
Sodium fluoroacetate

Pesticide Information Review

Authors/Compilers:

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Department of Conservation

Science and Capability Group

Private Bag 3072,

Hamilton 3240, New Zealand

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Version History:

Version	Date Written	Change/Reason for Change
2025/1	25/07/2025	New information added to sections 2.5.4, 3.2.1, 5.2.2
2024/2	09/09/2024	Section 3.2.1 and 3.2.3 updated with information on kea. Information added to 3.2.1 (kea and gull deaths) and 4.2.1 (tahr kills) from historic carrot operation. New information on bykill rate of stoats and feral cats added to 6.2.4.
2024/1	08/02/2024	Section 1.4 updated with product registrations. Section 2.5.4 updated with residue test results. Information added to section 3.2.1 with deaths of Southern Black Backed gulls, rowi and kea. Information added to section 3.2.3 from kea monitoring in Otira Taipo and Arthur's Pass West operations, Information on tahr survival trial through aerial 1080 operation added to section 4.2.
2022/3	16/09/2022	Information on weka added to sections 3.1 & 3.2. Pestex and Prodeer bait added to sections 4.2 and 6.2. Bait degradation info added to section 2.1.1.
2022/2	01/06/2022	Information on honey bees added to sections 2.5.4; 4.2.1.
2022/1	24/01/2022	Information on southern black-backed gulls added to sections 3.2.1 & 3.2.3
2021/4	13/10/2021	New information included in sections 1.8.3 (absorption, metabolism, excretion); 2.1.2 (solubility); 3.1.1 & 3.1.3 (earthworms and soil microorganisms); 5.1.1 (lethal dose estimates); 5.1.8 (sub-lethal effects on blood chemistry & organ function); 5.1.9 (refs from poisoning cases in humans); 6.1.1 (animal welfare impacts).
2021/3	26/07/2021	New information added to section 2.5.5 on persistence of 1080 in bone marrow of carcasses; 4.2.1 information on recorded by-kill of feral deer populations and by-kill of whitetail deer.
2021/2	25/06/2021	Corrected mistake in section 3.2.3. re number of aerial/handlaid operations where NI Brown Kiwi have been monitored.

2021/1	13/01/2021	Updated section 3.2.1 with new information for kea and takahe; New information added to section 3.2.3 for kea, rock wren and takahe.
2020/1	24/04/2020	New information added in section 2.2.1 for breakdown of feral cat 1g/kg 1080 baits; 3.2.1 and 3.2.3 updated with new information from kea monitored through 1080 cereal pellet operations.
2019/1	1/11/2019	New information included in section 3.2.1 (Table 7, new records for kea and whio); information added to section 3.2.2 (1080 positive whio scat samples); Information added and revised in section 3.2.3 (whio monitored through cereal pellet operations, kea monitored through cereal pellet operations, monitoring forest birds in Rolleston and Alexander Ranges). Updated LD ₅₀ for norway rat in 6.2.1. Updated Table 11, section 3.2.2.
2018/6	21/12/2018	Updated kea information in section 3.2.3
2018/5	6/11/2018	Updated sections 2.1.1 (dust); 2.5.4; 4.2.2 (captive reared whio); 3.2.3
2018/4	9/10/2018	Updated 1.6 Historical Development and Use section, inserted new section 1.7 Natural Occurrence, information about dust in Section 2.1.1., information about breakdown products in water in section 2.3.1, updated 5 Human Health
2018/3	30/08/2018	Corrected spelling mistakes and updated 'Effects on native non-target' summary
2018/2	06/06/2018	Information about No Possums® 1080 gel moved to Appendix 1; Efficacy data for aerial operations updated
2018/1	15/05/2018	Update information in Sections 2.5.4, 3.2.1 and 4.2.1
2017/3	4/9/2017	Updated field efficacy data 6.2.4 for possums, rats, mice and stoats.
2017/2	4/08/2017	Updated information in Sections 2.5.4, 3.2.1, 3.2.2, 3.2.3 (short-tailed bats). Corrected scientific names.
2017/1	12/07/2017	Updated information in Sections 2.2.1, 2.5.4, 3.2.2, 3.2.3 & 4.2.1 (kea)
2016/2	14/12/2016	Updated information in Section 2.3.1.
2016/1	15/08/2016	Updated information in Section 3.2.3 about Archey's frogs.
2015/2	23/12/2015	Noted that No Possums® 1080 gel has been de-registered

2015/1	30/06/2015	Efficacy data in Section 6.2.4 for possums, rats, mice, rabbits and stoats updated.
2014/3	15/12/2014	New data on trout in Sections 2.5.1 and 2.5.2
2014/2	12/12/2014	Formatting changes, and updates to Sections 3.2 and 6.2
2014/1	29/08/2014	New data on soil breakdown (Section 2.2.2), water samples (Section 2.3.1), native non-targets (3.2.3), and revised overview for native non-targets
2013/1	18/09/2013	New information on kea (Sections 2.5.4, 3.2.1 and 3.2.3) and morepork, kaka, robins, tomtits, grey warbler and rifleman (3.2.3).
2012/3	23/10/2012	New information on fernbirds (Sections 2.5.4, 3.2.1 and 3.2.3) & bees (4.2.1)
2012/2	17/10/2012	New information on 1080 residues in magpies (<i>Pica pica</i>) in 2.5.4, and LD ₅₀ for magpies in 4.1.1.
2012/1	12/04/2012	New information on 1080 in water 2.3.1, 2.3.2, and 2.3.3, and 3.2.1 (snails), corrected formatting and Table numbers.
2011/2	17/10/2011	New information (kea) 3.2.3
2011/1	13/1/2011	New information on fish and aquatic invertebrates 3.2.3
2010/2	31/08/2010	New information (kiwi) 3.2.3
2010/1	3/08/2010	New information 2.5.2, 3.2.2 & 3.2.3
2009/7	15/12/2009	3.2.3 (skinks and weka); 5.1.7, 6.2.4 (Rats)
2009/6	1/09/2009	Corrected number of operations monitored by Thomas et al. (2004) in section 2.1.1
2009/5	13/8/2009	New information in sections 2.5.4 (Quail) & 4.2.1 (0.2% carrot and 0.04% oat operations).
2009/4	20/7/2009	Rewrote sections 2.3.1, 2.4.2 and 2.4.3 based on new information.
2009/3	13/07/2009	New information in Section 3.2.2 (falcon); 6.2.4 (Mice)
2009/2	19/05/2009	New information in Section 6.2.2 (Mice)
2009/1	17/02/09	New information in Sections 2.5.1 & 2.5.4 (deer); 3.2.1 & 3.2.3 (Kakariki)
2008/1	18/09/08	New information in Sections 2.5.2; 2.5.4; 3.2.1 & 3.2.3 (kea); 4.1.4; 4.2.1; & 6.2.4
2006/2	10/08/06	New information in section 3.2.3 (paste baits)

2006/1	15/3/06	New information in sections 2.1.1; 2.5.5; 3.2.3; & 6.2.4.
2005/2	17/03/05	New information in sections 2.1.1; 2.4.2; 2.5.2; & 6.2.4.
2005/1	18/01/05	Up dated Section 1.4 pesticide uses
2004/2	8/10/2004	Residue and non-target native and feral animal information from Speedy (2003) included
2004/1	15/9/2004	Original document

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Overview

Introduction

Sodium monofluoroacetate (1080) is the most widely used poison for possum control in New Zealand for situations where possum numbers need to be reduced rapidly over large areas. Vertebrate pesticides containing 1080 are also registered for the control of rabbits, wallabies, deer, goats, cats and rodents. The manufactured 1080 used in toxic baits is chemically identical to the toxic compound found in some poisonous plants, and highly toxic fluoroacetate-producing plants are globally distributed. In plants, fluoroacetate appears to be a secondary plant compound that is biosynthesised at high concentrations as a chemical defence mechanism against browsing invertebrates and vertebrates.

Monofluoroacetate is converted within animals to fluoroacetate, which inhibits the tricarboxylic acid cycle. This results in accumulation of citrate in the tissues and plasma, energy deprivation, and death. Sodium monofluoroacetate (1080) is absorbed through the gastrointestinal tract or via the lungs if inhaled. Monofluoroacetate is not readily absorbed through intact skin, but it can be absorbed more readily through cuts and abrasions.

Fate in the Environment

1080 in baits may be defluorinated in 1–2 weeks under favourable conditions. However, under less favourable conditions breakdown may take several weeks and, in extreme cold and drought, 1080 residues could persist in baits for several months.

Degradation of 1080 is slow in soil and sediments, taking 1–4 weeks under favourable conditions. The rate of degradation will be influenced by the presence of soil or litter micro-organisms, and temperature, soil moisture and rainfall. Sodium monofluoroacetate is highly water soluble so leaching out of soil will occur.

While the concentration of 1080 in deionised (sterile) water remains relatively constant and independent of temperature, 1080 degradation occurs within 1–2 weeks in natural water. Temperature, and the presence of aquatic plants and microbes all affect 1080 degradation in aquatic environments. Water samples have been collected from streams following numerous pest control operations using 1080. 96.6% of these samples contained no residues of 1080. Where residues were found most of these had less than 1 µg l⁻¹ 1080. Where higher 1080 residues have been found in water, the samples were mostly from very small streams and/or associated with the presence of bait, during aerial operations.

While plants can take up 1080, it is unlikely to be in large amounts. If taken up, 1080 residues persist less than 38 days in plants.

1080 has a relatively short half-life in sub-lethally dosed animals and it is metabolised and eliminated from living animals within days. However, it can persist in carcasses for months. The rate of degradation of 1080 in carcasses will depend on moisture, temperature and the presence of micro-organisms.

Effects on Non-Target Native Species

Based on the few studies of native species available, and the large number of non-native species studied (Part 4) suggests 1080 is likely to be toxic to most native animals. There is wide variation in sensitivity between taxonomic groups with mammals more sensitive than birds and invertebrates (on a weight for weight basis). Sub-lethal effects have been demonstrated for native invertebrates in the laboratory. The small size of many native species (relative to the target pests) means that toxic baits used for pest control are capable of causing harm to almost any animal that eats the bait. Therefore, the level of exposure to the bait becomes important in determining the effects on non-target native species in the field.

Most information on non-target exposure to 1080 bait relates to aerial poisoning as this is thought to be the “worst case scenario” for studying non-target effects. Hand laid baits are sometimes used to approximate aerial poisoning in studies. Bait station studies are scarce. It could be assumed that native species are not more at risk using bait stations than distributing the same bait type aerially.

There are records of a range of native bird species found dead after aerial poisoning operations and many of these individuals have contained residues of 1080. However, when records are discounted from:

- operations which did not meet current bait quality standards (e.g. using unscreened, un-dyed carrot bait with berry fruit lures) or
- those animals which did not have detectable 1080 residues,

the Vertebrate Pesticide Residue Database (VPRD) between 1994-2018 recorded only 44 poisoned individuals representing 11 native species across all bait types used in aerial and handlaid operations. No conclusions about population effects can be drawn from this information but it is useful to focus further studies. Some native species (mainly invertebrates) have contained 1080 residues when sampled, an indication of potential risk to insectivores from secondary poisoning.

Loss of individuals in a population of native species as a consequence of 1080 poisoning can have variable significance to the long-term viability of the population depending on the context. Those animals with a large population and/or a high rate of increase can compensate for small losses. Poison-related mortality may be replacing deaths from predation or winter starvation. Threatened species usually have a poor ability to recover from additional mortality, making the consequences theoretically more concerning.

There have been numerous studies examining the effects of aerial poisoning on native non-target populations over the last 20 years. 24 species of native birds, particularly threatened species, have been monitored. None of the studies have identified population level mortality which threatened the viability of the species, although the only reliably calculated mortality rates are for kokako, kiwi, kaka and fernbirds. The upper 95% mortality rates for kokako, kiwi, and kaka are all less than 3.5%. The mean mortality rate for fernbirds is 9.4%.

Limited monitoring of short tailed bats and native frogs has not indicated detectable mortality due to aerial 1080 poisoning.

Invertebrate populations have been monitored in nine aerial poisoning operations and none have shown significant population effects on any species studied, nor is there evidence to suggest poisoned invertebrates are a significant factor in secondary poisoning of other animals. Long term monitoring of native land snails indicates substantial benefits to threatened populations in sites treated with aerial poisoning.

The risks 1080 operations pose to aquatic species is considered very low. Fish are very tolerant to 1080. Additionally, 1080 contamination of water is rarely found during 1080 operations and is at an extremely low level when it has occurred. No mortality of longfin eels, kōaro or upland bullies was observed during experiments where high densities of cereal 1080 pellets were placed in water just upstream of them. Eels and koura have survived experimental feeding of cereal 1080 pellets, and eels have survived feeding on possum tissue containing 1080. There have also been no detectable effects on aquatic invertebrate communities in field studies when 1080 baits were placed at high densities in streams.

Effects on Domestic and Feral Animals

There is wide variation between species in their susceptibility to 1080 poisoning. Dogs are especially vulnerable and highly likely to die if they eat 1080 baits or scavenge animals killed by 1080. Larger animals such as cattle need several possum baits to receive a lethal dose but deaths have been reported where animals have access to baits, including those contained in bait stations.

Sub-lethal effects at realistic dose rates have been recorded in sheep and other species, typically affecting the heart. Exposure to prolonged high doses resulted in mild foetal abnormalities in pregnant rats and damaged sperm in male rats but no mutagenic properties were found. No antidote is currently available for 1080 poisoning although veterinary treatment can be successful.

Feral deer population mortality from aerial poisoning operations targeting possums and rats has been highly variable. Across a number of 1080 cereal pellet operations deer mortality estimates were more often classed as low (0-33%) when sowing rates were at or below 1.5kg/ha and potentially at those sites that had been previously treated within 5 years. Field trials have indicated that deer-repellent baits can reduce the level of deer mortality relative to when non-repellent baits are used.

Birds are generally less susceptible to 1080 than mammals but introduced birds such as blackbirds and chaffinches are found dead after aerial poisoning operations. Lizards and fish appear quite tolerant of 1080, according to research on overseas species.

Although 1080 is toxic to honeybees, baits used in pest control are generally not attractive to honeybees. However, this may not be the case if honeybees are particularly hungry, and food resources are scarce. On occasion and under these conditions honeybees have been observed collecting and storing cereal pellet bait material in hive frames as a substitute for pollen. Tests of honey from affected hives found no trace of 1080. Paste baits containing 1080 were reformulated in the 1990s to reduce their attractiveness to bees.

Human Health

The estimated lethal dose of 1080 in humans lies in the range of 0.7 and 10.0 mg kg⁻¹. Sodium monofluoroacetate (1080) is absorbed through the gastrointestinal tract or via the lungs if inhaled. Monofluoroacetate is not readily absorbed through intact skin, but it can be absorbed more readily through cuts and abrasions. The onset clinical signs usually range from 30 minutes to about 2-3 hours. Signs of poisoning include nausea, vomiting, and abdominal pain initially, followed by respiratory distress, anxiety, agitation, muscle spasms, stupor, seizures, and coma.

1080 is not a mutagen and is unlikely to be a carcinogen. It has sub-lethal effects on reproduction and is classified as a teratogen.

There is no effective antidote for 1080 poisoning in humans and any treatment given is largely symptomatic and supportive.

Operational

1080 is considered to have medium humaneness for possums, however there has been little formal research into the humaneness of 1080 on other target species. Most deaths of pest species occur 8 – 48 hours after ingestion of a lethal dose.

All the registered target species have relatively high susceptibility to 1080. The short latent period means that bait shyness can develop in animals receiving a sub-lethal dose. Mice exhibit a marked avoidance of 1080 which is likely to result in control operation failures.

The majority of pest control operations using 1080 have target pest kills of greater than 80%.

1. Introduction

Sodium monofluoroacetate (1080) is the most widely used poison for possum control in New Zealand for situations where possum numbers need to be reduced rapidly over large areas. Vertebrate pesticides containing 1080 are also registered for the control of rabbits, wallabies, deer, goats, cats and rodents. The manufactured 1080 used in toxic baits is chemically identical to the toxic compound found in some poisonous plants, and highly toxic fluoroacetate-producing plants are globally distributed. In plants, fluoroacetate appears to be a secondary plant compound that is biosynthesised at high concentrations as a chemical defence mechanism against browsing invertebrates and vertebrates.

Monofluoroacetate is converted within animals to fluorocitrate, which inhibits the tricarboxylic acid cycle. This results in accumulation of citrate in the tissues and plasma, energy deprivation, and death. Sodium monofluoroacetate (1080) is absorbed through the gastrointestinal tract or via the lungs if inhaled. Monofluoroacetate is not readily absorbed through intact skin, but it can be absorbed more readily through cuts and abrasions.

1.1. Chemical name

Sodium monofluoroacetate

1.2. Synonyms

Sodium fluoroacetate, Monofluoroacetate, Compound-1080, 1080 ('ten-eighty')

1.3. CAS Numbers

62-74-8

1.4. Registered pesticides containing 1080 available in New Zealand

0.2 % 1080 Pellets (2 g kg⁻¹ 1080), Pesticide use numbers: 21, 22, 23

Pronature Possum & Rodent Pellet (previously 0.15% 1080 Pellets) (1.5 g kg⁻¹ 1080), Pesticide use numbers: 1, 2, 3, 98

0.08 % 1080 Pellets (0.8 g kg⁻¹ 1080), Pesticide use numbers: 7, 8, 9

0.08 % 1080 Rodent Pellets (0.8 g kg⁻¹ 1080), Pesticide use numbers: 10, 11, 12

0.04% 1080 Pellets (0.4 g kg⁻¹ 1080), Pesticide use numbers: 13, 14

1080 solution (200 g l⁻¹ 1080), Pesticide use numbers: 5, 6, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 37

0.10% 1080 Feral Cat Bait (1.0 g kg⁻¹ 1080), Pesticide use numbers: 38, 115
10% 1080 Gel (100 g kg⁻¹ 1080), Pesticide use numbers: 15
5% 1080 Gel (50 g kg⁻¹ 1080), Pesticide use numbers: 16
Pestoff Exterminator Paste (1.5 g kg⁻¹ 1080), Pesticide use numbers: 35, 36
Pestoff Professional 1080 Possum Paste 0.08% (0.8 g kg⁻¹ 1080), Pesticide use numbers: 41
Pestoff Professional 1080 Possum Paste 0.15% (1.5 g kg⁻¹ 1080), Pesticide use numbers: 42, 96
Pestoff Professional 1080 Possum & Rabbit Paste 0.06% (0.6 g kg⁻¹ 1080), Pesticide use numbers: 44
Pestex (1.5 g kg⁻¹ 1080), Pesticide use numbers: 140, 141, 142
Pestex DR (1.5 g kg⁻¹ 1080), Pesticide use numbers 149, 150, 151
Prodeer Possum and Rat Bait (1.5 g kg⁻¹ 1080), Pesticide use numbers 145, 146, 147, 148
Note: No Possums® 1080 gel was de-registered in 2015. Information about this product is contained in Appendix 1 (doc-2534486).

1.5. Chemical and physical properties

The empirical formula of 1080 is C₂H₂FNaO₂ (Figure 1). It has a molecular weight of 100.3. In its pure form 1080 is an odourless, colourless, non-volatile powder that decomposes at about 200°C. Although the compound is often said to be tasteless, dilute solutions are thought to taste like weak vinegar. Sodium monofluoroacetate is very water-soluble but has low solubility in organic solvents such as ethanol and oils. Monofluoroacetates are chemically stable, hence 1080 as a pure compound in powder form — or when prepared in an aqueous stock solution — will not readily decompose.

This section is from Eason and Wickstrom (2001).

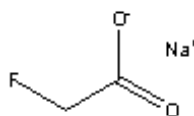


Figure 1. The chemical structure of sodium fluoroacetate.

1.6. Historical development and use

Sodium monofluoroacetate was first patented as a rodenticide in the late 1930's, with commercial use starting in the United States in 1944 to control gophers, ground squirrels, prairie dogs, field mice, and commensal rodents. In New Zealand the first trials were carried out in 1954, and by 1957 its use had become widespread. Currently in New Zealand the principal target species is possums and rodents. It is also registered for use against rabbits, wallabies, deer, goats and cats. 1080 was also used in a fish-based paste to control wasps in the late 1990s.

Recently, fluoroacetate has been investigated as a biomedical tool. Sodium fluoroacetate has been found to have a positive inotropic effect, increasing the muscular contractions of the heart (Korth et al., 1978), and could be used in studies of therapies for congestive heart failure (Eason, 2018). Radio-labelled fluoroacetate has also been trialled in positron emission tomography (PET) scanning for imaging glial metabolism (Marik et al., 2009), studying cerebral ischemia (Mizuma et al., 2013) and detecting cancer cells (Ponde et al., 2007).

