urewera National Park.* Department of Conservation. Conservation Advisory Science Notes No.96. Gisbourne, New Zealand.

McLennan, J.A. and McCann, A.J. 1991. *Ecology of great spotted kiwi, Apteryx haastii.* DSIR Land Resources Contract Report No.91/48 for Department of Conservation, Wellington. 36 pp.

McLennan, J.A. and Potter, M.A. 1992. Distribution, population changes and management of brown kiwi in Hawke's Bay. *New Zealand Journal of Ecology* 16: 91-102.

McLennan, J.A. and Potter, M.A. 1993. Juveniles in mainland populations of kiwi. *Notornis* 40: 294-297.

McLennan, J.A.; Potter, M.A.; Robertson, H.A.; Wake, G.C.; Colbourne, R.; Dew, L.; Joyce, L.; McCann, J.A.; Miles, J.; Miller, P. and Reid, J. 1996. Role of predation in the decline of kiwi *Apteryx* spp. in New Zealand. *New Zealand Journal of Ecology* 20: 27-35.

McLennan, J.A.; Rudge, M.R. and Potter, M.A. 1987. Range size and denning behaviour of brown kiwi, *Apteryx australis mantelli*, in Hawke's Bay, New Zealand. *New Zealand Journal of Ecology* 10: 97-107.

Miles, J. 1995. *(Unpublished). "Comparative ecology of northern brown kiwi (Apteryx australis mantelli) in Tongariro National Park and Tongariro Forest Park, central North Island"*. MSc. Thesis, Massey University, Palmerston North. 131 pp.

Millar, C.J. and Anderson, S. 1992. Impacts of aerial 1080 poisoning on the birds of Rangitoto Island, Hauraki Gulf, New Zealand. *New Zealand Journal of Ecology* 16: 103-107.

Millar, P.J. and Pierce, R.J. 1995. Distribution and decline of the North Island brown kiwi *(Apteryx australis mantelli)* in Northland. *Notornis* 42: 203-211.

Morgan, D.R. 1990. Behavioural response of brushtail possums, *Trichosurus vulpecula*, to baits used in pest control. *Australian Wildlife Research* 17: 601-613.

Morgan, D.R. 1994. Improved cost-effectiveness and safety of sodium monofluoroacetate (1080) possum control operations. *In:* Seawright, A.A. & Eason, C.T. (Eds), *Proceedings of the Science Workshop on 1080*, pp 144-150. Royal Society of New Zealand, Miscellaneous Series No.28, Christchurch, New Zealand.

Morgan, D.R.; Batchelor, C.L. and Peters, J.A. 1986. Why do possums survive aerial poisoning operations? *Proceedings Vertebrate Pest Conference.* pp 210-214.

Morgan, D.R. and Goodwin, M. 1995. *Identification of 1080 paste suitable for use in the presence of bees (314/92).* Landcare Research Contract Report No.LC9596/03. Prepared for the Animal Health Board, P.O. Box 3412, Wellington. 19 pp.

Morgan, D.R.; Ward-Smith, T. and McQueen, S. 1997. *Responses of native birds and bats to 'bee-safe' possum paste.* Landcare Research Contract Report No. LC9697/126. 20 pp.

Notman, P. 1989. A review of invertebrate poisoning by compound 1080. *New Zealand Entomologist* 12: 67-71.

Palmateer, S.D. 1990. Registration status of vertebrate pesticides. *Proceedings of the 14th vertebrate pest conference.* Sacremento. pp 113-115.

Pank, L. 1976. Effects of seed and background colours on seed acceptance by birds. *Journal of Wildlife Management* 40: 769-774.

Peterson, D.R.; Blaschke, P.; Gibbs, D.; Gordon, B. and Hughes, P. 1994. *Possum Management in New Zealand.* Parliamentary Commissioner for the Environment, P.O. Box 10-241 Wellington. 196 pp.

Pierce, R.J. and Montgomery, P.J. 1992. *The fate of birds and selected invertebrates during a 1080 operation.* Department of Conservation, Science and Research Internal Report No.121. 17 pp.

Potter, M.A. 1989. *(Unpublished). "Ecology and reproductive biology of the North Island brown kiwi (Apteryx australis mantelli)".* Ph.D. Thesis, Palmerston North, New Zealand. 135 pp.

Potter, M.A. 1990a. Apterygidae. *In:* Marchant, S. & Higgins, P.J. (Eds), *Handbook of Australian, New Zealand and Antarctic birds.* 1 Ratites to ducks. Pg 78. Oxford University Press, Melbourne.

Potter, M.A. 1990b. Movement of North Island brown kiwi *(Apteryx australis mantelli)* between forest remnants. *New Zealand Journal of Ecology* 14: 17- 24.

Pracy, L.T. 1974. *Introduction and liberation of the opossum (Trichosurus vulpecula) into New Zealand.* New Zealand Forest Service No.40. Wellington, New Zealand. 52 pp.

Rammell, C.G. and Fleming, P.A. 1978. *Compound 1080: properties and uses of sodium monofluoroacetate in New Zealand.* Animal Health Division, Ministry of Agriculture and Fisheries Wellington. 112 pp.

Reid, B. 1971a. The weight of the kiwi and its egg. *Notornis* 18: 245-249.

Reid, B. 1971b. Composition of a kiwi egg. *Notornis* 18: 250-252.

Reid, B. 1986. Kiwis, opossums and vermin. A survey of opossum hunting; and of target and non-target tallies. *Fur Facts* 7: 37-49.

Reid, B.; Ordish, R.G. and Harrison, M. 1982. An analysis of the gizzard contents of 50 North Island brown kiwis, *Apteryx australis mantelli*, and notes on feeding observations. *New Zealand Journal of Ecology* 5: 76-85.

Robertson, H.A.; Colbourne, R.M. and Nieuwland, F. 1993. Survival of little spotted kiwi and other forest birds exposed to brodifacoum rat poison on Red Mercury Island. *Notornis* 40: 253-262.

Rudge, M.R. 1990. Feral goats. *In:* King, C.M. (Ed), *The Handbook of New Zealand Mammals*, pp 406-424. Oxford University Press, Auckland.

Speed, H.J.; Bradfield, P.M.F.; Montgomery, P.J.; King, D.R. and Innes, J.G. 1988. *The monitoring of North Island kokako (Callaeas cinerea wilsoni) during an aerial 1080 operations in the Cowan wildlife refuge and Okahukura State Forest, Northern King Country*. Department of Conservation, Manipoto District Office (unpublished) Te Kuiti. 21 pp.

Spurr, E.B. 1979. A theoretical assessment of the ability of bird species to recover from an imposed reduction in numbers, with particular reference to 1080 poisoning. *New Zealand Journal of Ecology* 2: 46-63.

Spurr, E.B. 1991. Effects of brushtail possum control operations on non-target bird populations. *Acta XX Congressus Internationalis Ornithologici* 20: 2534-2545.

Spurr, E.B. 1993. Feeding by captive rare birds on baits used in poisoning operations for control of brushtail possums. *New Zealand Journal of Ecology* 17: 13-18.

Spurr, E.B. 1994a. Review of the impacts on non-target species of sodium monofluoroacetate (1080) in baits used for brushtail possum control in New Zealand. *In*: Seawright, A.A. and Eason, C.T. (Eds). *Proceedings of the Science Workshop on 1080.* pp 124-133. The Royal Society of New Zealand, Miscellaneous series No.28, Christchurch, New Zealand.

Spurr, E.B. 1994b. Impacts on non-target invertebrate populations of aerial application of sodium monofluoroacetate (1080) for brushtail possum control. *In*: Seawright, A.A. and Eason, C.T. (Eds). *Proceedings of the science workshop on 1080.* pp 116-123. The Royal Society of New Zealand, Miscellaneous series No.28, Christchurch, New Zealand.

Spurr, E.B. and Powlesland, R.G. 1997. *Impacts of aerial applications of 1080 on non-target native fauna: Review and priorities for research.* Department of Conservation, P.O. Box 10-420 Science for Conservation No.62. Wellington. 31 pp.

Taborsky, M. 1988. Kiwis and dog predation: Observations in Waitangi State Forest. *Notornis* 35: 197-202.

Twigg, L.E.; King, D.E.; Davis, H.M.; Saunders, D.A. and Mead, R.J. 1988. Tolerance to, and metabolism of, fluoroacetate in the emu. *Australian Wildlife Research* 15: 239-47.

Udy, P.B. and Pracy, L.T. 1981. Baits, Birds and Field Operations. *Counterpest* 6: 13-15.

Walker, K. 1997. Effects of aerial distribution of 1080 for possum control on weka, great spotted kiwi, morepork and fernbird. *Ecological Management* 5: 21-27.

Warren, A. 1984. *The effects of 1080 poisoning on bird populations in Tihoi, Pureora State Forest Park, winter 1983.* New Zealand Forest Service Internal Report (unpublished). 34 pp.

Wilson, P.R. 1984. The effects of possums on Mt Misery, Nelson Lakes National Park. *Proceedings of section A4e, 15th Pacific Science Congress.* Department of Lands and Survey, Wellington, New Zealand.

Wodzicki, K.A. 1950. *Introduced Mammals of New Zealand.* Department of Scientific and Industrial Research, Wellington, New Zealand. 250 pp.

The response of captive and wild kiwi to a range of non-toxic baits used for pest control in New Zealand.

ABSTRACT

A range of non-toxic plain baits (carrot, two types of cereal-based baits (No.7 and RS5), apple paste, and a starter paste) used in poisoning operations for control of brushtail possum (*Trichosurus vulpecula*) were offered to captive and wild North Island brown kiwi (*Apteryx australis mantelli*). The response of captive kiwi to the five bait types differed dramatically to that of wild kiwi. All captive kiwi trialled fed at least once on at least one bait type. Some kiwi showed high preferences for particular bait types which were not consistent between individuals. Kiwi did not prefer any bait type to their usual artificial diet. According to the proportion of captive kiwi which fed on baits at least once, baits were placed in decreasing order as: pulp/paste > carrot > No.7 > RS5, although the differences between each bait type were not significant. A similar order was obtained when baits were ranked according to the number of times kiwi fed on each bait type. Wild kiwi did not feed on any bait type placed outside their nest entrances but may have ingested apple or starter paste as they probed these bait types. The results of the captive trials indicate that cereal-based baits may be the safest bait to sow aerially in kiwi habitat. Both captive and wild trials suggest that apple paste baits may be highly acceptable to wild kiwi.

INTRODUCTION

Sodium monofluoroacetate (1080) is used in New Zealand for the control of mammal pests, particularly the brushtail possum (Batcheler 1978). 1080 may be distributed by air in carrot and cereal-based baits, or laid in paste form for ground control operations (Rammell and Fleming 1978). Although these baits are known to be eaten by a number of bird species (Spurr 1979; Spurr 1991; Morgan et al. 1997; Spurr and Powlesland 1997), monitoring suggests that most common birds are unaffected in the long term by control operations (Warren 1984; Spurr 1991; Millar and Anderson 1992; Spurr 1994).

Less is known of the effects of poisoning operations on rarer birds (Crook 1978, in Spurr 1993; Pierce and Montgomery 1992) and this is largely due to standard monitoring methods tending to target common species (Harrison 1978; Warren 1984; Calder and Deuss 1985). With advances in techniques such as radio-tagging it has now been possible to monitor the survival of the majority of bird species that are likely to encounter 1080-poison baits through operations (Spurr 1994; Spurr and Powlesland 1997). Bait acceptance trials have also been conducted using samples of some birds in the wild (Innes and Williams 1990; Pierce and Montgomery 1992; Lloyd and Hackwell 1993; Morgan and Goodwin 1995) and in captivity (McLennan et al. 1992; Spurr 1992; Spurr 1993) to assess potential risks of widespread bait use in the field. While a number of rarer species are now classed as low priority for monitoring throughout poisoning operations (e.g. kokako) there are still some species (e.g. kereru, kaka, morepork) for which monitoring remains high priority (Spurr and Powlesland 1997).

Kiwi are ground foraging, omnivorous birds which are highly likely to encounter and potentially feed on baits which they may find on the ground. Although a number of kiwi deaths have resulted from the use of baits containing cyanide poison (Reid 1986; Spurr 1991), no kiwi are reported to have died during monitored aerial applications of 1080 cereal-based bait (Pierce and Montgomery 1992; Lyall 1995; Walker 1997), carrot (Martin 1997, pers. comm.), or ground laid 1080 paste (H. Robertson, pers. comm.). From these studies it can be largely concluded that kiwi are unaffected by these operations. However, Pierce and Montgomery (1992) found traces of a dye, which had been impregnated into non-toxic cereal-baits, in two out of seventeen kiwi scats which they recovered. This showed that kiwi may feed on baits, and suggests that monitoring studies may have failed to detect mortality, or that to date only sub-lethal doses have been consumed by kiwi during poisoning operations.

Following radio-tagged birds has been the most common method used to determine the survival of individual kiwi throughout 1080 poisoning operations. However, radio-tagging is costly and involves skilled people to catch kiwi and fit transmitters (Robertson 1996). Consequently only small samples of birds (e.g. two to nine birds) have been monitored throughout each control operation (Pierce and Montgomery 1992;

Lyall 1995; Walker 1997). These studies provide valuable information on the survival of kiwi, but do not tell us whether kiwi are (1) encountering and rejecting baits, (2) feeding on them and surviving, or (3) failing to encounter them. Unlike other rarer native birds such as kokako (Innes and Williams 1990), the response of kiwi to baits has not been observed directly in the wild.

Possum control is likely to use 1080-poison baits for at least the next 10-15 years (Jolly 1993) so it is essential that we understand fully the potential risk of such operations to kiwi of different age classes and sex. If kiwi are assumed to encounter baits, then managers need to know the probability of kiwi feeding on them, and the proportion of birds likely to be affected. Although no kiwi have been reported dead from poison operations using 1080 carrot, cereal baits or apple paste, some bait types may carry greater risk than others. While the absence of reported kiwi deaths from these poisoning operations is promising for kiwi, managers have no guide as to which bait types, if any, are safest to use.

This chapter had two main aims. The first was to determine the response of captive kiwi to a range of four different types of bait used commonly as carriers of the poison 1080, plus an additional bait used to carry cyanide poison. Baits can then be placed in order of acceptablity to kiwi and therefore in order of potentially greatest risk.

The second aim was to directly observe the response of wild North Island brown kiwi (*Apteryx australis mantelli*) to the same range of bait types. These wild kiwi bait encounters are the first ever obtained, and will help strengthen the assessment of which baits carry greatest risk of poisoning to kiwi. A comparison of bait trials using captive and wild kiwi can also be made.

MATERIALS AND METHODS

Kiwi used

Captive kiwi

The captive kiwi used in this study were held at Otorohanga Kiwi House, Otorohanga, and Westshore Reserve, Napier. At Otorohanga three pairs of North Island brown kiwi and one pair of great spotted kiwi (*Apteryx haastii*) were available for trials which ran between August and November 1995. Of the birds with known history, two were bred at Otorohanga and had been captive for at least 8 years. Six were salvaged from the wild, five having been captive for at least 7 years, and one for 8 months (Appendix 1). All of these birds are now used primarily for breeding. Pairs were held in outside vegetated enclosures approximately 250 m^2 (Reid and Rowe 1978). During the trials two pairs of brown kiwi and the pair of great spotted kiwi were incubating eggs in their enclosures.

At Westshore Reserve one adult male kiwi which had been captive for at least 5 years, and one fifteen month old juvenile female kiwi which was hatched in captivity (Billing, pers. comm.) were available for trials in March 1997. Birds were held separately in outside vegetated enclosures approximately 20 m^2.

All kiwi received approximately 350 g of artificial food each night based on a diet given in Johnson (1996). At Otorohanga, kiwi received chopped ox heart, cooked oats, soya bean oil, wheat germ flakes and TVL Special Premix No. 178 (vitamin supplement). In addition kiwi were sometimes fed mixed corn and carrot, sultanas and tofu. Otorohanga birds were starved every Saturday to encourage them to forage naturally for food within their enclosures. Kiwi at Westshore Reserve were fed chopped ox-heart, soaked oats and TVL Special Premix No. 178 (vitamin supplement). They did not receive carrot, corn, tofu or sultanas in addition to this diet. All kiwi foraged freely in their outside enclosures and probably supplemented their food intake with soil invertebrates. Water was available *ad libitum* to all birds.

Wild kiwi

The data for this study were collected from nesting North Island brown kiwi. All kiwi used carried radio-transmitters and were part of existing projects investigating the impacts of introduced predators on kiwi recruitment, habitat use and population ecology (McLennan 1996).

Justification for using nesting kiwi

In these trials a range of baits were to be presented repeatedly to as many individual wild kiwi as possible. The kiwi chosen to be tested were those that were nesting. In the North Island of New Zealand the male kiwi alone incubates (McLennan 1988). Unlike roosting kiwi which may move to a different den or burrow each day (McLennan et al. 1987) those that are incubating generally return each night to the same nest. Using nesting kiwi restricted our observations to males but enabled us to place baits close to where kiwi would regularly pass. This overcame the difficulties in observing kiwi encounters with baits placed randomly in territories. The use of radio-tagged birds reduced the time spent searching for suitable nest sites, i.e. those which were accessible with video equipment and which had a clear entrance not covered by thick vegetation.

Wild kiwi study areas

The birds used came from Lake Waikaremoana, Te Urewera National Park ($38^0$47'S, $177^0$04'E and $38^0$46'S, $177^0$02'E), and Rarewarewa ($35^0$37'S, $174^0$08'E) and Riponui ($35^0$34'S, $174^0$09'E) bush patches in Northland (Figure 2.1). These two areas differ considerably in their habitat and density of kiwi. Te Urewera National Park contains the largest area of virgin forest in the North Island (Figure 2.2). Kiwi densities within the catchment area of the Lake vary from 0 to 2.8 birds per km^2, with bonded pairs defending territories of around 45 ha (McLennan 1996). In contrast the Northland landscape consists of fragmented bush patches surrounded by pasture (Potter 1989). Kiwi densities, however are high (approximately one bird per 2.5 ha) (Colbourne and Kleinpaste 1983; Potter 1989) compared to elsewhere in the North Island (McLennan et al. 1987; Miles 1995).

At Lake Waikaremoana two nesting male kiwi were trialled between January and March 1996, and November and December 1996. Both nests were on the lower slopes of the

catchment and within a few hundred metres of the lake edge (Figure 2.3). In these areas the forest consisted primarily of mixed beech (*Nothofagus* spp.), rimu (*Dacrydium cupressinum*) and tawa (*Beilschmiedia tawa*) mixed with tawari (*Ixerba brexioides*), kohekohe (*Dysoxylum spectabile*) and rewarewa (*Knightia excelsa*). In places supplejack (*Ripogonum scandens*) and crown fern (*Blechnum discolor*) formed a thick understorey.

Eight male kiwi were trialled at Rarewarewa and Riponui bush patches in Northland between July and September 1997. In some parts the bush was fenced, while other patches remained unfenced and open to grazing stock (Figure 2.4). The forested areas were covered with scattered kauri (*Agathis australis*), mixed podocarps such as totara (*Podocarpus totara*) and rimu (*Dacrydium cupressinum*), tanekaha (*Phyllocladus trichomanoides*), puriri (*Vitex lucens*) and kohekohe (*Dysoxylum spectabile*). Nests were located inside the bush, mostly within 50 metres of pasture, and were easily accessible.

Baits used

Trials involved presenting kiwi with five types of baits used most frequently in New Zealand for possum and wild mammal control. These were carrot, two types of cereal-based baits known as No.7 and RS5, apple paste (previously known as 'jam baits'), and starter paste. All baits, with the exception of starter paste, are commonly used carriers of the poison 1080 (Morgan and Goodwin 1995; Haydock and Eason 1997). Starter paste is a petroleum based bait used as a pre-feed to the carrier of cyanide poison. Carrot and cereal baits are generally broadcast aerially over large rugged areas of forest (Spurr 1994), while apple and starter paste are hand laid in areas where greater precision is required (Rammell and Fleming 1978; Morgan et al. 1997). Guidelines for laying starter paste (cyanide paste) have improved safety for kiwi and other ground feeding birds, however this bait was tested for comparative purposes.

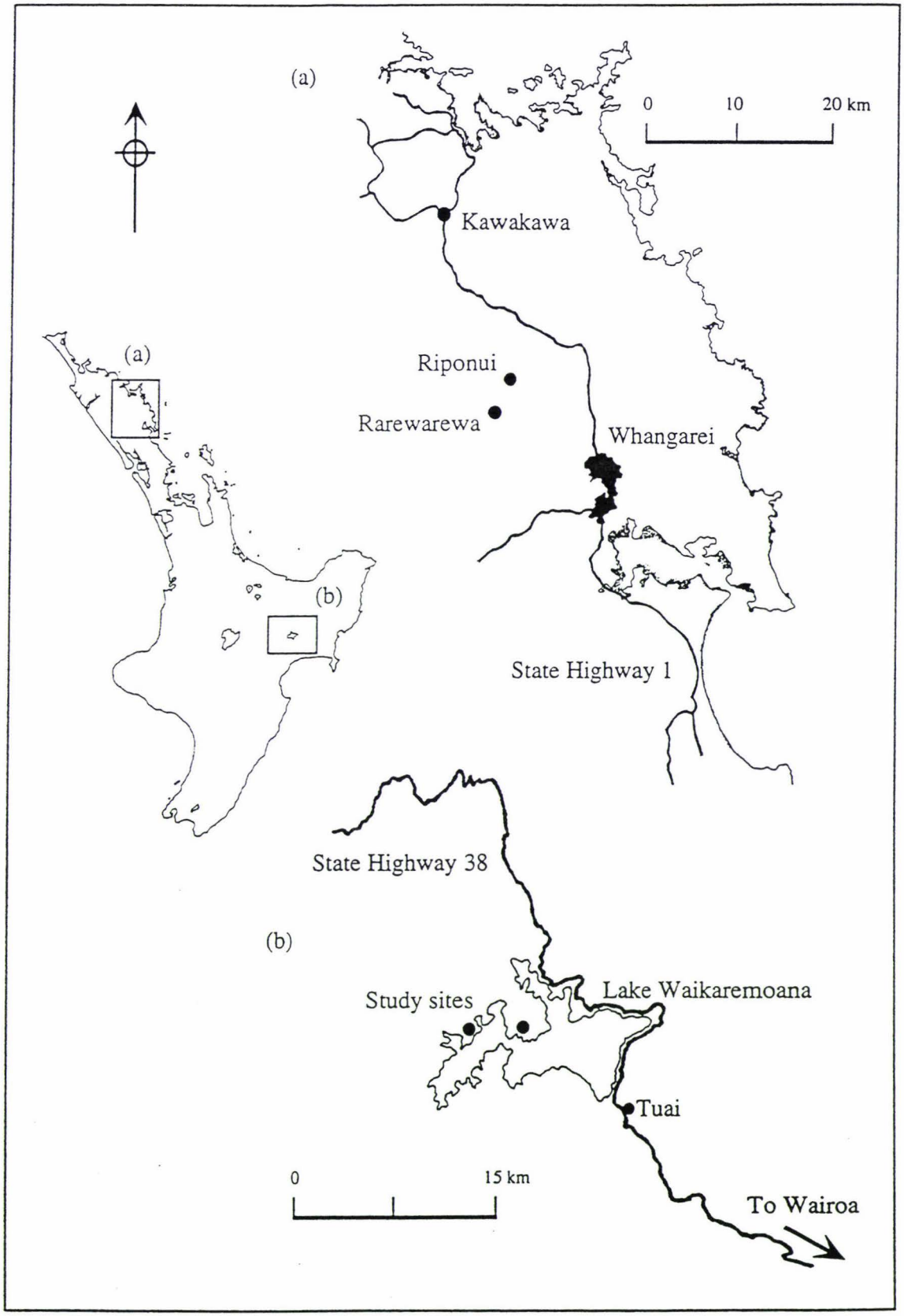


Figure 2.1 Location of wild kiwi sites at Rarewarewa and Riponui bush patches in Northland, and at Lake Waikaremoana, Te Urewera National Park in the North Island, New Zealand.

Figure 2.2 View across Lake Waikaremoana, Te Urewera National Park.

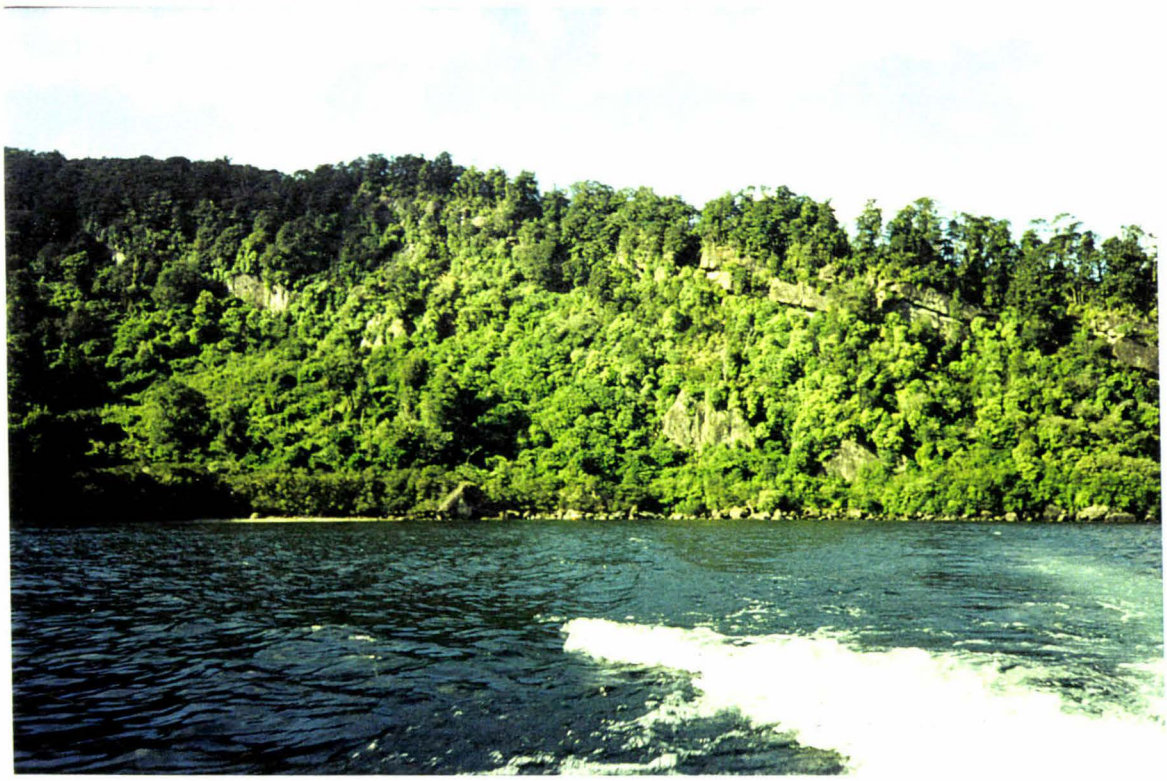


Figure 2.3 Looking towards the location of a video recorded kiwi nest approximately half way up the face on left hand side.

Figure 2.4 View of bush patches containing kiwi at Rarewarewa bush, Northland.

Figure 2.5 Position of the five bait types (1-5) outside the nest (n) of a kiwi at Rarewarewa bush, Northland.

Bait preparation

Carrot bait was prepared by chopping fresh carrot into chunks of approximately 3 g. The bait was then dyed green by soaking in a solution of Bayer V200 green dye (0.1% wt:wt).