1.7. Natural Occurrence

Manufactured 1080 for use in toxic baits is chemically identical to the toxic compounds found in some poisonous plants, with naturally produced 1080 inducing the same signs and symptoms in animals (de Moraes-Moreau et al., 1995). In plants, monofluoroacetate appears to be a secondary plant compound that is biosynthesised at high concentrations as a chemical defence mechanism against browsing invertebrates and vertebrates.

Highly toxic fluoroacetate-producing plants are globally distributed. Research in the 1940s identified monofluoroacetate, the active toxin in 1080, as the toxicant in the South African plant gifblaar, which has long been recognised as a hazard to livestock. Monofluoroacetate has also been identified as the toxic agent in many other poisonous plants, such as rat weed, native to Brazil (de Moraes-Moreau et al., 1995); and ratsbane, native to Africa (Atzert, 1971). Monofluoroacetate also occurs naturally in about 40 plant species in Australia (Twigg, 1994; Twigg et al., 1996a; Twigg et al., 1996b; Twigg et al., 1999).

Levels of monofluoroacetate can reach very high levels in these plants. For example, air-dried leaves of *Gastrolobium bilobum* (heart-leaf poison) and *G. parviflorum* (box poison), two Australian plants, can contain up to 2600 mg kg⁻¹ of monofluoroacetate, and seeds of *G. bilobum* can have in excess of 6500 mg kg⁻¹ of monofluoroacetate (Twigg, 1994; Twigg et al., 1996a; Twigg et al., 1996b; Twigg et al., 1999). The highest monofluoroacetate concentration so far reported from a plant is 8000 mg kg⁻¹ in the seeds of the East African *Dichapetalum braunii* (O'Hagan et al., 1993).

While most studies assessing monofluoroacetate concentrations in plants have focused on those species that are highly toxic to mammals, it would appear that the ability of plants to synthesise monofluoroacetate is more widespread than generally supposed. Monofluoroacetate occurs at extremely low concentrations in some Finnish plants (Vartiainen and Kauranen, 1980), in tea leaves (Vartiainen and Kauranen, 1984)

and guar gum (Twigg et al., 1996b; Vartiainen and Gynther, 1984) and puha (Ogilvie et al., 2006). Additionally, some plants when exposed to fluoride ions, can biosynthesise low levels of fluoroacetate. Fluorocitrate, the toxic metabolite of monofluoroacetate, has also been detected in tea leaves (Peters and Shorthouse, 1972). Fluoroacetate biosynthesis can also occur in some bacteria, notably *Streptomyces cattleya* (O'Hagan and Harper, 1999). In parts of Australia where fluoroacetate containing plants are common, native herbivores and seed-eaters have developed a high level of resistance to fluoroacetate compared to the same species elsewhere in Australia where plant species do not contain fluoroacetate. In South Africa the caterpillar of the moth, *Sindrus albimaculatus* (which feeds on *Dichapetalum cymosum*), can not only detoxify fluoroacetate, but also accumulates it and uses it as a defence against predation (Meyer and O'Hagan, 1992).

1.8. Toxicology and pathology

1.8.1. Mode of action

Monofluoroacetate is converted within animals to fluorocitrate, which inhibits the tricarboxylic acid cycle. This results in accumulation of citrate in the tissues and plasma, energy deprivation, and death. Synthesis of fluorocitrate occurs in the mitochondria, and the fluorocitrate formed inhibits mitochondrial aconitate hydratase. There is also evidence to suggest that fluorocitrate inhibits citrate transport into and out of mitochondria, and that fluorocitrate has an inhibitory effect on succinate dehydrogenase. The high levels of citrate concentration that occur during monofluoroacetate intoxication can also have an inhibitory effect on the glycolytic enzyme, phosphofructokinase.

Death from monofluoroacetate poisoning is caused by the inhibition of energy production which, in turn, results in either cardiac or respiratory failure. Fluorocitrate is commonly described as a specific metabolic inhibitor of glial cells in the brain. Glial cells are thought to be important for extracellular fluid ion and pH regulation, and the control of breathing (Erllichman et al., 1998).

This section is from Eason and Wickstrom (2001).

1.8.2. Pathology

Known target organs in animals following 1080 exposure include the heart, lungs, liver, kidney, testes, and foetus (Annison et al., 1960; Buffa et al., 1977; Chi et al., 1996; Chung, 1984; Eason et al., 1999; Gregg et al., 1998; McTaggart, 1970; Savarie, 1984; Schultz et al., 1982; Sullivan et al., 1979; Trabes et al., 1983; Twigg et al., 1988). The pathological changes observed at post-mortem appear to be largely the result of progressive cardiac failure with congestion of the abdominal viscera and lungs. Examination of monofluoroacetate-poisoned mammals usually reveals cyanosis of mucous membranes and other tissues. Diffuse visceral haemorrhage has been described in some animals, particularly cattle. Subepicardial haemorrhages on the epicardium and endocardium as well as on the epiglottis and trachea have been observed in sheep and possums poisoned with monofluoroacetate. The presence or

absence of tissue damage is likely to be dose-related, and subepicardial haemorrhages have been observed in rabbits receiving a lethal dose of monofluoroacetate but not in those receiving a sub-lethal dose. It is apparent that the target organs vary to some extent in different species, which may relate to the citrate response in different species, or the metabolic activity in different tissue. In birds a target organ appears to be wing muscle (Ataria et al., 2000) as well as the heart, which is a more common target in other species.

This section is from Eason and Wickstrom (2001).

1.8.3. Absorption, metabolism, and excretion

Sodium monofluoroacetate (1080) is absorbed through the gastrointestinal tract or via the lungs if inhaled. Monofluoroacetate is not readily absorbed through intact skin, but it can be absorbed more readily through cuts and abrasions.

After oral or intravenous dosing of laboratory rodents, 1080 is rapidly absorbed and distributed through the soft tissues and organs (Egeheze and Oehme, 1979; Hagan et al., 1950; Sykes et al., 1987). This contrasts with the action of commonly used anticoagulant rodenticides, such as brodifacoum, which preferentially bind to liver cells (Bachmann and Sullivan, 1983). Sodium monofluoroacetate is excreted as unchanged fluoroacetate and a range of non-toxic metabolites (Gal et al., 1961; Schaefer and Machleidt, 1971). Approximately 30% of a dose of 1080 administered to rats was excreted unchanged in the urine over 4 days (Gal et al., 1961). At least seven unidentified metabolites other than fluoroacetate and fluorocitrate, the toxic metabolite of 1080, were also detected in rat urine (Gal et al., 1961).

Administration of ¹⁴C-labelled fluoroacetate to rats showed that fluorocitrate, the toxic metabolite of 1080, accounted for only 3% of the radioactivity (Gal et al., 1961), and this was confirmed by Schaefer and Machleidt (1971). The major metabolite, unlike fluorocitrate, does not inhibit the activity of aconitase (Gal et al., 1961). Phillips and Langdon (1955) suggested that the unidentified metabolites include non-saponifiable lipids that probably serve as intermediates for cholesterol, and some radioactivity was found in fatty acids and cholesterol in the liver. Up to 3% of the radioactivity appeared as respiratory CO₂, which implied cleavage of the C-F bond (Gal et al., 1961).

Defluorination of 1080 or its metabolites, including fluorocitrate, has been demonstrated in animals and other living organisms (Egeheze and Oehme, 1979; Kirk and Goldman, 1970; Smith et al., 1977; Soifer and Kostyniak, 1983, 1984; Tecle and Casida, 1989; Twigg et al., 1986). Although fluoride is extensively excreted, primarily in urine, some deposition occurs in bone (Eason et al., 1993a; Eason et al., 1993b; Eason et al., 1994b; Rammell, 1993; Sykes et al., 1987).

The above section is from Eason and Wickstrom (2001).

Nishii et al (2012) studied the use of radio-labelled fluoroacetate in rhesus macaques as an imaging diagnostic tool for cancer tumors. Doses were tiny

(0.47ng). They observed rapid uptake into major organs followed by a rapid decline in tissue concentrations over three hours. Indicated by the radioactivity, most 1080 excreted in monkey urine during this period was unchanged (72.4%) while some had been metabolised and excreted as fluoride (27.6%). Bone deposition appeared minimal in this study.

2. Fate in the Environment

1080 in baits may be defluorinated in 1-2 weeks under favourable conditions. However, under less favourable conditions breakdown may take several weeks and, in extreme cold and drought, 1080 residues could persist in baits for several months. The 1080 in paste baits can still be present after >5000 mm of rain.

Degradation of 1080 is slow in soil and sediments, taking 1-4 weeks under favourable conditions. The rate of degradation will be influenced by the presence of soil or litter micro-organisms, and temperature, soil moisture and rainfall. Sodium monofluoroacetate is highly water soluble so leaching out of soil will occur.

While the concentration of 1080 in deionised (sterile) water remains relatively constant and independent of temperature, 1080 degradation occurs within 1-2 weeks in natural water. Temperature, and the presence of aquatic plants and microbes all affect 1080 degradation in aquatic environments. Water samples have been collected from streams following numerous pest control operations using 1080. 97.1% of these samples contained no residues of 1080. Where residues were found most of these had less than $1 \mu\text{g l}^{-1}$ 1080. Where higher 1080 residues have been found in water, the samples were mostly from very small streams and/or associated with the presence of bait, during aerial operations.

While plants can take up 1080, it is unlikely to be in large amounts. If taken up, 1080 residues persist less than 38 days in plants.

1080 has a relatively short half-life in sub-lethally dosed animals and it is metabolised and eliminated from living animals within days. However, it can persist in carcasses for months. The rate of degradation of 1080 in carcasses will depend on moisture, temperature and the presence of micro-organisms.

2.1. Bait pathway

2.1.1. How long do baits remain toxic?

Under favourable conditions, e.g. 11 - 20°C and 8 - 15% moisture, 1080 may be significantly defluorinated in 1 - 2 weeks (King et al., 1994). Under less favourable conditions breakdown might take several weeks and, in extreme cold and drought, 1080 residues could persist in baits for several months.

Pellets

On land

Booth et al. (1999a) reported that 1080 began leaching out of Wanganui #7, 6 gram, 0.15% 1080 Pellets after 20 mm of simulated rainfall and that the 1080 declined to near the limit of detection after 250 mm simulated rainfall. Bowen et al. (1995) found that both 0.08% and 0.15% 1080 6 gm RS5 cereal pellets lost 1080 more quickly than equivalent 6 gm Wanganui #7 cereal pellets under simulated rainfall. The RS5 cereal pellets were less water resistant and started to disintegrate after approximately 5 mm of rain. 1080, at both concentrations, had been completely leached out of the RS5 cereal pellets after 150 mm rain.

When 10 - 12 g 0.15% 1080 Wanganui #7 cereal pellets were exposed to a simulated rainfall of 20 mm/hour, most of the 1080 concentration was retained after exposure to 50 mm of rain. The 1080 concentration rapidly declined in the pellets over the following 50 mm of rainfall. By comparison, the 1080 concentration in 10 - 12 g 0.15% RS5 pellets declined at a steady rate. By 100 mm the 1080 had completely leached out of both types of pellets (Thomas et al., 2004). The 10 - 12 g cereal pellets in this study retained more 1080 when exposed to <100 mm of simulated rain than the 6 g cereal pellets examined by Bowen et al. (1995).

Ogilvie et al. (2004) reported that Wanganui #7 pellets lying on the ground in the field had a 99% reduction in the 1080 concentrations after 56 days. Over this time period 110 mm of rain fell.

During trials on long-life baits, Morgan (2004) found that 0.15% 1080 Pellets with a double wax coating placed in Philproof bait stations took 9 months for the toxicant concentration to decline by 30%.

Bait breakdown was monitored during the 1990 Rangitoto Island and Waipoua Forest Sanctuary possum control operations. Aerially distributed 6 g 0.08% 1080 Pellets were used in the operations, and most baits had less than 10% of their original 1080 concentration after 28 - 29 days. However, some baits only reached 10% of their original toxic loading after 41 days (Eason et al., 1991a, b).

Wright (2004) monitored the fate of 20 mm (12 g) 0.15% 1080 Wanganui #7 pellet baits at two sites during an 8600 ha aerial operation in the Hutt River upper catchment. On the day of application baits tested contained 1.43 g kg⁻¹ 1080. After 29 days baits from the two sites contained 0.05 g kg⁻¹ and 0.04 g kg⁻¹, and were still dyed green although damp and soft. Site one had received 30 mm of rain by this time and 70 mm for site two. After 40 days baits from both sites were pale green and had no detectable residues. Cumulative rainfall recorded by this time was 88 mm for site one and 186 mm for site two. Baits were still visible after 52 days, but by day 65 and 387 mm of rain they were not discernible at site two.

Thomas et al. (2004) analysed bait breakdown rates from data collected during 19 operations using 0.15% 1080 Wanganui #7 cereal pellets and 11 operations using 0.15% 1080 RS5 cereal pellets. Bait sizes used in the operations ranged from 3 - 12 grams. Most of the 1080 content, of both bait types, was removed following 150 - 200 mm of natural rainfall.

0.15% 1080 cereal pellets in bait bags stapled to trees four months after a possum control operation in Patterson Inlet, Stewart Island contained 188 - 475 mg kg⁻¹ 1080. 1080 residues in two 1080 cereal pellets in bait bags found lying on the ground were below the method detection limit (MDL) (VPRD & Pestlink 0809SISo2).

The concentration of 1080 in bait samples of 0.15% 1080 12g cereal pellets was monitored at the Marsden aerial treatment block in central westland during 2012. After 28 days with 56mm of rainfall the bait sample contained 12 mg kg⁻¹, therefore had lost 99.2% of the starting toxicity (van Klink 2013).

In water

Suren (2006) conducted laboratory experiments to examine the fate of pellet baits that fell into moving water and to quantify the rate that 1080 leached from the pellets. 0.15% 1080 Wanganui #7 pellets were placed in flow tanks that had a cobble base and water flowing through them at 20 cm s⁻¹. Eleven and 6 g baits were used in the experiment. Both bait sizes followed a similar pattern of breakdown. The baits remained relatively intact for the first 48 hours but lost their bright green colour. After 72 hours the baits had become swollen and started to fragment. At 84 hours the baits had disintegrated. While baits remained for up to 72 - 84 hours before they disintegrated, 1080 leached out of the baits far more rapidly. 1080 was rapidly lost from submerged baits within the first 8 - 12 hours. Fifty percent of the 1080 in the baits was lost after the baits had been submerged for 5 hours. By 24 hours, 90% of the original 1080 concentration had been lost, and no 1080 was detected in any baits after 36 hours.

Dust

There have been three studies that have looked at dust produced by aerial 1080 pellet operations.

Wright et al. (2002) assessed the dust produced during three 1080 pellet operations (at Rangataua Forest Park, Titirangi Reserve and Whitecliffs Forest) in 1997 and 1998. In these operations, 0.15% 1080 Whanganui #7 pellets were sown at a rate of 5 kg/ha. Dust collectors were set up within and at 200-m intervals to a distance of 1000 m downwind of the treatment area. The maximum concentration of 1080 found in the dust collectors was 25.2 µg 1080 m⁻² at one site within the Rangataua operational area 1 day after the operation. Mean 1080 dust concentrations within the operational area on day 1 ranged from 0.29 µg 1080 m⁻² at Titirangi Reserve to 3.81 µg 1080 m⁻² at Rangataua. 1000m down wind of the operational area the mean 1080 dust concentrations at day 1 ranged from 0.0 µg 1080 m⁻² at Titirangi Reserve to 0.09 µg 1080 m⁻² at Whitecliffs. By day 5 1080 dust levels within the operational area had declined to 0.05 µg 1080 m⁻² at Whitecliffs and 0.1 µg 1080 m⁻² at Rangataua Forest Park and Titirangi Reserve. On day 5, 1000m down wind of the operational area the mean concentrations of 1080 in dust were 0.0 µg 1080 m⁻² at Rangataua, 0.09 µg 1080 m⁻² at Whitecliffs and 0.13 µg 1080 m⁻² at Titirangi reserve.

1080 dust levels were monitored at loading site of the 2014 Te Maruia aerial 1080 operation (0.15% 1080 RS5 cereal pellets sown at a rate of 1 kg/ha). The concentration of 1080 dust recorded was between <0.00004 and 0.00021 mg m⁻³. Based on these results, the concentration of 1080 dust at other sites around the loading zone was estimated at <0.00004 to 0.00006 mg m⁻³. Using these figures, the worst case time weighted exposure to 1080 dust was estimated as 0.0048 mg m⁻³, which is only 10% of the Workplace Exposure Standard (0.05 mg m⁻³) (Jennings, 2014).

During an aerial 1080 operation (0.15% 1080 RS5 cereal pellets sown at a rate of 2 kg/ha) at Kumara in 2015, 1080 dust levels were monitored at 5 sites located within, at the boundary, and at 180 metres, 330 metres and 415 metres downwind of the operational area. Total suspended particulate (TSP) gauges were used to collect the dust and monitoring occurred for 1 day following the operation. 1080 was only

detected at the monitoring site 180 metres outside the operational area at a concentration of $0.0048 \mu\text{g } 1080 \text{ m}^{-3}$ (Wickham and Baynham, 2016).

Carrot

Thomas et al. (2004) subjected 12 g carrot baits containing 1.5 g kg^{-1} 1080 to two different simulated rainfall treatments. The first treatment involved subjecting carrot baits to 20 mm hr^{-1} simulated rainfall starting 1 hour after the 1080 was applied. The 1080 in the carrot leached out of the carrot rapidly, with the carrot losing approximately 74% of the 1080 after 10 mm of simulated rainfall. In the second treatment, which was designed to be more representative of field operations, involved starting the simulated rainfall started 48 hours after the 1080 was applied to the carrot. The carrot in this treatment retained more than 60% of its 1080 concentration after 500 mm of simulated rainfall.

Bowen et al. (1995) reported that 6 g carrot baits containing 0.8 g kg^{-1} 1080 showed no decrease in 1080 concentration after 200 mm simulated rainfall.

Using data collected during five 0.8 g kg^{-1} 1080 carrot operations, Thomas et al. (2004) estimated that most of the 1080 content was lost from the baits following 200 mm of natural rainfall. The authors noted the results conflicted with the simulated rainfall studies. They suggested that the difference may have been a result of the carrots being present in the field for a longer period than the 2-day duration of the simulated rainfall trials. During this period the carrots would have been subjected to decay and microbial action, which may have contributed to the more rapid 1080 loss.

Pastes

There was little loss of 1080 from Pestoff Professional 0.15% 1080 paste 49 hours after it was subjected 5 mm of simulated rain. Detoxification of Pestoff Professional 0.15% 1080 paste baits left on upturned spits took 80 days, but this was reduced to 40 days when the baits were buried (Morgan, 2000). Pestoff possum paste buried in both dry and damp soil still retained significant concentrations of 1080 after 20 days (Ross and Henderson, 2003).

When 10% 1080 Gel with a carbopol carrier was applied to kāpuka (NZ broadleaf), 90% of the 1080 was washed out of the baits by as little as 81 mm of rain (Batcheler and Challies, 1988). Parkes (1991) found that when 10% 1080 Gel in a carbopol carrier was applied to mahoe (*Melicytus ramiflorus*) leaves, 95.2% of the 1080 had leached from the baits after 208 mm of rain. In contrast, 10% 1080 Gel with a petrolatum carrier is highly resistant to leaching, with 78.8% of the 1080 still remaining in the baits after 64 days and 208 mm of rain. Challies and Thomson (1988) concluded that >5000 mm of rain was required to leach about 75% of the 1080 out of the baits.

Fish/meatmeal pellets (0.1% 1080 feral cat bait)

Degradation of fishmeal feral cat bait pellets containing 1g/kg 1080 was assessed on Auckland Island in winter 2019. The bait was placed directly on the ground under pest proof mesh cages in habitat including scrub, rata forest, tussock and coastal herffield at nine separate sites. After 14 days with 38.4mm of accumulated rainfall the concentration of 1080 in sampled baits from each site had declined by

88-100%. At this point baits were intact and most were firm and free of visible mould. After 32 days with 110.4 mm of accumulated rainfall the 1080 levels had declined by 100% (to <MDL) at six sites and by >95% at the remaining three sites. By this point baits were soft and mouldy and some had become mushy. After 98 days baits were tested from four of the sites and all had 1080 <MDL (Cox et al., 2019).

Seven months after 0.10% 1080 feral cat baits were handlaid on Raoul Island in August-September 2002, baits lying in the open were observed in good condition (S. Theobald pers. comm. 2003).

Other

The concentration of 1080 in eggs injected with 1 mg 1080 egg⁻¹ did not decline after 28 days at temperatures of 15 and 30°C (Spurr et al., 1998). Note: this product is not currently registered in New Zealand.

When 12000 kg of 1080 bait (11000 kg of 0.15% 1080 Wanganui #7 Pellets and approximately 1000 kg of 0.08% 1080 apple paste) was disposed on in a landfill site at Winton, central Southland, in August 1996 the 1080 concentration in the waste material showed a 90% decrease after 10 months (Bowman, 1999).

2.1.2. How soluble is 1080 in natural water?

Sodium monofluoroacetate is highly water soluble and mobile (Parfitt et al., 1994). Solubility in water at 25 °C is estimated at 111g/100g which is similar to table salt (O'Neil 2013 cited in PubChem Section 8.6).

Note: Solubility is the determining factor for the pesticide pathway beyond the bait.

2.2. Soil and sediment

2.2.1. What is the range of toxic residue levels observed in soil and sediment?

Soil

Two soil samples were taken from the helicopter loading site on the day of the November 2014 Catlins aerial 1080 operation (0.15% 1080 RS5 pellets). Both these soil samples tested positive for 1080 (0.008 and 0.215 mg kg⁻¹). Four further soil samples were taken 12 days later, with 1080 being detected in one sample (0.005 mg kg⁻¹). Two more soil samples were taken 23 days after the operation, with 1080 being detected in one sample (0.020 mg kg⁻¹) (Pestlink 1415MRH01).

During the October 2014 Waitutu aerial 1080 operation (0.15% 1080 RS5 pellets), three soils samples were taken from the helicopter loading site. No 1080 was detected in these samples (Pestlink 1314TEA07).

Neither of the two soil samples taken from the loading site of the August 2014 Waikaia aerial 1080 operation (0.15% 1080 RS5 pellets) tested positive for 1080 (Pestlink 1314MRH02).

Four soil samples were taken from the helicopter loading site approximately one week after the August 2010 Waitutu aerial 1080 operation (0.15% 1080 RS5 pellets). No 1080 was detected in the samples (Pestlink 1011MRH03).

On the day 0.15% 1080 Pellets were handlaid in a field trial in the Tararua Forest Park, 0.01 mg kg⁻¹ 1080 was detected in one of four litter samples. Following a field trial using 0.15% carrot baits in the Tararua Forest Park, litter samples had 1080 residues of between 0.0 - 0.6 mg kg⁻¹ on the day the baits were laid and between 0 - 16 mg kg⁻¹ seven days post poisoning (Spurr et al., 2002).

During 1997-98, 118 samples of soil were taken after three different aerial applications of Wanganui #7 0.15% 1080 Pellets. There were detectable, but low (mean 0.0092 mg kg⁻¹) 1080 residues in 6 of the soil samples taken from two of the three operations. The mean concentrations of 1080 in soil outside the two baiting areas (0.0006mg/kg) appeared to be lower than those inside (0.024 mg/kg) (Wright et al., 2002). During the same study, samples of leaf litter were also taken. There were low, but detectable, amounts of 1080 in the litter at Days 1, 5 and 30 post-baiting. The highest concentration found in a leaf litter sample was 0.19 mg kg⁻¹ on Day 5 from inside one treatment area. All remaining leaf litter samples with detectable 1080 were below 0.01 mg kg⁻¹ and were from up to 600 m outside one of the treatment areas. It was suggested that these 'outside' results were due to baits or fragments reaching the ground close to the sampling plots (Wright et al., 2002).

Soil samples (n=10) taken from two airstrips in 1997 had 1080 residues ranged from 0 - 0.0035 mg kg⁻¹ (P Fisher pers. comm. 2004).

Soil from three tip/landfill sites was sampled for 1080 residues in 1996-97. The Balgownie landfill, Wanganui had 1080 residues ranged from 330 - 930 mg kg⁻¹ (n=2). Winton tip, central Southland had 1080 residues ranged from 50 - 1450 mg kg⁻¹ (n=4) and at an unspecified landfill site where 1080 residues ranged from 0.0008 - 3 mg kg⁻¹ (n=11) (P Fisher pers. comm. 2004).

Sediments

During the July 2008 Lower Arthur Valley aerial 1080 operation (0.15% 1080 RS5 pellets), three sediment samples were taken from the Arthur River. No 1080 was detected in these samples (Pestlink 0809TEA03).

On the day of the June 2007 Upper Arthur Valley aerial 1080 operation (0.15% 1080 RS5 pellets), three sediment samples were taken from a low current area in the Arthur River. No 1080 was detected in these samples (Pestlink 0708TEA08).

Three samples were taken from sediments in the West branch of the Clinton River three days after the June 2006 Clinton Valley aerial 1080 operation (0.15% 1080 RS5 pellets). No 1080 was detected in the samples (Pestlink 0607TEA01).

2.2.2. How long does degradation of 1080 take in soil or sediment?

Degradation of 1080 is slow in soil and sediments, taking 1-4 weeks under favourable conditions.

Laboratory studies on the biodegradation of 1080 have shown that it is defluorinated by soil micro-organisms (Gentle & Clothier 2014; Walker and Bong, 1981; Wong et al., 1992) and within soils themselves (David and Gardiner, 1966; Parfitt et al., 1994). If 1080 is not degraded by micro-organisms present in most NZ soils, it is likely to be removed from soil by leaching (Parfitt et al., 1994).

Northcott et al. (2014) examined the breakdown of 1080 in podzol (Orikaka Sandy Loam, West Coast, South Island), brown soil (Matiri, West Coast, South Island) and pumice soil (Kaingaroa, Taupo, North Island) under laboratory conditions. In all three soil types the degradation products produced and the rate at which these products were formed were similar. The major degradation pathway was through microbial degradation to the hydroxyl metabolite, hydroxyacetic acid, and microbial mineralisation to CO₂. The authors reported that the dominant factor affecting the rate of degradation was temperature rather than soil type or moisture content. The transformation half-life (DT₅₀) of 1080 increased with decreasing temperature, ranging from 6 - 8 days at 20°C, 10 - 21 days at 10°C and 22 - 43 days at 5°C.

In a soil microbial nitrogen mineralisation test conducted to OECD guidelines, O'Halloran et al. (2005) found there was no evidence that 1080 inhibited nitrate production by soil microorganisms at concentrations of up to 1 g 1080 kg⁻¹ of soil.

During laboratory studies, 6.1 mg of 1080 (equivalent to one possum bait) was added to 14 g samples of Kaitoke silt loam. The time taken for the 1080 in the soil to decline by 50% was 10 days at 23°C, and 80 days at 5°C (Parfitt et al., 1994). The authors also reported that when 1080 was added to Conroy sandy loam the degradation was much slower under dry conditions than wetter conditions. In Conroy sandy loam with 20% water content, it took approximately 30 days for a 50% reduction in the 1080.

2.2.3. Are there environmental factors that affect degradation in soil?

The presence of soil or litter micro-organisms, and temperature, soil moisture and rainfall affect the rate of 1080 degradation in soil.

Some soil micro-organisms, e.g. *Pseudomonas* and *Fusarium* species, can metabolise 1080 (King et al., 1994; Walker and Bong, 1981). However, not all micro-organisms can readily defluorinate monofluoroacetate and the rate of metabolism differs between species of soil bacteria and fungi (King et al., 1994). 1080 could be expected to persist in soil much longer in the absence of micro-organisms, however sterile soil is unlikely to occur naturally.

Temperature and soil moisture content affect the rate at which micro-organisms in soil degrade 1080. At lower temperatures/moisture content degradation is slower and 1080 will persist in the soil longer (Parfitt et al., 1994). Studies have shown that substantial defluorination of 1080 occurs in soil at temperatures of 15 - 30°C and with moisture levels above 8.3%.

Rainfall is also a major factor in removing 1080 from soil due to 1080's water solubility. 1080 has a low preference for adsorption on soil minerals, so that 1080 in soil not removed by microbial action is likely to be leached (Parfitt et al., 1994).

Note: Environmental factors will determine how widely the breakdown times reported for specific sites can be applied. For example, because breakdown is significantly affected by temperature, rainfall, leaf litter, presence or types of micro-organisms, it may occur faster or slower than the time quoted in Section 2.2.2.

2.3. Fate in water

2.3.1. Where available, what is the range of toxic residue levels observed in natural water?

Water monitoring during operations

Between 1990 and December 2016 3527 water samples were collected from streams following aerial 1080 pest control operations throughout New Zealand. The samples were taken within 24 hours of the bait being laid and after subsequent heavy rain. 97.1% of these samples contained no residues of 1080. Residues ranging from 0.1 – 9.0 $\mu\text{g l}^{-1}$ were found in 101 samples but most of these had less than 1 $\mu\text{g l}^{-1}$ 1080. These samples were mostly from very small streams and/or associated with the presence of bait. Four of these six samples were likely to have been as a result of inadvertent contamination (Booth et al., 2007; L. Booth pers. comm. 2016; Parliamentary Commissioner for the Environment, 2011).

1299 of the total samples were taken from water used as human or stock drinking supplies, and 5 (0.38%) of these contained detectable 1080 residues ranging from 0.1 to 0.2 $\mu\text{g l}^{-1}$ (L. Booth, Landcare Research, pers. comm. 2016). All the positive samples were below the Ministry of Health maximum of 3.5 $\mu\text{g l}^{-1}$ for 1080 in drinking water (Ministry of Health, 2008).

A water monitoring program following aerial 1080 (0.15% and 0.08% 1080 Wanganui #7 Pellets at 5 kg ha⁻¹) possum control operations on Mt Taranaki/Egmont in 1993-94, showed no detectable 1080 in 159 (1993) and 72 (1994) water samples from surface water or treated water supplies (Fowles and Williams, 1997).

Following aerial possum baiting (0.08% 1080 Wanganui #7 Pellets) in Tararua Forest Park in 1993, 66 water samples from eight sites collected over 4 months had no detectable 1080 (limit of detection 0.3 $\mu\text{g l}^{-1}$) (Meenken and Eason, 1995).

Following aerial rabbit baiting (pre-feed baiting and carrot baits containing 0.023% 1080, sowing rates from 16 – 60 kg ha⁻¹ depending on rabbit densities) in Otago during 1992, streams and rivers were monitored for 4 weeks after the operation. 2 out of 29 samples contained measurable amounts of 1080 (0.3 and 0.6 $\mu\text{g l}^{-1}$). These samples occurred within 48 hours of bait application, and all subsequent samples were below the limit of detection (Hamilton and Eason, 1994).

No 1080 was detected in 36 water samples taken from six streams over a 4-month period at Waipoua following aerial possum control using 0.08% 1080 Pellets sown

at 5 - 6 kg ha⁻¹ in 1990. After the 1990 aerial possum control operation using 0.08% 1080 Pellets at 14 kg ha⁻¹ on Rangitoto Island 24 water samples were collected over 6 months from 2 surface water and 2 ground water sites. No 1080 was detected in any of these samples (Eason et al., 1992).

Field trials

Meenken et al. (2000) monitored water in a stream at the bottom of 14 ha catchment for the presence of 1080 after 0.15% Wanganui #7 pellets had been handlaid in a at a rate of 10.7 kg ha⁻¹. Monitoring occurred at regular intervals over the 17 hours after the bait was applied and during a rain event two days after the bait was laid. No 1080 was detected in any of the 52 water samples taken.

Srinivasan et al. (2012) investigated the fate of 1080 released from baits during a rainfall event immediately following an aerial 1080 operation. In this field study, stream and soilwater was sampled in a 148.8 ha headwater catchment of the Inangahua River, on the West Coast, following the application of 0.15% 1080 Wanganui #7 pellets. The pellets were applied at a rate of 2.5 kg ha⁻¹ within 24 hours of a rainfall event (28 mm in 8 hours, with an additional 100mm falling over the next 9 days). Water sampling occurred between 5 hours and 9 days after the 1080 was applied. The only stream sample that contained 1080 (at 0.1 µg l⁻¹) was collected 105 minutes after the rain started. None of the other 15 samples contained 1080 residues. Soilwater samples were taken approximately 200 mm downhill from baits after 34.4, 57.0 and 60.6 mm of rain had fallen. 1080 residues in these soilwater samples ranged from 0.5 - 61 µg l⁻¹.

Srinivasan and Suren (2018) investigated the transport of 1080 in surface and subsurface water flows down a hillside in a field trial on the West Coast. In the study they handlaid 2 kg of 0.15% 1080 RS5 cereal pellets in a 0.4 m² plot (equivalent to 25,000 times a 2 kg/ha sowing rate), 6 hours prior to a forecast rainfall event. During the rainfall event (7.4 mm of rainfall) and up to 168 hours after the bait application, they collected overland water flow, subsurface soil water and ground water samples at regular time intervals within and below the plot. Water samples were also taken from a small stream below the plot. Of the 59 water samples taken, only seven returned positive 1080 residues, four of which were just above the MDL (minimum detection limit of 0.1 µg l⁻¹). The positive samples were all from soil water samples closest to the baits, with the highest recorded 1080 residue (1.4 µg l⁻¹) in a soil water sample 32 hours after the rain had commenced. No 1080 was detected in any of the groundwater, overland flow or stream samples. The researchers noted that the absence of detectable 1080 in the majority of samples clearly demonstrated the importance of dilution as a key factor when 1080 leaches out of baits during rainfall events. Given the extremely large amount of 1080 applied to such a small area immediately prior to rain, and the limited number of positive 1080 samples, they also concluded that it is unlikely detectable 1080 contamination of surface, soil and groundwater will occur at normal application rates.

Landfill disposal

Concentrations of 1080 in bore groundwater surrounding a landfill site at Winton, central Southland, were measured following burial of 12000 kg of 1080 bait. 1080 was detected in 5 of 28 groundwater samples analysed (highest value $24 \mu\text{g l}^{-1}$). The amount of 1080 in groundwater sampled 5 and 13 metres from the disposal site decreased until none was detected after 10 months (Bowman, 1999).

1080 breakdown products

Fluoride is a principal breakdown product of 1080. In addition to the 1080 water sampling undertaken by Fowles and Williams (1997) following the aerial 1080 (0.15% and 0.08% 1080 Wanganui #7 Pellets at 5 kg ha^{-1}) possum control operations on Mt Taranaki/Egmont in 1993-94, they also monitored fluoride levels at the same water monitoring sites. No significant increases in fluoride concentrations above the natural background levels were recorded during or following the operations except in the Hawea public water supply. The South Taranaki District Council sporadically fluoridated this water supply, and the increased level of fluoride in the water occurred during equipment recommissioning trials.

2.3.2. How long does degradation of 1080 take in natural water?

1080 degradation will occur within 1 - 2 weeks in natural water. The overall degradation rate of 1080 in stream water, when measured in the laboratory, declined by approximately 25% in the first 24 hours. After this the rate of decline was temperature dependent (Ogilvie et al., 1995; Ogilvie et al., 1996).

Eason et al. (Eason et al., 1993b) showed that 1080 declined by approximately 70% in 1 day and dropped to below detectable limits in 4 days in aquaria containing plants and invertebrates.

In an aquarium study by Parfitt et al. (1994) 80 litre aquaria containing biologically active streamwater at 21°C were spiked with 0.1 mg l^{-1} of 1080 (the equivalent to adding 2-3 pellets per aquarium). Water samples were taken from the tanks at 2, 24, 48, 72, 79, 101 and 141 hours after the addition of the 1080. The 1080 was eliminated from the aquaria water within 48 - 141 hours.

When 40 0.15% 1080 Wanganui #7 pellets were placed in a stream simulator with a 5 litre s^{-1} flow rate, 1080 concentrations at the outlet of the simulator peaked at $1.1 \mu\text{g l}^{-1}$ after 2 days and no residues were detected in the water after 8 days (Suren and Bonnett, 2006).

Note: Natural/stream water implies the presence of aquatic plants, invertebrates and micro-organisms, and sediment.

2.3.3. Are there environmental factors that affect degradation in aquatic environments?

A number of factors affect the degradation of 1080 in aquatic environments. These include temperature, the presence of aquatic plants and microorganisms, and flow and volume of the waterway.

While the concentration of 1080 in deionised (sterile) water remains relatively constant and independent of temperature, the concentration of 1080 in stream water declines over time (Booth et al., 1999b). The rate at which 1080 degrades in stream water increases significantly as water temperature rises (Ogilvie et al., 1995; Ogilvie et al., 1996). The aquatic plants *Elodea canadensis* (Wright et al., 2001) and *Myriophyllum triphyllum* (Booth et al., 1999b) were found in laboratory trials to reduce the concentration of 1080 in water. In aquaria trials Parfitt et al. (1994) reported that the rate of 1080 degradation was dependent on the species of bacteria present.

Flow and volume of the waterway affect the dilution of 1080 in natural water. However, they are unlikely to significantly affect degradation at the low concentrations of 1080 that have been found in the environment.

Note: Environmental factors will determine how widely the breakdown times reported for specific sites can be applied. For example, because breakdown is significantly affected by temperature, pH, volume, still/running water, or presence or types of micro-organisms, it may occur faster or slower than the time quoted in Section 2.3.2.

2.4. Fate in plants

2.4.1. Is it likely that plants could take 1080 up in solution, based on molecular structure?

Many organic acids are phloem-mobile in plants, so it is likely that 1080 can be taken up by plants.

2.4.2. Is there evidence that plants either take up or don't take 1080 up?

1080 uptake has been reported in a number of plants including: kāpuka (New Zealand broadleaf) (Ogilvie et al., 1998), kāramuramu (Ogilvie et al., 2006), puha (Miller et al., 2009), broad beans (David and Gardiner, 1951), cabbage (David and Gardiner, 1953), *Elodia canadensis* (Ogilvie et al., 1996), *Helianthus annus* (Cooke, 1976), lettuce (Ward and Huskisson, 1972), peanut (Preuss and Weinstein, 1969), perennial ryegrass (Ogilvie et al., 1998) and sugar cane (Hilton et al., 1969).

However, not all plants appear to take up 1080. No uptake of 1080 was reported in pikopiko when single 0.15% 1080 Wanganui #7 pellets were placed at the base of pikopiko in the field, and the plants monitored for 1080 uptake (Ogilvie et al., 2006).

Where uptake occurs, it is unlikely to be in large amounts. Ogilvie et al. (1998) reported that rye grass took up only 0.015% of the available 1080 from pellets placed beside the grass. When single 0.15% 1080 Wanganui #7 pellets were placed at the base of kāramuramu in the field, the maximum concentration of 1080 detected in the plants was 5 $\mu\text{g kg}^{-1}$ of plant material. This concentration occurred 7 days after the bait was placed beside the plants, and declined to 2.5 $\mu\text{g 1080 kg}^{-1}$ plant material after 14 days (Ogilvie et al., 2006). In a similar field trial, Miller et al. (2009) placed a single 0.15% 1080 Wanganui #7 pellet at the base of puha plants. The highest level of 1080 detected in puha was 15 $\mu\text{g kg}^{-1}$ of leaf material 3 days after the pellets were placed at the bottom of the plants. Note: in this study 1080 residues were recorded in puha that had been used as controls (i.e. no 1080 pellets placed beside them). The authors could not rule out that 1080 occurs naturally in puha and are currently undertaking further research to confirm this.

To put these figures in perspective, based on the peak concentration observed in ryegrass (0.08 g kg^{-1}), a 50 kg sheep would need to eat (using an LD_{50} of 0.4 mg kg^{-1}) about 250 kg of grass to have a 50% chance of dying from 1080 (Ogilvie et al., 1998). Using an LD_{50} of 2 mg kg^{-1} for humans, a 70 kg person would need to eat 28 tonnes of kāramuramu or 9.3 tonnes of puha in one sitting to receive an LD_{50} and therefore a 50% chance of dying from 1080 (Miller et al., 2009; Ogilvie et al., 2006). Even to reach the chronic toxicity NOEL of 0.05 - 0.1 $\text{mg kg}^{-1} \text{ day}^{-1}$ a person would need to consume 0.7 - 1.4 tonnes of 1080-containing kāramuramu daily (Ogilvie et al., 2006).

A laboratory study by David and Gardiner (1951) showed that broad bean plants could take up fluoroacetate through their roots and subsequently become toxic to aphids feeding on them (i.e. 1080 acted as a systemic insecticide). However, 1080 concentrations in the plants necessary to kill the aphids were approximated 1 mg kg^{-1} of plant tissue, when applied to the plant through a cut tap-root. This is a much higher concentration of 1080 than any reported in field soil samples in the context of using 1080 baits for possum control.