Cereal baits No.7 and RS5 were prepared by Massey University Feed Processing Unit. Loose mixes of both these bait types were obtained from Animal Control Products Ltd., Wanganui. These were pelleted into baits of two size classes (small and large) with weights of approximately 3.3-4.0 g and 0.6 g respectively. Bayer V200 green dye was added to the loose mix at 0.1% wt:wt prior to pelleting.

Unflavoured and un-dyed apple paste and starter paste were obtained in 500 g tubes from Animal Control Products Ltd., Wanganui. Bayer V200 green dye was added to the pastes at a concentration of 0.075 g kg^{-1} (D. Morgan, pers. comm.).

Ensuring baits were non-toxic

All baits used in these trials were non-toxic. Carrot bait was prepared by hand and was guaranteed free of toxins. However, when we investigated the production of non-toxic cereal baits there was no guarantee that baits would be completely toxin-free. This was because non-toxic baits were made in machinery also used to prepare toxic baits. Although the equipment is cleaned thoroughly before non-toxic baits are prepared there was no guarantee that all traces of toxins would be removed. To overcome this concern, the baits used in these trials were pelleted with machinery used to prepare poultry diets. One consequence of this was that the baits differed in diameter to those used in actual poison operations. Standard large and small cereal baits manufactured for use in the field have a diameter of 16 mm and 10 mm respectively. The baits prepared using the alternative machinery had a diameter of 12 mm and 6 mm respectively.

Sub-samples of apple paste and starter paste were sent to Landcare Research, Toxicology Unit, Lincoln for toxin assaying. The sub-samples tested contained no detectable level of 1080 (Wright 1995). These two paste types will be referred to subsequently as pulp (i.e. apple paste) and paste (i.e. starter paste).

Captive kiwi trials

The five bait types were presented to kiwi for five consecutive nights as a multiple-choice feeding trial. Approximately 140 g and 70 g of each bait type was made available to pairs and single birds respectively. These quantities were approximately one fifth of the amount of artificial diet that paired, and single birds were allocated each night, and avoided kiwi feeding to excess on one particular bait type. Baits were placed separately into bowls similar to those in which kiwi receive their usual diet. No.7 and RS5 cereal baits were offered as equal quantities of large and small baits. Pulp and paste baits were placed as small walnut-sized portions on the base of the feeding bowls. Bowls were placed approximately 30 cm apart in a circle on the ground. Fresh baits were used each night. This was necessary because kiwi frequently knocked the bowls and walked through the baits. Other animals (e.g. possums, mice and ducks) also removed baits making it impossible to expose kiwi to the same baits for the five day trial. The position of each bait type was assigned randomly to bowls so that each type occurred only once in each bowl position during the five trial nights. This avoided any bias that may have resulted if kiwi preferred some feeding positions over others. Baits were placed within the kiwi enclosure half an hour before sunset. All activity within half a metre radius of the bowls was recorded using an infra-red camera positioned two metres away, with a time lapse recorder and monitor (displaying time/date/ recording time) out of sight. Video recording began every evening at dusk and continued until dawn.

The night prior to bait presentation kiwi were fed their usual artificial diet from five bowls placed on the ground in the same arrangement. This was to ensure that birds would feed from this design. Kiwi were starved for the first night that baits were presented. Their usual food was provided two hours after dark for each of the following four nights.

Data collected

The main parameters recorded were the sex of the bird investigating baits, the time spent feeding on each bait type, and the amount of each bait eaten. Since other animals within the kiwi enclosures also fed on baits it was not possible to quantify the amount of

each bait eaten by weighing baits before and after presentation to kiwi. Instead, the approximate amount of each bait eaten was estimated from the video. For carrot and pellet baits (No.7 and RS5) individual chunks and individual baits eaten, respectively, were recorded. For pulp and paste the number of swallows of bait was recorded.

The quantity of each bait type consumed was expressed as a proportion of the amount offered to kiwi each night. This was determined using the calculated average weights for carrot chunks, pellet baits, or the estimated average weight of pulp or paste consumed in a single swallow. Average weights of pulp and paste swallows had been determined previously in trials which allowed kiwi to feed on a known weight of bait for a set number of swallows. Remaining bait was then re-weighed and the average weight of paste/pulp consumed per swallow calculated by subtraction. Using this technique the approximate weight of each 'swallow' of paste or pulp was 1.2 g. Carrot chunks weighed approximately 3 g, while small and large pellet baits weighed 0.6 g and 3.3-4.0g respectively.

Statistical analysis

Differences between the proportions of kiwi which fed on each bait type were examined using the following equation:

$$S.E.p_1\text{-}p_2 = \sqrt{\ p_1(1\text{-}p_1)/n\ +\ p_2(1\text{-}p_2)/n}$$

Where S.E. is the standard error, p_1 and p_2 are the two proportions being compared, and n is the total number of kiwi. If the interval $(p_1\text{-}p_2) \pm 2\ S.E.p_1\text{-}p_2$ included zero then the proportions were not significantly different at the 0.05 level.

The duration (sec) that kiwi spent feeding on each bait type and their normal artificial diet was used to examine kiwi preferences for each of these food types, within and between nights. It was assumed that kiwi took a similar length of time to eat each unit of food (e.g. a chunk of carrot, or swallow of paste or usual food etc.). Data were examined using a Repeated Measures ANOVA and Least Squares Means comparisons in the General Linear Model Procedure of SAS (SAS Institute 1985). Differences

between the total duration spent feeding by kiwi on all bait types between nights were examined using ANOVA Least Significant Differences test. Data were log transformed prior to analysis.

Bait types were ranked from one to five (5 being most preferred) for each kiwi based on the number of times kiwi fed on a unit of bait (e.g. a chunk, pellet, or swallow of bait). A Kruskal-Wallis one-way analysis of variance was used to examine the effect of sex on bait rank. Ranks from one to ten (10 being kiwi which fed most) were also assigned to individual kiwi for each bait type based on the number of times kiwi fed on a unit of bait. A Kruskal-Wallis test was used to investigate sex differences in the ranking for the amount of each bait type consumed. A Chi-squared test was used to examine differences between the size class of cereal pellet baits eaten by kiwi.

Wild kiwi trials

Kiwi nests were located by tracking radio-tagged kiwi by day using a radio receiver (TR4) and a yagi three element aerial. An infra-red camera used to record kiwi at the nest was mounted on a tripod, or tied to a tree 2-3 m from the nest entrance and covered with a camouflage sheet. The time-lapse video recorder and monitor (providing the time/date/recording time) was positioned approximately 18 m away from the nest under plastic. Power was supplied by two car sized lead acid gel batteries (12 volt, 57 amp hr).

Natural feeding

In testing the response of kiwi to baits placed outside their nest entrance the assumption is made that (1) kiwi will feed on attractive food items close to their nest and (2) that human presentation of baits does not prevent kiwi from feeding on baits. This was investigated by determining whether kiwi would feed on natural foods such as cicada nymphs and earthworms placed in small piles outside the nest on the first night of video recording, when no baits were present. Other occasions when kiwi were observed feeding on natural foods (other then when supplied food was presented) were also recorded.

Presenting non-toxic baits to kiwi

One small pile (50 g) of each of the five bait types was placed on the ground outside the nest entrance in an area where kiwi frequently passed (Figure 2.5). On some occasions, it was necessary to identify the bait piles with small pieces of reflector which could be detected easily by the camera. Fresh baits were presented for each of the five nights. This overcame the problem of rats and possums frequently consuming all the baits before kiwi emerged. To minimise disturbance around kiwi preparing to emerge, human presence at the nest was restricted to at least one hour before sunset. The camera recorded all activity within 0.5 m radius of the baits (with nest entrance also in view) from sunset until sunrise. This provided continuous footage (without the delay incurred when using movement detectors to trigger recording), but required the two batteries and video tape to be changed each night.

Data collection and statistical analysis

The duration and number of all kiwi encounters with baits were recorded. An 'encounter' was defined as a kiwi within 0.5 m of bait. Any probing or feeding on baits, or on invertebrates by kiwi was noted.

One-way ANOVA followed by the Student-Newman-Keuls test were used to compare the number of times kiwi probed or fed on invertebrates and each bait type per minute. Due to a number of zeros in the data, 0.01 was added to each value prior to performing a log transformation to improve normality.

RESULTS

Captive kiwi trials

The proportion of kiwi that fed on each bait type

All ten captive kiwi which were trialled fed at least once on at least one of the five plain bait types presented. One bird fed on only one type, five birds fed on two, one bird fed on three, and three birds fed on four bait types. No kiwi fed on all five bait types. Based on the proportion of kiwi which fed on each bait type once (a), and more than

once (b) (Figure 2.6), baits were ranked in descending order as:

(a) **Pulp / Paste > Carrot > No.7 > RS5**

(b) **Pulp > Paste/Carrot > No.7 > RS5**

Ranking baits using kiwi which fed more than once on each type removed the 'one-off' feeders (those birds which fed only once on a bait type and did not return to feed again on that bait during the trial), but this made little difference to the overall bait order. Of the baits which were fed on at least once, pulp and paste were acceptable to the most kiwi, followed by carrot, with pellet baits, particularly RS5, being eaten by the least number of kiwi. A similar trend was observed for baits which were fed on more than once, although more kiwi returned to feed on pulp than other bait types, and paste and carrot ranked second equal. However, the differences between the proportions of kiwi which fed on each bait type in either rank were not significant ($p>0.05$ for all pair-wise comparisons made), therefore these trends provide only an indication of the acceptability of baits to the kiwi trialled.

Amount of each bait type eaten

Most kiwi ate only a few baits of any type and this was only a small percentage of the amount they were offered nightly (Appendix 2). There were no obvious trends in the number of kiwi which fed on each bait type with increasing nightly exposure (Table 2.1). However, there was considerable individual variation, with some kiwi demonstrating extreme preference for some bait types (Table 2.2). For example, one female (C2) consumed 33 of the 38 (86.8 %) No.7 baits, and 22 of the 24 (91.7 %) RS5 baits eaten by all kiwi during trials. Similarly, one male (C5) consumed 95 out of 133 (71.43%) swallows of pulp, and one female (C4) ate 34 out of 52 (65.4 %) swallows of paste. Only female C2 had a consistent preference across nights for No.7 and RS5 bait types (Appendix 3). Male C5 ate a large amount of pulp on the first night, when kiwi had no artificial diet, but did not return on subsequent nights when the usual diet was also available. Similarly, female C4 ate the greatest amount of paste on the first night and only a small amount on the second (Appendix 3). No bait type however, was completely eaten by any kiwi on any one night.

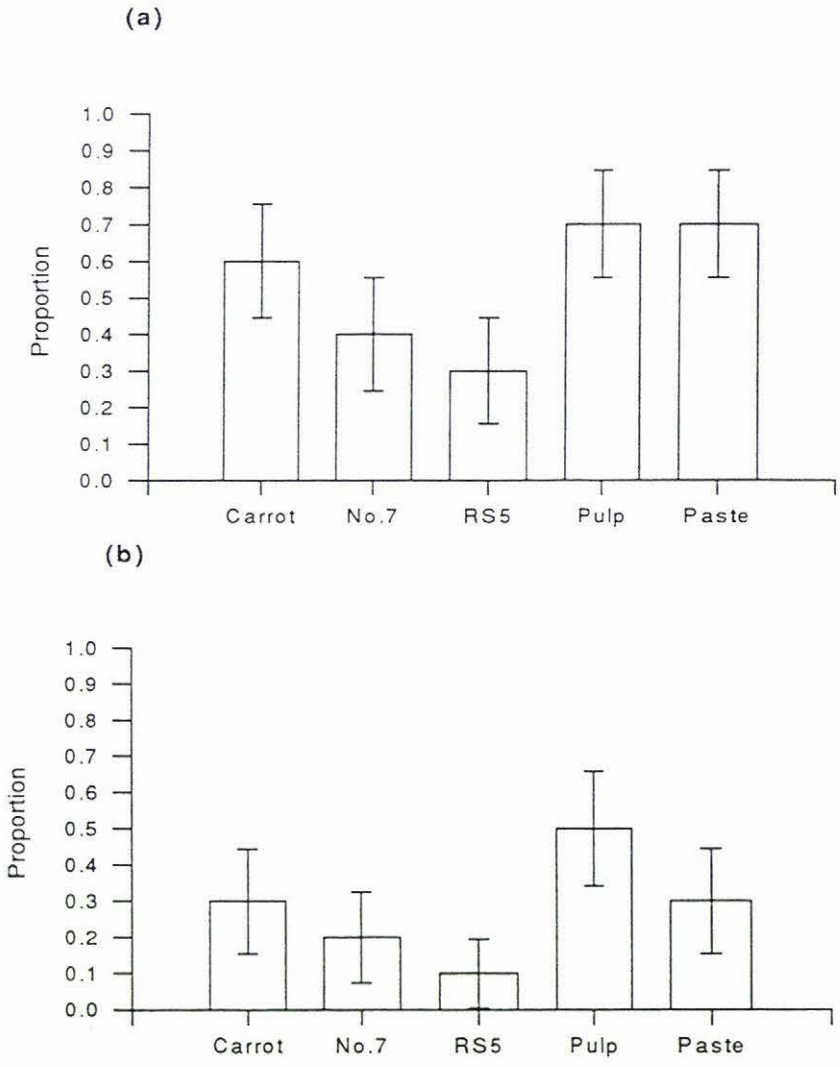


Figure 2.6 Proportion (± S.E.) of captive kiwi (n=10) which fed on each bait type at least once (a), and more than once (b).

Table 2.1 Number of kiwi (n=10) which fed on each bait type on nights one to five.

Bait type Night	Carrot	No.7	RS5	Pulp	Paste
1	1	1	1	4	3
2	1	1	1	2	3
3	5	2	2	3	4
4	1	2	1	0	1
5	1	1	1	3	0

Table 2.2 Total number (e.g. chunks of carrot, pellets of RS5 or No.7, and swallows of pulp or paste) of each bait type eaten by male and female kiwi over five nights of presentation. Numbers highlighted in bold indicate kiwi which fed the most on particular bait types.

Bait type Kiwi	Carrot	No.7	RS5	Pulp	Paste
Male					
C1	3	0	1	5	2
C3	3	0	0	0	0
C5	0	3	0	**95**	1
C7	1	0	0	0	4
C10	0	0	0	2	1
Female					
C2	1	**33**	**22**	2	0
C4	**5**	1	0	4	**34**
C6	0	0	1	22	0
C8	1	1	0	0	8
C9	0	0	0	3	2
Total	**14**	**38**	**24**	**133**	**52**

Kiwi preference for bait types and their usual artificial diet

The duration that kiwi fed on each bait type and their usual artificial diet was used to compare preferences for each of these potential foods. On night one, in the absence of their usual diet, there was no significant difference ($F_{4,45}$=1.21; p=0.322) between the duration that kiwi fed on each bait type. However, on nights 2, 3, 4 and 5 (when the usual diet was also presented), there was a highly significant difference between the duration that they fed on baits or the usual food (Table 2.3), and this trend did not differ significantly between nights ($F_{3,52}$=1.2860; p=0.2889). Pair-wise comparisons showed that kiwi fed significantly longer on their usual food each night than any bait type (all p<0.01, Figure 2.7). Between bait types no significant differences were detected.

Overall, there was no statistically significant difference in the total amount of usual food and baits consumed between nights 2, 3, 4 and 5 ($F_{3,52}$=1.2860; p=0.2889). There was also no statistically significant preference for any particular bait type or usual food on different nights ($F_{15,144}$=1.1618; p=0.3083).

When nights one to five were analysed with the duration spent feeding on usual food excluded, there was no significant difference between the duration that kiwi fed on any of the five bait types within any night (Table 2.4). Kiwi fed longer on average on all baits combined on night one (Figure 2.8), although the total feeding duration did not differ significantly between any night ($F_{4,20}$=1.04; p>0.05, LSD test). There was also no statistically significant preference for particular bait types on any night ($F_{16,129}$=0.9556; p=0.5088).

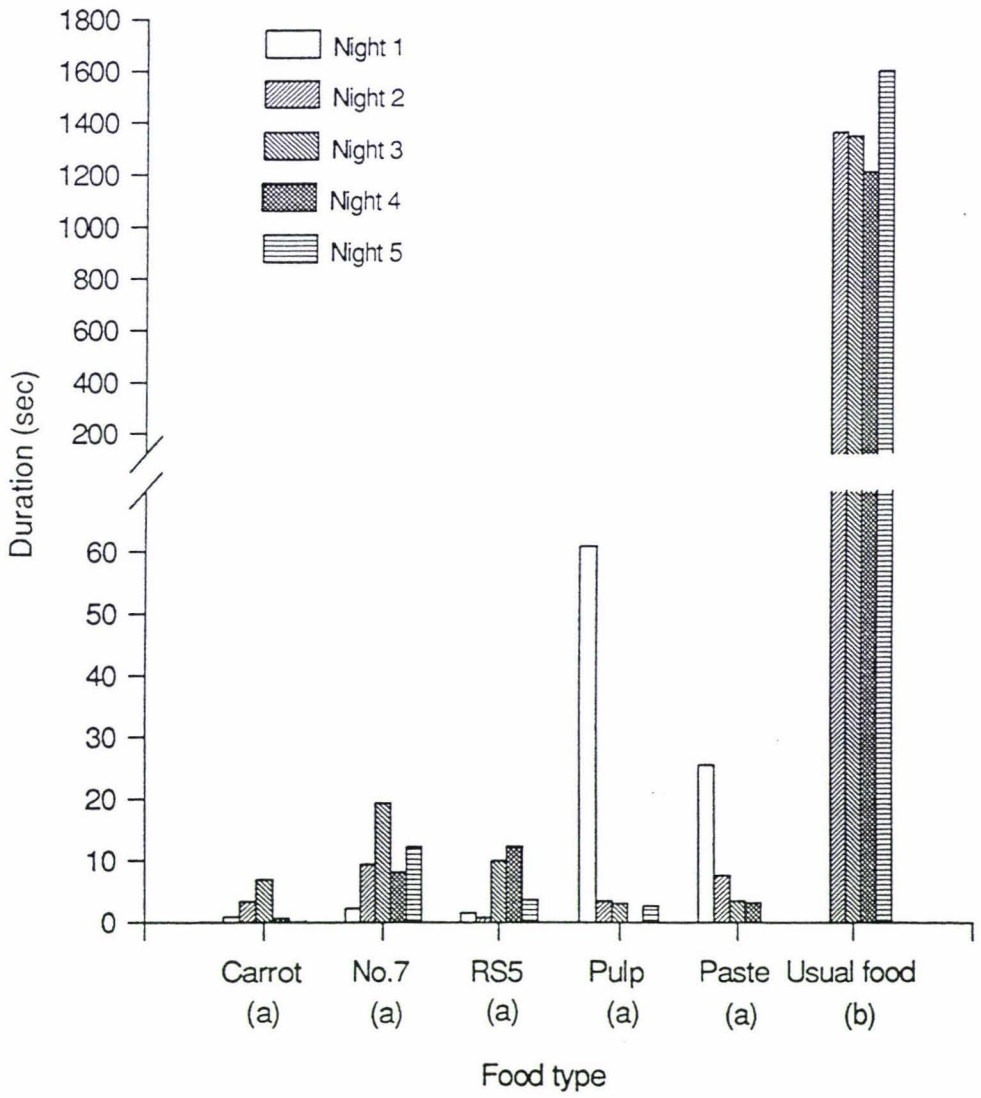


Figure 2.7 Mean duration (sec) spent feeding by captive kiwi on their usual food and each bait type on nights 1 to 5. Food types which do not share the same letter in brackets are significantly different at $p<0.01$ for pairwise comparisons made on each night.

Table 2.3 Repeated Measures analysis of variance results investigating differences in the duration (sec) that captive kiwi spent feeding on each of the five bait types and their usual food on nights two to five. Significance values are shown in the last column.

Night	DF	Mean Square	F-ratio	P
2	5,54	3073613.87	19.74	0.0001
3	5,54	2998295.07	14.10	0.0001
4	5,54	2493187.26	8.46	0.0001
5	5,54	4260792.46	14.65	0.0001

Table 2.4 Repeated Measures analysis of variance results investigating differences in the duration (sec) spent feeding on each bait type on night one (in the absence of usual food) and on nights two to five (when usual food was presented two hours after baits). Significance values are shown in the last column.

Night	DF	Mean Squares	F-ratio	P
1	4,45	6798.27	1.21	0.3215
2	4,45	122.17	0.46	0.7632
3	4,45	444.27	0.51	0.7316
4	4,45	280.07	0.67	0.6182
5	4,45	254.53	0.76	0.5561

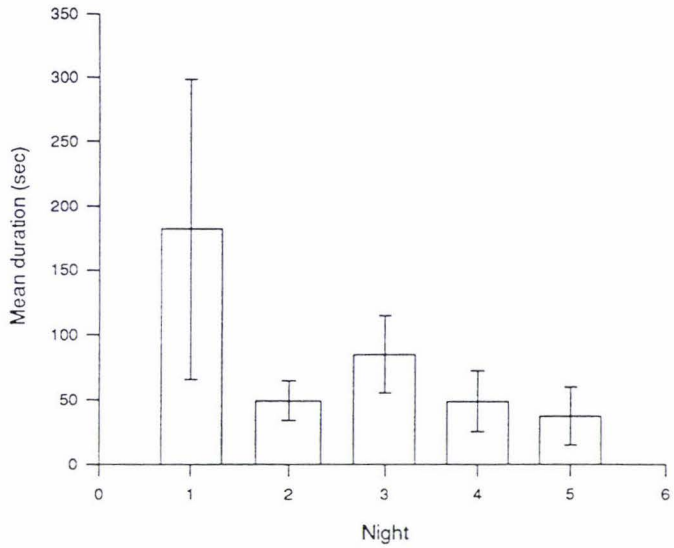


Figure 2.8 Total duration (sec) (± S.E.) spent feeding each night on all bait types by all kiwi (n=10). No significant differences in the total duration spent feeding were found between nights at $p<0.05$; LSD test.

Male and female preferences for bait types

When a rank was assigned from 5 to 1 (5 being most preferred), to each bait type based on the number of times each kiwi fed on a unit of bait, there was no significant difference in the ranking of baits between males and females (see Kruskal-Wallis values, Table 2.5) so these were combined. Baits were therefore ranked overall in decreasing order of preference as:

Pulp > Paste > Carrot > No.7 > RS5

However, there were no significant difference between the rankings of each bait type (Kruskal-Wallis; $p=0.079$; $H=8.39$; $df=4$). This means that no bait type ranked significantly higher than another and the rank sum totals therefore only indicate the above trend.

Table 2.5 Baits ranked (from 5 to 1) in decreasing order of preference for each individual kiwi. Kruskal-Wallis P and H (df=1) values for one-way analyses between sex and the rank assigned to each bait type for individual kiwi.

		Bait type				
Kiwi No.	Sex	Carrot	No.7	RS5	Pulp	Paste
C1	M	4	1	2	5	3
C3	M	5	2.5	2.5	2.5	2.5
C5	M	1.5	4	1.5	5	3
C7	M	4	2	2	2	5
C10	M	2	2	2	5	4
C2	F	2	5	4	3	1
C4	F	4	2	1	3	5
C6	F	2	2	4	5	2
C8	F	3.5	3.5	1.5	1.5	5
C9	F	2	2	2	5	4
	Rank sum	**30**	**26**	**22.5**	**37**	**34.5**
	Kruskal-Wallis value	**p = 0.513 H = 0.43**	**p = 0.578 H = 0.31**	**p = 0.914 H = 0.01**	**p = 0.737 H = 0.11**	**p = 1 H = 0**

When individual kiwi were ranked from 10 to 1 (10 indicating kiwi which fed the most) according to the number of times they fed on a particular bait type, bait ranking did not differ significantly between male and female kiwi for any bait type (see Kruskal-Wallis values, Table 2.6). Therefore, males and females preferred baits in a similar order, and did not feed differently on any individual bait type.

Kiwi preference for different sizes of No.7 and RS5 baits

Kiwi ate both small and large sizes of pellet No.7 and RS5 baits, but significantly preferred the larger size class of both bait types ($p<0.001$, $p<0.025$ respectively; Table 2.7) which they were more capable of picking up in their bills. Generally, pellet baits were picked up in the bill, moved around until they were positioned long ways, and then swallowed whole. Only whole baits were ever eaten by kiwi. One female did, however repeatedly push a large sized bait into the ground possibly in an attempt to break the bait up, but eventually gave up and swallowed it whole.

Table 2.6 Kiwi ranked from 10 to 1 (10 indicating kiwi which fed the most) for each bait type. Kruskal-Wallis P and H values (df=1) for one-way analyses between sex and bird ranking for each bait are shown.

		Bait type				
Kiwi No.	Sex	Carrot	No.7	RS5	Pulp	Paste
C1	M	8.5	3.5	8.5	8	6.5
C3	M	8.5	3.5	4	2	2
C5	M	2.5	9	4	10	4.5
C7	M	6	3.5	4	2	8
C10	M	2.5	3.5	4	4.5	4.5
C2	F	6	10	10	4.5	2
C4	F	10	7.5	4	7	10
C6	F	2.5	3.5	8.5	9	2
C8	F	6	7.5	4	2	9
C9	F	2.5	3.5	4	6	6.5
	Kruskal-Wallis value	**p = 0.913 H = 0.01**	**p = 0.288 H = 1.13**	**p = 0.439 H = 0.60**	**p = 1 H = 0**	**p = 0.670 H = 0.18**

Table 2.7 Number of small (0.6 g) and large (4 g) pellet baits eaten by kiwi. Chi-squared (df=1) and significance levels are listed.

	Number of baits eaten			
Bait type	Small	Large	χ^2	Significance level
No.7	1	37	34.105	<0.001
RS5	6	18	6	<0.025

Wild Kiwi Trials

During this study 14 wild kiwi were exposed to five types of bait used in wild mammal control. Ten of these kiwi were adult nesting males (W1 to W10, Appendix 1), two were chicks (W11 and W12, Appendix 1) which were only a few days old and returned to their natal nest each night, and two were females which encountered baits while passing by nest entrances (W13 and W14, Appendix 1). Four kiwi (two adult males and two chicks) were from Lake Waikaremoana and the remainder were from Northland. There were no obvious differences in the response of kiwi from these different locations towards baits, and so the results are presented together.

Feeding on natural foods

Eight out of ten male kiwi fed at least once on the food items presented outside their nest entrance on the first night of video recording (Table 2.8). This demonstrated that these kiwi would feed in the vicinity of their nest and that human presentation of these food items did not deter them from feeding. Testing the response of kiwi to baits placed outside their nest entrance was therefore justified. Five of the males were also observed feeding on food items (other than those presented) on subsequent nights (Table 2.8). These invertebrates could not be identified clearly from the video but appeared to be various species of beetle and weta. Chicks and adult females were never presented with invertebrates, and were not observed feeding on any other naturally occurring food items.

Table 2.8 Number of observations of kiwi feeding on the food presented (cicada nymphs and worms), and other invertebrates naturally occurring out-side their nest. Kiwi with * were never presented with food. W1 to W10 are adult males, W11 and W12 are chicks, and W13 and W14 are adult females.

Kiwi No.	No. observations of kiwi feeding		Total
	Presented food	Other invertebrates	
W1	1	0	1
W2	1	1	2
W3	1	7	8
W4	0	0	0
W5	5	2	7
W6	7	2	9
W7	0	0	0
W8	2	1	3
W9	1	0	1
W10	1	0	1
W11*	-	0	0
W12*	-	0	0
W13*	-	0	0
W14*	-	0	0
Total 14	19	13	32

Kiwi encounters with baits

The male kiwi and chicks encountered baits every time they emerged or re-entered their nests, while the two female kiwi encountered baits as they passed by the nest entrance. In total, 14 kiwi encountered carrot, No.7, RS5, pulp and paste baits 125, 119, 124, 118 and 119 times respectively (Table 2.9). Although all five baits were presented to kiwi simultaneously, the number of encounters with each bait type made by each kiwi sometimes differed. This was because other animals (e.g. possums, rats and mice) occasionally removed all of a particular bait type before kiwi emerged, or returned to their nest. Some kiwi also left the nest more than once in a night and therefore encountered baits more frequently. The number and total duration of encounters that kiwi made with each bait type are presented in Table 2.9. Recorded encounters include kiwi both emerging and entering their nests.

Behaviour of male kiwi towards baits

Generally, kiwi sniffed the air around the nest as they emerged and then quickly began flicking sticks and leaf material behind them in the direction of the entrance. During this time they foraged within a few centimeters of the bait piles, occasionally sniffing or probing baits but showing little interest in them. Each male then moved away from the nest in a direction which was used consistently every time he emerged.

No male kiwi were observed to feed on any carrot or cereal No.7 or RS5 bait types during encounters, although these baits were probed (Table 2.10). Similarly, kiwi made no attempts to actively feed on pulp or paste but did probe these bait types (9 and 5 kiwi out of 14 respectively, Table 2.10), and could potentially have ingested small amounts of bait. Kiwi also made contact with pulp and paste baits when they inadvertently picked up leaves which had bait on. This occurred once with pulp, and on three occasions with paste baits. Kiwi either flicked the paste-covered leaf towards the nest entrance, or rejected it, but were not deterred from continuing to toss material towards the nest entrance. The paste appeared to become stuck to their bills, which they opened and closed in an attempt to dislodge it. Pulp did not become stuck in the same way.

Table 2.9 Number and duration (hr:min:sec) of kiwi encounters with each bait type and presented worms or cicada nymphs. W1 to W10 are adult males, W11 and W12 are chicks, and W13 and W14 are adult females.

Bait	Carrot		No.7		RS5		Pulp		Paste		Worms or cicada nymphs	
Kiwi	No. of encounters	Total duration of encounters	No. of encounters	Total duration of encounters	No. of encounters	Total duration of encounters	No. of encounters	Total duration of encounters	No. of encounters	Total duration of encounters	No. of encounters	Total duration of encounters
W1	10	00:11:49	10	00:11:49	10	00:11:49	10	00:11:49	10	00:11:49	2	00:02:51
W2	10	00:13:18	10	00:13:18	10	00:13:18	10	00:13:18	10	00:13:18	2	00:02:01
W3	16	00:26:27	16	00:26:27	16	00:26:27	16	00:26:27	16	00:26:27	2	00:01:50
W4	10	00:07:17	10	00:07:17	9	00:07:00	9	00:07:17	7	00:06:36	2	00:01:53
W5	20	00:18:03	20	00:18:03	20	00:18:03	18	00:16:06	20	00:18:03	4	00:02:29
W6	20	00:15:06	18	00:13:18	20	00:15:06	20	00:15:06	20	00:15:06	2	00:02:51
W7	5	00:06:11	5	00:06:11	5	00:06:11	5	00:06:11	5	00:06:11	2	00:00:56
W8	3	00:04:06	3	00:04:06	3	00:04:06	3	00:04:06	3	00:04:06	2	00:01:07
W9	11	00:41:15	7	00:29:08	11	00:41:15	7	00:34:42	8	00:35:12	2	00:01:50
W10	10	00:15:00	10	00:15:00	10	00:15:00	10	00:15:00	10	00:15:00	2	00:01:24
W11	3	00:08:06	3	00:08:06	3	00:08:06	3	00:08:06	3	00:08:06	0	00:00:00
W12	3	00:05:55	3	00:05:55	3	00:05:55	3	00:05:55	3	00:05:55	0	00:00:00
W13	2	00:01:03	2	00:01:03	2	00:01:03	2	00:01:03	2	00:01:03	0	00:00:00
W14	2	00:02:06	2	00:02:06	2	00:02:06	2	00:02:06	2	00:02:06	0	00:00:00
Total	125	2:55:42	119	2:41:47	124	2:55:25	118	2:47:12	119	2:48:58	22	0:19:12

Behaviour of females towards baits

Only two female kiwi encountered the five bait types (W13 and W14, Table 2.9). No baits were fed on during any of these encounters, although one female probed the No.7 and RS5 baits (Table 2.10).

Behaviour of chicks towards baits

Only three encounters with each bait type were observed for each of the two kiwi chicks (W11 and W12, Table 2.9). During these encounters chicks were not obviously attracted towards any of the bait types, although one chick probed all of them except for paste (Table 2.9). Compared to the adult male birds, chicks were erratic in their behaviour as they emerged from the nest, frequently wobbling in the entrance way and falling over branches as they moved forward. They probed the ground and everything around them rapidly, including any baits they encountered.

Bait investigation by kiwi

Since no kiwi fed on any of the five bait types during this study, comparisons were made instead between the number of times kiwi investigated each bait type by probing, or probed or fed on the presented worms or cicada nymphs per minute. Values were calculated from the total duration that individual kiwi encountered baits or presented worms or cicadas (Table 2.9) and the number of times they were recorded probing each of these during that time (Table 2.10). Kiwi generally fed on any worms or cicada nymphs which they investigated and only two kiwi probed the worms without feeding on them (i.e. one on a single occasion and the other on five occasions). The combined number of times kiwi probed and fed on worms or cicada nymphs per minute was used, rather than only the number of times kiwi probed these food items.

There was a highly significant difference between the number of times that kiwi probed baits, or probed and fed on worms or cicada nymphs per minute ($F_{5,74}=5.78$; $p<0.0001$). This difference was due to the significantly higher frequency that kiwi probed worms or cicadas nymphs per minute compared to all baits (Student-Newman-Keuls test, $p<0.05$)). Between bait types however, no significant difference in the frequency of probe events could be distinguished (Figure 2.9).

Table 2.10 Total number of times kiwi probed each bait type, or probed or fed on presented worms or cicada nymphs during all individual encounters. The last row indicates the proportion of kiwi that probed each bait type, or probed or fed on worms or cicada nymphs. Kiwi with * were not presented with worms or cicadas.

Food type Kiwi	Carrot	No.7	RS5	Paste	Pulp	Worms or cicada nymphs
W1	0	2	1	1	1	1
W2	0	2	3	0	0	1
W3	1	4	4	1	3	2
W4	1	1	1	0	0	0
W5	5	0	0	2	1	10
W6	3	1	0	2	1	7
W7	0	1	1	1	0	0
W8	0	0	1	2	0	2
W9	1	2	5	2	0	1
W10	0	1	5	3	2	1
*W11	1	1	2	1	0	-
*W12	0	0	0	0	0	-
*W13	0	0	0	0	0	-
*W14	0	1	1	0	0	-
Proportion of kiwi	6 /14	10/14	10/14	9/14	5/14	8/10

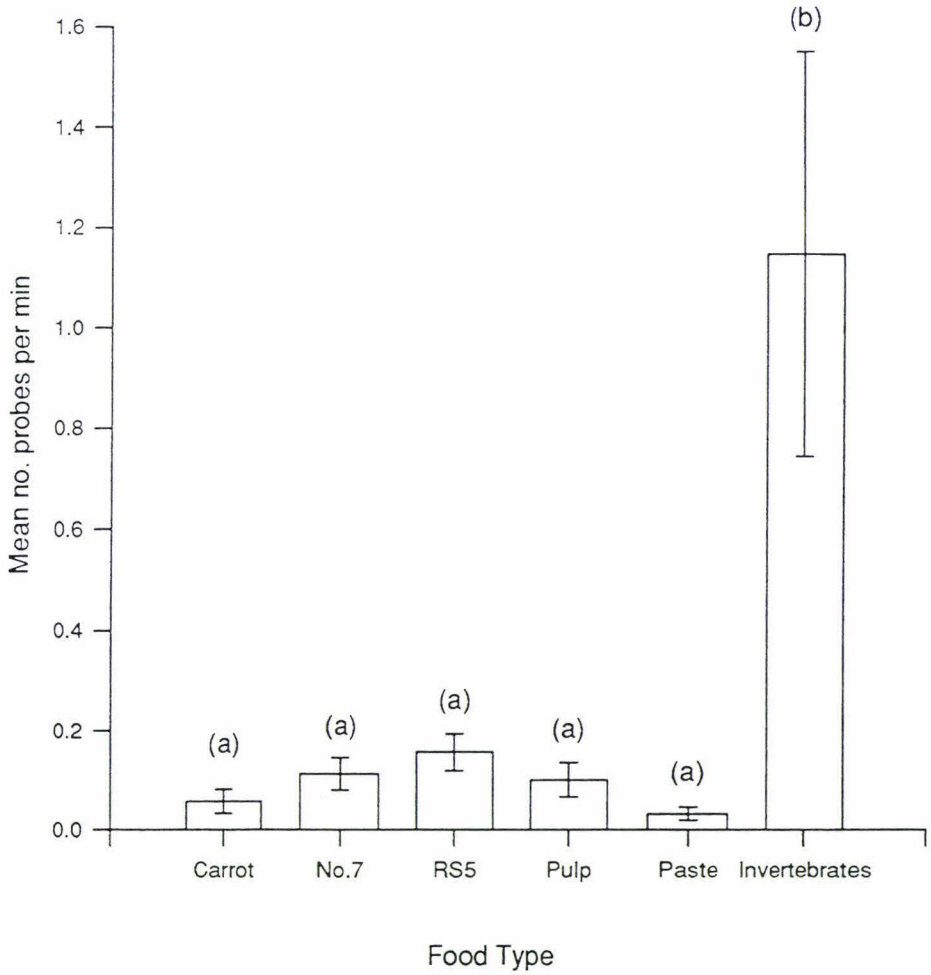


Figure 2.9 Mean number (± S.E.) of probes per minute by wild kiwi (n=14) on each bait type, and by wild kiwi (n=10) on presented invertebrates (worms and cicadas nymphs). Food types which do not share the same letter in brackets differ significantly at $p<0.05$, SNK test.

DISCUSSION

Captive kiwi trials

Did captive birds eat enough to receive a lethal dose?

Although most kiwi ate only a small quantity of any bait type, this may have been enough for a lethal dose had the baits been toxic. However, since there is no known LD_{50} (statistical estimate of the poison dose in terms of milligrams per kilogram of body mass required to kill 50 % of a population, McIlroy 1981) of 1080 for any species of kiwi, the amount of each particular bait required for kiwi to receive a lethal dose of 1080 cannot be calculated. The wide variation in the sensitivity of bird species to 1080 (McIlroy 1984) also makes it impossible to accurately predict an LD_{50} from related or similar sized species (McIlroy 1986). So, in the absence of any experimentally determined LD_{50} of 1080, it is safer to assume that any quantity of bait may contain sufficient 1080 poison for kiwi to receive a lethal dose.

The LD_{50} of cyanide for kiwi is also unknown but it is possible that all seven captive birds which fed on the paste may have consumed a lethal dose had the bait been toxic. This is based on reports that a number of kiwi have been found dead from cyanide poisoning (Reid 1986), and must have consumed only a small quantity of the bait since cyanide paste is generally laid in small pea-sized portions (approx. 0.4 g, Ministry of Agriculture and Fisheries 1991). Kiwi in this study were calculated to consume approximately 1.2 g of paste in each swallow.

Kiwi preference for baits and their usual diet

Although kiwi fed on baits, they preferred their normal diet when it was available. This indicated that baits were not particularly attractive and not a preferred item. Spurr (1993) also found that although captive weka fed on baits, they preferred the meat-based pellets which they were offered regularly in their diet, while captive kaka and red-crowned parakeets preferred seeds.

On the first night of exposure to baits in the absence of their usual diet kiwi fed longer on average (although not significantly so) on all baits combined compared to the following nights when they also had the option of feeding on their normal artificial diet. The higher average duration spent feeding on the first night largely reflected the preference shown by some individuals for particular bait types. Also, it is likely that kiwi have learnt to look for food in their bowls but found only baits on the first night, so feed on them instead as nothing else was available.

The high preference shown by some kiwi for particular bait types differed between kiwi, and was rarely consistent within the same individual on more than one night. Only one female returned to feed on most nights on No.7 and RS5 baits. Spurr (1993) also found that within the species he tested some individuals were more inquisitive than others and therefore more prone to trying novel foods such as baits. For example, only one female kokako out of four fed on any of the carrot or cereal baits offered. Since individual preferences for particular bait types were not consistent between kiwi of the same sex or from the same establishment, such variation may also occur amongst wild kiwi.

Kiwi handling of baits and preference for bait sizes

Although both small and large sizes of cereal baits were eaten, kiwi preferred the larger sized baits which appeared to be easier for them to pick up and manipulate in their bills. Large baits were also preferred by larger birds in Spurr's (1993) captive trials, since they were easier for birds to hold in their claws. Kiwi also ate only whole baits of carrot, No.7 or RS5, and were unable to break baits up, or peck at the bait surface. Birds such as kokako have been observed to peck at bait surfaces and may ingest less poison if the toxin is distributed throughout the bait (Innes and Williams 1990). For kiwi however, baits which are impregnated or surface coated with poison will place the birds at equal risk of poisoning (assuming that baits are fully digested).

Kiwi ranking for bait types

When bait types were ranked according to the proportion of kiwi which fed on them at least once, pulp and paste baits were eaten by most kiwi, followed by carrot, and lastly the cereal bait types No.7 and RS5. A similar trend occurred when baits were ranked for each kiwi in order of the number of times they fed on each type. Therefore kiwi ate

greater quantities of the bait types which more kiwi sampled.

During actual control operations not only the bait type, but also the method used to distribute that bait, will influence which types are most likely to be eaten by kiwi. In areas of large or inaccessible tracts of forest, carrot or cereal baits are frequently distributed by aircraft, and land on the ground where they are accessible to a range of non-target species such as herbivorous and omnivorous ground feeding birds (Spurr 1979). Of the baits we tested that may be aerially sown (e.g. carrot, No.7 and RS5), the cereal bait RS5 was eaten in the smallest quantity and by the fewest kiwi. This was followed by cereal No.7 bait, with carrot likely to be eaten in greater quantities by more kiwi than either of the cereal baits. The preference for carrot bait over cereal baits has also been observed with common bird species during monitoring of early control operations (Harrison 1978). Poison operations which used carrot bait frequently resulted in high numbers of non-target bird deaths, especially if the bait contained small fragments of chaff (Forest Research Institute 1981.; R. Powlesland, pers. comm.). Although bird deaths could be reduced by sieving out carrot 'chaffs', mortality of non-target species was reduced further if cereal baits were used (Harrison 1978). This study has shown that cereal baits may also be the safest bait type to sow aerially in kiwi habitat.

Two types of bait used in ground-based control of pests were tested. These were a pulp bait used as a carrier for 1080 poison (referred to in the field as 1080 paste), and a paste bait used with cyanide poison. Of the five bait types trialled in this study, pulp and paste ranked as most acceptable to captive kiwi. Although little is known about the effects of 1080 pulp use in the field on kiwi, early possum control operations using cyanide paste have been responsible for deaths in all three kiwi species (Spurr 1991). In a 1984 survey, 66 hunters reported finding 37 kiwi that had been poisoned by paste baits containing cyanide (Reid 1985). As a consequence, guidelines were developed to describe safe methods for laying cyanide baits in areas containing ground dwelling birds (e.g. kiwi and weka, Department of Conservation 1995). These include setting baits in containers off the ground, destroying or removing bait within three days of laying, and using only lures which are unattractive to kiwi and weka.

In contrast, there are no similar guidelines for the safe laying of 1080 apple paste baits in areas known to contain ground feeding birds. This study has shown that pulp/apple paste baits may be the most acceptable bait type to kiwi (out of those trialled). This bait is also commonly laid on turned earth, or 'spits' on the ground (Morgan et al. 1997) where it is easily accessible to ground feeding species. Although no monitored kiwi were reported to have died following use of this bait type in Northland (H. Robertson, pers. comm.), this study suggests that the formulation of apple paste baits, and current techniques used to lay these baits, make them potentially the highest risk bait type to kiwi. Safer laying techniques similar to those described for cyanide paste (Department of Conservation 1995), need to be developed for apple paste.

Wild kiwi trials

Bait investigation and feeding on natural foods

None of the wild kiwi trialled fed on any of the five bait types during recorded encounters. Generally, kiwi were not curious about the baits as potential foods, and rarely investigated them beyond an occasional probe or sniff in their direction. Considering the high number of kiwi-bait encounters observed it is likely that baits are not a preferred food item, although this is not to say that kiwi will not feed on baits. Evidence from a previous study has already shown that wild kiwi will sometimes feed on non-toxic cereal baits (Pierce and Montgomery 1992), while, as previously mentioned, paste baits containing cyanide have killed a number of kiwi in the past (Reid 1985) prior to the implementation of safer bait laying techniques.

Eight wild kiwi in this study fed on offered worms or cicada nymphs, or other invertebrates around the nest entrance. This contrasts with no wild kiwi feeding on any of the bait types and clearly demonstrates that kiwi much prefer natural food. While natural foods are available, kiwi may be less inclined to feed on novel items such as baits. Distribution of toxic baits may therefore be safest at times of the year when natural kiwi foods are known to be abundant such as in early winter (Kleinpaste 1990). Most large scale possum control operations are scheduled for winter months and may therefore already take place during the 'safest' months for kiwi. However, with the increasing need to control possums it is likely that poison operations will take place

more frequently, and at more times throughout the year (Morgan 1995). The potential for wild kiwi to be more inclined to sample baits when natural foods are scarce requires further investigation.

While kiwi did not feed on baits, they sometimes probed them. With pulp or paste baits there is potential for kiwi to ingest small quantities of bait in this way. Similarly, if the cereal baits had not been fresh, but had softened through weathering, there would also be potential for kiwi to consume these baits by probing, but this risk is likely to be much less. Kiwi are far more likely to inadvertently ingest ground laid pulp baits (apple paste).

Risks to juvenile kiwi

Understanding the risks that poisoning operations pose to different age classes of birds is an important consideration for managers, since birds of different ages may respond differently to particular bait types. In trials on Kapiti Island, juvenile kaka were considered to be more likely to investigate novel foods, and therefore be at greater risk than adult birds of consuming carrot baits (Lloyd and Hackwell 1993). In this study, although the chicks showed little attraction towards any bait type, their general behaviour appeared to potentially increase their chances of contacting baits. The young chicks probed at everything and would probably probe a bait if they encountered it on the ground.

The decline in populations of mainland kiwi is thought to be primarily due to high levels of predation on juveniles and chicks (McLennan et al. 1996). Additional mortality which may arise from young kiwi probing baits should therefore be minimised by laying or dispensing baits when fewer chicks are around. Again, this is likely to be early to mid-winter. A study is required on how the response of chicks to novel items such as baits, changes as chicks age.

Bait encounters and justification for using nesting kiwi

A critical requirement for this study was to demonstrate that presenting baits to kiwi outside their nest entrance was a realistic experiment that simulated a natural bird-bait encounter. By showing that most kiwi would feed around their nest entrances on

attractive food items that had been placed by hand it was established that the bait rejection shown by kiwi was not a result of human presentation of these items, or because kiwi were too pre-occupied with nest-covering to ever feed close to their nest. Rather, the explanation had to be that kiwi did not find baits attractive.

Observing bait encounters with rarer species is challenging and not a matter of sitting and waiting for an encounter to occur. Often bait encounters have to be induced. For example, kokako have been presented with non-toxic baits on feeding platforms up in trees, and enticed closer by attaching ripe red *Cotoneaster* or *Coprosma* fruits to the platform, or by clanking a chain against a climbing ladder. In the same study, bolas (two baits tied together with cotton) were also thrown up into trees close to feeding kokako (Innes and Williams 1990) to force encounters.

Kiwi are nocturnal and particularly difficult to observe in the wild. Consequently there have been no previous observations of kiwi encounters with baits in the wild, and most studies have monitored the survival of birds throughout actual poisoning operations (Robertson et al. 1993; Lyall 1995; H. Robertson, pers. comm.; Walker 1997). By recording encounters of kiwi with baits placed out-side nest entrances this study was limited to guaranteeing bait encounters with male kiwi only (although we were fortunate to also observe encounters by two females and two juveniles). However, the use of nesting males overcame the difficulty of locating birds at different roost sites each night, and other problems which may have resulted from attempting to entice kiwi into a bait encounter. While it was a challenge to find nesting male kiwi which were accessible with video equipment, this proved to be a robust method of determining directly the response of wild kiwi to a range of bait types, and is the first study to do so.

Captive verses wild kiwi

The results clearly demonstrate that the behavioural response of captive kiwi to baits differs dramatically to that of their wild counterparts. Given that all captive kiwi fed at least once on at least one of the five bait types presented, a management strategy based on the results of captive trials would have to advise that all baits are acceptable to kiwi and therefore potentially harmful. In direct contrast none of the wild kiwi fed on any of

the baits presented. This suggests that in the wild, baits are less acceptable to birds not habituated to feeding on an artificial diet, and even though captive birds are supplied with an excess of food they are more likely to feed on novel items such as baits. The wild results support other studies that have found kiwi to be largely unaffected by operations using these bait types (Pierce and Montgomery 1992; Lyall 1995; H. Robertson, pers. comm.; R. Martin, pers. comm.; Walker 1997), but raise questions over the value of using captive birds in trials that ultimately aim to provide guidance for bait use in the wild. However, while the response of captive kiwi to baits did not directly reflect the response of wild kiwi, there were some similarities. For example, no wild kiwi fed on any carrot, No.7 or RS5 baits during trials and these bait types ranked the three lowest in preference to captive kiwi. Similarly, the only bait types which wild kiwi may have ingested were pulp and paste, and these bait types were the two types most preferred by captive kiwi. While captive studies provide no information on the quantities of bait likely to be consumed by wild birds, they are useful for indicating a rank for which baits birds are potentially most likely to feed on when natural foods are limited.

Conclusions

Kiwi face a number of threats to their continued survival on mainland New Zealand (McLennan et al. 1996) so it is essential that poisoning operations do not place them at greater risk. The decision to use poison in an area containing rare species (e.g. kiwi) should only be made if the need to control pests such as possums is high (e.g. to protect habitat of rare species), and the proportion of wild birds in a population likely to feed on bait low (Spurr 1993). Possums are considered to threaten kiwi in a number of ways; directly by preying on eggs (McLennan 1988.; Reid et al. 1994.; P. Millar, pers. comm.), causing nest desertions, and killing adult birds (McLennan 1996), and indirectly by reducing habitat quality (Spurr 1991) and competing for food. The benefits to kiwi resulting from a reduction in possum numbers may therefore out weigh the potential risk of poisoning kiwi, since this study has shown that the chances of wild kiwi feeding on toxic baits, particularly those used in aerial control, is extremely low. In addition, kiwi may also benefit indirectly from a reduction in rats as a result of 1080 poisoning (Warburton 1989.; Murphy and Bradfield 1992.; Innes et al. 1995), and directly through

the secondary poisoning of stoats and cats (Gillies 1997.; Murphy 1997).

The main points arising from this study are:

1. The response of captive kiwi to the five bait types differed dramatically to that of wild kiwi.

Captive Trials

2. All the captive kiwi tested sampled at least one of the bait types and may have eaten enough for a lethal dose had the baits been toxic.

3. Although no bait type could be ranked significantly higher than another, according to the proportion of kiwi which fed on at least one bait type bait, baits were placed in descending order as: Pulp/Paste > Carrot > No.7 > RS5, and according to the number of times kiwi fed on each unit of bait as: Pulp > Paste > Carrot > No.7 > RS5.

4. Kiwi did not prefer any bait type over their usual artificial diet.

5. Some kiwi showed high individual preferences for particular bait types.

6. Kiwi preferred large sized cereal baits to the small sized cereal baits.

Wild Trials

7. No kiwi fed on carrot or cereal based baits.

8. Kiwi may have ingested pulp or paste baits when they probed or contacted with these bait types.

9. Juvenile kiwi may be at greater risk of poisoning from operations using ground laid 1080 pastes than adults.

10. The results of these trials support previous studies which have found kiwi to be unaffected by aerial 1080 control operations.

11. Testing the response of kiwi to baits placed outside their nest entrance is a robust method of assessing the attractiveness of baits to wild kiwi.

RECOMMENDATIONS

There are two main points which may have valuable implications for management of pest control operations in kiwi habitat.

1. Cereal baits RS5 and No.7 appear to be the safest bait types to distribute aerially in areas known to contain kiwi.

2. In areas where kiwi are present, 1080 apple paste baits should be laid using similar methods to those described by the Department of Conservation for the safe laying of cyanide paste in areas containing ground feeding birds. This may involve;

    - placing the paste in small bait stations (e.g. 'KK", 'Romark', or small flower pots mounted horizontally) above the ground as in Morgan (1997), OR
    - applying the paste directly to trees above the ground.

REFERENCES

Batcheler, C.L. 1978. *Compound 1080, its properties, effectiveness, dangers and use.* New Zealand Forest Service, Wellington, New Zealand.

Calder, B. and Deuss, F. 1985. *The effect of 1080 poisoning on bird populations in Motere, Pureora State Forest, Winter 1984.* New Zealand Forest Service (unpublished) Internal Report ODC 148.2:414.11. Auckland. 34 pp.

Colbourne, R. and Kleinpaste, R. 1983. A banding study of North Island brown kiwis in an exotic forest. *Notornis* 30: 109-124.

Department of Conservation - *Te Papa Atawhai.* 1995. *National Requirements for Trapping and the use of Cyanide.* Department of Conservation, Wanganui Conservancy, Private Bag 3016, Wanganui. 2 pp.

Forest Research Institute. 1981. The effect of 1080-poisoning operations on non-target bird populations. *What's New in Forest Research?* 94: 4 pp.

Gillies, C. 1997. Monitoring the effects of secondary poisoning in predators at Trounson Kauri Park. *National Predator Management Workshop 1997.* St. Arnaud, Nelson Lakes. Department of Conservation, P.O. Box 10-420, Wellington, New Zealand. pp 79-81.

Harrison, M. 1978. The use of poisons and their effect on birdlife. *Seminar on the takahe and its habitat, 1978.* Te Anau. Prepared and Published by the Fiordland National Park Board, Invercargill, New Zealand. pp 203-221.

Haydock, N. and Eason, C. 1997. *Vertebrate Pest Control Manual: Toxins and Poisons.* Department of Conservation, Wellington, 1997. 88 pp.

Innes, J.; Warburton, B.; Williams, D.; Speed, H. and Bradfield, P. 1995. Large-scale poisoning of ship rats (*Rattus rattus*) in indigenous forests of the North Island, New Zealand. *New Zealand Journal of Ecology* 19: 5-17.

Innes, J. and Williams, D. 1990. *Do large-scale possum control operations using 1080, gin traps, or cyanide kill North Island kokako?* Northern Wildlands, Forest and Wildlands Ecosystem Division, Forest Research Institute. Contract report FWE 90/26. Rotorua.

Johnson, T. 1996. *Husbandry Manual for North Island Brown Kiwi (Apteryx australis mantelli).* Rainbow and Fairy Springs, Rotorua, New Zealand.

Jolly, S.E. 1993. Biological control of possums. *New Zealand Journal of Ecology* 20: 335-339.