Where fluoroacetate is distributed in plants is likely to vary as available publications report conflicting information. For example, in *Helianthus annuus*, ammonium fluoroacetate metabolites were rapidly translocated to the shoot with little accumulation in the roots (Cooke, 1976). Conversely, sugarcane was found to strongly adsorb monofluoroacetate ion onto its roots with only minor translocation to leaves and stem (Hilton et al., 1969).

Even where 1080 uptake occurs in plants, most plants are relatively insensitive to the effects of 1080 (Bong et al., 1980). However, duckweeds have been shown to have a high sensitivity, with the growth of *Spirodela polyrrhiza* being totally inhibited by 0.5 mmol of 1080, and total growth inhibition of *S. oligorrhiza* and *Lemna minor* occurring at 1 mmol 1080 (Bong et al., 1980). Oxygen consumption in pea seedling roots was almost completely blocked when exposed to 10 mmol l^{-1} monofluoroacetic acid for more than 6 hours (Polter, 1967).

Plants are capable of metabolising and degrading fluoroacetate (Dichapetalum cymosum - Meyer and Grobbelaar, 1991; peanuts - Preuss and Weinstein, 1969; lettuce - Ward and Huskisson, 1972).

2.4.3. Where evidence exists for plant uptake, how long do residues persist?

The maximum length of time 1080 residues persist in plants is approximately 38 days (Miller et al., 2009; Ogilvie et al., 1998).

In a laboratory experiment by Ogilvie et al. (1998), single 0.15% 1080 RS5 pellets were added to the soil of pots containing either kāpuka (NZ broadleaf) or ryegrass. The 1080 residues in the plants were near the Method Detection Limit (MDL) after 38 days in kāpuka (NZ broadleaf) and 7 days in ryegrass.

Ogilvie et al. (2004) reported that after kāramuramu took up 1080 during field trials, the concentration of 1080 in the plants decreased to zero at 28 days. The authors recommended that a withholding period of 30 days after an aerial application of 1080 could be adopted for plants within the operational area that are used for rongoa (medicinal) purposes.

When 0.15% 1080 Wanganui #7 pellets were placed beside puha plants in the field, 1080 that had been taken up by the puha was near the MDL after 28 days and below the MDL after 38 days (Miller et al., 2009). The authors suggested a withholding period of at least 38 days could be observed on harvesting wild grown puha immediately after an aerial 1080 operation. Note: in this study 1080 residues were recorded in puha that had been used as controls (i.e. no 1080 pellets placed beside them). The authors could not rule out that 1080 occurs naturally in puha.

2.5. *Animal residues*

2.5.1. What is the range of toxic residue levels recorded for sub-lethally exposed animals?

A number of laboratory studies have measured 1080 residue levels in sub-lethally poisoned mammals, marsupials, birds and insects.

When sheep and goats were orally dosed with an aqueous 1080 solution at 0.1 mg kg⁻¹ b.w. (equivalent to one-quarter of the published LD₅₀ for sheep and less than a quarter of the LD₅₀ for goats) the maximum 1080 residues recorded in plasma were 0.16 - 0.33 mg l⁻¹ and 0.22 - 0.26 mg l⁻¹ respectively. In the sheep, 2.5 hours after dosing the mean 1080 concentrations of were 0.098 mg l⁻¹ in plasma, 0.042 mg kg⁻¹ in muscle, 0.052 mg kg⁻¹ in the heart, 0.057 mg kg⁻¹ in the kidney and 0.021 mg kg⁻¹ in the liver. The mean 1080 concentrations declined to less than 0.003 mg kg⁻¹ in all tissues sampled 96-hours after dosing (Eason et al., 1994a).

Rabbits orally administered a sub-lethal dose of 1080 at 0.1 mg kg⁻¹ b.w. (equivalent to one-quarter of the published LD₅₀) and sampled at intervals after dosing had maximum 1080 concentrations of 0.121 - 0.167 mg l⁻¹ in plasma, 0.019 - 0.025 mg kg⁻¹ in muscle, 0.014 - 0.08 mg kg⁻¹ in kidney and 0.001 - 0.002 mg kg⁻¹ in liver (Gooneratne et al., 1995).

During both these studies, the highest concentrations of 1080 residues were found in the blood/plasma, with moderate levels in muscle and kidneys, and lowest concentration in the liver (Eason et al., 1994a; Gooneratne et al., 1994).

A deer 'run down and killed' following a poisoning trial using 1080 carrot baits in 1958 had 1080 concentrations of 1.50 mg kg⁻¹ in its meat, 0.47 mg kg⁻¹ in the heart and 0.92 mg kg⁻¹ in the liver (McIntosh and Staples, 1959).

When possums were orally dosed with an aqueous 1080 solution at 0.1 mg kg⁻¹ b.w. the maximum 1080 residues recorded in plasma were 0.11 - 0.31 mg l⁻¹ (Eason et al., 1993b).

In sub-lethally poisoned mallard ducks, a maximum concentration of 1080 was 12.95 mg ml⁻¹ in serum and 8.01 mg g⁻¹ in heart two hours after dosing with 8 mg kg⁻¹ 1080 (Ataria et al., 2000).

Lyver et al. (2005) reported that five out of 8 captive long-finned eels fed 1080 contaminated possum muscle had sub-lethal residues of 0.0174 ± 0.0104 mg kg⁻¹, while three out of nine eels fed gut tissue containing 1080 had residues of 0.0306 ± 0.0220 mg 1080 kg⁻¹ b.w..

Suren and Bonnett (2006) exposed caged koura to single 6 g 0.15% 1080 Wanganui #7 baits for up to 8 days. The maximum recorded 1080 residue level in the viscera was 3.3 µg g⁻¹ in an animal collected 1 day after being exposed to bait. The maximum recorded 1080 residue in tail muscle was 5 µg g⁻¹ in an individual collected after 4 days exposure. The highest recorded total 1080 residue (viscera + muscle tissue) was 7.7 µg g⁻¹ from an individual sampled 1 day after the bait was placed in its cage.

In trout dosed with a very high sub-lethal dose of 1080 (~6.4 mg kg⁻¹) the maximum concentrations measured in the tissue (up to 4.7 mg kg⁻¹) were recorded at 24 hours and 48 hours after ingestion. The concentration of 1080 in the tissue decreased to ~2 mg kg⁻¹ after 48 hours (Champeau et al., 2014)

Two laboratory studies have looked at 1080 residues in sub-lethally poisoned terrestrial invertebrates. Booth and Wickstrom (1999) recorded a mean 1080 concentration of 5.51 mg kg⁻¹ in ants (*Huberia striata*) one day after sub-lethally dosing them with 0.3 g 1080 kg⁻¹. Tree weta dosed with 15 g 1080 kg⁻¹ had residues of between 0.033 and 5.8 mg kg⁻¹ (Eason et al., 1993b).

Animals have also been sampled during pest control operations to test for sub-lethal 1080 residues. These results are presented in Table 1.

24 hours after an aerial rabbit control operation (0.4 g kg⁻¹ aerial carrot at 25 kg ha⁻¹) on Motuihe Island, Auckland in July 2002, 5 live cockles and 6 live marine mussels were tested for 1080 residues. None contained 1080 residues (VPRD 4928 - 4938).

During the February 2010 Egmont National Park aerial 1080 operation (0.15% 1080 Wanganui #7 pellets, 2.3 kg ha⁻¹) freshwater and marine mussels were monitored for 1080 residues. Freshwater mussels were sampled from 11 sites within the operational area. Marine mussels were sampled at 2 sites approximately 20 km from the operational area. No 1080 was detected in any of the samples (VPRD).

Note: The information in this section is derived from direct analyses for 1080 in animal tissues, from animals known to have received a sub-lethal dose of 1080. Analyses of associated metabolites (e.g. citrate, fluorine) in tissues are difficult to compare directly with analysis of 1080 concentrations, so this information is not included.

Table 1. 1080 residue levels recorded in sub-lethally exposed animals during pest control operations.

Species	Sample Type	Residues (mg kg ⁻¹)	Reference
<i>Arthropods</i>			
Beetles	Mixed samples	<0.1	1
Invertebrates (various)	7 mixed samples	0.0-0.75	2,3
Weta	Whole body	2.7	1

1 Spurr et al. (2002); 2 Eason et al. (1991b); 3 VPRD.

2.5.2. How long do toxic residues of the pesticide persist in sub-lethally exposed animals?

Mammals

Rabbits given sub-lethal doses of 1080 showed rapid elevation of plasma 1080 in the first hour post dose. Plasma 1080 concentration then declined rapidly at first and slowly thereafter, with very little 1080 being detected in plasma at 6 hours. The sub-lethal dose was cleared from tissues within 3 hours (Gooneratne et al., 1995). Sub-lethally dosed goats and sheep rapidly eliminated 1080, with only traces detected after 18 hours in goat plasma, and after 96-hours in sheep plasma and tissue (Eason et al., 1994a). Gooneratne et al. (2008) reported serum 1080 concentrations in ewes dosed with 0.30 mg kg⁻¹ were undetectable 3 days after dosing and no 1080 was detected in the skeletal muscle, kidneys of liver of animals that survived for 14 days after dosing. In possums only traces of 1080 were detected possum plasma 24 hours after receiving a 1 mg kg⁻¹ sub-lethal dose. All traces of 1080 were eliminated from the tissues of the rabbits, possums, goats and sheep within one week (Eason and Gooneratne, 1993). A withholding period of 5 days has been suggested as adequate for animals suspected to have received a sub-lethal dose of 1080 (Gooneratne et al., 2008).

Birds

Mallard ducks dosed with a 8 mg 1080 kg⁻¹ sub-lethal dose substantially eliminated the 1080 from heart muscle and blood within 24 hours (Ataria et al., 2000).

Invertebrates

Tree weta orally dosed with 15 µg 1080 g⁻¹ eliminated >90% of the 1080 within 4 - 6 days (Eason et al., 1993b). Ants dosed with 0.3 g 1080 kg⁻¹ still had detectable levels of 1080 (0.27 mg kg⁻¹) seven days after dosing (Booth and Wickstrom, 1999).

Aquatic organisms

When koura were sub-lethally poisoned from eating 1080 baits, the concentration of 1080 in the tail muscle and viscera initially increased, and then declined between days 4 - 8. After eight days the mean residue levels in the tail muscle were less than 0.5 µg/g, a decrease by a factor of five, presumably as a result of the animals metabolising or excreting the compound (Suren and Bonnett, 2006).

One long-finned eel fed a bolus of fed gut tissue containing 8.3 mg 1080 kg⁻¹ still had 1080 residues (0.02 mg 1080 kg⁻¹) in its tissue 9 days later (Lyver et al., 2005).

1080 could still be detected in the tissue of trout 5 days after they were dosed with a very high sub-lethal dose of 1080 (~6.4 mg kg⁻¹) (Champeau et al., 2014).

Note: This information is derived from direct analyses for 1080 in tissues from animals known to have received a sub-lethal dose of 1080. Analyses of associated metabolites e.g. citrate, fluorine in tissues are difficult to compare directly with analysis of 1080 concentrations, so this information is not included.

2.5.3. What is the half-life of 1080 in sub-lethally exposed animals?

Data on the half-life of 1080 in plasma and tissues is presented in Table 2.

Table 2. Half-life of 1080 in plasma and tissue.

Species	Sample Type	T ¹ / ₂ (hours)	Reference
Sheep	Plasma	10.8	1
	Muscle	12.0	2
	Liver	3.0	2
Goat	Plasma	5.5	1
Possum	Plasma	9.1	3
Rabbit	Plasma	1.1	4
	Muscle	0.4	4
	Kidney	0.8	4
Mouse	Plasma	2.0	5

	Muscle	1.7	5
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1 Eason et al. (1994a); 2 Rammell (1993); 3 Eason et al. (1993b); 4 Gooneratne et al. (1994); 5 Sykes et al. (1987).

2.5.4. What is the range of residue levels recorded in carcasses of animals killed by 1080?

In sheep dosed with a lethal amount of 1080 ($200 \mu\text{g kg}^{-1}$), the concentration of 1080 in the muscle of sheep sacrificed post-dosing reached a maximum of $111 \mu\text{g kg}^{-1}$ in 4 hours and declined exponentially thereafter. In the liver a maximum concentration of $38 \mu\text{g kg}^{-1}$ was recorded at 2 hours with exponential decline thereafter (Rammell, 1993). Sheep that died 22 - 25 hours after receiving a 0.30 mg kg^{-1} dose of 1080 had 1080 concentrations of $0.061 - 0.75 \mu\text{g g}^{-1}$ in the heart, $0.058 - 0.72 \mu\text{g g}^{-1}$ in the skeletal muscle and $0.047 - 0.051 \mu\text{g g}^{-1}$ in the liver. In sheep that died 43 - 52 hours after dosing (0.30 mg kg^{-1}) the 1080 residues in skeletal muscle was $0.023 - 0.031 \mu\text{g g}^{-1}$, but was undetectable in the heart and liver. The concentration of 1080 in the rumen contents of sheep that died within 24 hours of dosing was $0.15 - 0.27 \mu\text{g g}^{-1}$ (Gooneratne et al., 2008).

Residues in rabbits given lethal doses of 1080 (0.8 mg kg^{-1}) were measured in the liver, kidney and muscle at the time of death and at one, two and three weeks after death. The residue concentrations were highly variable, but concentrations measured at 3 weeks were generally lower than other sample times. The maximum residue concentrations were not specified (Gooneratne et al., 1995).

Burns and Connolly (1992) reported that residues of 1080 in the breast muscle of Eurasian magpies were dose depended, with higher doses resulting in higher 1080 residues. Additionally, within dose levels, birds that survived longer had lower residues. For birds that died within 24 hours of dosing, the mean concentration of 1080 in the breast muscle was $0.73 \mu\text{g g}^{-1}$ at a 1080 dose of $1.59 \text{ mg kg}^{-1} \text{ b.w.}$, $0.70 \mu\text{g g}^{-1}$ at a dose of $2.00 \text{ mg kg}^{-1} \text{ b.w.}$, $0.84 \mu\text{g g}^{-1}$ at a dose of $2.52 \text{ mg kg}^{-1} \text{ b.w.}$ and $1.16 \mu\text{g g}^{-1}$ at a dose of $2.52 \text{ mg kg}^{-1} \text{ b.w.}$ In birds that died the day after being dosed the concentrations in the breast muscle were: $0.23 \mu\text{g g}^{-1}$ ($1.59 \text{ mg kg}^{-1} \text{ b.w.}$ dose), $0.39 \mu\text{g g}^{-1}$ ($2.00 \text{ mg kg}^{-1} \text{ b.w.}$ dose), $0.50 \mu\text{g g}^{-1}$ ($2.52 \text{ mg kg}^{-1} \text{ b.w.}$ dose) and $0.64 \mu\text{g g}^{-1}$ ($3.17 \text{ mg kg}^{-1} \text{ b.w.}$ dose).

Ants (*Huberia striata*) lethally poisoned with sugar water containing $1.5 \text{ g 1080 L}^{-1}$ had 1080 residues of 56 mg kg^{-1} , while ants lethally poisoned with 0.15% 1080 Wanganui #7 pellets had residues of 4.78 mg kg^{-1} (Booth and Wickstrom, 1999).

1080 residues have also been recorded in animal tissues sampled from field situations (Table 3).

Table 3. 1080 residue levels recorded in carcasses in New Zealand during pest control operations.

Species	Sample Type	Residues (mg kg ⁻¹)	Reference
<i>Birds</i>			
Blackbird	Muscle	0.01–32.0	1; 2; 3; 4
Chaffinch	Muscle	0.14–5.80	1; 4
Dunnock	Muscle	0.28–1.75	4
Hedge Sparrow	Muscle	0.03	1
Kea	Muscle	0.036 – 19.2	1
	Stomach	0.018–0.107	1
Keruru/Kukupu	Muscle	0.01	1
Kiwi (Rowi)	Muscle ^a	0.008–0.012	1
Morepork/ruru	Muscle	0.01	1
California Quail	Crop	18 - 76	5
Rifleman	Abdominal cavity	0.016–0.863	1
NI Robin	Muscle	0.37–3.80	6
Silvereye	Muscle	0.68	1
Thrush	Muscle	2.01	4
Tomtit	Abdominal cavity	0.298–0.406	1; 2; 4
	Muscle	0.23–4.2	
Tui	Muscle	0.012	1
Weka	Muscle	0.012–4.3	1; 19; 20
Whio	Muscle	0.0012	1
Fernbird	Muscle	0.14 – 0.75	7
<i>Marsupials</i>			
Possum	Bone	0–0.01	1; 8; 9
	Liver	1.5–8.4	
	Muscle	0.003–4.74	
	Stomach	0.05–~70	

Species	Sample Type	Residues (mg kg ⁻¹)	Reference
Mammals			
Short-tailed bat	Muscle	0.013	10
Cat	Muscle	0.06-1.24	1
	Stomach	0.36	
Cattle	Muscle	0.003-0.46	1
	Stomach	0.04-9.1	
Deer	Muscle	0.012-7.37	1; 2; 3; 11; 21
	Stomach	0.33-51	
	Heart	0.85-8.12	
	Liver	0.75-4.05	
Dog	Muscle	0.014-0.41	1
	Stomach	0.028-0.7	
	Intestine	0.44	
	Vomit	1.07	
Ferret	Muscle	0.004-13	1; 12; 13; 14
Rat - kiore	Muscle	69	1
Mouse	Whole body	0.001-55	1
	Muscle	9.1-10.3	
	Liver	7.8-17.6	
Pig	Muscle	0.03-0.21	1
	Stomach	56	
Sheep	Muscle	0.021-0.3	1
	Liver	0.04	
	Plasma	0.35	
	Stomach	0.001-1.3	
Stoat	Muscle	0.002-1.07	1; 11; 15; 16
	Stomach	0-0.146	

Species	Sample Type	Residues (mg kg ⁻¹)	Reference
Goat	Muscle	0.36	21
Chamois	Muscle	0.23	21
<i>Invertebrates</i>			
Honeybee	2 whole animals	0-10.8	1
Honeybee	Pooled samples of bees	0.059-1.43	18
Honeybee	Corbicula ('pollen sac')	1050.85	1
Honeybee	Honey (27 samples extracted from 73 hives)	0	18
Wasp	wasps	5-38	17
	larvae	66-255	
	Nest debris	17-96	

Variation in these residue concentrations will be due to: amount of 1080 ingested over what time, time taken to death variation between species and within individuals of that species.

a. Two kiwi (Okarito Rowi) found dead had 1080 detected in muscle samples, but in both cases there was evidence for other potential causes of death (predation, starvation) and it is not known if 1080 poisoning was a cause or contributing factor to either death.

1 VPRD; 2 Speedy (2003); 3 Nugent et al. (2004); 4 Morriss et al. (2016); 5 Evans and Soulsby (1993); 6 Powlesland et al. (1999b); 7 van Klink et al. (2013); 8 Eason et al. (1991a); 9 Meenken and Booth (1997); 10 Edmonds et al. (2017); 11 McIntosh and Staples (1959); 12 Gillies and Pierce (1999); 13 Heyward and Norbury (1999); 14 Parliamentary Commissioner for the Environment (1994); 15 Murphy et al. (1999); 16 Dilks and Lawrence (2000); 17 Eason et al. (1991b); 18 Pattemore and Fale (2022); 19 van Klink (2013); 20 Tinnemans et al. (2019); 21 Morriss et al 2019.

2.5.5. How long do residues of 1080 persist in carcasses of animals killed by the pesticide?

While 1080 is metabolised and eliminated from living animals it can persist in carcasses for months where it will degrade more slowly than indicated by the half-life in living mammalian metabolism. The rate of degradation of 1080 in carcasses will depend on moisture, temperature and the presence of micro-organisms.

The retention of 1080 in tissue was greater in rabbits dosed with a lethal dose than in those that received a sub-lethal dose. In this study 1080 was detectable (~0.03 mg kg⁻¹) in rabbit muscle 3 weeks after death following a lethal dose of 1080 (Gooneratne et al., 1995).

Tissue from possum carcasses monitored following possum and wallaby control on Rangitoto Island in 1990 still contained high 1080 residues 13 days after the operation. By day 28 the carcasses had significantly decomposed and consisted of pelts and bone so no further samples were taken (Eason et al., 1991a).

The mean concentrations of 1080 in possum stomachs and contents collected 75 days after the estimated date of death from 0.08% 1080 paste in May - June 1994 was 4.90 mg kg⁻¹. This was significantly less than the mean of 30.06 mg kg⁻¹ in possum stomachs and contents samples taken on day 25 (Meenken and Booth, 1997).

Wright (2004) monitored the fate of possum carcasses at two sites after an 8600 ha aerial 1080 operation in the Hutt River upper catchment in 2003. At site one the carcasses had lost most of their fur and were described as "very putrid" 52 days after the bait was applied, 156mm of rain had fallen by this time. By day 65 bones were exposed on carcasses at site two. The stomach remains of carcasses from both sites were tested at day 73 and found to contain 6 mg kg⁻¹ and 13 mg kg⁻¹ at sites one and two respectively. Cumulative rainfall recorded by this time was 231 mm for site one and 458 mm at site two. Three possum carcasses found downstream at about this time were contained 1080 residues of 6 mg kg⁻¹, 7 mg kg⁻¹ and <MDL. A red deer carcass also found on the river bank contained 0.5 mg kg⁻¹. The last carcass tested for residues 178 days following the bait application was found to contain green dyed bait in its stomach, but residue tests were <MDL.

Note: This information is derived from direct analyses for 1080 in tissues from animals known to have died from 1080 poisoning. Analyses of associated metabolites e.g. citrate, fluorine in tissues are difficult to compare directly with analysis of 1080 concentrations, so this information is not included.

Persistence of 1080 in the carcasses of poisoned sika deer was studied by Ross and McCoskery (2012). Bone marrow had comparatively low levels of 1080 for at least 213 days. Using this data in a review of secondary poisoning risks, Eason et al (2013) calculated that a 20kg dog would have to eat 2.4 kg of deer bone marrow at the concentration seen at day 30 to be seriously at risk. However the authors cautioned that 1080 residues in possum bone marrow had not been studied and given that possum stomach residues are often higher than those measured in deer, could pose a risk to dogs.

3. Effects on Non-Target Native Species

Based on the few studies of native species available, and the large number of non-native species studied (Part 4) suggests 1080 is likely to be toxic to most native animals. There is wide variation in sensitivity between taxonomic groups with mammals more sensitive than birds and invertebrates (on a weight for weight basis). Sub-lethal effects have been demonstrated for native invertebrates in the laboratory. The small size of many native species (relative to the target pests) means that toxic baits used for pest control are capable of causing harm to almost any animal that eats the bait. Therefore, the level of exposure to the bait becomes important in determining the effects on non-target native species in the field.

Most information on non-target exposure to 1080 bait relates to aerial poisoning as this is thought to be the “worst case scenario” for studying non-target effects. Hand laid baits are sometimes used to approximate aerial poisoning in studies. Bait station studies are scarce. It could be assumed that native species are not more at risk using bait stations than distributing the same bait type aerially.

There are records of a range of native bird species found dead after aerial poisoning operations and many of these individuals have contained residues of 1080. However, when records are discounted from:

- operations which did not meet current bait quality standards (e.g. using unscreened, un-dyed carrot bait with berry fruit lures) or
- those animals which did not have detectable 1080 residues,

the Vertebrate Pesticide Residue Database (VPRD) between 1994-2018 recorded only 44 poisoned individuals representing 11 native species across all bait types used in aerial and handlaid operations. No conclusions about population effects can be drawn from this information but it is useful to focus further studies. Some native species (mainly invertebrates) have contained 1080 residues when sampled, an indication of potential risk to insectivores from secondary poisoning.

Loss of individuals in a population of native species as a consequence of 1080 poisoning can have variable significance to the long-term viability of the population depending on the context. Those animals with a large population and/or a high rate of increase can compensate for small losses. Poison-related mortality may be replacing deaths from predation or winter starvation. Threatened species usually have a poor ability to recover from additional mortality, making the consequences theoretically more concerning.

There have been numerous studies examining the effects of aerial poisoning on native non-target populations over the last 20 years. 24 species of native birds, particularly threatened species, have been monitored. None of the studies have identified population level mortality which threatened the viability of the species, although the only reliably calculated mortality rates are for kokako, kiwi, kaka and fernbirds. The upper 95% mortality rates for kokako, kiwi and kaka are all less than 3.5%. The mean mortality rate for fernbirds is 9.4%.

Limited monitoring of short tailed bats and native frogs has not indicated detectable mortality due to aerial 1080 poisoning.

Invertebrate populations have been monitored in nine aerial poisoning operations and none have shown significant population effects on any species studied, nor is there evidence to suggest poisoned invertebrates are a significant factor in secondary poisoning of other animals. Long term monitoring of native land snails indicates substantial benefits to threatened populations in sites treated with aerial poisoning.

The risks 1080 operations pose to aquatic species is considered very low. Fish are very tolerant to 1080. Additionally, 1080 contamination of water is rarely found during 1080 operations and is at an extremely low level when it has occurred. No mortality of longfin eels, kōaro or upland bullies was observed during experiments where high densities of cereal 1080 pellets were placed in water just upstream of them. Eels and koura have survived experimental feeding of cereal 1080 pellets, and eels have survived feeding on possum tissue containing 1080. There have also been no detectable effects on aquatic invertebrate communities in field studies when 1080 baits were placed at high densities in streams.

3.1. Toxicity

3.1.1. What is the lethal dose (LD₅₀) range for each taxon?

The LD₅₀ values available for native mammals, birds and arthropods are presented in Table 4. While there is no information for any native reptiles, amphibians, fish or molluscs, Section 4 has information on overseas species in these taxa which is useful.

Table 4. Acute oral toxicity of 1080 for native taxa.

Species	LD ₅₀ (mg kg ⁻¹)	References
Birds	Range: 8.00 - 9.25	
Grey duck	10.0	1
Silvereye	~ 9.25	1
Weka	~ 8.1	2
Mammals		
Short tailed bat	0.15 ('Worst case' LD value)	3
Invertebrates	Range: 42.00 - 91.00	
NZ ant	72.00 (24 hr LD ₅₀)	4
	42.00 (48 hr LD ₅₀)	4
Wellington tree weta	91.00	4
Earthworms (<i>Eisenia fetida</i>)	No mortality from soil exposures up to 865 mg/kg	5

1 McIlroy (1984); 2 McIntosh et al. (1966); 3 Lloyd and McQueen (2000); 4 Booth and Wickstrom (1999); 5 O'Halloran et al. 2005.

Aquatic Invertebrates

Based on sub-lethal exposure trials, Suren and Bonnett (2006) suggest that the 1080 LC₅₀ for koura is relatively high.

3.1.2. Based on the mode of action, are there any taxa that are unlikely to be affected by 1080?

1080 is considered a broad-spectrum toxicant although variation in LD₅₀'s and body size of animals suggests that some native species could survive low exposure to 1080. The susceptibility of a specific animal is linked to its metabolic rate (McIlroy, 1994), so cold-blooded animals may be more tolerant to 1080 as their metabolic rate is likely to be much lower. Fish have been found to be highly tolerant of 1080 in overseas studies (Fagerstone et al., 1994).

3.1.3. Have sub-lethal effects on birds, mammals, reptiles/amphibians, fish, arthropods, or molluscs been described for 1080?

Birds

There was a significant difference in the activity of Western weka for 3 days after an aerially applied 1080 cereal pellet operation block compared with birds over the same period in a non-treatment block. In the 3 days following the 1080 operation, the average daily activity of weka with diagnostic transmitters dropped by $31.2\% \pm 4.6\%$ (standard error of the mean) ($N = 10$) and $8.0\% \pm 4.3\%$ ($N = 6$) in the treatment and non-treatment blocks respectively. All individuals in the treatment block had a pronounced drop in activity during the 3 days following the poison operation compared to 7 days immediately prior to the operation, but seemed to revert to normal daily activity levels within approximately 7 days (Tinnemans et al. 2019).

Reptiles/amphibians

An Australian study of shingleback lizards found a decrease in testosterone levels in the plasma in study animals and a degeneration of seminiferous tubules in some individuals when high sublethal doses of 1080 were administered intraperitoneally (Twigg et al., 1988).

Invertebrates

A laboratory study of **Auckland tree weta** by Hutcheson (1990) found poisoned animals, including those sub-lethally poisoned, became active during the day rather than sheltering as is their normal behaviour demonstrated by a control group and a group which fed on non-toxic baits.

Cockroaches that had eaten 1080 baits in a laboratory study appeared drugged and their normal response to predators was suppressed (McIntyre, 1987).

Smith and Grosch (1976) studied the sub-lethal effects of 1080 on *Bracon hebetor*, a **parasitoid wasp** found in North America. They found egg production decreased after a single sub-lethal dose. There was also low hatchability of eggs laid in the first few days post dosing.

In **compost worms**, used as an surrogate for native earth worms, cocoon production and the number of live juveniles decreased progressively as 1080 concentrations increased, particularly at 1080 concentrations in the soil of ≥ 100 mg kg⁻¹. These soil concentrations were well above those that normally occur following the field use of 1080 (up to 0.08 mg/kg) (O'Halloran et al., 2005).

The presence of up to 1g/kg 1080 in soil did not affect the ability of soil **microorganisms** to mineralize nitrogen (O'Halloran et al 2005). This is an absurd amount, the equivalent of mixing over 600kg of 1080 pellets into 1 kg of soil.

3.1.4. How much bait needs to be ingested for poisoning, based on pen trials with native species?

Based on the information given in section 3.1.1, the amount of bait native species need to ingest to be poisoned is given in Table 5.

Table 5. Amount of bait needed to be ingested to result in death based on LD₅₀ for native species.

Species	LD ₅₀ (mg kg ⁻¹)	Av. Weight Female (g)	Amount of 0.4g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 0.8g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 1.6g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 1.5g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 2.0g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 50g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 100g kg ⁻¹ Bait (g) for LD ₅₀
Birds									
Silvereye	9.25	13	0.30	0.15	0.12	0.08	0.06	0.002	0.001
Weka	8	700	14.00	7.00	5.60	3.73	2.80	0.11	0.06
Mammals									
Short-tailed bat	0.15	14	0.005	0.006	0.002	0.001	0.001	0.00004	0.00002
Arthropods									
NZ ant	42	0.002	0.00021	0.00011	0.00008	0.00006 ^b	0.00004	0.000002	0.0000008
Tree weta	91	1	0.228	0.114	0.091	0.061	0.046	0.002	0.001

^a Weights for birds from Heather and Robertson (1996) & weights of bats from Lloyd and McQueen (2000); ^b A single 6 g 0.15% 1080 pellet has enough toxin to deliver an LD₅₀ dose to >100 000 ants with a mean bodyweight of 2 mg each (Booth and Wickstrom, 1999).

Note: The LD₅₀ values given in section 3.1.1 have been used in the calculations. The body weights used to calculate the amount of bait required for an LD₅₀ are average weights of females, which are generally more susceptible to poisoning because of smaller body weight and physiological factors therefore a 'worst case scenario' for poisoning.

3.2. Exposure

3.2.1. What species (individual animals) have been reported as non-target deaths in field operations with 1080 use?

Aerial and Handlaid Operations

Individual animals have been found dead after aerial and handlaying operations using 1080 carrot and cereal pellet baits (Table 6, Table 7). The information presented in the tables includes animals found dead or assumed to have been lethally poisoned from the presence of 1080 residues. The information has been restricted to those operations where the basic performance standards could be verified.

Deaths of 4 kea and eight southern black-backed gulls were reported from a trial where 1080 carrot bait was aerially applied for tahr control (Douglas 1967). The baits used (chopped carrot pieces up to 200g, 0.14-0.36% 1080, green dyed) did not met current standards for registered 1080 products.

Table 6. Non-target native species deaths reported during aerial operations using 0.08% or 0.15% carrot baits (0.08% 1080 unless stated).

Species	No. Found Dead	No. of Operations	Cases Where Residues Confirmed	Sowing Rate (kg ha ⁻¹)		Ref.
				Prefeed	Toxic	
Birds						
Morepork	2	2 ^a	2		15	1
Tomtit	8	4 ^a	8		10 - 15	1; 2
	3	1 ^b	3		5	3
NI Robin	3	1 ^a	3	5	15	4
Kereru	6	3	1		15	1; 5; 6
Rifleman	5	1	5		15	1
Grey warbler	1	1	0		15	5
Tui	1	1	1	?	?	7
Weka ^c	1	1	1		5	8
	1	1	1	3	5	9

^a 1 of these operations was at Tahae (Pureora) where there is some evidence that the carrot was not screened adequately to meet bait specifications (Powlesland et al.,

1999a); ^b In this operation the carrot bait was coated with EDR deer repellent; ^c 0.15% 1080 carrot

Records of 1 tui and 1 whitehead from Kapiti island 1984 are not included above as there is some evidence that the carrot was below specs and the birds were not residue tested (Sherley, 1992). Records of robin, grey warbler, fantail, morepork/ruru, and Tomtit from 1978/79 not included above because carrot bait not to current quality standards.

1 Spurr and Powlesland (1997); 2 VPRD: T0171 & T1195; 3 Speedy (2003); 4 Powlesland et al. (1999a); 5 Greene (1998); 6 VPRD: T1223; 7 VPRD: T1809; 8 VPRD: 10210; 9 VPRD.

Table 7. Non-target native species deaths reported during aerial & handlaid operations using 0.15% or 0.08% 1080 pellets.

Species	No. Found Dead	No. of Operations	Cases Where Residues Confirmed	Sowing Rate (kg ha ⁻¹)		Ref.
				Prefeed	toxic	
Birds						
Silvereye	1	1 ^a	1		2	1
	1	1 ^a	0 ⁱ	?	1.5 - 2.5	16
Morepork	2	1 ^b	1 ^c		5	3; 4
	2	2	0 ⁱ	1	2	5
Tomtit	5 ^d	3 ^a	0 ^e		5 - 7	3; 6
	2	1 ^a	2	Yes	3	7
	1	1	1	2 + 2	4	32
Weka	2	2 ^a	2		3 - 5	8; 9
	2	2 ^{a,f}	1 ^{g,h}		1	10; 11
	2	2	2	1	2	27
	1	1	1	1	1	28
Kakariki	2	1 ^a	2	3	3	12
	1	1	0 ⁱ	2	2	13
Kereru	4	3 ^a	1 ^j		2 - 3	14
Kiwi	1	1 ^{a,f}	0 ⁱ		1	15
Kiwi (Rowi)	2 ^k	1	2	2	2	29

Kea	52	14 ^a	36	1 - 3	1 - 4	16; 24; 30
Tui	1	1	0 ⁱ	2	2	17
	1	1	0 ⁱ	?	2	18
	1	1	0 ⁱ	1	1	19
Fernbird	3	1 ^a	3	2	1	20
Grey warbler	3	1 ^a	0 ⁱ	?	1.5 - 2.5	2
Takahe	3	1	3	1.5	1.5	25
Whio	2	1	1	2	2	23
Southern black-backed gull	120	1	2	1.5	1.5	31
Southern black-backed gull	556	1	4	2 + 2	4	26
Mammals						
Short-tailed bat	1	1	1	1	1	21
Frogs						
Hochstetter's	1	1 ^a	0 ⁱ		7	22

^a toxic loading of baits 0.15%; ^b toxic loading of baits 0.08%; ^c the second bird was not tested; ^d number found in second operation unspecified, assumed at least 1; ^e none of these birds were tested for residues; ^f baits handlaid; ^g this bird also had cyanide residues which is thought to be the cause of death; ^h the second bird tested negative, assumed to have come from handlaid treatment block – see Pestlink report 0203SND28; ⁱ tested negative; ^j two other kereru tested negative; ^k for each of these Rowi there was evidence for other potential causes of death (predation, starvation) and it is not known if 1080 poisoning was a cause or contributing factor for either death.

Note: 1 kokako record (Rotoehu 1994) omitted as baits were experimental (Flux and Innes, 2001; Spurr and Powlesland, 1997).

1 VPRD: T1534; 2 VPRD T3567; 3 Spurr and Powlesland (1997); 4 VPRD: T0283; 5 VPRD T5712; 6 Calder and Deuss (1985); 7 Morriss et al. (2016); 8 Walker (1997); 9 VPRD: T0169 & T2061; 10 VPRD: T1370 & T1467; 11 Pestlink: 0203SND12 & 0203SND28; 12 Rhodes et al. (2008); 13 VPRD 13305; 14 VPRD: T2061; 10206 & 1427; 15 VPRD: T1283; 16 VPRD: L23934, L23949, L35852, L41021, L41026, L23948, T5227 T5245, T7093, T7416, T7418, T7479, T8343, T7869; 17 VPRD 13306; 18 VPRD; 19 VPRD T4372; 20 van Klink et al. (2013); 21 Edmonds et al. (2017); 22 McNaughton and Greene (1994); 23 VPRD: T7287 & N. Lightbourne pers comm.; 24 Kemp et al. (2019); 25 VPRD T7505; 26 VPRD T7821; 27 van Klink (2013); 28 Tinnemans et al. (2019); 29 VPRD: T8093 & T8078; 30 Young et al. (2023); 31 P. Eschenmoser pers. comm.; 32 VPRD 28890.

Bait stations

Individual animals have been found dead after bait station operations using 1080 carrot and cereal pellet baits (Table 8). The information presented in the table includes animals found dead or assumed to have been lethally poisoned from the presence of 1080 residues. The information has been restricted to those operations where the basic performance standards could be verified.

Table 8. Non-target native species deaths reported during operations using 0.15% 1080 pellets in bait stations.

Species	No. Found Dead	No. Of Operations	No. Of Cases Where Residues Confirmed	Sowing Rate (kg ha ⁻¹)		Ref.
				Prefeed	Toxic	
Birds						
Kea	1	1	1		1	1
Tui	1	1	0 ^a		?	2

^a tested negative

1 VPRD: T0597; 2 VPRD: 8692.

Other methods

No information on deaths after the use of other methods and bait types could be located.

3.2.2. In which species have residues of 1080 been detected following operations?

Aerial and Handlaying Operations

1080 residues have been detected in a number of living animals following aerial and handlaying operations using 1080 cereal pellets (Table 9).

24 hours after an aerial rabbit control operation (0.4 g kg⁻¹ aerial carrot at 25 kg ha⁻¹) on Motuihe Island, Auckland in July 2002, 5 live cockles and 6 live marine mussels were tested for 1080 residues. None contained 1080 residues (VPRD 4928 - 4938).

During the February 2010 Egmont National Park aerial 1080 operation (0.15% 1080 Wanganui #7 pellets, 2.3 kg ha⁻¹) freshwater and marine mussels were monitored for 1080 residues. Freshwater mussels were sampled from 11 sites within the operational area. Marine mussels were sampled at 2 sites approximately 20 km from the operational area. No 1080 was detected in any of the samples (VPRD).

The information in this section includes the results of laboratory analysis from live animals captured or killed for sampling from treatment areas. Residues from

animals found dead are presented in section 3.2.1 above. The information has been restricted to those operations where the basic performance standards could be verified.

During a field trial in Egmont National Park in 2016, RS5 pellets were prefeed on four occasions (4 kg/ha; 2 kg/ha; 1 kg/ha and 1 kg/ha 21-48 days apart) followed by 0.15% 1080 RS5 pellets at a sowing rate of 4 kg/ha over 1,600 ha. The surrounding area was prefeed once at a sowing rate of 1 kg/ha, followed by 0.15% 1080 RS5 pellets at a sowing rate of 2 kg/ha. 11 green coloured whio scats were found following the toxic drop, attributed to 5 individual birds, with the majority of the scats (9) found within the trial area. Nine of the scats were tested for 1080 residues with 3 testing positive. The whio present at the site where the positive samples were collected disappeared. (D Worthy & J Scrimgeour pers. comm.).

Following a 1080 operation (aerially applied 2kg/ha prefeed, 2kg/ha 0.15% 1080 6g RS5 bait) on Mt Taranaki in June 2019, 19 green coloured whio scats were found and all tested positive for 1080 residues (VPRD). The locations of 1080-positive whio scats indicated they were likely to be from a number of different individual birds. The proportion of whio that consumed 1080 bait is unknown as is the identity and fate the birds that did eat bait. Of 19 radio tagged birds from the same area 17 were alive and 2 were found dead after the operation (see section 3.2.3). Seven of the radio tagged birds were present on sections of river where 1080-positive scats were found and none of the birds died of poisoning. (N. Lightbourne pers. comm.).

A green whio scat collected from the Waingaro River in Kahurangi National Park following an aerial 1080 pellet operation (1.5 kg/ha prefeed, 1.5 kg/ha 0.15% 1080 6g RS5 bait) tested positive for 1080 (VPRD).

Table 9. Residues detected in live non-target native species during aerial and handlaid pest control operations using 0.15% and 0.08% 1080 pellets.