Kleinpaste, R. 1990. Kiwis in a pine forest habitat. *In*: Fuller, E. (Ed), *Kiwis*, pp 97-138. Swanhill Press, Shrewsbury, England.

Lloyd, B. and Hackwell, K. 1993. *A trial to determine whether kaka consume carrot baits, Kapiti Island, May 1993*. Department of Conservation, Science and Research Internal Report No.62. 14 pp.

Lyall, J. 1995. *Great spotted kiwi monitoring in Karamea following a 1080 possum control programme*. Department of Conservation, Report to the Animal Health Board. 12 pp.

McIlroy, J.C. 1981. The sensitivity of Australian mammals to 1080 poison. I. Intra-specific variation and factors affecting acute toxicity. *Australian Wildlife Research* 8: 369-383.

McIlroy, J.C. 1984. The sensitivity of Australian animals to 1080 poison. VII. Native and introduced birds. *Australian Wildlife Research* 10: 507-12.

McIlroy, J.C. 1986. The sensitivity of Australian animals to 1080 poison IX. Comparisons between the major groups of animals, and the potential danger non-target species face from 1080-poisoning campaigns. *Australian Wildlife Research* 12: 113-18.

McLennan, J.A. 1988. Breeding of North Island brown kiwi, *Apteryx australis mantelli*, in Hawke's Bay, New Zealand. *New Zealand Journal of Ecology* 11: 89-97.

McLennan, J.A. 1996. *Ecology of brown kiwi and causes of population decline in the catchment of Lake Waikaremoana, Te Urewera National Park.* Department of Conservation. Conservation Advisory Science Notes No.96. Gisbourne, New Zealand. 25 pp.

McLennan, J.A.; Potter, M.A.; Robertson, H.A.; Wake, G.C.; Colbourne, R.; Dew, L.; Joyce, L.; McCann, J.A.; Miles, J.; Miller, P. and Reid, J. 1996. Role of predation in the decline of kiwi *Apteryx* spp. in New Zealand. *New Zealand Journal of Ecology* 20: 27-35.

McLennan, J.A.; Rudge, M.R. and Potter, M.A. 1987. Range size and denning behaviour of brown kiwi, *Apteryx australis mantelli*, in Hawke's Bay, New Zealand. *New Zealand Journal of Ecology* 10: 97-107.

Miles, J. 1995. *(Unpublished). "Comparative ecology of northern brown kiwi (Apteryx australis mantelli) in Tongariro National Park and Tongariro Forest Park, central North Island".* MSc. Thesis, Massey University, Palmerston North. 131 pp.

Millar, C.J. and Anderson, S. 1992. Impacts of aerial 1080 poisoning operations on the birds of Rangitoto Island, Hauraki Gulf, New Zealand. *New Zealand Journal of Ecology* 16:103-107.

Ministry of Agriculture and Fisheries. 1991. Sodium Cyanide ('Cyanide') in Pest Control. *Controlled Pesticides*, Agricultural Compounds Unit, Wallaceville Animal Research Centre, Ward Street, P.O. Box 40063, Upper Hutt, New Zealand.

Morgan, D.R. and Goodwin, M. 1995. *Identification of 1080 paste suitable for use in the presence of bees (314/92).* Landcare Research Contract Report No.LC9596/03. Prepared for the Animal Health Board, PO Box 3412, Wellington. 19 pp.

Morgan, D.R.; Ward-Smith, T. and McQueen, S. 1997. *Responses of native birds and bats to 'bee-safe' possum paste.* Landcare Research Contract Report No. LC9697/126. 20 pp.

Murphy, E. 1997. *Secondary poisoning of stoats in a New Zealand forest.* Rare bits 27: 30

Murphy, E. and Bradfield, P. 1992. Changes in diet of stoats following poisoning of rats in a New Zealand forest. *New Zealand Journal of Ecology* 16: 137-140.

Pierce, R.J. and Montgomery, P.J. 1992. *The fate of birds and selected invertebrates during a 1080 operation.* Department of Conservation, Science and Research Internal Report No.121. 17 pp.

Potter, M.A. 1989. *(Unpublished). "Ecology and reproductive biology of the North Island brown kiwi (Apteryx australis mantelli)".* Ph.D. Thesis, Palmerston North, New Zealand. 135 pp.

Rammell, C.G. and Fleming, P.A. 1978. *Compound 1080: properties and uses of sodium monofluoroacetate in New Zealand.* Animal Health Division, Ministry of Agriculture and Fisheries Wellington. 112 pp.

Reid, B. 1985. The opossum trappers - our maligned conservators. *Fur Facts* 6: 18-23.

Reid, B. 1986. Kiwis, opossums and vermin. A survey of opossum hunting; and of target and non-target tallies. *Fur Facts* 7: 37-49.

Reid, B. and Rowe, B. 1978. *Kiwis and their management in captivity.* Progress Report Otorohanga.

Reid, J.; Joyce, L. and Lyall, J. 1994. *Monitoring of breeding of Okarito brown kiwi in Westland National Park 1993-1994.* Department of Conservation, Unpublished Internal Report Hokitika, New Zealand. 34 pp.

Robertson, H.A. 1996. *Kiwi Recovery Plan 1996-2001* (in draft). Department of Conservation. Wellington, New Zealand.

SAS Institute. 1985. *SAS User's Guide*. Cary, North Carolina.

Spurr, E.B. 1979. A theoretical assessment of the ability of bird species to recover from an imposed reduction in numbers, with particular reference to 1080 poisoning. *New Zealand Journal of Ecology* 2: 46-63.

Spurr, E.B. 1991. Effects of brushtail possum control operations on non-target bird populations. *Acta XX Congressus Internationalis Ornithologici* 20: 2534-2545.

Spurr, E.B. 1992. *Feeding by captive kaka on baits used in 1080-poisoning operations.* Department of Conservation, Conservation Advisory Science Notes No.3. Wellington. 3 pp.

Spurr, E.B. 1993. Feeding by captive rare birds on baits used in poisoning operations for control of brushtail possums. *New Zealand Journal of Ecology* 17: 13-18.

Spurr, E.B. 1994. Review of the impacts on non-target species of sodium monofluoroacetate (1080) in baits used for brushtail possum control in New Zealand. *In*: Seawright, A.A. and Eason, C.T. (Eds). *Proceedings of the Science Workshop on 1080.* pp 124-133. The Royal Society of New Zealand, Miscellaneous series No.28. Christchurch New Zealand.

Spurr, E.B. and Powlesland, R.G. 1997. *Impacts of aerial applications of 1080 on non-target native fauna: Review and priorities for research.* Department of Conservation, P.O. Box 10-420 Science for Conservation No.62. Wellington. 31 pp.

Walker, K. 1997. Effects of aerial distribution of 1080 for possum control on weka, great spotted kiwi, morepork and fernbird. *Ecological Management* 5: 21-27.

Warburton. 1989. *The effects of a routine aerial 1080 poisoning operation on rat numbers*. Forest Research Institute Contract Report (unpublished). 14 pp.

Warren, A. 1984. *The effects of 1080 poisoning on bird populations in Tihoi, Pureora State Forest Park, winter 1983*. New Zealand Forest Service Internal Report (unpublished). 34 pp.

Wright, G.R.G. 1995. *Manaaki Whenua* Landcare Research, Toxicology Laboratory, Weeds and Pests Group Toxin Report No.T243. Lincoln.

Appendix 1 Description of Captive and Wild Kiwi used in bait and flavour trials.

M = male, F = female, A = adult, J = juvenile, NIB = North Island brown kiwi (*Apteryx australis mantelli*), GS = Great spotted kiwi (*Apteryx haastii*).

Captive

Kiwi No.	Species	Sex	Age	Location	Captive bred or from wild?	Approximate length of time in captivity at time of trials
C1	NIB	M	A	Otorohanga	Wild	8 months
C2	NIB	F	A	Otorohanga	Wild	14 years
C3	NIB	M	A	Otorohanga	Wild	14 years
C4	NIB	F	A	Otorohanga	Wild	14 years
C5	GS	M	A	Otorohanga	Wild	14 years
C6	GS	F	A	Otorohanga	Captive	8 years
C7	NIB	M	A	Otorohanga	Wild	9 years
C8	NIB	F	A	Otorohanga	Captive	At least 10 years
C9	NIB	F	J	Westshore	Captive	15 months
C10	NIB	M	A	Westshore	Wild	5 years
C11	NIB	F	A	Otorohanga	Wild	7 years

Wild

Kiwi No.	Kiwi name	Species	Sex	Age	Location
W1	Kim	NIB	M	A	Northland
W2	Rimu	NIB	M	A	Northland
W3	Fence male	NIB	M	A	Northland
W4	Mikhail	NIB	M	A	Northland
W5	The Boxer	NIB	M	A	Northland
W6	Jock	NIB	M	A	Waikaremoana
W7	Enis	NIB	M	A	Waikaremoana
W8	Data logger	NIB	M	A	Northland
W9	The Knight	NIB	M	A	Northland
W10	White male	NIB	M	A	Northland
W11	Enis' chick	NIB	Unknown	J	Waikaremoana
W12	Jock's chick	NIB	Unknown	J	Waikaremoana
W13	Visiting Rimu	NIB	F	A	Northland
W14	Visiting White	NIB	F	A	Northland
W15	Visiting Kim	NIB	F	A	Northland

Appendix 2 Mean number (± S.E.) and mean percentage (± S.E.) of each bait type eaten per night (n=5) by kiwi. * denotes the unit used to express amount of each bait.

Carrot * chunks (mean weight of chunk = 3.023 g ± 0.12)

Kiwi	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*Mean*
Amount	0.6 ± 0.4	0.2 ± 0.2	0.6 ± 0.4	1 ± 0.63	0 0	0 0	0.2 ± 0.2	0.2 ± 0.2	0 0	0 0	0.28 ± 0.11
%	1.29 ± 0.86	0.43 ± 0.43	1.29 ± 0.86	2.14 ± 1.36	0 0	0 0	0.43 ± 0.43	0.43 ± 0.43	0 0	0 0	0.6 ± 0.23

No.7 * pellets (mean weight of large pellet = 4.014 g ± 0.06, small pellet = 0.59 g ± 0.006)

Kiwi	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*Mean*
Amount	0 0	6.6 ± 2.02	0 0	0.2 ± 0.2	0.6 ± 0.6	0 0	0 0	0.2 ± 0.2	0 0	0 0	0.76 ± 0.65
%	0 0	18.37 ± 5.93	0 0	0.57 ± 0.57	1.71 ± 1.71	0 0	0 0	0.57 ± 0.57	0 0	0 0	2.12 ± 1.81

RS5 * pellets (mean weight of large pellet = 3.308 g ± 0.05, small pellet = 0.6 g ± 0.004)

Kiwi	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*Mean*
Amount	0.2 ± 0.2	4.4 ± 1.33	0 0	0 0	0 0	0.2 ± 0.2	0 0	0 0	0 0	0 0	0.48 ± 0.44
%	0.09 ± 0.09	8.44 ± 3.07	0 0	0 0	0 0	0.47 ± 0.47	0 0	0 0	0 0	0 0	0.90 ± 0.84

Pulp * swallows (mean weight per swallow = 1.2 g)

Kiwi	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*Mean*
Amount	1 ± 0.77	0.4 ± 0.4	0 0	0.8 ± 0.37	19 ± 19	4.4 ± 3.67	0 0	0 0	0.6 ± 0.6	0.4 ± 0.4	2.66 ± 2.24
%	0.86 ± 0.66	0.34 ± 0.34	0 0	0.69 ± 0.32	13.57 ± 13.57	3.77 ± 3.14	0 0	0 0	1.03 ± 1.03	0.69 ± 0.69	2.37 ± 1.91

Paste * swallows (mean weight per swallow = 1.2 g)

Kiwi	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*Mean*
Amount	0.4 ± 0.4	0 0	0 0	6.8 ± 6.55	0.2 ± 0.2	0 0	0.8 ± 0.58	1.6 ± 0.93	0.4 ± 0.4	0.2 ± 0.2	1.04 ± 0.66
%	0.34 ± 0.34	0 0	0 0	5.83 ± 5.62	0.17 ± 0.17	0 0	0.69 ± 0.5	1.37 ± 0.8	0.69 ± 0.69	0.34 ± 0.34	0.94 ± 0.56

Appendix 3 Number (e.g. chunks of carrot, individual No.7 or RS5 pellets, or swallows of pulp or paste) of each bait type eaten by each kiwi on nights one (in the absence of their usual diet) and nights two to five (when their usual diet was presented after two hours).

Night 1

Kiwi	Carrot	No.7	RS5	Pulp	Paste
C1	0	0	0	1	2
C2	0	0	4	0	0
C3	0	0	0	0	0
C4	2	0	0	2	33
C5	0	3	0	95	1
C6	0	0	0	19	0
C7	0	0	0	0	0
C8	0	0	0	0	0
C9	0	0	0	0	0
C10	0	0	0	0	0
Total	**2**	**3**	**4**	**117**	**36**

Night 2

Kiwi	Carrot	No.7	RS5	Pulp	Paste
C1	2	0	0	0	0
C2	0	11	0	0	0
C3	0	0	0	0	0
C4	0	0	0	0	0
C5	0	0	0	0	0
C6	0	0	1	2	0
C7	0	0	0	0	3
C8	0	0	0	0	5
C9	0	0	0	0	0
C10	0	0	0	3	1
Total	**2**	**11**	**1**	**5**	**9**

Night 3

Kiwi	Carrot	No.7	RS5	Pulp	Paste
C1	1	0	1	4	0
C2	0	9	6	0	0
C3	1	0	0	0	0
C4	3	1	0	1	1
C5	0	0	0	0	0
C6	0	0	0	1	0
C7	1	0	0	0	1
C8	1	0	0	0	1
C9	0	0	0	0	2
C10	0	0	0	0	0
Total	**7**	**10**	**7**	**6**	**5**

Night 4

Kiwi	Carrot	No.7	RS5	Pulp	Paste
C1	0	0	0	0	0
C2	0	4	8	0	0
C3	2	0	0	0	0
C4	0	0	0	0	0
C5	0	0	0	0	0
C6	0	0	0	0	0
C7	0	0	0	0	0
C8	0	1	0	0	2
C9	0	0	0	0	0
C10	0	0	0	0	0
Total	**2**	**5**	**8**	**0**	**2**

Night 5

Kiwi	Carrot	No.7	RS5	Pulp	Paste
C1	0	0	0	0	0
C2	1	9	4	2	0
C3	0	0	0	0	0
C4	0	0	0	1	0
C5	0	0	0	0	0
C6	0	0	0	0	0
C7	0	0	0	0	0
C8	0	0	0	0	0
C9	0	0	0	2	0
C10	0	0	0	0	0
Total	**1**	**9**	**4**	**5**	**0**

Response of captive and wild kiwi to a range of flavours added to baits used for pest control in New Zealand.

ABSTRACT

The response of captive North Island brown kiwi (*Apteryx australis mantelli*) to cinnamon, aniseed, orange and clove flavours commonly added to baits used for pest control, was evaluated by presenting these to kiwi in portions of their usual artificial diet and on No.7 cereal baits. The response of wild kiwi to cinnamon and orange flavoured No.7 cereal baits placed outside nesting burrows was also determined. None of the flavours significantly attracted, or deterred captive kiwi from feeding on their usual artificial diet either in the first two hours of the night or throughout the whole night. Insufficient flavoured cereal No.7 baits were eaten by captive kiwi to determine whether any bait and flavour combination affected kiwi response to these flavours. No wild kiwi were attracted by cinnamon or orange flavours to feed on No.7 cereal baits during recorded encounters, but these flavours did not deter kiwi from probing baits either. No flavour appeared to be effective for use as a kiwi deterrent, although cinnamon and orange flavours are unlikely to increase the risk of wild kiwi feeding on baits.

INTRODUCTION

Baits used in mammal pest control operations in New Zealand have been modified in a number of ways to reduce mortality of non-target birds. These include removing bait fragments found to be harmful to small passerines (Harrison 1978), and dying baits green, a colour found to be least attractive to birds (Kalmbach and Welch 1946; Caithness and Williams 1971; Pank 1976; Udy and Pracy 1981; Brunner and Coman 1983; Bryant et al. 1984). In addition, flavours found to be attractive to possums and rodents, and repellent to some bird species have also been added to baits to increase target specificity (Udy and Pracy 1981).

Flavours added to baits in New Zealand

Studies overseas and in New Zealand have shown that the addition of flavours to baits improves their acceptance to some target species (Bullard and Shumake 1977; Morgan 1990), by attracting the pest to the bait and by masking from them the smell and taste of the poison (Udy and Pracy 1981). In New Zealand, compounds which have been added to baits for such purposes have been food-based flavours such as cinnamon, aniseed, almond, banana, clove, eucalyptus, juniper, raspberry, rose and wintergreen (Reid 1986). Cinnamon was also identified in trials on Kapiti Island to have the additional characteristic of being repellent to weka, kaka and ducks (Udy and Pracy 1981), and consequently has been added routinely to a number of baits used in pest control since 1983 (Pracy et al. 1982; Morgan et al. 1986; Morgan 1990). Other flavours (e.g. juniper, rose, raspberry and wintergreen) have been banned from use because of their known attractiveness to kiwi (Udy and Pracy 1981), and for causing high mortality of common birds during some early 1080 operations (e.g. raspberry lure, Harrison 1978). A range of flavours are currently now added to baits in New Zealand. Cinnamon essence is commonly used on cereal pellet baits (Haydock and Eason 1997), cinnamon, orange, aniseed, plum, cherry and lemon are used with carrot baits (Haydock and Eason 1997), and cinnamon, orange, lemon, allspice, clove, eucalyptus and aniseed are used primarily as lures on cyanide paste (P. Thomson, pers. comm.; B. Bancroft, pers. comm.).

Testing flavours on non-target bird species

Although birds are thought to have rarely more than 100 taste buds (in comparison to mammals which may have several thousand (Wenzel 1973)) it has been shown that birds are capable of discriminating between different flavours (Kare 1965; Berkhoudt 1985). A concern with adding flavours to baits for the purpose of increasing target specificity, is that some flavours may also be attractive to birds and potentially encourage them to feed on baits. Kiwi have a large olfactory bulb ratio in comparison to forebrain size and are considered to have a well developed sense of smell (Wenzel 1968). They may therefore have a greater capacity to discriminate flavours than other bird species, and could be at greater risk of consuming toxic baits if they contain a flavour which kiwi find attractive.

In New Zealand, flavours which are added to pest control baits have been shown to have limited repellent effect on some bird species (e.g. cinnamon), or have not caused substantial deaths of non-target bird species in the past (e.g. orange, aniseed, clove). However, the response of non-target native bird species to any of the flavours which are used currently has been little tested. In a captive study some individuals from each of seven species of native birds fed on baits lured with cinnamon (Spurr 1993). Cinnamon was effective at deterring North Island kaka, Antipodes Island parakeets and kokako from feeding on baits for the first day of presentation only, while saddlebacks were undeterred by cinnamon lure (Spurr 1993). Only one study has investigated the response of captive kiwi to cinnamon and other potential bait lures such as dimethyl anthranilate (DMA), optamint and amyl acetate (McLennan et al. 1992). None of these four chemicals which were added to portions of the kiwis' normal food, significantly reduced their feeding, although amyl acetate repelled birds for the first few hours of darkness and DMA partially repelled three of the birds. Cinnamon did not prevent kiwi from feeding despite their food smelling strongly to human observers (McLennan et al. 1992). Although no kiwi mortality has been detected following poisoning operations using cinnamon lured cereal baits (Pierce and Montgomery 1992; H. Robertson, pers. comm.), it is unresolved whether cinnamon has any deterrent effect, since wild kiwi are known to have fed on non-toxic cinnamon lured pollard baits (Pierce and Montgomery 1992).

Ideally, any compound or flavour which is added to pest control baits needs to possess attributes which render it (1) attractive to the pest species and (2) unattractive, or deterrent to non-target species. While there are a number of bird repellents known from overseas that could potentially be used to protect birds from feeding on toxic baits (Crocker 1990; Clark 1991; Spurr 1995; Watkins 1996), the focus for adding flavours to baits in New Zealand has been primarily focused towards attracting the pest species. The aims of this study were firstly to determine whether the flavours cinnamon, aniseed, orange or clove are (1) deterrent or (2) attractive to captive kiwi, by placing these flavours into separate portions of their usual artificial diet, and on to No.7 cereal baits. The second aim was to video record the response of wild kiwi towards cinnamon and orange flavoured cereal No.7 baits placed outside their nest entrance.

For a flavour to be classified as safe for use on baits in kiwi habitat (i.e. kiwi are deterred or indifferent) the response of kiwi to the portion of their artificial diet containing that flavour should either be significantly reduced, in comparison to the unflavoured or other flavoured portions, or should not differ. By adding flavours to No.7 baits it was possible to investigate whether there was any bait flavour interaction which affected the response of captive kiwi to the bait. The encounters of wild kiwi with flavoured baits will be the first to be recorded directly.

MATERIALS AND METHODS

Materials

Four flavoured oils were chosen for testing; cinnamon, aniseed, orange and clove, as they are added to a range of bait types, including cereal, carrot and paste (Haydock and Eason 1997; P. Thomson, pers. comm.). The flavoured oils were obtained from Animal Control Products Ltd., Waimate.

The baits used in the flavoured trials were non-toxic cereal No.7 baits. These were tested as they are a main bait type used for possum control in large and/or accessible areas of forest (Spurr 1994). Baits had a mean weight of 4.0 g, and were dyed green with Bayer V200 0.1% wt:wt bait, to be within the colour range of 221-267 of the New Zealand Standards Specification 7702 1989 (Haydock and Eason 1997). For a description of bait preparation, see Chapter 2 (Materials and Methods).

Captive kiwi trials

The birds used were captive North Island brown kiwi (*Apteryx australis mantelli*) held at Otorohanga Kiwi House, Otorohanga, and Westshore Reserve, Napier. A description of the kiwi enclosures and the artificial diet fed daily is provided in Chapter 2 (Materials and Methods).

Presenting flavours to kiwi in their artificial diet

Kiwi Used

Seven kiwi were available for trials. Two kiwi pairs and one single female kiwi were held at Otorohanga Kiwi House, and one single juvenile female, and one adult male kiwi were held at Westshore Reserve Napier. The kiwi are identified as C3, C4, C7, C8, C9, C10 and C11, in Appendix 1, Chapter 2.

Method

Kiwi preference for five flavours; cinnamon, aniseed, orange, clove and unflavoured, was evaluated by adding these flavours to portions of their usual artificial diet and comparing the duration spent feeding on each. Kiwi were presented with their usual nightly ration of food in five separate equal portions placed into separate bowls. One of each of the four flavours was added to a portion of the food at a concentration of 0.1% v:wt (which is a standard concentration added to baits, Haydock and Eason 1997), while one portion remained unflavoured. Bowls containing the food portions were placed on the ground 40 cm apart in a square design with a bowl at each corner, and the unflavoured portion placed in the centre. For each of four nights, flavoured food portions were assigned randomly to bowl positions so that each flavour occurred only once in every position. This avoided bias which may have arisen from birds having preferred feeding positions.

The sex of the kiwi (when in pairs), and the duration (sec) spent feeding on each of the flavoured portions in the first two hours of the night, and throughout the whole night was recorded. Flavour concentrations were expected to decline as the night progressed. Therefore, the duration that kiwi fed on flavoured portions in the first two hours of the night was recorded since this was when kiwi may have shown most preference for particular flavours over others.

Trials were recorded using a video camera with an infra-red light source attached. The camera was positioned at least 2 m away and recorded all activity within 0.5 m radius of the bowls. The time-lapse recorder and monitor (displaying the time/date/recording time) were located either inside a shed within the kiwi enclosure, or under plastic in an

adjacent enclosure. In each feeding trial the bowls were positioned in the kiwi enclosure at least half an hour before sunset. Recording began each night at dusk and continued until dawn.

Analysis

The duration (sec) that kiwi fed on each food portion was used to investigate preferences for individually flavoured and unflavoured food portions, in the first two hours of the night, and throughout the whole night. Data were examined using the General Linear Model Procedure of SAS (SAS Institute 1985). A Repeated Measures ANOVA was used to investigate the feeding duration on separate food portions within, and between nights. Duration data for feeding in the first two hours of the night were log transformed to improve normality prior to analysis.

Presenting flavoured baits to kiwi

Kiwi Used

Six kiwi were available for flavoured bait trials. One pair of kiwi and two single females were held at Otorohanga Kiwi House, while one juvenile female and one adult male were held at Westshore Reserve, Napier. The kiwi are identified as C3, C4, C8, C9, C10, and C11, in Appendix 1, Chapter 2.

Method

One of each of the flavours to be tested (cinnamon, aniseed, orange and clove) was added to the surface of 100 g (approximately 25 baits) of non-toxic cereal No.7 baits at a concentration of 0.1 % v:wt using a small syringe. 100 g of cereal No.7 bait was left unflavoured. Portions of flavoured bait were placed in separate bowls on the ground in a circle approximately 40 cm apart. Baits were presented to kiwi in this way for five consecutive nights. Each portion of flavoured bait was assigned randomly to a separate bowl position so that flavours occurred only once in each position during the trial. The sex of the kiwi feeding on baits, and the number of flavoured baits eaten by that bird were recorded using a video camera with an infra-red light source attached, as in the flavoured food trials.

Wild kiwi trials

Six radio-tagged nesting male North Island brown kiwi from Rarewarewa Bush, Whangarei, Northland (35°37'S, 174°08'E) (see Figure 2.1, Chapter 2) were used in trials which ran between July and September 1997. The kiwi are identified as W1, W2, W3, W4, W5, and W10, and are listed in Appendix 1, Chapter 2. A description of the kiwi habitat and justification for using nesting kiwi is provided in Chapter 2 (Materials and Methods).

The baits used were non-toxic cereal No.7 baits identical to those used in the captive kiwi flavoured bait trials. Orange or cinnamon flavours were added to the surface of the baits at a concentration of 0.1 % v:wt using a small syringe.

Pre-treatment of kiwi

The wild kiwi used in this trial had been previously exposed for five nights to a range of non-toxic unflavoured baits used in wild mammal control, and these included cereal No.7 baits. During these prior bait encounters no kiwi fed on any of the unflavoured No.7 baits presented (but see Wild Results, Chapter 2). Five out of the six male kiwi (W1, W2, W3, W5 and W10) had however, been observed feeding on food items presented to them outside their nest entrance, and on other naturally occurring invertebrates (see Table 2.8, Chapter 2). The later results were used to illustrate that these kiwi would feed on attractive food items presented to them by humans around their nest, and therefore if baits had been rejected it was not due to human presentation. It was unnecessary therefore to re-demonstrate for this trial that the same kiwi would feed on natural foods in this way. We assumed that presentation of flavoured baits outside the nest entrance was a legitimate method of testing the response of kiwi to these flavoured baits.

Since kiwi had not fed previously on unflavoured cereal No.7 baits it was only possible to investigate in this study whether the addition of orange or cinnamon flavours encouraged kiwi to feed on these baits, and not whether these flavours were effective at deterring them from feeding.

Presenting cinnamon and orange flavoured baits

Flavoured cereal No.7 baits were presented to kiwi for four consecutive nights immediately following the trials in which kiwi had been presented a range of unflavoured bait types. Approximately 100 g of flavoured cereal No.7 bait was placed on the ground outside the nest entrance. Half of the kiwi tested were presented with cinnamon flavoured baits for two nights followed by two nights of orange flavoured bait, the other half received orange flavoured baits first. Kiwi encountered the baits as they emerged and re-entered their nest. 'Encounters' were defined as the duration (sec) that kiwi spent within 0.5 m of baits and were recorded using a low-light video camera with an infra-red light source attached. The camera was positioned approximately two metres from the nest entrance either behind, or up a tree, and recorded continuously from dusk until dawn. The recorder and monitor were located 18 m away under a plastic cover.

In addition to the number and duration of encounters, any bait investigation by kiwi such as the number of times they probed (defined as kiwi contacting bait with their bills), or fed on baits was recorded.

RESULTS

Captive kiwi trials

Response of kiwi to flavours added to their artificial diet

Kiwi generally fed from the first bowl they encountered and did not appear to discriminate between any of the flavoured, or unflavoured food portions. Kiwi always had food remaining in every bowl at the end of the each night. The exception to this was one occasion when a cat climbed into the enclosure of kiwi C10 and ate most of the orange-flavoured food portion on night two.

Feeding during the first two hours

The duration that kiwi fed on each the five food portions in the first two hours of the night did not differ significantly within any night of the trial (Table 3.1). Figure 3.1

shows the mean duration that kiwi fed on food portions during the first two hours of each night. There was also no significant difference between nights in the total duration that kiwi fed on all the food portions combined in the first two hours of the night ($F_{3,18}$=0.1361; p=0.9372) and no statistically significant preference for any food portion that changed with night ($F_{12,48}$=0.7920; p=0.6562).

Table 3.1 Repeated Measures Analysis of Variance investigating differences between the duration spent feeding on each flavoured food portion (cinnamon, aniseed, orange, clove, unflavoured) on nights 1 to 4, during the first two hours of presentation. Significance values are shown in the last column.

Night	DF	Mean Squares	F-ratio	P
1	4,20	0.4286	0.38	0.8214
2	4,20	0.6317	0.53	0.7129
3	4,20	1.4101	1.99	0.1356
4	4,20	0.4860	0.47	0.7569

Feeding throughout the whole night

On no night of the trial was a statistically significant difference found between the total duration that kiwi fed on each food portion (Table 3.2). Kiwi also showed no statistically significant preference for any food portion that changed with night ($F_{12,48}$=0.5592; p=0.8632). Figure 3.2 shows the mean duration spent feeding on each food portion by kiwi throughout the whole night.

Table 3.2 Repeated Measures Analysis of Variance investigating differences between the total duration that kiwi fed on each flavoured portion of food (cinnamon, aniseed, orange, clove, unflavoured) on nights 1 to 4. Significance values are shown in the last column.

Night	DF	Mean Squares	F-ratio	P
1	4,20	71192.86	0.46	0.7662
2	4,20	10942.06	0.13	0.9680
3	4,20	139327.44	2.25	0.1001
4	4,20	33164.24	0.78	0.5488

Kiwi preferences for flavours

1. Cinnamon

Only one kiwi fed marginally longer on average on cinnamon than on unflavoured food ((b) Figure 3.3) during the trial. One male kiwi ((a) Figure 3.3) did not feed on cinnamon in the first two hours of exposure but did eventually during the night, while cinnamon effectively deterred one female from feeding during the first two hours of exposure to this flavour, and throughout the whole night ((e) Figure 3.3). The same female only ever fed on unflavoured food during the first two hours of presentation of food.

2. Aniseed

All kiwi trialled fed at some stage on aniseed flavoured food. Only one kiwi avoided feeding on this flavour during the first two hours of the night, while another fed only minimally ((e) and (f) respectively, Figure 3.3).

3. Orange

All kiwi trialled fed on orange flavour, although two kiwi avoided feeding on this flavour during the first two hours of the night ((a) and (e), Figure 3.3).

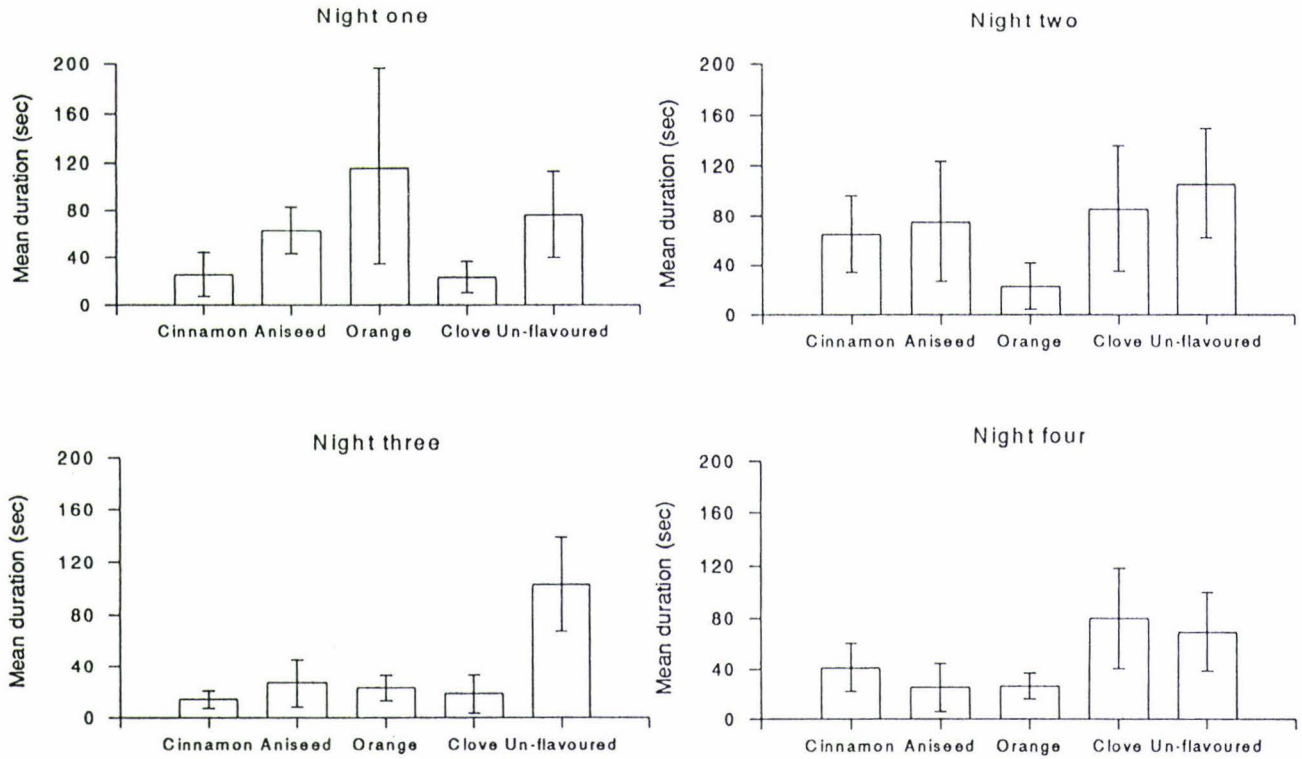


Figure 3.1 Mean duration (sec) (± S.E.) spent feeding by captive kiwi (n=7) on flavoured food in the first two hours of exposure to food on nights one to four. No significant differences were found between any flavoured or unflavoured portions on any night.

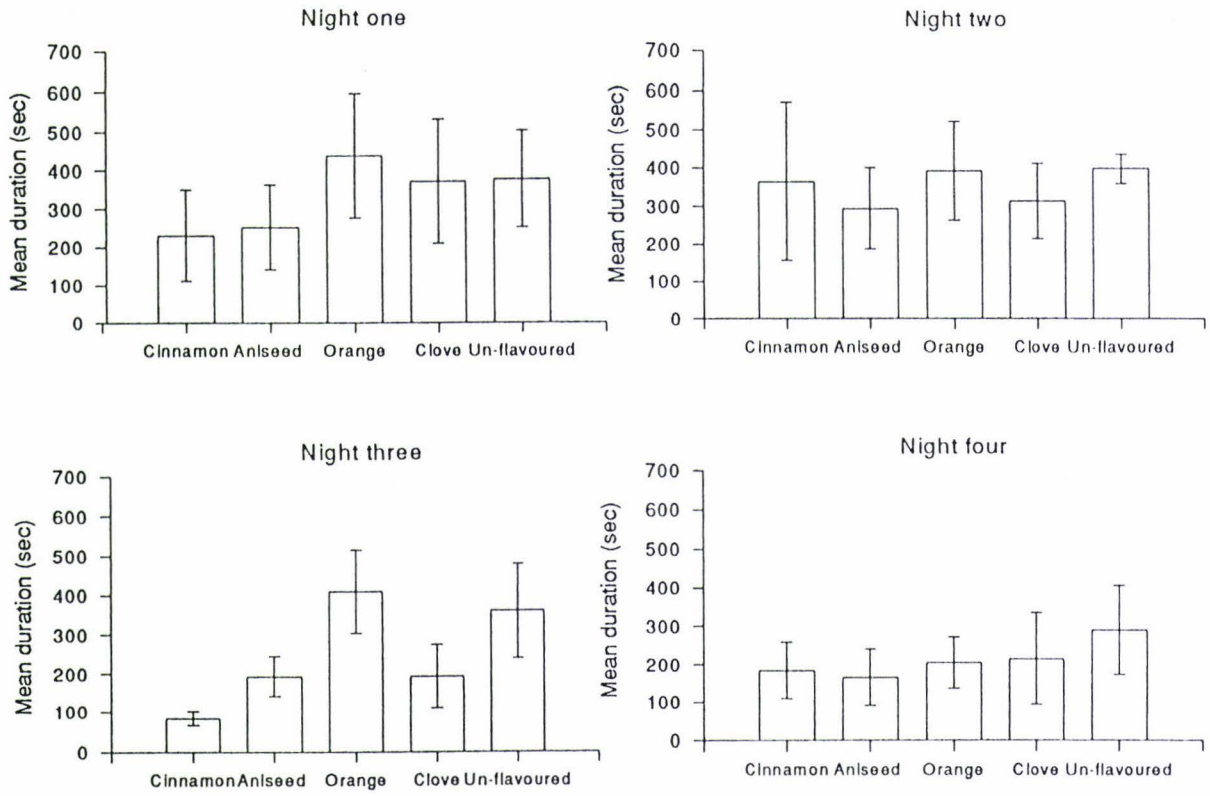


Figure 3.2 Mean duration (sec) (± S.E.) spent feeding by captive kiwi (n=7) on flavoured food throughout the whole night on nights one to four. No significant differences were found between any flavoured or unflavoured food portions on any night.

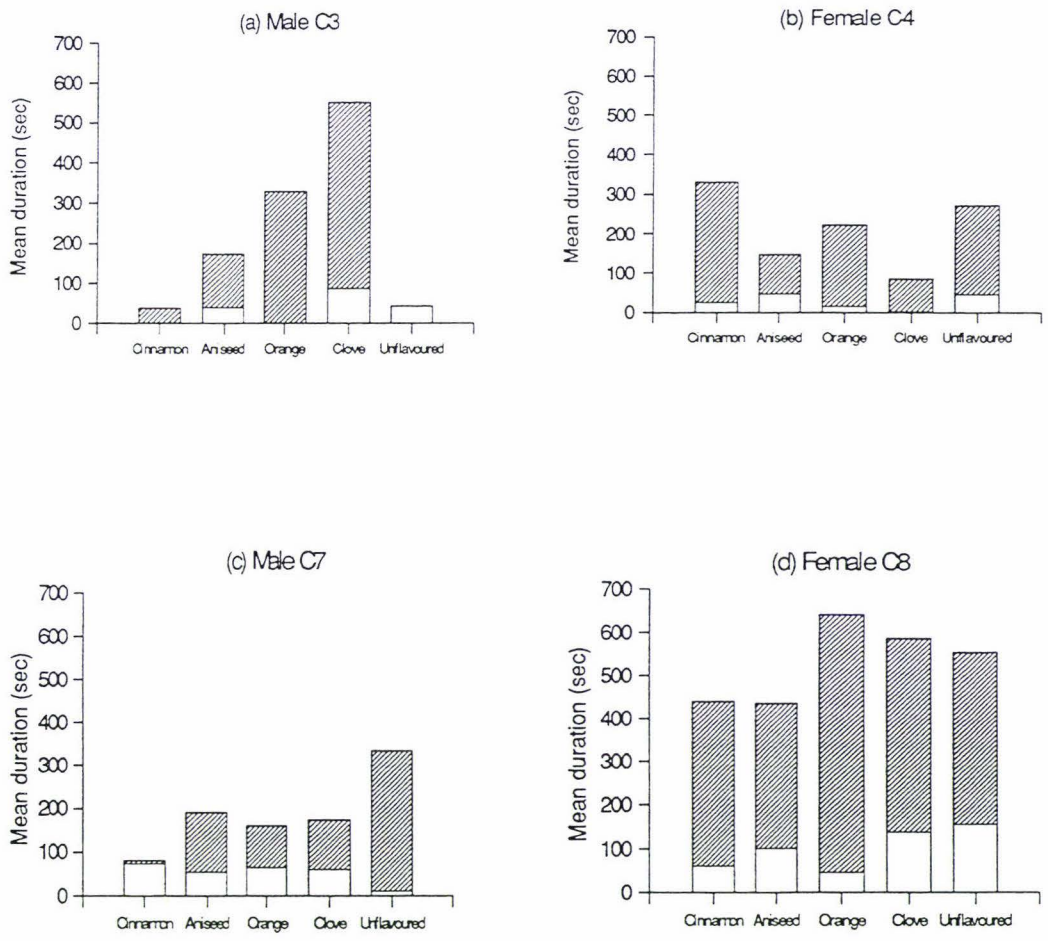
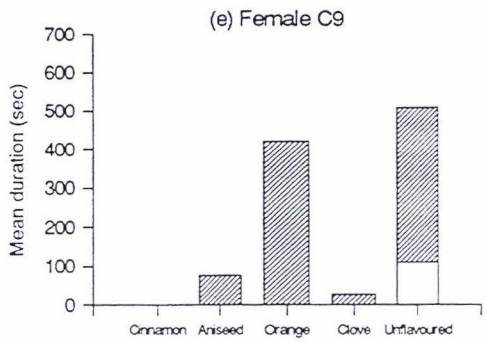
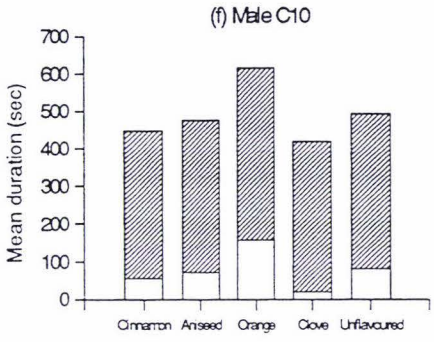


Figure 3.3 Mean duration (sec) spent feeding by captive kiwi (a-f) on each portion of food (i.e. cinnamon, aniseed, orange, clove, unflavoured) in the first two hours of the night (clear section of the bar), and throughout the whole night (clear and hatched sections of the bar).





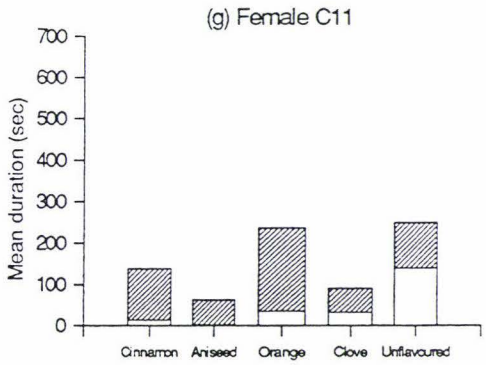


Figure 3.3 Continued.

4. Clove

All kiwi trialled fed on clove flavoured food, although one kiwi only fed minimally during the first two hours of the night ((b) Figure 3.3), and one kiwi totally avoided feeding on this flavour during first the two hours ((e), Figure 3.3). One male kiwi showed a greater preference for clove compared to unflavoured food, but also preferred aniseed, and orange to unflavoured food ((a) Figure 3.3).

Rejection of flavoured food by kiwi

Although kiwi fed on flavoured food there was some indication that the birds were reluctant. On five occasions three kiwi were observed 'cleaning' the food, once each with cinnamon and aniseed, and three times with orange flavoured food. This involved picking up shreds of the flavoured meat or tofu and dragging them through the grass, or soil before feeding on them. Occasionally, the food was still rejected and dropped on the ground even after 'cleaning'. This behaviour was never recorded when kiwi fed on unflavoured food.

Four of the kiwi trialled also rejected the flavoured food immediately as it was picked up. In the first two hours of exposure to the flavoured food one kiwi rejected three pieces of cinnamon, two pieces of aniseed and two pieces of clove meat during the four nights of the trial. Another kiwi rejected one piece of each of cinnamon and orange tofu, while a female also rejected two pieces of orange tofu. Flavoured food was also rejected later on in the night by two females each immediately dropping a piece of orange tofu.

Kiwi response to flavoured baits

Kiwi ate few flavoured baits during the five nights of the trial (Table 3.3). Most (91%) of the baits that were eaten were consumed by one kiwi (C4), and a high proportion (57%) of those were clove flavoured. Kiwi ate only flavoured baits which were whole and did not break them up.

Table 3.3 Total number of flavoured baits eaten by kiwi (n=6) over five trial nights.

Flavour Kiwi no.	Cinnamon	Aniseed	Orange	Clove	Unflavoured	**Total**
C3	0	0	0	0	0	**0**
C4	6	6	2	24	4	**42**
C8	0	0	2	1	0	**3**
C9	0	0	0	0	0	**0**
C10	0	0	0	0	0	**0**
C11	1	0	0	0	0	**1**
Total	**7**	**6**	**4**	**25**	**4**	**46**

Wild kiwi trials

During this study seven wild kiwi were exposed to cinnamon and orange flavoured cereal No.7 baits. Six of these were nesting males and one was an adult kiwi which passed close to a nest during video recording. These are identified as kiwi W1, W2, W3, W4, W5, W10 and W15 respectively, in Appendix 1, Chapter 2.

Feeding on natural foods

Five out of the six kiwi had been previously recorded feeding on food items presented to them outside their nest, and this justified presenting them with flavoured baits. However, two kiwi were also observed to feed on invertebrates around their nest during the flavoured bait trials. Kiwi W3 fed twice on invertebrates in the presence of cinnamon flavoured baits, while kiwi W5 fed on invertebrates once in the presence of cinnamon flavoured baits and twice in the presence of orange flavoured baits. Although the invertebrates had not been presented to kiwi, this still supports our initial observations of kiwi feeding around their nest.

Response of kiwi to orange and cinnamon flavoured baits

The male kiwi encountered flavoured cereal No.7 baits each time they emerged or re-entered their nest during the night. Each nesting kiwi was video recorded encountering baits for a total of four nights (two nights with each of cinnamon and orange flavours). However, the number of individual kiwi encounters with each flavoured bait sometimes

differed. This was due to two of the male kiwi leaving and returning to their nest more than once during the night and therefore encountering baits more frequently (Kiwi W3 and W5; Table 3.4, and W5; Table 3.5).

In total, kiwi encountered cinnamon baits 34 times, for a total duration of 57 min 6 sec (Table 3.4), and orange baits 29 times, for a total duration of 37 min 12 sec (Table 3.5). During these recorded encounters there was only one occasion where a bait was picked up. This bait was orange-flavoured and was dropped immediately by the kiwi (Table 3.5). Kiwi were observed to sniff and sometimes probe baits (Tables 3.4 and 3.5) but no other attempts were made to pick baits up, or to feed on them.

Behaviour of males as they emerged and re-entered the nest

All nesting male kiwi with the exception of one, emerged from their nest and began covering the entrance with sticks and leaf material. Kiwi then stepped forward continuing to flick material towards the entrance and eventually moved out of view using a route similar to that which they had used previously during the earlier unflavoured bait trials (see Wild Trials results, Chapter 2). When kiwi returned to their nest they approached the entrance again via a regular route and entered quickly. This behaviour was observed with all but one of the kiwi tested. This male frequently sniffed the air in the direction of the flavoured baits as he emerged from the nest. He began flicking stick and leaf material towards the entrance but stepped back after sniffing towards the flavoured baits. He then either climbed up the back of the nest, or clambered over branches piled up at the side, instead of walking out at the front. This behaviour was observed during encounters with both cinnamon and orange cereal No.7 baits and had not been previously recorded during trials with unflavoured baits. The male however, re-entered the nest at the front by walking over or between the baits.

The kiwi which passed close to the nest entrance (Kiwi W15; Table 3.5) encountered orange-flavoured cereal No.7 baits only once. The bird walked up to the nest entrance, probed the ground close to the piles of baits and then backed away from the nest without making any contact with the baits.

Table 3.4 Total number and duration of kiwi encounters with cinnamon-flavoured cereal No.7 baits, and number of times baits were probed by kiwi.

Kiwi no.	Total no. encounters with cinnamon No.7	Total duration (min:sec) of encounters with cinnamon No.7	Total no. times kiwi observed probing cinnamon No.7
W1	4	02:03	0
W2	4	05:29	1
W3	6	17:33	3
W4	4	02:33	0
W5	12	17:44	6
W10	4	11:44	0
W15	0	0	0
Total	**34**	**57:06**	**10**

Table 3.5 Total number and duration of kiwi encounters with orange-flavoured cereal No.7 baits, and number of times baits were probed by kiwi. NB. * indicates a bait which was picked up by a kiwi and dropped immediately.

Kiwi	Total no. encounters with orange No.7	Total duration (min:sec) of encounters with orange No.7	Total no. times kiwi observed probing orange No.7
W1	4	03:09	0
W2	4	05:22	0
W3	4	05:42	1*
W4	4	04:29	4
W5	8	08:01	0
W10	4	09:52	3
W15	1	00:37	0
Total	**29**	**37:12**	**8**

DISCUSSION

Captive kiwi flavour trials

Response of kiwi to flavours added to their artificial diet

Captive kiwi did not discriminate significantly between the five different flavoured portions of food during the first two hours of presentation, or throughout the whole night. The strength of the flavours were expected to decline as the night progressed and therefore any preference that kiwi may have had towards particular flavoured or unflavoured food portions to be most pronounced during the first few hours of the night. Additionally, during the early hours of the night kiwi may also have had less time to become accustomed to distasteful flavours. However, this was not the case, and if flavours were stronger in concentration during the early hours of the night then this had no significant influence over the way in which kiwi fed on each food portion.

Although none of the four flavours were effective at deterring kiwi from feeding on their usual artificial diet (in comparison to unflavoured food), there was some indication that the flavoured portions of food were not always acceptable to kiwi. This was illustrated by some birds cleaning flavoured food before attempting to eat it, while others rejected pieces of flavoured food completely. Despite some individuals displaying this behaviour, all but one kiwi fed on all of the four flavours during the trial. This kiwi was completely deterred from feeding on cinnamon flavoured food every night of presentation, and only ever fed on unflavoured food during the first two hours of each night. The kiwi was the youngest trialled (only fifteen months old) and had been captive for the shortest period out of all the birds tested. While this individual's response to food flavoured with cinnamon oil may have been a one-off event, it may also indicate that cinnamon has some repellent effect. Kiwi which have been captive for long periods of time may have become accustomed to feeding on any food provided regardless of whether it tastes nice or not. The fact that some kiwi found cinnamon food distasteful but still fed on it reinforces this.

In captive trials, Spurr (1993) found that cinnamon was effective at deterring some of the birds tested (e.g. North Island kaka, red-crowned parakeets, Antipodes Island parakeets and North Island kokako) from feeding on baits until the second day of presentation. Cinnamon had some initial repellent effect, but this wore off as the baits aged and the strength of cinnamon flavour decreased. Additional trials using other juvenile kiwi, or birds which have been captive for only short periods of time would be beneficial in further investigating the potential for cinnamon to act as a deterrent to kiwi.

Our results are similar to those of McLennan et al. (1992) who found that cinnamon oil did not significantly reduce feeding in captive kiwi. Their study also showed that other known bird repellents (e.g. dimethyl anthranilate, optamint oil and amyl acetate) were also ineffective at significantly deterring captive kiwi from feeding (McLennan et al. 1992). This result may have been expected since bird species are known to differ considerably in their response to different flavours, with some compounds found to be repellent to one species and not necessarily to another (Duncan 1960; Berkhoudt 1985). However, the fact that in both McLennan et al. (1992) and this study no repellent or flavour that was tested significantly deterred kiwi from their usual food suggests either that identifying an effective repellent for kiwi may be challenging, or that captive kiwi may not be reliable at predicting the response of wild kiwi to flavours/repellents. The results of this study suggest that the latter may be feasible since kiwi did show signs of rejecting flavoured food. While Spurr (1993) considered that the response of captive birds to the flavour which he tested could be validly extrapolated to wild birds, I believe that the kiwi in this study were habituated to feeding on the food provided. Extrapolation of the response of captive kiwi to the flavours tested may therefore not accurately reflect the response of wild kiwi, although this requires further testing.

With the exception of cinnamon oil, none of the three other flavours (i.e. aniseed, orange or clove) have been proven in the field to have any repellent effect on birds, and did not significantly deter captive kiwi. A positive outcome however, is that no flavour significantly increased the length of time that kiwi fed, in comparison to unflavoured or any other flavoured food portion. Therefore, the addition of cinnamon, aniseed, orange

or clove flavours to pest control baits is unlikely to increase the risk of kiwi feeding on those baits.

Response of kiwi to flavoured baits

Overall, captive kiwi showed little response to flavoured cereal No.7 baits. Few baits were eaten, and by few kiwi, and no bait flavour combination was consistently attractive to all kiwi. Only one kiwi showed any interest in flavoured cereal baits, particularly those flavoured with clove. However, this appeared to be an individual preference which was not shared by other kiwi trialled.

The observation that captive kiwi ate only whole cereal baits and did not attempt to break baits, may have value when considering suitable compounds to add to baits to deter bird species. Some known bird repellents (e.g. cinnamamide) deter birds by inducing an aversive response when the treated food is tasted (Gill et al. 1994). Birds which are capable of pecking at the bait surface (e.g. kokako, kaka) may therefore only consume a small quantity before rejecting the bait. In contrast, kiwi which appear more inclined to swallow whole cereal baits may ingest a potentially lethal quantity before they have an aversive response. The method by which native birds consume baits may be an important consideration before deciding on a suitable bait repellent. Ideally, for kiwi, any bait compound which may be used to prevent consumption of toxic baits needs to deter birds on smell alone since eating any amount of bait may be lethal (McLennan et al. 1992).

Wild kiwi flavoured bait trials

No wild kiwi fed on any of the non-toxic cinnamon or orange flavoured No.7 baits during this study. An orange flavoured bait was picked up on one occasion and this represented only 3% (1 out of 29) of total kiwi encounters with orange flavoured baits. No cinnamon flavoured baits were picked up by kiwi during any of the 34 observed encounters. These results show that kiwi are unlikely to feed on orange or cinnamon flavoured cereal-based baits, and support other studies which have found kiwi to be unaffected by possum control operations using these flavours and bait type (Pierce and Montgomery 1992; H. Robertson, pers. comm.; R. Pierce, pers. comm).

Generally, each night of the flavoured bait trials kiwi emerged from their nest and immediately began to flick material towards the entrance. Kiwi then moved away out of camera view via a route that had been used previously during encounters with unflavoured baits (see Wild Results, Chapter 2). Only one kiwi altered his behaviour in the presence of flavoured baits. Instead of stepping forward over baits as he had done during encounters with unflavoured baits, the kiwi either climbed out the back of the nest, or out at the side, apparently choosing to completely avoid the area where baits had been laid. For this kiwi, but not others, it appeared that flavoured baits had some deterrent effect.