Species	Residues (mg kg ⁻¹)	No. Of Samples	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
Birds					
Kiwi	0.011	1 ^d		3 ^a	1
Weka	4.35	1 ^d		5 ^a	2
Whio	0.06-1.51	3 ^d	2x at 4 & 2	4	10
	0.003-0.198	19 ^d	2	2	11
	0.081	1 ^d	1.5	1.5	12
Mammals					

Short-tailed bat	0.013	1	1	1	3
<i>Invertebrates</i>					
Bush weta	2.7	1	1.5	1.5 ^a	4
Tree weta	66	1 ^e		5 ^a	5
	8.6	1		5 ^a	6
Cave weta	32-130	4 ^f		5 ^a	5
	4	1		5 ^a	6
Weevil	10	1			6
Kauri snails	0	4		5 ^{b,c}	7; 8
Arthropods (mixed)	0.05-0.75	4		5 ^{b,c}	7; 8
Spiders (mixed)	14	1 ^g		5 ^a	5
Arthropods (mixed)	14-46	3 ^h		5 ^a	5
	0-0.006	3		5 ^b	9

^a toxic loading of baits 0.15%; ^b toxic loading of baits 0.08%; ^c baits were handlaid; ^d faecal dropping sample selected for testing because green colour suggested toxic bait consumption; ^e 1 sample totalling 26 individuals collected from pitfall traps in treatment area; ^f four samples totalling 9 individuals; ^g 1 samples of 4 spiders, 2 collected from baits and 2 from pitfall traps; ^h 3 samples totalling 58 individuals collected off 1080 baits.

1 VPRD: T0819; 2 VPRD: T0169; 3 Edmonds et al. (2017); 4 VPRD: T6452; 5 Lloyd and McQueen (2000); 6 Spurr and Berben (2004); 7 Pierce and Montgomery (1992); 8 VPRD: R004; 9 VPRD: 139 & 146; 10 VPRD: T6388, T6403 & T6405; 11 VPRD: T7183, T7184, T7197; 12 VPRD: T7198

3.2.3. What evidence is there to suggest that use of 1080 causes, or doesn't cause, a population decline of native species at sites where it is used?

Aerial and hand laying operations using 0.15% or 0.08% 1080 Pellets

Birds

44 radio-tagged **great spotted kiwi** have been monitored through four 0.15% 1080 Pellet aerial operations and none died from 1080 poisoning (Table 10).

Table 10. Great spotted kiwi monitored during aerial 1080 operations using 0.15% 1080 pellets.

Operation	No. of Birds Exposed	No. killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1994 (Aug) Saxon River	9	0		5	1
1994 (Dec) Karamea	7	0		5	2
2009 (Sept) Goulard Downs	8	0	1	2	3
2009 (Sept) Hawdon	20	0	1	2	4

1 Walker (1997); 2 Robertson et al. (1999); 3 S. Forder pers. comm. Pestlink: o809GDBo8; 4 Veltman and Westbrooke (2011)

A total of 243 **NI brown kiwi** have been monitored during aerial and handlaid 1080 pellet operations during 8 operations and none have died from poisoning (Table 11). Kiwi call count monitoring during the Waipoua operation did not indicate significant 1080 related mortality (Pierce and Montgomery, 1992). Table 11. NI brown kiwi monitored during aerial and handlaid 1080 operations using 0.15% or 0.08% 1080 pellets.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1990 (June) Waipoua	5	0		5 ^a	1
1990 (Sept) Waipoua	6	0		5	1
1995 Rewarewa	22	0		3 ^{b,c}	2
2001 (Sept) Tongariro Forest	27	0	2	3 ^b	3
2006 (Sept) Tongariro Forest	68	0	2	4 ^b	3
2011 (Sept) Tongariro Forest	44	0	1.5	2 ^b	3
2014 (Aug) Tongariro Forest	39	0	0.75	0.75 ^b (strip sowing)	3
2017 (Aug) Tongariro Forest	32	0	1.5	1.5 ^b	3

^a toxic loading of baits 0.8 g kg⁻¹; ^b toxic loading of baits 1.5 g kg⁻¹; ^c baits were handlaid.

1 Pierce and Montgomery (1992); 2 Robertson et al. (1999); 3 H. Robertson & J. Guillootel pers. comms.

46 **Rowi** were monitored during an aerial 0.15% 1080 Wanganui #7 pellet operation at Okarito in November 1998 with no deaths being reported (Veltman and Westbrooke, 2011). 19 **Haast tokoeka** were monitored during an aerial 0.15% 1080 Wanganui #7 pellet operation (2 kg ha⁻¹ prefeed, 3 kg ha⁻¹ toxic) in the Haast Kiwi Sanctuary in May 2001, with no deaths being recorded (H Robertson pers. comm.).

Based on a meta-analysis of 199 kiwi (all species) from 10 surveys between 1994 and 2009, Veltman and Westbrooke (2011) calculated the upper bound of the 95% confidence interval for an estimate of zero mortality at 1.5%.

A total of 302 NI **kokako** has been exposed to this method and bait type over 13 operations and 2 have disappeared after poisoning (Table 12). Between 1986 and March 1998, 366 kokako (including 6 juveniles) have been monitored through 31 aerial poisoning operations (of all bait types and toxins combined), although the number exposed and known to have survived is greater. Of the monitored birds, 4 have disappeared after poisoning, leading to a maximum estimate for kokako mortality of 1.4% per operation with a 5% chance that it will exceed 4% (Flux and Innes, 1999). Based on a meta-analysis of 129 radio tagged and banded kokako that were monitored through 8 aerial 1080 operations between 1986 and 2001, Veltman and Westbrooke (2011) calculated the upper bound of the 95% confidence interval for an estimate of zero mortality at 2.3%.

Table 12. NI kokako monitored during aerial and handlaid 1080 operations using 0.15% or 0.08% 1080 pellets.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1986 Pureora Nth Block	16	0		10-12 ^{b,d}	1
1986 Okahukura Forest	11	1		10-12 ^{b,d}	1
1986 Meyers Farm (Pureora)	5	0		8-10 ^c	1
1987 Pureora Nth Block	23	0		8 ^{c,d}	1
1988 Mapara	3	0		10 ^c	1
1988 Cowan WR/ Okahukura Forest	24	0		8-10 ^c	1
1990 Waipoua	6	1e		5 ^c	2

1990 Mapara	52	0		8 ^c	3
1989 Moki Forest	12	0		9 ^c	4
1990 Kaharoa Forest	24	0		6 ^b	5
1991 Mapara	48	0		8 ^c	3
1992 Mapara	50	0		8 ^c	3
1992 Kaharoa Forest	28	0		6 ^b	6
1994 Rotoehu	26	0		2 ^b	7
2001 Mapara	16	0	yes	2 ^b	7

^a monitoring method assumes birds which disappear have died from poisoning; ^b toxic loading of baits 0.15%; ^c toxic loading of baits 0.08%; ^d These operations used 'Mapua' surface coated cereal pellets which are no longer used; ^e this bird least fitted the basic assumptions of the monitoring method and probably should not have been included in the assessment- according to the authors.

1 Innes and Williams (1990); 2 Pierce and Montgomery (1992); 3 Bradfield (1993); 4 Spurr (1994b); 5 Speed (1992); 6 Speed (1993); 7 Veltman and Westbrooke (2011).

A total of 132 **weka** have been exposed to this method and bait type over 8 operations and 4 have died from poisoning (Table 13). The pooled mortality rate from monitoring 90 Western weka across four pre-fed aerially applied 1080 cereal pellet operations is 3.3% (0.7–9.4% CI) (Tinnemans et al. 2019).

Table 13. Weka monitored during aerial and handlaid 1080 operations using 0.15% 1080 pellets.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1994 Saxon River	7	0		5	1
1994 Tennyson inlet	17	1		5	1
1994 Rotumanu	8	0		5	2
2000 Copland	10	0		3	3; 4
2012 Pukaki block (Central Westland)	12	1	1	2	5
2012 Marsden block (Central Westland)	20	1	1	1	5
2013 Tennyson	26	1	1	1	6

2014 Tennyson	32	0	1	1	6
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1 Walker (1997); 2 Spurr and Powlesland (1997); 3 van Klink and Tansell (2003); 4 Pestlink: 02/03SWS22; 5 van Klink (2013); 6 Tinnemans et al. (2019).

A total of 47 radio tagged **morepork/ruru** has been exposed to this method and bait type over 6 operations and none have died from poisoning (Table 14). Call count monitoring at Waipoua did not indicate any significant 1080 related mortality (Pierce and Montgomery, 1992).

Table 14. Morepork/ruru monitored during aerial and handlaid 1080 operations using 0.15% or 0.08% 1080 pellets.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1990 Waipoua	2	0		5 ^a	1
1994 Saxon River	6	0		5 ^b	2
1994 Tennyson Inlet ^c	1	0		5 ^b	2
1998 Pureora	3 ^d	0		5 ^a	3
2010 Waitutu	11	0	1	2 ^b	4
2014 Hokonui	24	0	Yes	Unknown	5

^a toxic loading of baits 0.08%; ^b toxic loading of baits 0.15%; ^c six of the birds monitored were at Goulard Downs; ^d This study followed 28 radio tagged birds over 3 years. Significant natural mortality (18%) was observed over hard winters.

1 Pierce and Montgomery (1992); 2 Walker (1997); 3 Powlesland et al. (1999b); 4 Greene et al. (2013); 5 Dilks (2015).

A total of 59 **fernbirds** has been exposed to this method and bait type over 3 operations and 7 have disappeared after poisoning (Table 15).

In the 2010 study in Ianthe Forest, 36 radio-tagged **South Island fernbirds** were monitored during an aerially applied 1080 cereal pellet operation. 5 birds dropped their transmitters, 1 was killed by a predator and 3 died from 1080 poisoning. Based on this, the mortality of fernbirds due to 1080 poisoning was estimated at 9.4% (2.4-22.6% 95% CI). The authors concluded that the impact of aerial 1080 operations on fernbird numbers is small, and the survival and improved breeding success that would have resulted from introduced predators being reduced during the 1080 operation would have outweighed the losses (van Klink et al., 2013).

Table 15. Fernbirds monitored during aerial and handlaid 1080 operations using 0.15% or 0.08% 1080 pellets.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1990 Waipoua	14 ^d	0		5 ^a	1
1994 Goulard Downs	9	4 ^c		5 ^b	2
2010 Ianthe Forest	36	3	1	2 ^b	3

^a toxic loading of baits 0.8 g kg⁻¹; ^b toxic loading of baits 1.5 g kg⁻¹; ^c due to the banded birds not being roll called immediately prior to the poisoning this study was inconclusive about cause of disappearance; ^d includes 2 banded birds.

1 Pierce and Montgomery (1992); 2 Walker (1997); van Klink et al. (2013)

A total of 55 colour banded **NI robins** have been exposed to this method over 2 operations and 10 have disappeared after poisoning (Table 16).

Twenty-one colour banded and 5 unbanded **SI robins** monitored during 2 aerial 1080 pellet operations all survived (Table 16)

Table 16. Robins monitored during aerial and handlaid 1080 operations using 0.15% 1080 pellets.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1994 Saxon River	2	0		5	1
1998 Waitotara	38	10		4	2
1998 Long Ridge, Pureora	17	0		5	2
2011 Silver Peaks, Dunedin	24	0	1.5	2	3

^a monitoring method assumes birds which disappear have died from poisoning.

Not included here is monitoring of robins using the 5-minute count method which can only reliably detect very large population changes (Powlesland et al. 1999).

1 Walker (1997); 2 Powlesland et al. (1999b); 3 Schadewinkel et al. (2014).

A total of 29 colour banded **NI tomtit** have been monitored during two non-prefed aerial 1080 cereal pellet operations, with 1 bird disappearing (Table 17).

A monitoring study in Tongariro Forest (2001) using distance sampling found no significant difference in the mortality of **tomtits** between the treatment (2 kg ha⁻¹

prefeed followed by 3 kg ha⁻¹ 0.15% 1080 pellets) and non-treatment sites (Westbrooke et al., 2003). Distance sampling of tomtits also occurred during an aerial 1080 operation (2 kg ha⁻¹ prefeed followed by 2 kg ha⁻¹ 0.08% 1080 pellets) on Mt Pureora in 2003. There was no decline in male tomtits counts in this operation (Westbrooke and Powlesland, 2005). These results led the Westbrooke and Powlesland (2005) to conclude that aerial poisoning operations using cereal pellets at low sowing rates causes “...little, if any...” short term impacts on tomtit populations.

Monitoring of **tomtits** using distance sampling has also been undertaken during two operations using cereal pellets coated with **EDR** deer repellent. Oates (2008b) monitored **North Island tomtits** at three sites during an aerial 1080 pellet operation in Rotoaira Forest in 2007. The three sites were: a block where deer repellent coated 1080 pellets were used; a block where standard, uncoated pellets were used; and a non-treatment site where no possum control occurred. Tomtit numbers declined by between 20 – 36% at all sites. This led the author to conclude some factor (possibly too long a time period between the pre and post control surveys) other than the use of the deer repellent or 1080 caused the decline. In 2008, **South Island tomtits** were monitored during an aerial operation using **EDR** deer repellent coated pellets (2 kg ha⁻¹ prefeed followed by 2 kg ha⁻¹ 0.15% 1080 pellets) in the Waianakarua Scenic Reserve southwest of Oamaru and at a nearby non-treatment site when no possum control occurred. At both these sites tomtits increased by similar amounts (~13%) during the post control monitoring (Oates, 2008a).

Table 17. Tomtits monitored during aerial and handlaid 1080 operations using 0.15% or 0.08% 1080 pellets.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1998 Pureora	14	0		5 ^a	1
2001 Tongariro	15	1		3 ^b	2

^a toxic loading of baits 0.08%; ^b toxic loading of baits 0.15%. 12 g baits used; ^c monitoring method assumes birds which disappear have died from poisoning.

Not included here is monitoring of tomtit using the 5-minute count method which can only reliably detect very large population changes (Powlesland et al. 1999).

1 Powlesland et al. (2000); 2 Westbrooke et al. (2003).

Transect counts of **SI tomtits**, **grey warbler**, **SI robins** and **riflemen** were conducted before and after the 2010 Waitutu aerial 1080 operation (1 kg ha⁻¹ prefeed followed by 2 kg ha⁻¹ 0.15% 1080 pellets). The transects were located at five sites, three within the operational area and two in a non-treatment area. While the numbers of tomtits and grey warblers detected on the transects changed following the application of the 1080, the scale and direction of the changes (decreases for

tomtits and increases for grey warbler) was similar at all five sites. The pre- and post-control counts of rifleman and SI robins were similar between the operational area and non-treatment sites. The authors therefore concluded there was no evidence for population level impacts from 1080 on any of these species (Greene et al., 2013).

Van Vianen et al. (2018) monitored **bellbird, silvereeye, SI tomtit, rifleman, brown creeper, grey warbler** and **fantail** using five minute bird counts pre- and post-aerial 1080 operations (1 kg ha⁻¹ prefeed followed by 2 kg ha⁻¹ 0.15% 1080 pellets) in the Rolleston Range and Alexander Range in 2012. The five-minute bird count monitoring occurred in the operational areas and at nearby non-treatment areas. None of the monitored species declined significantly more within the operational areas compared to the non-treatment sites, indicating 1080 did not have an impact on the populations.

Sixty-four **whio** have been monitored through aerial 1080 pellet operations where bait was sown over the river habitat where the monitored birds were present. Two of these birds died (Table 18). The two birds that died were from a sample of 19 radio tagged birds from an operation on Mt Taranaki in June 2019. Only one of the 2 dead whio could be tested, and was found to have 1080 residue at 0.0012 µg/g in a muscle tissue sample (VPRD, N. Lightbourne pers. comm.).

Another 62 **whio** have been monitored through 1080 pellet operations that had bait exclusion areas on the main rivers so if monitored birds foraged only in the main river bed they may not have been exposed to toxic bait. None of these birds died of poisoning (Table 18).

There was no reduction in visual counts of whio in the Otira valley after application of 0.15% 1080 Pellets at 6 kg ha⁻¹ in 1989 (Spurr and Powlesland, 1997).

Table 18. Whio monitored during aerial 1080 operations using 0.15% or 0.08% 1080 pellets.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
Tongariro Forest (2006) ^a	28	0	2	4	1
Pukepoto-Mangatepopo (2007) ^a	34	0	2	3 & 5	1
Oparara (2008) ^b	15	0	2	3	1
Wangapeka/Fyfe (2011) ^b	12	0	Yes	2	3
Wangapeka (2016) ^b	18	0	1.5	1.5	4
Mt Taranaki (2019) ^b	19	2 ^c	2	2	5

a These operations included bait application exclusions of ≥20m from main rivers.

^b These operations did not have bait application exclusions over the rivers where monitored who were present.

^c One of these birds was tested and positive for 1080, the other was too decayed to allow for testing and is acknowledged as potentially killed by poisoning based on timing of death.

1 Veltman and Westbrooke (2011); 2 Veltman et al. (2014); 3 Steffans pers. comm.; 4 Malham pers. comm.; 5 Lightbourne pers. comm.

A total of 60 radio tagged **Kaka** have been exposed to this method and bait type over 4 operations and none have died from poisoning (Table 19). Additionally, 38 radio tagged birds have been exposed to 0.08% carrot baits over 2 operations and none have died from poisoning (Greene, 1998; Powlesland et al., 2003). Based on a meta-analysis of the kaka monitored through the 5 pellet and carrot operations between 1994 and 2008, Veltman and Westbrooke (2011) calculated the upper bound of the 95% confidence interval for an estimate of zero mortality at 3.5%.

Table 19. Kaka monitored during aerial 1080 operations using 0.15% 1080 pellets.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
Windbag (1998)	15	0		5	1
Waipapa (2001)	20	0		5	1
Waipapa (2008)	10	0	1	1.5	2
Waitutu (2010)	15	0	1	2	3

1 Powlesland et al. (2003); 2 Veltman and Westbrooke (2011); 3 Greene et al. (2013)

Kereru (NZ pigeon/kukupa) have not been monitored individually when exposed to this method and bait type. However none of six birds ate non-toxic cereal pellets offered in a trial on Kapiti island (Spurr and Powlesland, 1997). Monitoring of kereru during 5 aerial 1080 operations using cereal pellets did not detect population changes using the five minute count method (Spurr and Powlesland, 1997). Additionally, all 15 radio tagged birds exposed to an aerial 1080 operation using carrot bait survived (Powlesland et al., 2003).

21 marked (8 radio-tagged and 13 banded) adult **NZ falcon** were monitored through three 0.15% 1080 cereal pellet operations undertaken in Kaingaroa Forest during 2013-2014 by Horikoshi et al. (2018). All the marked falcon survived the operations. Using the live-recaptures model in Program MARK 8.1, the researchers estimated of the 95% C.I. survival of adult falcon through the operations at 84-100%.

Seaton et al. (2009) collected productivity data from 87 **falcon** nests in Kaingaroa pine plantation during three breeding seasons, 2003 - 2006. During this time 1080 pellets and carrots were ground laid or aerially applied in forest compartments where falcon bred. The numbers of chicks successfully fledged was not related to time since 1080 application (1 month to >3 years), application method or bait type. During the study the breeding falcon population increased from 20 to 36 pairs, leading to the authors concluding that 1080 did not have a negative impact on falcon, and probably had a positive impact by reducing predation pressure on the falcon.

Falcon territories remained occupied, presumably by the resident birds, during four aerial 1080 operations using cereal pellets (Pureora 1984, Mapara 1990-92) and one using carrot bait (Waihaha 1994) (Spurr and Powlesland, 1997). The total number of falcon involved in this monitoring was about 13, although the Mapara birds (3 pair) were exposed in three consecutive years (Bradfield, 1993; Calder and Deuss, 1985; Greene, 1998).

Kakariki (parakeet) nests have been monitored during two aerial cereal 1080 operations. Fifteen nests were monitored during the October 2007 Hurunui Valley operation and a further seven nests were monitored during a 1080 operation in the Dart Valley. Dead chicks in a failed nest in the Hurunui Valley operation contained 1080 residues and the female was not seen after the nest failed. All the monitored nests in the Dart Valley operation were successful, however two unmonitored Kakariki were found dead with 1080 residues in their tissues. The combined estimate of mortality of nesting parakeets from these operations was 2.27% (0.1-12 % 0.95 CI) (Rhodes et al., 2008). The authors concluded that while some Kakariki were killed during the 1080 operations, given the rate of nest predation observed in areas where no predator control was carried out, the net benefit from the 1080 operations was positive. No detectable impact could be determined through five minute bird count monitoring before and after four aerial 1080 operations using carrot or cereal pellet baits (Spurr and Powlesland, 1997). Additionally following an intensively monitored aerial 1080 operation in Waihaha in 1994 using carrot bait, Greene (1998) observed "...kakariki remained common within the study area...".