While the addition of orange or cinnamon flavours to cereal No.7 baits did not attract kiwi to feed on baits, these flavours had no obvious deterrent effect either. The orange and cinnamon flavours did not prevent kiwi from probing baits and there is therefore potential for kiwi to ingest small quantities through contact with baits which may have softened through weathering. The only other study which has evidence of kiwi contacting with flavoured baits was in Waipoua, Northland. Kiwi fed on non-toxic cinnamon-flavoured cereal bait (Pierce and Montgomery 1992) which showed that this flavour did not appear to have any deterrent effect on some kiwi.

This work testing the response of wild kiwi to flavoured baits was intended as a pilot study. Flavoured baits were presented to kiwi on nights which followed consecutively after trials in which unflavoured baits had been offered to the birds (see Chapter two). For this reason caution is required with interpretation of the results. For example, prior exposure to the unflavoured baits may have influenced kiwi to reject flavoured baits. However, of primary interest was whether the addition of cinnamon or orange flavours attracted kiwi to feed on baits, and in this study no kiwi did.

Typically, wild kiwi responded to flavoured baits in a similar manner to unflavoured baits. It is therefore likely that cinnamon or orange flavours have a neutral effect on kiwi, neither deterring, nor attracting them to feed on baits. Recently it has been suggested that alternating bait types with the lures cinnamon and orange (which has been shown to be an effective alternative to cinnamon (Morgan 1990)), may help to

reduce bait shyness in the target species (Morgan et al. 1996). That neither orange or cinnamon flavours attracted kiwi to feed on cereal baits is positive for kiwi, since these flavours are likely to be used more widely on ground laid (R. Pierce, pers. comm.) and aerially distributed baits.

Conclusions

While cinnamon, aniseed, orange and clove flavours did not deter captive kiwi from feeding on their usual food, or on cereal baits, they did not increase feeding either. Also, wild kiwi were not attracted to feed on cereal baits flavoured with cinnamon and orange. These results suggest that the addition of such flavours to pest control baits, primarily to mask the smell and taste of 1080 poison from the pest, may not place kiwi at greater risk from feeding on baits. However, these flavours should not be considered to reduce the potential for kiwi to feed on baits either. There is clearly more scope for research into identifying suitable bait lures that are deterrent to kiwi, and that are also known to be acceptable to mammal pests.

The main points arising from this study are:

Captive flavour trials

1. Cinnamon, aniseed, orange and clove flavours did not significantly affect the response of kiwi to portions of their usual artificial diet.

2. All kiwi except for one juvenile fed on all the flavoured portions of their usual diet.

3. Kiwi fed only minimally on No.7 baits flavoured with cinnamon, aniseed, orange and clove and not one of these bait and flavour combinations was preferred overall by kiwi.

4. Kiwi ate only flavoured cereal No.7 baits as whole baits.

Wild flavour trials

4. Wild kiwi did not feed on any orange or cinnamon flavoured No.7 baits placed outside their nest entrance.

5. Orange and cinnamon flavours did not encourage kiwi to feed on baits but did not prevent them from probing baits either.

6. Only one wild kiwi picked up an orange No.7 bait during trials, but this was dropped immediately.

7. Only one wild kiwi exhibited behaviour which indicated that it was deterred by the cinnamon and orange flavours.

RECOMMENDATIONS

1. Further research is required to investigate the response of juvenile, or newly captive kiwi to the range of flavours tested in these trials.

2. Cinnamon, aniseed, orange and clove should not be considered to have any significant repellent effect on kiwi.

3. Cinnamon and orange flavours did not encourage wild kiwi to feed on baits, and are therefore unlikely to increase the risk of kiwi consuming toxic baits during control operations using these flavours as lures.

REFERENCES

Berkhoudt, H. 1985. Structure and function of avian taste receptors. *In:* King, A.S. & McClelland, J. (Eds), *Form and Function in Birds*, pp 346-496. Academic Press No.3, New York.

Brunner, H. and Coman, B.J. 1983. The ingestion of artificially coloured grain by birds, and its relevance to vertebrate pest control. *Australian Wildlife Research* 10: 303 - 10.

Bryant, H.; Hone, J. and Nicholls, P. 1984. The acceptance of dyed grain by feral pigs and birds. *Australian Wildlife Research* 11: 509-16.

Bullard, R.W. and Shumake, S.A. 1977. Food-base flavour additive improves bait acceptance by ricefield rats. *Journal of Wildlife Management* 41: 290-297.

Caithness, T.A. and Williams, G.R. 1971. Protecting birds from poisoned baits. *New Zealand Journal of Agriculture* 122: 38-43.

Clark, L.; Shah, P.S. 1991. Nonlethal bird repellents: in search of a general model relating to repellency and chemical structure. *Journal of Wildlife Management* 55(3): 538-545.

Crocker, D.R.; Perry, S.M. 1990. Plant chemistry and bird repellents. *Ibis* 132: 300-308.

Duncan, C.J. 1960. Preference tests and the sense of taste in the feral pigeon. *Animal Behaviour* 8: 54-60.

Gill, E.L.; Serra, M.B.; Canavelli, S.B.; Feare, C.J.; Zaccagnini, M.E.; Nadian, A.K.; Hefferman, M.L. and Watkins, R.W. 1994. Cinnamamide prevents captive chestnut-capped blackbirds (*Agelaius ruficapillus*) from eating rice. *International Journal of Pest Management* 40: 195-198.

Harrison, M. 1978. The use of poisons and their effect on birdlife. *Seminar on the takahe and its habitat, 1978.* Te Anau. Prepared and Published by the Fiordland National Park Board, Invercargill, New Zealand. pp 203-221.

Haydock, N. and Eason, C. 1997. *Vertebrate Pest Control Manual: Toxins and Poisons.* Department of Conservation, Wellington, 1997. 88 pp.

Kalmbach, E.R. and Welch, J.H. 1946. Coloured rodent baits and their value in safe guarding birds. *Journal of Wildlife Management* 10: 353-360.

Kare, M.R. 1965. The special senses. *In:* Sturkie, P.D. (Ed), *Avian Physiology*, Cornell University Press, 2nd Edition, Ithaca, New York.

McLennan, J.A.; Porter, D. and Cowan, P. 1992. *Compounds to prevent non-target animals from eating poisonous baits laid for possums.* DSIR Land Resources Contract Report No. 92/55. 10 pp.

Morgan, D.R. 1990. Behavoural response of brushtail possums, *Trichosurus vulpecula*, to baits used in pest control. *Australian Wildlife Research* 17: 601-613.

Morgan, D.R.; Batchelor, C.L. and Peters, J.A. 1986. Why do possums survive aerial poisoning operations? *Proceedings Vertebrate Pest Conference.* pp 210-214.

Morgan, D.R.; Morriss, G. and Hickling, G.J. 1996. Induced 1080 Bait-shyness in Captive Brushtail Possums and Implications for Management. *Wildlife Research* 23: 207-211.

Pank, L. 1976. Effects of seed and background colours on seed acceptance by birds. *Journal of Wildlife Management* 40: 769-774.

Pierce, R.J. and Montgomery, P.J. 1992. *The fate of birds and selected invertebrates during a 1080 operation.* Department of Conservation. Science and Research Internal Report No.121. 17 pp.

Pracy, L.T.; Robertson, B.A. and Udy, P.B. 1982. Flavours tested on Kapiti. *Counterpest* 8: 10-11.

Reid, B. 1986. Kiwis, opossums and vermin. A survey of opossum hunting; and of target and non-target tallies. *Fur Facts* 7: 37-49.

SAS Institute. 1985. *SAS User's Guide*. Cary, North Carolina.

Spurr, E.B. 1993. Feeding by captive rare birds on baits used in poisoning operations for control of brushtail possums. *New Zealand Journal of Ecology* 17: 13-18.

Spurr, E.B. 1994. Review of the impacts on non-target species of sodium monofluoroacetate (1080) in baits used for brushtail possum control in New Zealand. *In:* Seawright, A.A and Eason, C.T (Eds). *Proceedings of the Science Workshop on 1080.* pp 124-133. The Royal Society of New Zealand, Miscellaneous series No.28. Christchurch, New Zealand.

Spurr, E.B.; Porter, R.E.R. and Thomson, C. 1995. *Repellents to reduce the risks to birds from brodifacoum used for poisoning rats. Part 1. Palatability of bird repellents to rats.* Landcare Research Contract Report No.LC9596/01. 10 pp.

Udy, P.B. and Pracy, L.T. 1981. Baits, Birds and Field Operations. *Counterpest* 6: 13-15.

Watkins, R.W. 1996. Efficacy of cinnamaminde as a repellent for vertebrate and invertebrate pests. *Pesticide Outlook* (August): 21-24.

Wenzel, B.M. 1968. Olfactory prowess of the kiwi. *Nature* 220: 1133-1134.

Wenzel, B.M. 1973. Chemoreception. *In:* Farner, D.S., King, J.R. & Parkes, K.C. (Eds), *Avian Biology.* pp 389-415. Academic Press No.3. New York.

Behaviour of incubating kiwi and predators at nesting burrows.

ABSTRACT

The nests of ten incubating male North Island brown kiwi (*Apteryx australis mantelli*) were recorded using time-lapse infra-red video equipment to observe patterns of incubation, chick behaviour and the presence of predators at nesting burrows. Male kiwi generally left the nest each night, except for one male that remained on the nest two days either side of the chick hatching. Most kiwi left the nest once a night, although two kiwi sometimes left the nest twice in a night, and one of these sometimes left the nest three times. The period that kiwi were active each night did not appear to be influenced by the number of times they emerged. Male kiwi tended to spend less time away from their nest each night towards hatching, following which they increased the length of time away from the nest. Chicks may have been as young as 1-3 days old when they made their first trip away from nest. Possums, rats, and mice were recorded around kiwi nest entrances 297, 707 and 159 times respectively, during 118 nights of video recording, but did not appear to deter male kiwi from incubating, or to harm their eggs or chicks during this time. A possum was recorded entering an unattended nest only once.

INTRODUCTION

Kiwi breeding behaviour

Studies on the nesting behaviour of kiwi have been difficult because they are a nocturnally active bird. Early naturalists such as Layard (1863) and Buller (1888) provided descriptive accounts on nest sites, clutches and breeding times, but it has not been until relatively recent advances in areas such as night vision and the use of radio-transmitters and telemetry equipment, that knowledge of kiwi nesting behaviour has improved considerably. Night viewing gear has made it possible to directly observe the behaviour of nesting adult kiwi and chicks, and has also enabled data to be collected on

emergence and return times of kiwi to the nest (McLennan 1988). Similar information on the active periods of kiwi have been obtained by listening for variations in radio-transmitter signals to indicate whether birds are moving or stationary; and also by electronic timers activated by kiwi breaking a cotton trip wire set up across the nest entrance (McLennan 1988; Potter 1989). Remote video recording at the nest of a pair of brown kiwi at Okarito in the South Island has also provided lengthy footage on incubation patterns, the behaviour of male and female kiwi at the nest, and their relationship with chicks (Reid et al. 1992). No such video recording of nesting behaviour has been successful with North Island brown kiwi.

Kiwi and predators

Introduced mammals have a detrimental affect on native forest birds (Moors 1983; Innes et al. 1995; McLennan et al. 1996; Brown 1997). For kiwi, possums have been implicated as causing nest desertions, preying on eggs (McLennan 1988; P. Millar, pers. comm.; Reid et al. 1994), and even the killing of adult kiwi (McLennan 1996). Stoats are considered to be the chief predators of kiwi chicks (McLennan et al. 1996), while dogs, ferrets and pigs have also killed adult kiwi (Taborsky 1988; McLennan 1996). In most cases the evidence points conclusively to the culprit (e.g. possum fur lodged under the claws of a dead kiwi (McLennan 1996), possum hair adhering to shell of kiwi egg (McLennan 1988), stoat canine marks in skulls of dead chicks (pers. obs.)). In some cases however, eggs disappear from kiwi nests without positive evidence of predation or any other cause (McLennan 1988; Potter 1989; Reid et al. 1992; McLennan et al. 1996; Reid et al. 1996; D. Ravine, pers. comm.). At Okarito a video camera was set up at a nest specifically to determine the causes of such breeding failure, since previous nest monitoring techniques did not provide sufficient information (Reid et al. 1992). The footage revealed that possums regularly visited and entered kiwi burrows, potentially cracking eggs and causing nests to fail (Reid et al. 1994). However, adult kiwi appeared able to defend themselves from both possums and stoats (Reid et al. 1992; Reid et al. 1994). Since males and females share incubation in the Okarito brown kiwi (R. Colbourne, pers. comm. cited in McLennan (1989)) most nest visits by predators occurred when one of the adult birds was present, and there were only few occasions when neither bird was present (Reid et al. 1994). In the North Island, where incubation

is the sole responsibility of the male kiwi (McLennan 1988), there may be greater opportunity to determine the outcome of predator visits to nests in the male's absence.

In this study direct infra-red, time-lapse video recording was used to describe (1) the nesting behaviour of ten North Island brown kiwi, (2) the behaviour of predators at these nests, and (3) the outcome of predator encounters with kiwi, in remote locations at Lake Waikaremoana, Te Urewera National Park, and in Northland. The data were collected concurrently during video recording of the response of kiwi to a range of non-toxic baits placed on the ground outside their nests. The presence of these baits was expected to increase the rate of predator visits to the nest, and the frequency of predator encounters with kiwi.

Study areas

Data were collected from North Island brown kiwi at Lake Waikaremoana, Te Urewera National Park ($38^0$47'S, $177^0$04'E and $38^0$46'S, $177^0$02'E), and at Rarewarewa ($35^0$37'S, $174^0$08'E) and Riponui ($35^0$34'S, $174^0$09'E) bush patches in Northland (see Figure 2.1, Chapter 2). The vegetation of the kiwi habitat in these locations is described in Chapter 2.

Introduced mammals

There are a number of introduced mammals present at both study areas. Lake Waikaremoana is home to possums (*Trichosurus vulpecula*), red deer (*Cervus elaphus scoticus*), feral pig (*Sus scrofa*), feral goats (*Capra hircus*), feral cat (*Felis catus*), rabbit (*Oryctolagus cuniculus cuniculus*), European hare (*Lepus europaeus*), mouse (*Mus musculus*), Norway rat (*Rattus norvegicus*), ship rat (*Ratus rattus*), stoat (*Mustela erminea*), weasel (*Mustela nivalis vulgaris*), and ferret (*Mustela furo*). Northland has all of the above introduced mammals, with the exception of red deer. Additionally, grazing cattle have access to some unfenced bush areas in Northland. Dogs have been seen in both areas, but particularly in Northland where the bush patches border farmland.

METHODS

The nesting male kiwi used in this study were involved in existing kiwi projects. The birds were individually named and carried active radio transmitters enabling nests to be located by day using a radio receiver and a three element yagi aerial. An infra-red camera for night time viewing was mounted on a tripod, or tied to a tree 2-3 m from nest entrances between January 9th 1996 and September 19th 1997. The camera was positioned so that the nest entrance and at least 1-1.5 m in front of the nest was in view, to cover the area where kiwi moved away. The time-lapse video recorder and monitor (providing the time/date/recording time) were positioned approximately 18 m away from the nest under plastic. Recording was programmed to begin each night at sunset and continued until dawn. Power was supplied by two car sized lead acid gel batteries (12 volt, 57 amp hr) which were changed daily.

Data collection and analysis

Recordings were made on: the time that kiwi emerged and re-entered the nest during the night, the time that kiwi took to emerge and move one metre away from the nest, the behaviour of kiwi as they emerged, i.e. whether they covered their nest, the total time that males were active each night, the behaviour of males in relation to chicks hatching, the frequency and type of predators visiting nests, and the outcome of predator nest visits and interactions with kiwi.

The total time that male kiwi remained away from the nest each night was compared to the number of days that kiwi had been incubating. Assuming incubation (until the hatching of the first chick) takes approximately 90 days (McLennan 1988; Potter 1989) three categories were defined; stage 1 = day 1 to 30, stage 2 = day 31 to 60, stage 3 = day 61 to 90. Similar categories have been used previously to investigate trends in the stage of incubation and time of emergence after sunset (McLennan 1988). Two additional categories were also included; stage 4 = days between the hatching of first chick until the hatching of the second chick, and stage 5 = days following the hatching of the second chick. The incubation stage of each kiwi was determined either from knowing when incubation began, or estimated by counting back from the date when the first chick was known to have hatched.

Where possible *t*-tests were used to compare the total time that individual kiwi spent away from their nests during different stages of incubation. The same test was also used to compare the total time spent away from the nest, and times of emergence after sunset for one kiwi on nights when it emerged once to those nights when it emerged twice.

RESULTS

Activity around the nests of ten incubating male kiwi was recorded for a total of 118 nights. Six males were video recorded for ten nights, and the remaining four birds were video recorded for four, thirteen, sixteen and twenty-five nights respectively.

Video monitoring of kiwi

Behaviour of incubating males

Incubating and brooding male kiwi left their nests most nights (113 out of 118 recorded nights). However, one male remained on a nest for two nights immediately before the first chick was seen in the nest entrance, and two consecutive nights following. A second male also remained on the nest for a whole night but this occurred at least 55 days before his first chick was confirmed to have hatched.

Eight of the ten male kiwi left and returned to their nests consistently once a night (n=98). The two remaining kiwi displayed a different pattern; one sometimes left and returned to the nest twice in a night (six out of ten nights), and another left and returned to the nest twice (eight out of ten nights) and sometimes three times in a night (two out of ten nights). Kiwi which left the nest twice a night emerged sooner on average after sunset than birds which came off the nest once only (mean ± S.E. = 01:58:56 ± 00:10:56 (hr:min:sec, n=14) and 04:12:09 ± 00:12:48 (hr:min:sec, n=74), respectively). However, the high variation between the average emergence times after sunset for all kiwi makes any trends difficult to observe (Figure 4.1).

When the average time spent away from the nest was compared for all kiwi, the two birds which emerged twice a night (i.e. 'Boxer' and 'Fence') represented both the

longest and shortest times spent away from the nest, out of all kiwi video recorded (Figure 4.2). This indicates that the length of time that kiwi were active each night was not influenced by the number of times that they emerged. Overall, kiwi spent on average (± S.E.) 03:42:11 ± 00:22:47 (hr:min:sec, n=9) away from the nest each night.

The one kiwi which left the nest once on some nights and twice on others (i.e. 'Fence') did not spend a significantly different length of time away from the nest on these occasions ($p=0.85$, $t=-0.19$, T-test, see 'Fence' in Figure 4.2). However, the time that this kiwi emerged after sunset, was close to being significantly earlier (at $p<0.05$) on nights when it left the nest more than once ($p=0.051$, $t_8=0.69$, T-test, see 'Fence' Figure 4.1). No other kiwi displayed this behaviour and so similar comparisons for other kiwi were not possible.

Kiwi which left the nest twice in a night (i.e. 'Boxer' and 'Fence') also differed from each other in the length of time they spent away from the nest on their first excursion (01:14:37 ± 00:14:56 (hr:min:sec, mean ± S.E., n=8) and 04:50:34 ± 00:36:03 (hr:min:sec, mean ± S.E., n=6) respectively), and the time that they emerged after sunset for the second excursion (06:21:20 ± 00:43:40 (hr:min:sec, mean ± S.E., n=6) and 10:52:28 ± 00:28:30 (hr:min:sec, mean ± S.E., n=8) respectively), although both spent approximately an hour away from the nest on the second emergence each time.

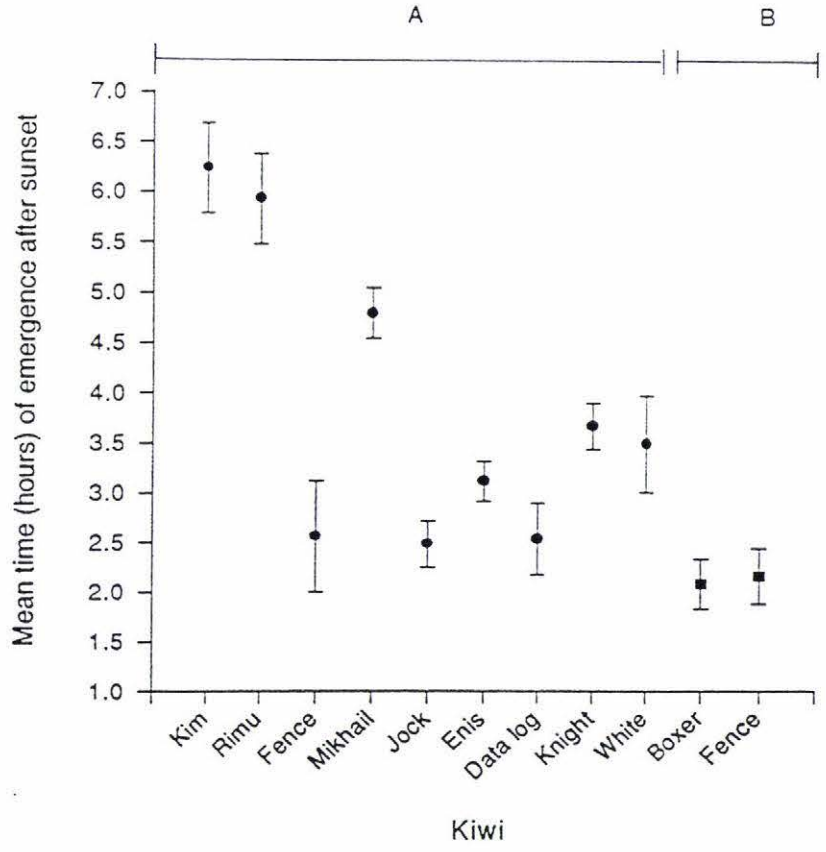


Figure 4.1 Mean (± S.E.) time (hours) of emergence after sunset for incubating kiwi. Area A (circles) indicates kiwi which emerged only once in a night. Area B (squares) indicates kiwi which emerged more than once in a night. Note that the Fence bird emerged only once on some nights and more than once on other nights, and appears twice in the figure.

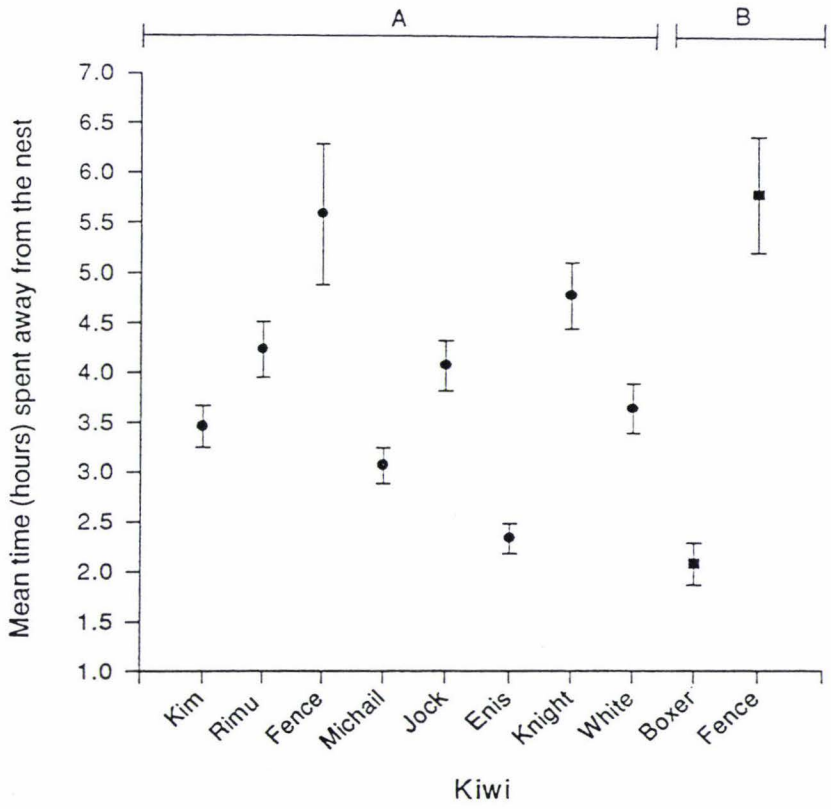


Figure 4.2 Mean (± S.E.) duration (hours) spent away from the nest each night for incubating kiwi. Area A (circles) indicates kiwi which emerged only once in a night. Area B (squares) indicates kiwi which emerged more than once in a night. Note that the Fence bird emerged only once on some nights and more than once on other nights, and appears twice in the figure.

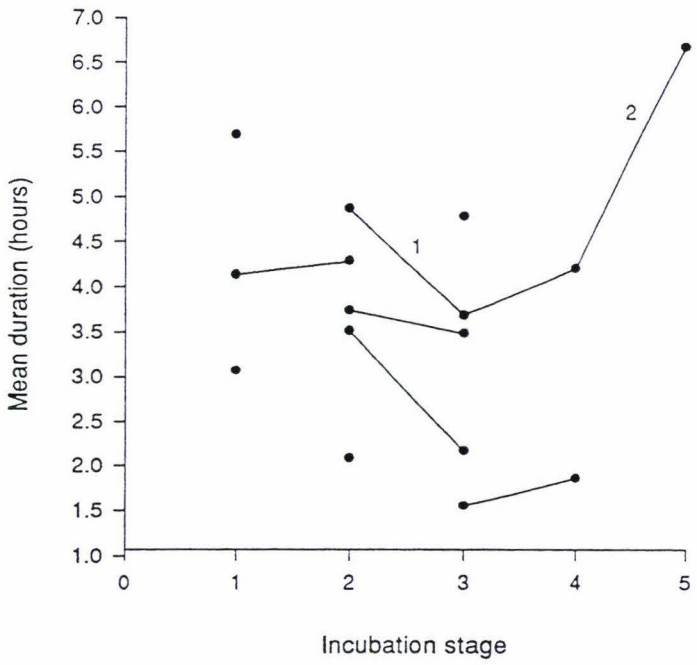


Figure 4.3 Mean duration in hours spent away from the nest with increasing stage of incubation. Stage 1 = day 1 to 30, stage 2 = day 31 to 60, stage 3 = day 61 to 90 or hatching of first chick, stage 4 = days after hatching of first chick but before hatching of second chick, stage 5 = days after hatching of second chick. Single dots indicate kiwi which were video recorded during only one incubation stage. Dots connected by lines indicate kiwi which were video recorded over more than one incubation stage. Numbers 1 and 2 shown above lines on the graph were the only comparisons which showed significant differences between stages of incubation ($p=0.014$, $t_9=3.03$ and $p=0.05$, $t_5=-2.55$, respectively).

For most kiwi (for which video recording spanned at least two stages of incubation) the mean time spent away from the nest tended to decrease as incubation progressed. Kiwi which were video recorded in stages 3 and 4, and in stages 4 and 5 showed an increase in the time spent away from the nest after the hatching of the first chick and a further increase following the hatching of the second chick (Figure 4.3). Differences between the times spent away from the nest were significant however, for only two out of six comparisons made between stages of incubation for kiwi for which sufficient data were available (Figure 4.3).

Male behaviour at the nest

Before emerging from the nest kiwi could sometimes be seen shuffling around inside for periods of up to 12 minutes. At one nest the male frequently probed around in the entrance during this time, and sometimes reached out of the nest with his bill to pull in leaves and fern fronds, which he then pushed in behind and under himself.

As they emerged, kiwi used their bill to lean on and to manoeuvre themselves out of the nest. Generally, they balanced forward and pushed their body out using their legs, sometimes even leaning down on the side of their head to help wriggle themselves out of the nest (Figure 4.4). Only three of the ten males consistently covered the nest entrance each time they emerged. The remaining birds usually covered their nest, but occasionally only sniffed around the entrance before moving off (Table 4.1). One of these kiwi was blown away by a strong gust of wind as soon as it emerged, and on another occasion a kiwi leaped out of the nest to chase off a possum and did not return to cover the nest.

Kiwi used mainly twigs, branches, leaves and fern fronds to cover the nest entrance. They often had to search around for material, which they picked up in the bill and then flicked in the general direction of the nest. Pieces of vegetation sometimes landed up to 30 cm away from the entrance. Frequently, flying vegetation could be seen landing in the vicinity of the nest from kiwi which had moved out of camera view. At one nest where a lot of leaf material could be seen, the male kiwi sometimes used his feet to kick vegetation towards the entrance. No kiwi were recorded pulling material in over the entrance after they had re-entered the nest, although kiwi could be seen shuffling around

(a)

(b)

(c)

Figure 4.4 'Boxer' emerging from his nest. (a) Inside the nest preparing to leave, (b) leaning down on his head to wriggle his body out, (c) standing at the entrance after emerging.

(a)

(b)

Figure 4.5 (a) Possum with its head in a kiwi nest, (b) possum moving around the nest entrance. The male kiwi and a chick were present in the nest during (a) and (b).

inside. It took on average 140 ± 10 seconds (± S.E., n=123) for kiwi to emerge and move a metre away from the entrance out of camera view, and an average of 23 ± 2 seconds (± S.E., n=121) to re-enter the nest from a metre out.inside.

At two nests the camera was positioned in such a way that it was possible to see directly inside. At Enis' nest the egg was often visible after the male had emerged, and on occasions when the male was present. The egg was periodically uncovered and pushed forward, then covered with leaf material by the male using his bill. 'Fence' could also be seen shuffling inside the nest, periodically uncovering the egg, and then scraping material back around it using his bill. On some nights the male could be seen moving around inside on up to 23 separate occasions in between times when he was away from the nest. The male was sometimes active in the nest for up to 24 minutes at one time, with periods of rest between bouts of activity ranging from 1 hour 40 minutes to only 29 seconds. After shuffling around, this male was occasionally seen laying his head on its side in the nest entrance.

Table 4.1 Percentage of times kiwi emerged and covered their nest and mean time (sec) ± S.E. taken to cover nest. Numbers in brackets indicate total number of times kiwi were recorded emerging.

Kiwi	Percentage of times kiwi emerged and covered the nest	Mean duration (sec) ± S.E. taken to cover nest
Boxer	86.4% (22)	100 ± 11
White	70.0% (10)	203 ± 37
Jock	85.0% (20)	83 ± 9
Mikhail	80.0% (10)	75 ± 14
Enis	81.8% (11)	151 ± 49
Kim	91.0% (11)	107 ± 13
Data loggers	75.0% (4)	77 ± 23
Fence	100% (15)	183 ± 31
Rimu	100% (10)	135 ± 11
Knight	100% (10)	335 ± 37

Hatching and chick behaviour

Two nests were video recorded during periods which included eggs hatching and the chicks making their first trips out of the nest. Enis' chick was video recorded in and around the nest for a total of nine nights, while Jock's chick/s were video recorded periodically for a total of fifteen nights. However, due to battery failure and problems with clock-setting, data from only eight nights could be used.

Jock

On 9 March 1996 a chick was first seen inside the nest entrance. On the following night, at possibly only one day old, the chick made its first trip outside the nest, probing around the entrance for 8 minutes 15 seconds before re-entering. The chick was recorded leaving the nest on the next night for 04:29:50 (hr:min:sec), and for varying periods of time of up to 10:20:12 (hr:min:sec) on eleven recorded nights, between 12 and 27 March 1996. The chick emerged before the adult on four out of five occasions, but approximately within 30 minutes of each other. The chick also re-entered the nest on average 01:45:28 (hr:min:sec, n=6) after the adult kiwi, but sometimes returned two (n=2) or three (n=1) times to the nest during the night, and always returned before dawn. A second chick could be seen in the nest on 23 March 1996 and this chick began leaving the nest on 25 March 1996.

Enis

On the 10 and 11 December 1996 the adult male kiwi remained on the nest for the whole of the night. An egg could be seen on occasions underneath the adult on 11 December as he shuffled around inside the nest. Eventually on the 12 December the adult left the nest 01:44:37 (hr:min:sec) after sunset and while he was absent a chick was first seen in the entrance. The chick moved to the front of the nest probing continuously and then disappeared back inside a total of six times, for periods ranging from 43 seconds up to 1 hour 30 minutes. This night also coincided with a visit to the nest by a female kiwi.

For the next two nights both the adult male and the chick again remained on the nest. On 15 December 1996 the adult emerged 01:48:14 (hr:min:sec) after sunset. The chick was seen again at the entrance for short periods and eventually probed around half a

metre outside the nest for 7 minutes 15 seconds before re-entering. The chick was approximately three days old. On each of the next five nights the chick left the nest for longer periods ranging from 03:54:21 up to 07:03:12 (hr:min:sec), emerging each night (n=5) on average 01:22:49 (hr:min:sec) before the male, and re-entering the nest on average 02:47:47 (hr:min:sec) after the male (n=6), on all nights except for the chick's first trip out of the nest. The chick left and returned to the nest twice on the 17 December 1996, and once on each of the other four recorded nights. On 18 December 1996 a second egg could be seen inside the nest under the adult.

Kiwi visitors to the nest

On ten occasions kiwi other than the incubating male were recorded visiting six different nests. These visits occurred at times close to when chicks were expected to hatch, and at other stages during incubation. At one nest a female kiwi visited the nest on 12 March 1996, three nights after a chick was first seen in the entrance. She sniffed up to and around the entrance, put her head partly inside and then moved away. A kiwi which could not be clearly identified (but which was probably the same female) visited the same nest again on the 20 and 21 March 1996. The male kiwi was out of the nest on each visit. A second chick was seen in the nest entrance two days later on 23 March 1996.

Another female kiwi also visited a nest on the first night that a chick was seen in the nest entrance. The female sniffed around the entrance and moved away without looking inside. The male was present at the time.

Females were also recorded visiting nests at stages early on in incubation; on 24 and 27 July 1997 approximately 56 days away from the first chick hatching (the male was in at the time), and at another nest on 12 and 13 September 1997, approximately 33 and 34 days before a chick was first recorded to have hatched. The male was in the nest on one of those occasions.

A sub-adult was also recorded foraging past the front of a nest entrance. The incubating male was out at the time and the sub-adult showed little interest in the nest.

Video monitoring of predators at the nest

Possums were recorded outside the entrances of nine of the kiwi nests a total of 297 times during 118 nights of recording. On seven occasions possums entered the nest at least up to their mid-back: five times when the adult was in the nest; once when both the adult and a chick were in the nest; and once when the nest was unattended. When the adult was present, the possum either jumped backwards from the entrance, or retreated quickly. On the one occasion when a possum entered the nest in the absence of the adult kiwi, it pushed its head into the nest and then completely disappeared inside, re-emerging eight seconds later. At least one egg was in the nest at the time but was not damaged, and later two chicks hatched successfully from the nest.

Possums were recorded looking into nests and putting only their heads in on 51 other occasions; 27 times when the adult was absent, and 24 times when the adult kiwi was in the nest (Figure 4.5).

Possums were chased away from the nest entrance on three occasions; twice by kiwi which returned to find possums outside the nest entrance, and once when a kiwi lurched out of the nest and chased off a possum which had persisted around the entrance for the previous two hours.

Ship rats were recorded passing by nine of the nests on 707 occasions, and entered nests on 16 of these occasions; thirteen times when the adult kiwi was in, and three times when the adult was out of the nest (Figure 4.5). On one occasion a rat was sitting about 15 cm from the entrance when the male kiwi returned to the nest. The kiwi chased the rat across the nest entrance and returned into view a few seconds later looking ruffled and aggressive, and then re-entered the nest. Mice were also recorded around nests 159 times, but entered nests on only four occasions; only once when the kiwi was away from the nest. No other birds or mammals were recorded around kiwi nests.

Predator encounters with chicks

One chick encountered rats at the edge of the nest entrance on four occasions. Two encounters occurred on the first night that the chick was seen in the nest, and the second

two encounters the following night. During the first encounters the adult kiwi was away from the nest. The rat and chick faced each other approximately 30 cm apart for a couple of seconds before the rat moved away. On the second night the rat and chick faced each other in a similar way, except on one occasion the rat moved forward appearing to sniff towards the chick for approximately 20 seconds, before moving off.

Outcome of video recorded nests

Of the ten nests which were video recorded during this study, four later hatched two chicks successfully, two hatched at least one chick, one nest failed because it was trampled by cattle, another hatched one chick which was later found dead in the nest with a snapped bill while the other egg in the nest was deserted (P. Millar, pers. comm.), and one nest was abandoned by the male after a minimum of 80 days; one of the eggs was infertile and the second contained an embryo which had ceased developing early in incubation (S. Bassett, pers. comm.). Only one potentially failed during the egg stage (i.e. failed to hatch at least one chick) as a result of predators, other than accidental damage by cattle.

DISCUSSION

Video monitoring of kiwi

Behaviour of incubating males

In this study the behaviour of two male kiwi was recorded during periods when chicks were hatching. One of these kiwi remained on the nest for two nights prior to hatching and an additional two nights after the chick had hatched. The other male did not alter his behaviour in this way and continued to leave the nest on all nights close to when chicks were hatching. Other studies have reported incubating kiwi remaining on the nest 1 to 2 days immediately before chicks hatched (McLennan 1988; Potter 1989), although not two days before, and two days after as in this study. Except for one kiwi which remained on the nest for one night towards the later stage of incubation, all other incubating males left the nest each night.

Two out of the ten incubating kiwi sometimes left the nest more than once a night. This has not been reported previously in North Island brown kiwi and may be due to the behaviour being rare, or techniques other than direct video recording failing to detect kiwi which show this level of activity. For example, studies which used cotton trip wires set across the nest entrance to determine when kiwi left and re-entered their nest (McLennan 1988; Potter 1989) only re-set the cotton once after the kiwi had emerged. Therefore, kiwi emerging for a second time would not be detected as they would have triggered the timer the first time they re-entered the nest. Similarly, listening for the radio-transmitter signal of kiwi emerging and re-entering the nest is time consuming, has not been done consistently for a number of nights at one nest, and may actually inhibit the behaviour of males leaving the nest (M. Potter, pers. comm.) because to be accurate the observer must remain close to the nest. Studies conducted in such a way may therefore also have failed to detect birds which leave the nest more than once a night.

The stage of incubation (i.e. both kiwi were in early stages 1 and 2) or environmental conditions (e.g. weather, moon phase), are possible factors which may have influenced kiwi to make more than one excursion from the nest each night. However, both these fail to explain this behaviour, since five other kiwi monitored during the early stages of incubation emerged only once a night, as did one other kiwi which was also recorded at a nearby location on the same night.

Unfortunately, since only two of the ten video recorded kiwi sometimes emerged more than once in a night it was not possible to statistically investigate whether the time which they emerged after sunset, or the total length of time they spent away from the nest each night, differed from kiwi which emerged only once. Overall however, it appeared that the length of time that kiwi were active each night was not related to whether they emerged once, twice, or three times in a night. The average time spent away from the nest for kiwi monitored during this study was similar to that reported by Potter (1989) for kiwi in Paerata, Northland, which averaged 3 hours 37 minutes off their nests each night, approximately 1 hour 17 minutes less than active periods reported for kiwi in Hawke's Bay (McLennan 1988).

The data recorded from kiwi during this study also suggest that males may reduce their time spent away from the nest towards chick hatching, after which they progressively increase their time spent away from the nest. Supporting evidence for this was, however, limited due to kiwi being video recorded for only a small proportion (e.g. ten days) of the total incubation time which, consequently, did not always span more than one of the defined incubation stages. Previous published studies have not shown a relationship between stage of incubation and the length of time males are active each night. However, observations from a study in Aotuhia, Taranaki, does support similar trends in the behaviour of kiwi throughout incubation and following the hatching of a chick as those observed in this study (D. Ravine, pers. comm.). Further investigation of the incubation trends observed in this study are justified.

Chick behaviour and female visits

One chick may have left the nest at little more than a day old, while the other two chicks were approximately two and three days old. This is younger than the five to seven days reported for chicks leaving the nest for the first time in previous studies (McLennan 1988; Potter 1989) and may be due to video monitoring accurately detecting the first appearance of chicks. All chicks in this study were recorded returning to the nest before dawn each night. The camera was not set to record during the day so it was not possible to determine whether these chicks were strictly nocturnal, or sometimes active during the day as has been reported for Okarito brown kiwi chicks (Reid et al. 1992) and chicks in captivity (Robson 1958; Reid and Williams 1975). The occasional trips made to the nest by female kiwi occurred throughout incubation and appeared to be nothing other than brief nest visits.

Predator visits to the nest

The presence of baits at the nest entrance almost certainly elevated the frequency of mammals (e.g. possum, rats and mice) at the nest. However, during 297 possum, 707 rat and 159 mice visits to kiwi nests over 118 days, we found no evidence of kiwi eggs being lost to any of these potential predators. These results are supportive of other studies in which kiwi egg loss to predators was found to be low in mainland forests, with possums or mustelids definitely responsible for only 2% of egg predation events (McLennan et al. 1996). In Aotuhia, Taranaki, however, predation of kiwi eggs was

found to be much higher, with at least four out of six eggs lost to predators most likely to be ferrets during the 1997/1998 breeding season (D. Ravine, pers. comm.).

Although possums frequently visited nests in the absence of the male kiwi, possums only looked inside on approximately half of those visits, and only fully entered a nest once. The egg inside was not damaged on this occasion since two chicks later hatched in the nest. However, at Okarito an egg was suspected to have been cracked by a possum which entered an unattended kiwi nest for approximately two minutes. The incubating male kiwi altered his behaviour after this possum visit, and later a rotten smell was detected around the burrow (Reid et al. 1994). While it is possible that possums may break some kiwi eggs, adult kiwi may also damage their own eggs (McLennan 1988). Possums are also known to use kiwi burrows as shelters (Morrin 1989). It is unknown therefore whether they enter kiwi nests out of interest in the burrow, the eggs, the chicks or even the adult bird, but once inside, being opportunistic feeders (Cowan 1990) they are likely to feed on already damaged eggs. Video evidence in these situations is useful for detecting when kiwi eggs may be damaged, but cannot confirm that these nests fail as a direct result of predators. Evidence of predators removing kiwi eggs from nests has not been recorded.

The few kiwi encounters recorded with possums and rats outside the nest entrance suggested that adult male kiwi are capable of defending themselves and the nest from these potential predators. When the male kiwi was present in the nest possums never ventured in further than their shoulders, and quickly retreated. On one occasion a possum was even chased away from the entrance by the male kiwi as he emerged. These observations complement other studies which have reported adult kiwi to be capable of defending themselves and the nest from possums (Reid et al. 1992). A previous study also recorded an adult female Okarito brown kiwi defending herself on the nest from repeated attacks by a stoat (Reid et al. 1994). I have also observed captive kiwi actively defending their food bowls from possums and domestic cats on a number of occasions. Wild kiwi encounters with cats, however, have yet to be recorded.

Ship rats and mice also frequently investigated and entered kiwi nests in the presence and absence of the male, but they did not appear to harm eggs or chicks. The potential, however, for rats to prey on young kiwi chicks should not be ruled out. Rats did show interest in chicks during the few encounters recorded, although on those occasions the adult kiwi was present in the nest and may have prevented further investigation by the rat.

Further video monitoring of kiwi nests in a similar manner to this study will provide valuable information on the predator pressures that incubating male kiwi face. Despite the high number of potential predators recorded around kiwi nests, the outcome of these nests was positive with only one of the ten possibly failing at the egg stage as a result of predators.

REFERENCES

Brown, K. 1997. Predations at the nests of two New Zealand endemic passerines; implications for bird community restoration. *Pacific Conservation Biology* 3: 91-98.

Buller, W.L. 1888. *A history of the birds of New Zealand.* pp 318-319. 2nd Edition. London..

Cowan, P.E. 1990. Brushtail possum. *In:* King, C.M. (Eds), *The Handbook of New Zealand Mammals*, pp 68-98. Oxford University Press, Auckland.

Innes, J.G.; Brown, K.P.; Jansen, P.; Shorten, R. and Williams, D. 1995. *Kokako populations studies at Rotoehu Forest and Little Barrier Island.* Department of Conservation.Science for Conservation Series 30. Wellington, New Zealand.

Layard, E.L. 1863. Ornithological notes from the Antipodes. *Ibis XIX* pp 241-250.

McLennan, J. and McCann, T. 1989. Incubation by female great spotted kiwis. *Notornis* 36: 325-326.

McLennan, J.A. 1988. Breeding of North Island brown kiwi, *Apteryx australis mantelli*, in Hawke's Bay, New Zealand. *New Zealand Journal of Ecology* 11: 89-97.

McLennan, J.A. 1996. *Ecology of brown kiwi and causes of population decline in the catchment of Lake Waikaremoana, Te Urewera National Park.* Department of Conservation. Conservation Advisory Science Notes No.96. Gisbourne, New Zealand.

McLennan, J.A.; Potter, M.A.; Robertson, H.A.; Wake, G.C.; Colbourne, R.; Dew, L.; Joyce, L.; McCann, J.A.; Miles, J.; Miller, P. and Reid, J. 1996. Role of predation in the decline of kiwi *Apteryx* spp. in New Zealand. *New Zealand Journal of Ecology* 20: 27-35.

Moors, P.J. 1983. Predation by mustelids and rodents on the eggs and chicks of native and introduced birds at Kowhai Bush, New Zealand. *Ibis* 125: 137-154.

Morrin, P. 1989. Possum in a kiwi burrow. *Notornis* 36: 148-149.

Potter, M.A. 1989. *(Unpublished). "Ecology and reproductive biology of the North Island brown kiwi (Apteryx australis mantelli)".* Ph.D. Thesis, Palmerston North, New Zealand. 135 pp.

Reid, B. and Williams, G.R. 1975. The kiwi. *In:* Kuschel, G. (Eds), *Biogeography and Ecology in New Zealand*, pp 301 - 330. D.W. Junk, The Hague.

Reid, J.; Joyce, L. and Lyall, J. 1994. *Monitoring of breeding of Okarito brown kiwi in Westland National Park 1993-1994.* Department of Conservation, Unpublished Internal Report. Hokitika, New Zealand. 34 pp.

Reid, J.; Joyce, L. and Lyall, J. 1996. *The monitoring, breeding and protection of the Okarito brown kiwi in Westland National Park, 1994-1995.* Department of Conservation, Unpublished Internal Report. Hokitika, New Zealand. 26 pp.

Reid, J.; Lyall, J. and Colbourne, R. 1992. *Monitoring breeding of Okarito brown kiwi in Westland National Park 1990-1992*. Department of Conservation Unpublished Internal Report. Hokitika, New Zealand. 15 pp.

Robson, F.D. 1958. *Kiwis in captivity:* Bulletin of the Hawke's Bay Museum, Napier. 8.

Taborsky, M. 1988. Kiwis and dog predation: Observations in Waitangi State Forest. *Notornis* 35: 197-202.

Testing the response of native birds to a new formulation of 1080 apple paste.

ABSTRACT

A new 'improved' apple-based possum paste was tested on a range of 21 bird species prior to its approval for use in the field. Five species - robin, saddleback, blackbird, pukeko and weka - fed on a non-toxic cinnamon-lured form of the paste. Captive weka found the paste highly palatable, while 24% of robins tested and possibly half of a pukeko family fed on the paste. Birds other than those that feed on the ground rarely encountered the paste baits. All bird visits to the paste bait declined after the first day of exposure. It is recommended that in areas where robin, weka, pukeko, or saddleback are present paste bait should be laid in bait stations off the ground.

INTRODUCTION

Background

1080 paste is used in New Zealand for possum control, commonly where aerial distribution of bait may pose a risk to stock or humans (Rammell and Fleming 1978). In some areas of New Zealand 1080 paste is the primary method of possum control on council administered farmland (H. Robertson, pers. comm.). In 1993/94 it was estimated that 40 tonnes of 1080 paste would be used in New Zealand as ground bait for Tb-related control of possums over 1 million hectares of land (Livingstone 1994).

Traditional 1080 pastes were very similar to domestic table jams and consisted of a fruit base with added sugar. However, since the late 1970s apple pulp has been used as the paste base in place of 'jam', after reports that the jam seeds were attractive to some birds (Livingstone 1994) and the high sugar content of the bait attracted bees (McIntosh et al. 1964). Cinnamon is added to mask the smell and flavour of 1080 from possums and baits are dyed green to deter birds from feeding (Caithness and Williams 1971), as well as indicating a toxic component to users.

When 1080 paste was first used in New Zealand there were concerns over possible effects that its use may have on the honey bee (*Apis melifera*) industry (McIntosh et al. 1964). In early paste trials however, although bees were found to be attracted to jam pastes, there had been no reports of mass bee mortality in the field (McIntosh et al. 1964). This was considered to be largely a result of 'safe' bait laying by approved operators in conjunction with possum operations coinciding with times of year when bee food supplies were plentiful (Anon 1989).

With the need to increase possum control, 1080 apple paste is now used more frequently throughout the year. And, with increasing paste use, beekeepers have reported incidences of high bee mortalities (Goodwin and Ten Houten 1991), and have also observed green dye in some honey as a result of bees feeding on paste (Lowe 1994). To avoid these problems beekeepers have had to relocate their hives before the paste is used in the area. This is inconvenient and reduces honey production.

Research that focused on identifying repellents that could be used to deter bees from feeding on the paste was largely unsuccessful. Compounds were found that were repellent to bees but not to possums (Morgan 1985; Goodwin and Ten Houten 1991). Isovaleric acid was recommended to be a suitable deterrent to bees and attractive to possums, but in practice was too repugnant to use by field staff (Morgan and Goodwin 1995).

An alternative approach to reducing the attraction of bees to paste baits has been to develop a new sugar free apple paste. Trials testing this new paste found that it was highly palatable to possums, less attractive to bees, and relatively unattractive to some captive native birds compared to a standard paste (Morgan and Goodwin 1995). Recently, the paste has been thickened, and made more resistant to dehydration and 1080 loss (Morgan et al. 1996).

Non-target species testing

Research has focused primarily on developing a paste bait that can be used safely around honey bees without compromising the effectiveness of possum control.

However, before apple paste baits can be used widely in the field it is also important that the potential adverse effects of paste use on non-target species (other than bees) are also considered. While the response of seven species of captive birds and short-tailed bats to apple paste has been tested (Morgan and Goodwin 1995) there have been no field trials testing the new improved formulation of apple paste on non-target native bird species.

This report details the results of trials testing the new paste formulation on a range of non-target native bird species under natural and semi-natural conditions.

Objective

- To assess the response of native bird species (including frugivorous, insectivorous and nectar feeding birds) to the new formulation of apple paste.

METHODS

Methods to test a non-toxic form of the new apple paste were developed on a species by species basis with the aim of maximising bird-bait encounters. With the exception of kereru, paste was presented to birds in the same way in which they would encounter it in the field. This involved laying small walnut-sized portions (5 g) of paste directly on to turned soil or earth 'spits' (Rammell and Fleming 1978) approximately 3-5 m apart. Earth 'spits' were then turned over at the end of the trial. In the field, Regional Council control operations also involve pre-feeding for three days with non-toxic, un-dyed paste. At spits where pre-feed has been removed, or at every third spit pre-feed is then replaced with toxic paste (Morgan, D. from the draft DoC Toxin manual).

Bird visits, or encounters with the paste, were defined as the duration that a bird spent within one metre of the bait. All encounters or visits were recorded by direct observations, or with a video camera. The main parameters recorded were the number and duration of visits made to the bait by each species, the number of visits in which feeding was observed, and the duration birds spent feeding on bait.

Bait used

Apple paste baits were obtained from Animal Control Products, Wanganui. All baits were non-toxic, but otherwise the same as those used in poisoning operations, i.e. dyed green and lured with cinnamon. To ensure that pastes contained no poison, sub-samples from each tube were sent for 1080 analysis at the Toxicology Unit, Landcare Research, Lincoln.

General forest birds

Study site

The response of forest birds to the paste bait was trialled on Tiritiri Matangi Island in the Hauraki Gulf from 21/1/97 to 4/2/97. Tiritiri Matangi Island is approximately 220 ha in size and is situated 3 km off Whangaporoa Peninsula, 25 km North of Auckland, New Zealand (see Figure 5.1). Around 60 % of the island is covered in mature, naturally regenerating, or planted areas of coastal broad-leaf forest characteristic of the region (R. Walters, pers. comm. in (Galbraith and Hayson 1994). Tiritiri Matangi was gazetted as a Scientific Reserve in 1980 and later given the status of "open sanctuary". As such it has been the site for translocations of several endangered native bird species (Galbraith and Hayson 1994). In the absence of introduced predators, the island now contains healthy populations of a number of bird species. Forest bird encounters with bait laid using standard field techniques were expected to be few compared to other direct methods (e.g. attracting birds to paste placed on feeding tables). However, on Tiritiri Matangi Island where birds are abundant and some frequently observed feeding on the ground, bird-bait encounters were expected to be greater than at typical mainland sites.