Australasian harrier have not been monitored individually when exposed to this method and bait type. However no detectable impact could be determined through five minute bird count monitoring before and after an aerial 1080 operation using cereal pellets on Rangitoto island and "the small resident population was still seen...throughout the year following the poisoning" (Miller and Anderson, 1992). Additionally, Pierce and Maloney (1989) found no evidence of dead harriers after aerial 1080 poisoning of rabbits in the McKenzie basin.

Kea survivorship with this method was analysed using information from 29 operations where radio-tagged kea were monitored (Table 20). A total of 271 individual radio tagged kea were exposed across these operations. Because some tagged kea were exposed to more than one operation there were 318 kea to operation records. Forty-nine kea were killed across 13 of the 29 operations, an overall mean mortality rate of 15.4%. Mortality rate and sample sizes varied greatly between operations and the average operation-level mortality rate was 13.4% (Cieraad 2024).

Table 20. Kea monitored during aerial 1080 operations using 0.15% 1080 pellets. Data from Cieraad (2024).

Operation	No. of kea observed	No. of observed kea killed	No. of prefeeds	Toxic pellet size (g)	Toxic pellets per hectare
Abby Rocks 2011	8	0	1	12	167
Abby Rocks 2014	20	1	1	6	167
Anatoki 2014	2	0	1	6	167
Arawhata 2008	4	0	1	12	333
Arthurs Pass East 2022	26	4	1	6	250
Arthurs Pass West 2022	22	4	1	6	250
Copland 2012	2	0	1	12	167
Fox-Franz 2008	17	6	1	12	208
Hawdon 2009	10	0	1	6	333
Hawdon 2012	6	0	1	12	167
Hawdon 2014	4	0	1	6	167
Hawdon 2017	4	0	1	6	333
Hawdon 2019	6	0	1	6	500
Hawdon 2019_2	6	1	1	6	250
Matukituki 2020	10	6	2	6	250
Mt Arthur 2009	12	0	1	12	167
Mt Arthur 2014	5	0	1	12	167
Okarito 2011	36	8	1	12	167
Oparara 2014	5	2	1	12	167
Oparara 2016	3	0	1	6	250
Otira-Taipo 2022	28	7	1	6	167
Ortira 2013	11	4	1	12	167
Perth Phase 1 2019	14	2	2	6	667

Perth Phase 2 2019	13	0	2	6	333
Rotoiti 2014	2	1	1	6	167
Wangapeka 2011	13	0	1	12	167
Wangapeka 2014	8	0	1	6	167
Wangapeka 2016	15	0	1	6	250
Wet Jacket 2020	6	3	1	6	250

Thirteen radio tagged **rock wren** were monitored through an operation with aerially applied 0.15% 1080 6g pellets applied at 1.5 kg/ha in the Oparara-Grange area of Kahurangi National Park in November 2019. All birds were alive 10 days after the bait application. Twenty days after the bait application 12 of the birds could still be tracked. Ten of these were still alive, one was found dead on its nest and tested negative for 1080 residue, and another bird had been predated (likely by a falcon) (T. Rawlence pers. comm.).

Eighteen **takahe** in the Goulard Downs area of Kahurangi National Park (where Takahe were released in 2018) were monitored during an aerial 1080 operation in August 2020. The operation (Aorere block of Kahurangi NP) had a 587-hectare 1080 bait exclusion zone over the area where most of the takahe were present. Six monitored birds were present in the 1080 bait application area (0.15% 1080 6g pellets at 1.5kg/ha) during the operation and three of these died of poisoning (Kiss et al., 2020).

Five-hundred and fifty-six **southern black-backed gulls** (*Larus dominicanus*) were killed in an aerial 1080 operation (0.15% 1080 6g pellets at 4kg/ha following 2 prefeed applications of 6g pellets at 2kg/ha) at South Okarito in November 2021. A high proportion of the dead gulls were found at a nesting colony that was included in the treatment area, though carcasses were also found on the riverbed and coastal strip boundary of the treatment area (ZIP 2021). There was no monitoring of before and after gull abundance and the local population size was not known. Although southern black-backed gulls are highly abundant in New Zealand, the number of recorded deaths from this operation indicate there was likely to have been some reduction in the local population.

Reptiles/amphibians

Lizards and frogs were not monitored in any 1080 poisoning operations prior to 1994; however, none have been reported killed by 1080. Captive **McCann's skinks** ate non-toxic cereal pellets (RS5 and Agtech), especially when the baits were wet, but the level of consumption (0.01 - 0.02 g over 2 days) was probably insufficient for the animals to have received a lethal dose had the baits been toxic (Freeman et al., 1997).

The attractiveness of non-toxic RS5 cereal pellets (dyed green and lured with cinnamon) to wild **grand** and **Otago skinks** were tested by Marshall and Jewell (2007). The baits were offered in two sizes - small pieces no larger than 6 mm and large baits (whole pellets). The baits were offered dry or wet. All bait types were

sampled (licked, nudged or bitten) by both species of skink, with small pieces sampled more often than large baits. No animals tried to consume large pieces of cereal bait. However, 1/10 grand skinks and 3/20 Otago skinks consumed small, wet pellet fragments.

Monitoring of a population of **Archeys frog** in the Coromandel Ranges before and following application of 0.15% 1080 Pellets at 5 kg ha⁻¹ in 1995, showed no decline in Archeys frog (Perfect, 1996). Ongoing monitoring of **Archeys frogs** has occurred in Whareorino Forest, King Country, since 2005. This includes monitoring before and after an aerial 1080 operation (2kg ha prefeed, 2 kg ha 0.15% 1080 Whanganui #7 pellets) in May 2012. The frog population size and survival was not affected by the 1080 operation (Bridgeman, 2015).

Hochstetters frogs were counted at 3 sites pre- and post- application at 7 kg ha⁻¹, 1994 Hunua Ranges. One frog found dead immediately following poison operation tested negative for 1080. Fluctuations in frog numbers counts were influenced so strongly by short term environmental effects that any effect of the poison drop could not be detected (McNaughton and Greene, 1994).

Bats

Edmonds et al. (2017) monitored individually marked **Short-tailed bats** before, during and after an aerial 1080 operation in the Eglinton Valley in December 2014. In this 10 939 ha operation, RS5 pellets were prefeed at a 1 kg/ha followed by 1 kg/ha 0.15% 1080 RS5 pellets approximately 6 weeks later. 764 out of 771 marked bats (99.1%) were alive one week after the operation. One bat pup found dead under a roost tree tested positive for 1080 residues. However, any immediate impact of 1080 was assessed as minimal because the calculated annual survival rates of female bats was high (91.5%).

Lloyd (1994) offered non-toxic cereal pellets to captive **Short-tailed bats** and hand broadcast baits containing a fluorescent marker throughout an area known to be inhabited by bats and concluded "...short-tailed bats are unlikely to eat carrot or grain-based baits...". However short-tailed bats are possibly vulnerable to secondary poisoning because they are known to feed on arthropods that have been recorded feeding on 1080 baits and residues in these prey can in theory be enough to kill a bat (Lloyd and McQueen, 2000).

In a study in Rangataua forest where 0.15% 1080 Pellets were aerially broadcast (3 – 5 kg ha⁻¹) over "...almost the entire winter range..." of the study animals, a total of 269 **short-tailed bats** were caught at their roost following poisoning and held for 48 hours to determine mortality or signs of poisoning. All animals survived and showed no signs of 1080 poisoning (Lloyd and McQueen, 2000).

Fish

Native fish have not been monitored during 1080 operations. However, a field experiment has been conducted to study the impact of 1080 on **longfin eels**, **kōaro** and **upland bullies**. Four headwater streams were selected in the Mawhera Forest in the Grey Valley, West Coast. In each stream four sites were selected – 10 m and 100 m downstream, and 10 m and 100 m upstream from where 1080 baits were to be placed in the stream. At each site 8 fish of each species were placed in individual

cages. Fish mortality was recorded after 1 and 4 days. Baits (6.5 g, 0.15% 1080 Wanganui #7 pellets) were then placed in the streams at a density equivalent to a sowing rate of 25 – 30 kg ha⁻¹ (this represented an extreme scenario of 10 x normal sowing rates). Fish survival was monitored 1 and 4 days after the bait was placed in the water. No fish died after the baits were added to the water, suggesting all three species were tolerant to 1080 in water at the concentrations used in the study (Suren and Lambert, 2006).

Terrestrial invertebrates

Invertebrate populations have been monitored during eight 1080 aerial poisoning operations using cereal pellets. None of these studies suggest significant population effects on any species studied nor is there evidence to suggest poisoned invertebrates are a significant factor in secondary poisoning of other animals.

An extensive study of forest invertebrates found on 1080 baits by Sherley et al. (1999) found that at any time only a small proportion of baits had invertebrates on them, and the few individuals per bait represented a small section of the fauna present in the litter. The number of invertebrates recorded on baits in treatment grids declined when 0.15% 1080 Pellets were laid at 18 kg ha⁻¹, but started to return to original levels (relative to control grids) within 6 days of removal of the toxic baits. The reduction in invertebrate numbers did not extend further than 20 cm around each bait.

Another study by Spurr and Berben (2004) hand laid 0.15% 1080 Pellets at 5 kg ha⁻¹ to simulate aerial poisoning in Tararua Forest Park in 1999 and monitored the occupancy of artificial refuges by **tree weta** and **cave weta** (*Isoplectron sp.*). No significant impact of bait application was found for these species nor was there any effect observed on numbers of **slugs**, **spiders** and **cockroaches** which also commonly used the same refuges.

No impact was detected on populations of **weta** in Waipoua Forest and all **cockroaches**, **centipedes**, **millipedes**, **kauri snails** and all but one **beetle** survived in enclosures with 0.08% 1080 Pellets (Pierce and Montgomery, 1992).

Spurr (1994a) found no impacts on populations of **amphipods**, **ants**, **beetles**, **collembolans**, **millipedes**, **mites**, **slugs**, **snails**, **spiders** and **cave weta** at Puketi Forest or Titirangi Scenic Reserve where 0.08% 1080 Pellets were aerially applied at 5 kg ha⁻¹.

In Mapara where 0.08% 1080 Pellets were aerially applied in three consecutive years 1990-92, a comparison of invertebrate fauna showed a greater number of predatory insects in the treatment site, characteristic of a healthy forest, and more fungal eating insects in the non-treatment site, characteristic of unhealthy forest (Bradfield, 1993).

A range of invertebrate species on Rangitoto Island were sampled using a range of collection techniques, before and after aerial poisoning with 0.08% 1080 Pellets at 12 kg ha⁻¹. No population effects were observed (Anon., 1990).

Aquatic invertebrates

In the early 1990's, the Taranaki Regional Council monitored aquatic invertebrates in streams before and after two aerial 1080 operations. No effect of the aerial 1080 operations on the invertebrate communities could be demonstrated. However, the post control samples were collected between 32 and 42 days after the aerial operation, and the sampling protocol could have resulted in any short-term reductions in invertebrate numbers being missed (Suren and Lambert, 2006).

Suren and Lambert (2006) therefore conducted an experiment to assess the ecological impact of 1080 leaching from baits on aquatic invertebrate communities. The experiment was conducted in four streams in the Mawhera Forest in the Grey Valley, West Coast. In each stream four sites were selected – 10 m and 100 m downstream, and 10 m and 100 m upstream from where 1080 baits were to be placed in the stream. At each site invertebrate communities on 10 replicate rocks were quantified 4 days and 1 day prior to baits being placed in the stream. The invertebrate communities were dominated by **Caddisflies** (*Helicopsyche*, *Pycnocentroides*, and *Pycnocentria*), **orthoclad midges**, and the **mayfly** *Deleatidium*. Baits (6.5 g 0.15% 1080 Wanganui #7 pellets) were then placed in the streams at a density equivalent to a sowing rate of 25 – 30 kg ha⁻¹ (this represented an extreme scenario of 10 x normal sowing rates). The invertebrate communities were re-sampled 1 day and 4 days after the bait was placed in the stream. No biologically significant effects on the invertebrate communities as a result of the 1080 were observed.

Aerial and hand laying operations using 0.08% and 0.15% carrot baits

Birds

Two **NI brown kiwi** followed in a 0.08% 1080 carrot operation did not die from poisoning (Table 21). Following a non-toxic bait trial on Kapiti Island in May 1993, when carrot containing the biomarker pyranine was aerially sown at 10 kg ha⁻¹, none of five **little spotted kiwi** droppings examined fluoresced (Lloyd and Hackwell, 1993). Other kiwi species have not been monitored during carrot operations.

Table 21. NI brown kiwi monitored during aerial 1080 operations using 0.08% carrot baits.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1995 Tongariro Forest	2	0		?	1

1 Robertson et al. (1999).

A total of 44 **NI kokako** has been exposed to 0.08% 1080 carrot baits over 2 operations and none have disappeared after poisoning (Table 22). Between 1986 and March 1998, 366 kokako (including 6 juveniles) have been monitored through 31 aerial poisoning operations (of all bait types and toxins combined), although the

number exposed and known to have survived is greater. Of the monitored birds, 4 have disappeared after poisoning, leading to a maximum estimate for kokako mortality of 1.4% per operation with a 5% chance that it will exceed 4% (Flux and Innes, 2001).

Table 22. Kokako monitored during aerial 1080 operations using 0.08% carrot baits.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1993 Pureora Nth Block	10	0	5	10	1
1996 Pureora Nth Block	34	0	7	15	2

^a monitoring method assumes birds which disappear have died from poisoning.

1 Speed et al. (1993); 2 Marsh (1996)

Twenty-eight **Weka** were monitored during an aerial 1080 carrot operation at Turiwhate in Central Westland in August 2008. Non-toxic pre-feed carrot (12 g) were sown at a rate of 3 kg ha⁻¹. Ten days later toxic carrot (1.5 g kg⁻¹ 1080) lured with orange was sown at 5 kg ha⁻¹. One bird died for 1080 poisoning (confirmed by residue testing). All the other birds survived for at least two months after the operation. The estimated mortality rate of weka during the operation was 0.2 - 17.8% (95% confidence intervals) (van Klink, 2008). 5 minute counts of weka in the Copland valley operation in 1986 (20 kg ha⁻¹ 0.2% screened carrot bait) found no detectable effect (Spurr, 1988). During a non-toxic carrot bait trial on Kapiti Island in May 1993, carrot containing the biomarker pyranine was aerally sown at 10 kg ha⁻¹. 10 of 87 weka droppings examined following the drop fluoresced from the pyranine. Weka were observed feeding on the baits on several occasions (Lloyd and Hackwell, 1993).

A total of 6 **morepork/ruru** has been exposed to this method and bait type over 1 operation and one has died from poisoning (Table 23).

Table 23. Morepork/ruru monitored during aerial 1080 operations using 0.08% carrot baits.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1996 Tahae (Pureora)	6	1 ^a	7	15	1

^a there is some evidence that the carrot was not screened adequately to meet bait specifications

1 Powlesland et al. (1998).

16 marked (15 radio-tagged and 1 banded) adult **NZ falcon** were monitored through two 0.08% 1080 carrot operations undertaken in Kaingaroa Forest during 2013-2014 by Horikoshi et al. (2018). One of the falcon was found dead following an operation but no 1080 residues were detected in its tissues. Using the live-recaptures model in Program MARK 8.1, the researchers estimated of the 95% C.I. survival of adult falcon through the operations at 68-100%.

Seaton et al. (2009) collected productivity data from 87 **NZ falcon** nests in Kaingaroa pine plantation over three breeding seasons, 2003-06. During this time 1080 carrots and pellets were aerially applied or ground laid in forest compartments where falcon bred. The numbers of chicks successfully fledged was not related to time since 1080 application (1 month to >3 years), application method or bait type. During the study the breeding falcon population increased from 20 to 36 pairs, leading to the authors concluding that 1080 did not have a negative impact on falcon, and probably had a positive impact by reducing predation pressure on the falcon.

Falcon territories remained occupied, presumably by the resident birds, during an aerial 1080 operation using carrot bait in Waihaha in 1994 (Spurr and Powlesland, 1997).

A 53 colour banded **robins** have been exposed to this method and bait type over 2 operations and 15 have disappeared after poisoning (Table 24).

Table 24. Robins monitored during aerial 1080 operations using 0.08% carrot baits.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1996 Tahae (Pureora)	22	12 ^b	7	15	1
1997 Waimanoa (Pureora)	31	3 ^c	5	10	2

^a monitoring method assumes birds which disappear have died from poisoning.

^b there is some evidence that the carrot was not screened adequately to meet bait specifications (Powlesland et al., 1999b).

^c 1 bird also disappeared from the non-treatment site during the study period

Not included is monitoring of robins using the 5 minute count method which can only reliably detect very large population changes (Powlesland et al., 1999b).

1 Powlesland et al. (1998); 2 Powlesland et al. (1999a).

A total of 19 colour banded **tomtit** has been exposed to this method and bait type over two operations and 16 have disappeared after poisoning (Table 25). During the 1997/98 nesting season, tomtit pairs in the 1997 treatment area had high nesting success (80% of nests fledged chicks, mean of four fledglings per nest). Even so, by the following spring it seemed that the population had not recovered to its pre-poison level. (Powlesland et al., 2000).

Table 25. Tomtit monitored during aerial 1080 operations using 0.08% carrot baits.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1996 Tahae (Pureora)	5 ^c	5 ^b	7	15	1
1997 Waimanoa (Pureora)	14	11	5	10	1

^a monitoring method assumes birds which disappear have died from poisoning; ^b there is some evidence that the carrot was not screened adequately to meet bait specifications (Powlesland et al., 1999b);

^c tomtit data in this study was opportunistically collected as part of a robin study. Only 2 of the birds were banded, no non-treatment area was used.

1 Powlesland et al. (2000)

A distance sampling study of an aerial operation in 2002 using carrot bait at 2 kg ha⁻¹ found the **tomtit** population increased by over 60% between pre-poison (winter 2002) and post poison (winter 2003) (Hamilton, 2004).

Westbrooke and Powlesland (2005) reported the results of distance sampling of **tomtits** carried out during three 2003 aerial carrot operations (Kokmoka Forest, Mohaka Forest and Waimanoa). In these operations prefeed carrots were sown at 3-5 kg ha⁻¹ followed by 0.8% 1080 carrots sown at 3-5 kg ha⁻¹. Tomtit numbers declined by between 15 -47% during each of these operations.

During August-September 2006 transect counts of male **North Island tomtits** were carried out during an aerial 1080 carrot operation in Aorangi Forest Park, to examine whether carrots with **EDR deer-repellent** applied to them posed a risk to tomtits. The operation was divided into two blocks: a 1200 ha block where the toxic carrot was applied without deer-repellent, and a 9,800 ha block where the toxic carrot contained deer-repellent. Following pre-operation monitoring of the tomtits, both blocks were prefed at a rate of 3 kg ha⁻¹. 13 days later the toxic bait (0.8% 1080) was applied at a rate of 5 kg ha⁻¹. Post control, there was no decline in the number of tomtits recorded in either block. It was concluded that the addition of the deer-repellent to carrot baits did not pose an increased risk to tomtits (Ross, 2007).

Whio are unlikely to eat carrot baits and their aquatic invertebrate prey is unlikely to be contaminated by 1080. All 19 radio tagged whio survived for at least four weeks following a pre-fed aerial application of carrot bait (0.08%) at 15 kg ha⁻¹ (Greene, 1998).

A total of 38 radio tagged **Kaka** has been exposed to this method and bait type over 2 operations and none have died from poisoning (Table 26).

Non-toxic carrot containing the biomarker pyranine was aurally sown at 10 kg ha⁻¹ on Kapiti Island in May 1993. Over the 11 days following the drop, 20 **kaka** were caught a total of 25 times and inspected for fluorescence due to the pyranine. Only

one juvenile kaka showed traces of pyranine. A large number of kaka droppings were also inspected, but no fluorescence was observed (Lloyd and Hackwell, 1993).

Table 26. Kaka monitored during aerial 1080 operations using 0.08% carrot baits.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha ⁻¹)		Ref.
			Prefeed	Toxic	
1994 Waihaha (Pureora)	21	0	10	15	1
2000 Whirinaki	17	0	5	10	2

Kaka monitored using 5 minute count method are not reported here because this technique cannot reliably detect population changes for kaka (Powlesland et al., 2003).