Bait presentation

One turned earth 'spit' containing approximately one 5 g portion of paste was presented to birds in four locations on the island composed of mature, or naturally regenerating bush: Bush 1, Bush 22, Wattle valley 1 and Wattle valley 2 (see Figure 5.1). Eighteen bird species were observed in the areas where bait was laid: tui, bellbird, hihi, kakariki, rosella, North Island robin, saddleback, whitehead, silvereye, kereru, fantail, warbler, harrier, blackbird, sparrow, yellowhammer, brown quail and myna (generic names listed

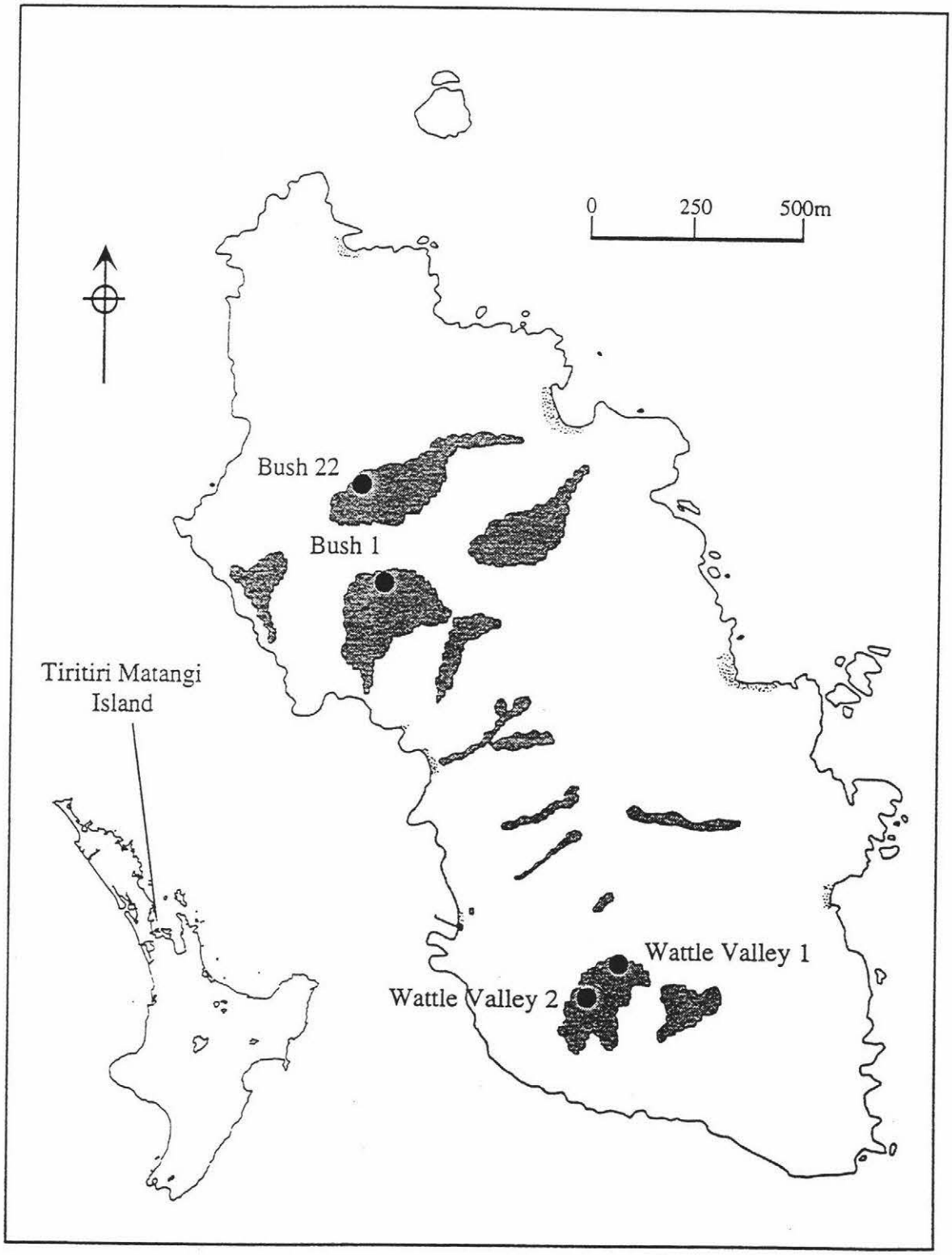


Figure 5.1 Location of Tiritiri Matangi Island in the Hauraki Gulf, North Island, New Zealand. Video recorded sites are shown as black dots. Shaded areas indicate bush patches.

in Appendix 1). At each location bird activity around the paste bait was recorded from dawn until dusk for three consecutive days using a time-lapse video camera. The same paste bait was presented each day. This allowed bait to 'age' and enabled us to examine the responses of birds to bait with time.

Analysis

The number of visits to baits that were made by robins, saddlebacks and blackbirds were examined using Chi-Squared analysis. The same test was used to examine differences in the number of feeding visits made by each of these species. The duration of visits to the paste and the duration spent feeding on paste were compared across these species using one-way ANOVA. Visit duration data were log transformed prior to analysis.

The visit duration and feeding visit duration made by all species with day of bait exposure (i.e. day 1, day 2, or day 3) were tested using one-way ANOVA. Visit duration data were log transformed prior to analysis.

The number of visits to the bait in which feeding was observed for all species with day of bait exposure were compared using Kruskal-Wallis one-way analysis test.

Robins

Although robins were expected to encounter paste during the forest bird trials, further trials were conducted to expose this species to the paste. Apple paste portions (each approximately 5 g) were placed on three earth 'spits' three metres apart within the territories of twelve robin pairs and one single male robin on Tiritiri Matangi Island (described above). Robin territories were all located within bush. The response of each pair and the single male to the bait was observed for one day for three forty-minute periods. Observations were made between 6.30 and 9.30 a.m. (morning), 12.00 and 3.00 p.m. (afternoon) and 5.30 and 8.30 p.m. (evening) between 21 January and 4 February 1997.

Kereru

The response of kereru to the paste bait was tested in an area of private bush at Otorohanga between 13 and 15 April 1997. Five portions of paste (each approximately

5 g) were placed on each of three feeding platforms. Platforms were suspended at a height of approximately three metres within kowhai, lucerne and plum trees where kereru were frequently observed. The birds were encouraged to visit by placing slices of apple on the platforms.

Weka

The response of weka to paste was determined using 50 captive birds at Karori Reserve, Wellington. The birds were located in a 50 x 50 m outside semi-natural enclosure. Weka were fed an artificial diet of porridge, sultanas, chopped ox heart and seaweed each day between 10:00 and 11:00 a.m. Two paste portions (approximately 5 g each) were presented to weka on turned earth 'spits', five times daily at dawn, mid-morning, after feeding, mid-afternoon, and evening, for two consecutive days (from 18 to 19 February 1997). Visits made to the bait by weka were recorded with a video camera hidden in blackberry two metres away.

Pukeko

The response of pukeko to the apple paste bait was determined at three locations; Levin, Ashurst Domain and Tiritiri Matangi Island. At Levin in an area of farmland adjacent to a lake, a family group of eight individuals (two sub-adults and six adult birds, one identifiable by its limp) was identified. Paste portions (each approximately 5g) were placed on to eight turned earth 'spits' dug along the edge of pasture in an area where pukeko were frequently seen to forage. All pukeko visits to bait were observed from a tent 50 m away using binoculars from 6:30 a.m. until 7:30 p.m. for three consecutive days from 11 to 13 March 1997. Uneaten baits were left to age for the three days of observations.

At Ashurst Domain the response of pukeko to paste bait (eight earth 'spits' each containing 5 g portions of paste) was observed for two mornings between 6:00 am and 1:00 p.m., and on Tiritiri Matangi Island (four earth 'spits' each containing 5 g portions of paste) for one hour between 7:00 and 8:00 a.m. for five days.

RESULTS

General forest birds

In total 154 hours were spent video recording paste baits in the four bush locations. During that time robins made 78 visits, saddlebacks 26 visits and blackbirds 19 visits to the paste bait, with feeding on paste observed during 22, 13 and 7 of those visits respectively (Table 5.1).

Robins located paste quickly but generally investigated bait from a distance before moving in closer to forage for invertebrates in the surrounding earth. Although saddleback encountered bait frequently, most encounters appeared to be incidental, and as with blackbirds, occurred generally whilst the birds were foraging through the area. Only four species other than robin, saddleback or blackbird encountered bait and none of these was observed to feed on the bait (Table 5.1).

Table 5.1 Number of visits to paste bait, and the mean time (min:sec) spent visiting and feeding on baits by seven bird species over three days. Means which share the same letter are not significantly different (at $p<0.05$). Kakariki, bellbird, brown quail and spotless crake were excluded from the analysis.

Bird species	No. visits to paste	Mean duration spent visiting bait	No. visits to paste where feeding was observed	Mean duration spent feeding on bait
Robin	78	00:37[a]	22	00:15[a]
Saddleback	26	00:32[a]	13	00:13[a]
Blackbird	19	00:24[a]	7	00:16[a]
Kakariki	1	00:31	0	0
Bellbird	1	00:23	0	0
Brown quail	1	00:22	0	0
Spotless Crake	-1	00:16	0	0

Robins visited and fed on paste bait on significantly more occasions than either blackbirds or saddlebacks (χ^2=48.9, p<0.01 and χ^2 =8.14, p<0.05 respectively, Chi-squared test). However, the length of time that robins visited bait did not differ significantly to that of either saddlebacks or blackbirds ($F_{[2,120]}$=2.93; p=0.0571). There was also no significant difference between the length of time that each species was observed feeding on bait ($F_{[2,39]}$=0.35; p=0.7094).

The number of visits that all species made to the bait declined significantly over the three days that bait was left out ($F_{[2,9]}$=7.19; p=0.015), although the duration of these visits did not differ significantly with day of bait exposure ($F_{[2,124]}$=2.14; p=0.1215, Table 5.2). There was also no significant difference in the number or duration of visits in which feeding was observed with day of exposure (H=2.93; df=2; p=0.231 and $F_{[2,39]}$=0.96; p=0.391 respectively, Table 5.3).

Table 5.2 Number and mean duration (min:sec) of visits to paste by all species combined over the three days of exposure to the bait.

Day	1		2		3	
Site	No. visits	Mean duration of visits	No. visits	Mean duration of visits	No. visits	Mean duration of visits
Bush 1	21	00:49	2	00:09	2	00:16
Bush 22	16	00:40	3	01:08	2	00:47
Wattle valley 1	23	00:35	19	00:29	9	00:22
Wattle valley 2	14	00:24	7	00:20	5	00:33

Table 5.3 Number and mean duration (min:sec) of feeding visits to paste for all species combined over the three days exposure to the bait.

Day	1		2		3	
Site	No. visits	Mean duration spent feeding	No. visits	Mean duration spent feeding	No. visits	Mean duration spent feeding
Bush 1	2	00:02	0	0	0	0
Bush 22	1	00:08	0	0	0	0
Wattle valley 1	16	00:20	11	00:13	2	00:18
Wattle valley 2	6	00:13	3	00:09	1	00:06

Robins

Twelve robin pairs and a single lone male (25 individuals in total) were presented with apple paste within their territories. Fifteen (60%) of these individuals made visits to the paste baits and six (24%) were observed feeding on bait, although only two (8%) returned repeatedly to feed on it. During 24 hours of observation, robins investigated paste for a total of 1 hr 26 min 7 sec and were observed feeding on paste for a total of 5 min 22 sec of that time (Table 5.4).

Twelve of the 15 birds which investigated paste baits were male. Paired male robins investigated bait significantly more often than the female from the pair (Fisher's Exact Test, $p<0.05$) and were generally more conspicuous within their territories. Five (42%) of the 12 males which encountered paste were observed feeding on paste and only one of the three females which encountered paste fed on it.

Robins were quickly attracted to the area where bait was laid, which was consistent with robin behaviour around disturbed ground. Robins generally investigated bait with caution from a distance, before hopping in closer. In some cases where feeding was observed the robin appeared to carefully probe at the surface of the paste. When the bait was later examined a number of invertebrates were found trapped on the surface.

During one recording period a robin displayed to the bait spit. It periodically leaped in and out of the paste while fanning its wings. During the following few minutes the robin tried to pull the paste off its feet using its bill. Another robin was also observed removing paste from its feet in a similar way after it had stood in the bait whilst foraging in the surrounding litter.

Other visitors to the paste

Six other bird species visited the baits during robin observations though none was observed to feed on paste (Table 5.5).

Kereru

Kereru were frequently observed close to the platforms and were likely to have seen the paste bait. However, none fed at the platforms or showed any interest in baits during the four days of observations.

Weka

During the two days of recording it was obvious that the paste was highly palatable to captive weka. Responses varied from a single individual consuming a complete portion of bait in 1 minute 28 seconds, to a group of 21 individuals taking 29 minutes 26 seconds, during which much fighting and squabbling was observed. On average bait was located and consumed by birds within 6 minute 23 seconds of it being placed within the enclosure, and interest in the soil and grass tainted with bait continued for up two hours after the bait had been eaten. The paste baits were readily consumed even when presented soon after the weka had been fed their artificial diet. Placing the bait out before dawn only resulted in delaying weka from feeding on it until first light.

Table 5.4 The number and duration (min:sec) of visits and feeding visits made to paste bait by male and female robins. In addition to the territory holding males in pairs 7 and 11, neighbouring males (*) also visited paste. Pair 10 was not seen investigating paste. Male 13 was a single lone male.

Robin pair	Male or Female?	No. of visits to bait	Total time spent visiting bait	No. visits feeding observed	Total time spent feeding on bait
1	M	5	03:09	1	00:01
1	F	2	00:52	0	0
2	M	5	08:57	0	0
3	F	10	32:22	8	01:35
4	M	4	02:38	0	0
5	M	4	07:35	0	0
6	M	4	04:11	1	00:19
7	M	2	00:23	0	0
7	M*	1	01:04	0	0
8	M	4	04:46	1	00:18
9	M	3	01:00	0	0
11	M	3	04:51	1	00:12
11	M*	1	01:14	0	0
12	F	10	04:57	0	0
13	M	11	08:08	8	02:57
Total		69	1 hr 26 min 7 sec	20	0 hr 5 min 22 sec

Table 5.5 Number and duration (min:sec) of visits to paste made by species other than robin.

Species	No. visits to paste	Time spent visiting paste	No. visits feeding
Tui	7	03:45	0
Saddleback	3	03:39	0
Whitehead	2	00:22	0
Bellbird	2	00:29	0
Fantail	1	00:12	0
Blackbird	1	00:19	0

Pukeko

During the three days that the group of pukeko at Levin were observed, the birds encountered paste baits 144 times and fed on paste during four of those visits (Table 5.6). Although it was not possible to distinguish individuals confidently, the birds which were observed feeding on bait were all adults. Therefore it was possible that half of the group may have sampled the paste bait.

Pukeko encounters with the paste bait at Ashurst Domain and Tiritiri Matangi Island were low in comparison to those at Levin and no birds were observed to feed on the paste at either of these locations (Table 5.6).

Pukeko generally showed little interest in the paste baits and earth 'spits'. However, when feeding was observed it was preceded by pukeko appearing to suddenly notice the paste bait, and then circling it a few times with their necks arched, before probing into it. On one occasion where a group of four birds simultaneously encountered the paste, one bird prevented the others from approaching closer while it investigated and then proceeded to feed on the paste. After feeding, pukeko spent a few seconds trying to swallow the paste stuck around their bills. Another pukeko was also observed wiping its bill on the ground to try and remove paste.

Other visitors to paste

Other species also made visits to the paste baits during pukeko observations. These included a farm dog, a heifer, sparrows and blackbirds. The farm dog and stock were frequently observed feeding and actively sought out paste baits.

Table 5.6 Number and duration (hr:min:sec) of visits to paste baits by pukeko, and number of visits in which pukeko were observed to feed on paste. The last column indicates the number of times pukeko made contact with the paste.

Location	Day	No. visits to paste	Time spent visiting paste	No. visits feeding observed	No. probes in bait
Levin	1	35	00:21:39	3	6,2,1
	2	29	00:09:00	0	0
	3	80	00:32:30	1	2
Total		**144**	**01:03:09**	**4**	**11**
Ashurst	1	10	00:04:47	0	0
	2	2	00:00:35	0	0
Total		**12**	**00:05:22**	**0**	**0**
Tiritiri Matangi	1	8	00:03:51	0	0
	2	4	00:00:35	0	0
	3	9	00:02:22	0	0
	4	23	00:06:53	0	0
Total		**44**	**00:13:41**	**0**	**0**

DISCUSSION

Of the 21 bird species exposed to new 'improved' possum paste, only robin, saddleback, blackbird, weka and pukeko were observed to feed on it.

Forest birds

Continuous filming of bait in the four locations enabled all bird visits to be recorded throughout each day. Robin, saddleback and blackbird were the three species which were recorded frequently investigating and feeding on the apple paste. This may have been expected because these species were often observed feeding and foraging on the ground, and were therefore more likely to encounter bait than other species which feed predominantly in the canopy. Overall, the total number of all species' visits to the paste declined markedly with increasing days of paste exposure and this may have been due to a number of factors:

- the paste or turned earth may have become less novel with increasing length of exposure.
- invertebrates that were present when earth 'spits' were first turned may have declined in abundance with time, making the bait area less attractive.
- something in the bait may have changed (e.g. texture) as it weathered, which made it less attractive.
- birds may have had a bad 'first' experience with the bait and therefore not returned on subsequent days.

Factors which obviously changed with time were the decline in the abundance of invertebrates around the bait, and the bait's appearance. After three days the paste had seeped into the earth 'spit' leaving only a thin coating on the surface. For whatever reason however, the fact that bird visits to paste baits declined with increasing day of exposure could have useful implication for reducing non-target bird mortality with this bait type. Regional Council operations involve pre-feeding for three days with a non-toxic bait. Pre-feeding may therefore allow bird interest in the bait, or bait area to decline before toxic baits are laid, and thus reduce the number of bird encounters with toxic bait.

Recently, however Morgan et al. (1996) suggested that pre-feeding may reduce the effectiveness of 1080 apple paste at killing possums, and its elimination could save considerable cost (Thomas and Morgan 1997). Techniques to improve target kills may therefore conflict with those to reduce the risk of killing ground-feeding native birds in areas where these types of birds may encounter baits. However, there is need for further work in this area. Laying toxic baits at night may also reduce bird attraction to the bait area, particularly for species such as robin which are be attracted to the presence of humans (pers. obs.).

The paste bait changed in appearance and became runnier as the days of exposure increased. This has been reported previously, and may cause the bait to lose 1080 more rapidly (Morgan and Goodwin 1995). In dry summer weather similar to that experienced during the trials on Tiritiri Matangi Island possum kills may be higher if a thicker paste type, more resistant to de-hydration, is used. However, if the paste retains its form and does not seep into the earth, there may be more visits by birds over the period of exposure. Further trials involving daily presentation of fresh bait to birds would help to investigate this.

Although it was not possible to record the amount of paste eaten by birds, and there is also no LD_{50}'s of 1080 for robins or saddlebacks, it was likely that most birds which fed on paste ate enough to have consumed a lethal dose had the bait been toxic. Blackbirds, however have a known LD_{50} for 1080 of 0.76mg/kg. They would need to eat approximately 1 g of the paste (0.08% conc. 1080) to receive a lethal dose (McIlroy 1994) and were likely to have eaten enough to have been killed.

Robins

Robins are naturally inquisitive and therefore were expected to be attracted to humans laying paste baits within their territory. Turning earth 'spits' to lay bait also exposed invertebrates and may have increased the likelihood of robins probing close to and possibly feeding on bait. Furthermore, invertebrates trapped in the paste may have increased the attraction of the paste to robins. Invertebrate ground feeding species such

as robin may consequently be at risk from feeding on poisonous bait and poisoned invertebrates.

The display behaviour by one robin towards paste is a similar response to that sometimes used to warn off intruders into their territories (Falla et al. 1993). Udy (1981) observed similar displays, or what he described as 'attacking' behaviour of robins towards orange and green pellets used in bait trials on Kapiti Island. If robins 'attack' paste baits then they have even greater chance of contacting with and subsequently ingesting paste. The bias towards males inspecting paste may also be of consequence, particularly if this increases the chances of birds feeding on paste. Populations may become effectively extinct if males are reduced significantly more than females during poisoning operations. However, there was no difference in the proportions of male and female robins that disappeared during a recent aerial possum control operation using 1080 carrot bait, (R. Powlesland, pers. comm.), although paste baits may be more noticable than carrot on the ground and therefore more likely to be investigated intentionally by robins.

During robin observations, visits to baits by other species (excluding robin, saddleback or blackbird) were incidental and did not appear to be a result of these birds finding the bait, or surrounding earth attractive. Tui, whiteheads, bellbirds and fantails were rarely observed feeding on the ground but did land to drink from water holes. While too few bird-bait encounters were obtained to be able to state that these 'other' species are unlikely to consume bait, the chances of them encountering bait appeared to be low.

Kereru

The fact that no kereru visited feeding tables may be due to a combination of factors including: birds avoiding feeding from novel structures, natural food supplies being plentiful (rendering additional novel foods unattractive), or birds not recognising paste as a potential food. If natural foods are abundant and birds are consequently uninterested in additional foods offered, then this may indicate that in April (when trials took place) kereru are unlikely to feed on novel items such as paste baits. However, it is

recommended that these trials are repeated in mid-winter when natural foods are expected to be less plentiful.

Weka

Weka were extremely attracted to the paste and even fought amongst themselves to gain access to baits. Responses to pastes were similar regardless of whether birds had just been fed or had not received food for several hours. The level of hunger did not therefore appear to be affect the birds' response to the paste. However, these results must be treated with caution. The captive birds at Karori Reserve were maintained under semi-natural conditions where bird densities were high and competition for food likely to be higher than that which wild birds may experience. The weka were fed daily and may also have become accustomed to feeding on items provided by humans. However, despite the attraction to apple paste, not all of the food items which were offered to the birds were palatable. Weka refused to feed on blackberries and feeding on 'trial' flour pellets presented in another study was only minimal (pers. obs).

It is likely that a number of the birds would have consumed sufficient paste to have received a lethal quantity of 1080 had the bait been toxic. A 1 kg weka needs to consume approximately 10 g of paste containing 0.08% 1080 to receive a lethal dose based on an experimentally determined LD_{50} of 8 mg 1080/kg (McIntosh et al. 1966). If wild weka are attracted to baits in a similar manner as captive birds, it is possible that they may encounter and consume enough paste for a lethal dose. Further trials of this paste on free living weka are however required.

Pukeko

Pukeko encountered paste frequently but only occasionally appeared to notice baits. However, although there is no LD_{50} for 1080 reported for pukeko, it is possible that half of the pukeko family may have consumed a lethal dose had the bait been toxic.

General comments

The likelihood of an animal being killed by pest-control programs with 1080 depends on many factors. These include the sensitivity of the animal to the poison, the chances of

the animal encountering and feeding on bait, and whether the amount of bait likely to be consumed contains sufficient poison to be deadly (McIlroy 1994).

The species identified as feeding on paste bait in this study are those that have also been found to feed on paste in other trials (e.g. weka and robin, Morgan and Goodwin 1995), and which have also been affected by control operations using different bait types and poisons (Spurr 1991; Spurr 1994; Spurr 1995). For example, over 90% of pukeko were killed during an aerial Talon 20P (brodifacoum) poisoning operation for kiore eradication on Tiritiri Matangi Island, while additional searches for dead birds found that North Island saddleback, blackbird and spotless crake had also fed on the baits (C.R Veitch, pers. comm. cited in Spurr, 1995). These species are naturally inquisitive, forage frequently on the ground, and also have a herbivorous or omnivorous diet, characteristics which increase the likelihood of birds encountering baits and feeding on them.

Although bird densities on Tiritiri Matangi Island were high, paste bait encounters by native species other than robin and saddleback were infrequent. This suggests that although these 'other' species may be highly susceptible to 1080 the chances of them encountering and feeding on paste bait is low.

RECOMMENDATIONS

Management

- In areas where ground feeding species such as weka, robin, pukeko and saddleback are present 1080 apple paste bait should be placed in bait stations above the ground. Kiwi are also likely to be potentially at risk from feeding on ground laid pastes. Precautions to lay bait safely for ground feeding species should be extended to include areas known to contain kiwi.

Research

- Undertake further trials using the improved formulation of apple paste on kereru in mid-winter and on free-living weka.

- Further investigation is required on the use of pre-feeding as a strategy for reducing the risk of poisoning ground-feeding birds.
- Further investigation of the response of dogs and livestock to the paste is required.

REFERENCES

Anon. 1989. Trials seeking bee-proof 1080 paste. *New Zealand Farmer* 111: 7.

Caithness, T.A. and Williams, G.R. 1971. Protecting birds from poisoned baits. *New Zealand Journal of Agriculture* 122: 38-43.

Falla, R.A.; Sibson, R.B. and Turbott, E.G. 1993. *Collins Field Guide to the Birds of New Zealand.* HarperCollins Publishers (New Zealand) Limited, P.O. Box 1. Auckland. 247 pp.

Galbraith, M.P. and Hayson, C.R. 1994. Tiritiri Matangi Island, New Zealand: public participation in species translocation to an open santuary. *In:* Serena, M. (Eds), *Reintroduction Biology of Australian and New Zealand Fauna*, pp 149-154. Surrey Beatty and Sons Pty Limited, New South Wales, Australia.

Goodwin, R.M. and Ten Houten, A. 1991. Poisoning of honey bees (*Apis mellifera*) by sodium monofluoroacetate (1080) in baits. *New Zealand Journal of Zoology* 18: 45-51.

Livingstone, P.G. 1994. The use of 1080 in New Zealand. *In:* Seawright, A.A. & Eason, C.T. (Eds), *Proceedings of the Science Workshop on 1080*, pp 1-9. The Royal Society of New Zealand, Miscellaneous Series No. 28, Christchurch, New Zealand.

Lowe, M. 1994. *1080 in honey from possum baits, Rahotu - Taranaki.* Taranaki Healthcare (Unpublished) 16 pp.

McIlroy, J.C. 1994. Susceptibility of target and non-target animals to 1080. *In:* Seawright, A.A. & Eason, C.T. (Eds), *Proceedings of the Science Workshop on 1080*, pp 90-96. The Royal Society of New Zealand, Miscellaneous Series No.28, Christchurch, New Zealand.

McIntosh, I.G.; Bell, J.; Poole, W.S.H. and Staples, E.L.J. 1966. The toxicity of sodium monofluoroacetate (1080) to the North Island weka (*Gallirallus australis greyi*). *New Zealand Journal of Science* 9: 125-128.

McIntosh, I.G.; Palmer-Jones, T. and Staples, E.L.J. 1964. 1080 poison baits for animal pests: Wallaceville shows that proper use will not endanger bees or affect honey. *New Zealand Journal of Agriculture* 108: 141-143.

Morgan, D.R. 1985. Possum control - Making toxic baits more acceptable. *What's New in Forest Research?* 137.

Morgan, D.R. and Goodwin, M. 1995. *Identification of 1080 paste suitable for use in the presence of bees (314/92).* Landcare Research Contract Report No.LC9596/03. Prepared for the Animal Health Board, PO Box 3412, Wellington. 19 pp.

Morgan, D.R.; Harris, R.J. and Goodwin, R.M. 1996. *Enhancing the formulation and performance of "bee-safe" possum paste.* Landcare Research Contract Report No.314/92. 18 pp.

Rammell, C.G. and Fleming, P.A. 1978. *Compound 1080: properties and uses of sodium monofluoroacetate in New Zealand.* Animal Health Division, Ministry of Agriculture and Fisheries Wellington. 112 pp.

Spurr, E.B. 1991. Effects of brushtail possum control operations on non-target bird populations. *Acta XX Congressus Internationalis Ornithologici* 20: 2534-2545.

Spurr, E.B. 1994. Review of the impacts on non-target species of sodium monofluoroacetate (1080) in baits used for pest control in New Zealand. *In*: Seawright, A.A. and Eason, C.T. (Eds). *Proceedings of the Science Workshop on 1080.* pp 124-133. The Royal Society of New Zealand, Miscellaneous series No.28, Christchurch, New Zealand.

Spurr, E.B.; Eason, C.T. 1995. Review of the toxicity and impacts of brodifacoum on non-target wildlife in New Zealand. *New Zealand Journal of Zoology* 22: 371-379.

Thomas, M.D. and Morgan, D.R. 1997. *The effect of prefeeding in ground control operations against possums (40/90).* Landcare Research Contract Report (unpublished) LC9697/63. 7 pp.

Udy, P.B. and Pracy, L.T. 1981. Baits, Birds and Field Operations. *Counterpest* 6: 13-15.

Appendix 1 Generic names of bird species tested

Common name	Generic name
Bellbird	*Anthornis melanura*
Blackbird	*Turdus merula merula*
Fantail	*Rhipidura fuliginosa*
Grey warbler	*Gerygone igata*
Harrier	*Circus approximans*
Hihi	*Notiomystis cincta*
Kakariki	*Cyanoramphus novaezelandiae*
Kereru	*Hemiphaga novaezelandiae*
Myna	*Acridotheres tristis*
North Island saddleback	*Philesturnus carunculatus rufusater*
Pukeko	*Porphyrio porphyrio melanotus*
Brown quail	*Synoicus ypsilophorus*
North Island robin	*Petroica australis longipes*
Rosella	*Platycercus eximius*
Silvereye	*Zosterops lateralis lateralis*
Sparrow	*Passer domesticus domesticus*
Spotless crake	*Porzana tabuensis plumbea*
Tui	*Prosthemadera novaeseelandiae*
Weka	*Gallirallus australis*
Whitehead	*Mohoua albicilla*
Yellowhammer	*Emberiza citrinella caliginosa*