1 Greene (1998); 2 Powlesland et al. (2003).

Kakariki (parakeet) have not been monitored individually when exposed to this method and bait type. However no detectable impact could be determined through five minute bird count monitoring before and after four aerial 1080 operations using carrot and cereal pellet baits (Spurr and Powlesland, 1997). Additionally following an intensively monitored aerial 1080 operation in Waihaha in 1994 using carrot bait, Greene (1998) observed "...kakariki remained common within the study area...".

Kea have been monitored using 2 radio tagged individuals in one aerial operation using carrot bait (0.08%) at 5 kg ha⁻¹ in Hohonu Range. Both birds survived (Kemp and van Klink, 2008).

Kereru (NZ pigeon/kukupa) have been monitored using radio tagged individuals in one aerial operation using carrot bait (0.08%) at 10 kg ha⁻¹ in Whirinaki. All 15 birds survived (Powlesland et al., 2003). Monitoring of kereru during 9 aerial 1080 operations using screened carrot bait did not detect population changes using the five minute count method (Spurr and Powlesland, 1997).

During a non-toxic carrot bait trial on Kapiti Island in May 1993, carrot containing the biomarker pyranine was aerially sown at 10 kg ha⁻¹. Two kereru caught were examined for traces of pyranine, but none was observed. However, fluorescence due to pyranine was observed in one kereru dropping (Lloyd and Hackwell, 1993).

None of the three **tui** and two **bellbirds** examined fluoresced, after non-toxic carrot containing the biomarker pyranine was sown at 10 kg ha⁻¹ on Kapiti Island in May 1993 (Lloyd and Hackwell, 1993).

Call counts of **Australasian bittern/Makutu** were conducted pre- and post- aerial 1080 (3 kg ha⁻¹ pre-feed, 3 kg ha⁻¹ 0.8 g 1080/kg orange lured carrot) control of possums in the South Taupo wetlands in 2004. Of the 10 birds present in the treatment area pre-control, 90% were located post-control. In the non-treatment area, 5/9 birds were located post-control. The change in call counts in the non-treatment area were attributed to nightly variation in booming by the birds and not an actual decline in numbers. The researchers considered that the poison operation

had little to no impact on bittern in the wetland (Oates and Beath, 2005). As bitterns in the study were neither colour-banded nor fitted with transmitters their individual fates could not be reliably linked to the distribution of poisonous baits (Veltman et al., 2014).

Reptiles/amphibians

Lizards and frogs were not monitored in any 1080 poisoning operations prior to 1994; however, none have been reported killed by 1080. There has been limited population monitoring of aerial poisoning operations using cereal pellets but none using carrot baits.

The attractiveness of non-toxic carrot baits (dyed green and lured with cinnamon) to wild **grand** and **Otago skinks** were tested by Marshall and Jewell (2007). The baits were offered in two sizes – small pieces no larger than 6mm and large baits (whole rounds of sliced carrot). Both bait sizes were sampled (licked, nudged or bitten) by both species of skink, with small pieces sampled more often than large baits. While the carrot baits were sampled, none were consumed.

Bats

Short-tailed bat have not been individually monitored when exposed to this method and bait type. Lloyd (1994) offered non-toxic carrot baits to captive bats and hand broadcast baits containing a fluorescent marker throughout an area known to be inhabited by bats and concluded “...short-tailed bats are unlikely to eat carrot or grain-based baits...”. However short-tailed bats are possibly vulnerable to secondary poisoning because they are known to feed on arthropods that have been recorded feeding on 1080 baits and residues in these prey can, in theory, be enough to kill a bat (Lloyd and McQueen, 2002).

In a study in Rangataua forest where 0.15% 1080 Pellets were aerially broadcast (3 – 5 kg ha⁻¹) over “...almost the entire winter range...” of the study animals, a total of 269 short-tailed bats were caught at their roost following poisoning and held for 48 hours to determine mortality or signs of poisoning. All animals survived and showed no signs of 1080 poisoning (Lloyd and McQueen, 2000).

Invertebrates

Invertebrate populations have been monitored in two 1080 aerial poisoning operations using carrot baits. None of these studies suggest significant population effects on any species studied nor is there evidence to suggest poisoned invertebrates are a significant factor in secondary poisoning of other animals.

No impacts on the numbers of **ground-dwelling invertebrates** caught in pitfall traps up to 1 year following aerial application of carrot bait at 15 kg ha⁻¹ at Waihaha Forest in 1994 (Spurr, 2000a).

Powlesland et al. (2005) monitored invertebrate numbers every second or third month for a year before a 5 kg ha⁻¹ 1080 carrot operation, and for two years afterwards. Numbers of **tree weta**, **cave weta**, **cockroaches**, **spiders** and **harvestmen**, and **leaf-veined slugs** did not decline substantially in refuges in the treatment area relative to those in the non-treatment area immediately after the poison operation. From the results, the authors concluded that aerial 1080 carrot

operations are unlikely to have a detrimental effect on invertebrates that occupy cavities above ground.

An extensive study of **forest invertebrates** found on 1080 baits by Sherley et al. (1999) found that at any time only a small proportion of baits had invertebrates on them, and the few individuals per bait represented a small section of the fauna present in the litter. Each month between June to October 1995 and from April to October 1996, non-toxic carrot baits were sown at 18 kg ha⁻¹ and observed for 7-10 days. Fewer invertebrates were found on non-toxic (green dyed, cinnamon lured) carrot baits than non-toxic cereal pellets. The number of invertebrates visiting the carrot baits increased as time progressed, from a low of 7% usage on day one to 17% on day three. There was no evidence that invertebrates found on baits were drawn from further than 20cm around a bait.

1080 pellets or carrot baits in bait stations

Birds

11 **NI brown kiwi** were monitored during a 1080 cereal bait station operation in September 2009 in Northland with no deaths being reported (P Graham pers. comm.).

Captive birds were offered bait on plastic dishes and wild birds were observed interacting with bait placed in bowls on tree mounted platforms and on the ground. None of three **kaka**, 4 **kereru** and 5 **kakariki** in captivity ate any bait. Two **brown kiwi** and 3 **weka** in captivity ate tiny amounts. A total of 87g of bait was eaten by 6 kea over the 2 days of the captive trial. **Bellbird**, **fantail**, **kereru**, **silveryeye** and **tui** observed within 3m of the bait in the field study showed no interest while South Island **robin** investigated the bait briefly. Three **weka** were observed feeding on the bait placed on the ground during the field trial for a total of 16.9 minutes (Morgan, 1999).

Reptiles

Of the 10 **Common skinks** offered non-toxic bait in captivity, 2 investigated the bait but none was eaten (Morgan, 1999).

Bats

Of the 6 **short-tailed bats** offered non-toxic bait in captivity, none fed on it (Morgan, 1999).

Invertebrates

Of the 8 **Wellington tree weta** offered non-toxic bait in captivity, one fed on it briefly. Of the 8 **large land snails** (*Powelliphanta hochstetteri hochstetteri*) offered non-toxic bait in captivity, 3 fed on it. Of the 6 **ground beetles** (*Megadromus bullatus*) offered non-toxic bait in captivity, none fed on it (Morgan, 1999).

Pestoff Professional Possum Paste (0.08% and 0.15%)

Birds

In pen trials at Orana park, Christchurch, **kaka**, **brown kiwi**, **weka**, **kea**, **kereru** and **kakariki** were offered BB13 and BB16 paste for two days. Kaka, brown kiwi, weka and kea all ate appreciable quantities (greater than 5.1 g of at least one of the paste types) (Morgan, 1999).

All 14 monitored **NI brown kiwi** survived exposure to 0.08% paste baits laid in Northland forest in 1995 (Robertson et al., 1999).

Bats

Captive **short-tailed bats** fed on non-toxic paste bait on all three nights that this food was presented. On average 5.73 g of paste was eaten (Morgan, 1999).

Reptiles

Two out of 8 **common skinks** fed on non-toxic paste over two nights during laboratory trials. The total time spent feeding on the paste was 2.8 minutes (Morgan, 1999).

Invertebrates

One out of 8 **giant land snails** (*Powelliphanta hochstetteri hochstetteri*) spent a total of 21.5 minutes feeding on non-toxic paste over two nights during laboratory trials. Two out of 10 **Wellington tree weta** fed on non-toxic paste for a total of 5.9 minutes (Morgan, 1999).

Bark beetles were observed feeding on 1080 paste in bait bags during a possum control operation at Mount Stanley, Nelson Marlborough Conservancy in April 2002. None were found dead (B. Mehrtens pers. comm.)

10% 1080 Gel

No information could be found

Cut apple bait

No information could be found on population effects. However some testing of non-toxic bait has been done with native species (Thomas et al., 2003). Note that this study presented bait in open dishes rather than bait stations and the behaviour of captive animals is not always typical of those in the wild.

Birds

Of 8 **kereru** offered non-toxic cut apple bait (green dyed, orange lured), none fed on it. The one **kaka** tested spent over 11 minutes per day on average feeding on the bait. **Kakariki**, **silveryeye** and **weka** spent a similar time feeding on the bait. Four **kea** spent over an hour feeding on the bait. The authors concluded that this bait presented a risk to native birds and should only be used in bait stations (Thomas et al., 2003).

3.2.4. What evidence is there to suggest that 1080 use causes or doesn't cause a population decline of native species in aquatic ecosystems?

The effects of 1080 in aquatic ecosystems have not been well studied in New Zealand because the concentrations of 1080 observed in waterways have been negligible (see Section 2.3). Studies of 1080 toxicity to fish (non-native species see Section 4), suggest fish can tolerate concentrations many thousands of times higher than the highest ever recorded in water sampling after aerial poisoning operations.

Lyver et al. (2005) reported that there was no evidence captive **longfinned eels** would eat 1080 cereal pellets added to their water, nor was there any 1080 detected in eel tissue from water contaminated by baits. In the same study, eels did eat 1080 contaminated possum tissue but none died.

During trials by Suren and Bonnett (2006), 1080 was not detected in any **koura** exposed to water containing 1080. While koura did eat Wanganui #7 baits, none died.

4. Effects on Domestic and Feral Animals

There is wide variation between species in their susceptibility to 1080 poisoning. Dogs are especially vulnerable and highly likely to die if they eat 1080 baits or scavenge animals killed by 1080. Larger animals such as cattle need several possum baits to receive a lethal dose but deaths have been reported where animals have access to baits, including those contained in bait stations.

Sub-lethal effects at realistic dose rates have been recorded in sheep and other species, typically affecting the heart. Exposure to prolonged high doses resulted in mild foetal abnormalities in pregnant rats and damaged sperm in male rats but no mutagenic properties were found. No antidote is currently available for 1080 poisoning although veterinary treatment can be successful.

Feral deer population mortality from aerial poisoning operations targeting possums and rats has been highly variable. Across a number of 1080 cereal pellet operations deer mortality estimates were more often classed as low (0-33%) when sowing rates were at or below 1.5kg/ha and potentially at those sites that had been previously treated within 5 years. Field trials have indicated that deer-repellent baits can reduce the level of deer mortality relative to when non-repellent baits are used.

Birds are generally less susceptible to 1080 than mammals but introduced birds such as blackbirds and chaffinches are found dead after aerial poisoning operations. Lizards and fish appear quite tolerant of 1080, according to research on overseas species.

Although 1080 is toxic to honeybees, baits used in pest control are generally not attractive to honeybees. However this may not be the case if honeybees are particularly hungry and food resources are scarce. On occasion and under these conditions honeybees have been observed collecting and storing cereal pellet bait material in hive frames as a substitute for pollen. Tests of honey from affected hives found no trace of 1080. Paste baits containing 1080 were reformulated in the 1990s to reduce their attractiveness to bees.

4.1. Toxicity

4.1.1. What is the lethal dose range for each taxon?

The LD₅₀ values for a range of domestic and feral animals are presented in Table 27. For completeness, it includes information on species not present in New Zealand.

While no LD₅₀ data is available, mortality rates of pregnant ewes exposed to 1080 are higher compared to non-pregnant ewes (O'Connor et al., 1999)

Table 27. Acute oral toxicity (LD₅₀ mg kg⁻¹) of 1080 for non target domestic and feral animals.

Species	LD ₅₀ (mg kg ⁻¹)	Ref.
Birds	Range: 2.1 - 12.6	
Mallard duck	4.8	1
Maned duck	12.6	2
Common pigeon	4.25	3
Leghorn hens	10.0	4
White leghorn chicken ^a	7.5	5
Rhode Island red chicken	6.5	6
Plymouth rock chicken	5.5	7
Eurasian magpie	2.12	8
Chukar partridge	3.51	3
Ring-necked pheasant	6.46	3
California quail	4.6	9
European goldfinch	3.5 (approx.)	2
Australian magpie	9.9	2
House sparrow	2.5	10
Marsupials	Range: 0.210 - 0.79	
Bennett's wallaby	0.21	11
Brush-tailed possum	0.79	12
Dama wallaby	0.27	11
Mammals	Range: 0.06 - 8.3	
Dog	0.06	7
	0.07 (LD ₁₀₀ : 0.1)	14
Cat	0.28	14

Ferret	1.41	3
Rabbit	0.35	15
House mouse	8.3	16
Norway rat	0.22-3.0	7
Cattle	0.393	17
Deer (not specified)	0.5	14
Horse	0.32-1.00	18
Pig	0.4	18
Sheep	0.25-0.64	18
Goat	0.3-0.7	18
Reptiles/Amphibians	Range: 43.6 - >500	
Spotted grass frog	c. 60	19
American Bullfrog	54.4	3
Leopard frog	150	7
South African clawed frog	>500	20
Blotched blue-tongued lizard	336.4	19
Shingle-back lizard	205.9 ^b	19
Gould's monitor	43.6	19
Fish	Range: 54 - 3500 mg l ⁻¹	
Bream & bass	> 370 ^c	21
Rainbow trout	54	22
Fingerling trout	>1000 ^d	14
Harlequin fish	3500 ^e	23
Bluegill sunfish	>970 ^f	22
Aquatic arthropods	Range: 0.05 - 3500 mg l ⁻¹	
<i>Daphnia magna</i>	350 ^g	22

Mosquito larvae (<i>Anopheles quadrimaculatus</i>)	0.05-0.1 (approx.)	24
Terrestrial arthropods	Range: 8 - 21	
Honeybee	8	25
Housefly	21	26

^a laying hens appeared to be more susceptible to 1080 poisoning than hens that were not laying; ^b non-tolerant populations from South Australia, Western Australian populations LD₅₀ reported as 524 mg kg⁻¹; ^c survived indefinitely at this concentration; ^d survived this concentration; ^e substance tested was Fluoroacetamide (a compound related to 1080); ^f no effects observed at this level; ^g 48-hour EC₅₀

1 Hudson et al. (1972); 2 McIlroy (1984); 3 Tucker and Crabtree (1970); 4 Kalmbach (1945); 5 Cottral et al. (1947); 6 Ward and Spencer (1947); 7 Chenoweth (1949); 8 Burns and Connolly (1992); 9 Hudson et al. (1984); 10 Peacock (1964); 11 Munday (1978); 12 Bell (1972); 13 Rammell and Fleming (1978); 14 Eason and Frampton (1991); 15 McIlroy (1982a); 16 McIlroy (1982b); 17 Robison (1970); 18 Atzert (1971); 19 McIlroy et al. (1985); 20 Quin and Clark (1947); 21 King and Penfound (1946); 22 Fagerstone et al. (1994); 23 Bauermeister et al. (1977); 24 Deonier et al. (1946); 25 Booth and Wickstrom (1999); 26 Matsumura and O'Brien (1963).

4.1.2. How much bait needs to be ingested for poisoning, based on pen-trials with non-target feral and domestic species?

The amount of bait needed to be ingested by non-target domestic animals for poisoning is presented in Table 28 and for feral animals in Table 29.

Fish

No information relating to bait intake (oral LD₅₀ values) could be found. Force-feeding cereal pellets containing approximately 4 mg of 1080 to two fingerling trout and five adult **trout**, and about 8 mg of 1080 to two adult trout had no visible effect (Rammell and Fleming, 1978).

All toxicity values for fish reflect concentration of 1080 in water (LC₅₀ values) which is more relevant when assessing likely risks to fish from possum baits. To achieve the 96-hour LC₅₀ of 54 mg l⁻¹ for rainbow trout, all the 1080 in 3.6kgs of 1.5 g 1080 kg⁻¹ bait would have to leach out of the bait, and then remain in 100 litres of still water, without breaking down, for 96-hours. This is highly unlikely to occur in under pest control conditions in New Zealand.

Table 28. Amount of bait needed to be ingested to result in death based on LD₅₀ for non target domestic animals.

Species	LD ₅₀ (mg kg ⁻¹)	Av. Weight Female (g)	Amount of 0.4g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 0.8g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 1.0g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 1.5g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 2.0g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 50g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 100g kg ⁻¹ Bait (g) for LD ₅₀
Birds									
Chicken	7.5	900	16.88	8.44	6.75	4.50	3.38	0.13	0.08
Mammals									
Cat	0.28	2500	1.75	0.88	0.70	0.47	0.35	0.01	0.001
Cattle	0.393	170000	167.03	83.51	66.81	44.54	33.41	1.34	0.67
Red Deer	0.5	80000	100.00	50.00	40.00	26.67	20.00	0.80	0.40
Dog	0.06	8000	1.20	0.60	0.48	0.32	0.24	0.01	0.005
Goat	0.3	35000	26.25	13.13	10.5	7.00	5.25	0.21	0.11
Horse	0.32	190000	152.00	76.00	60.80	40.53	30.40	1.22	0.61
Pig	0.4	120000	120.00	60.00	48.00	32.00	24.00	0.92	0.48
Sheep	0.25	50000	31.25	15.63	12.50	8.33	6.25	0.25	0.13
Invertebrates									
Honeybee	8	0.1	0.002	0.001	0.0008	0.0005	0.0004	0.00002	0.000008

The LD₅₀ values given in section 4.1.1 have been used in the calculations and the average weights of females have been used, as females are generally smaller and therefore a 'worst case scenario' for poisoning. Where LD values were cited as greater (>) or less (<) than a value, this value was used to make the calculations.

Table 29. Amount of bait needed to be ingested to result in death based on LD₅₀ for non target feral animals.

Species	LD ₅₀ (mg kg ⁻¹)	Av. Weight Female (g)	Amount of 0.4g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 0.8g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 1.0g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 1.5g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 2.0g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 50g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 100g kg ⁻¹ Bait (g) for LD ₅₀
Birds									
Mallard duck	4.8	1100	13.20	6.60	5.28	3.52	2.64	0.11	0.05
Goldfinch	3.5	15	0.13	0.07	0.05	0.04	0.03	0.001	0.0005
Australian magpie	9.9	350	8.66	4.33	3.47	2.31	1.73	0.07	0.03
Chukar partridge	3.51	500	4.39	2.19	1.76	1.17	0.88	0.04	0.02
Common pigeon	4.25	400	4.25	2.13	1.70	1.13	0.85	0.03	0.02
Pheasant	6.46	1200	19.38	9.69	7.75	5.17	3.88	0.16	0.08
California quail	4.6	180	2.07	1.04	0.83	0.55	0.41	0.02	0.01
House sparrow	2.5	30	0.19	0.09	0.08	0.05	0.04	0.002	0.0008
Mammals									
Red Deer	0.5	80000	100.00	50.00	40.00	26.67	20.00	0.80	0.40
Goat	0.3	35,000	26.25	13.13	10.50	7.00	5.25	0.21	0.11
Pig	0.4	120,000	120.00	60.00	48.00	32.00	24.00	0.92	0.48
Rabbit	0.35	800	0.70	0.35	0.28	0.19	0.14	0.01	0.003

The LD₅₀ values given in section 4.1.1 have been used in the calculations and the average weights of females have been used, as females are generally smaller and therefore a 'worst case scenario' for poisoning. Where LD values were cited as greater (>) or less (<) than a value, this value was used to make the calculations.

4.1.3. Based on the mode of action, are there any taxa that are unlikely to be affected by 1080?

No, all species appear to be susceptible to the mode of action of 1080. However, there is a wide variance in dose rates required to produce observable effects. This means the degree of exposure is important in assessing risk.

4.1.4. Have sub-lethal effects on birds, mammals, marsupials, reptiles/amphibians, fish, arthropods, or molluscs been described for 1080?

Domestic animals

Even small doses of monofluoroacetate result in myocardial damage in **sheep**, and this damage is cumulative with subsequent exposure (Annison et al., 1960). In sheep that received multiple sub-lethal doses of 1080, myocardial degeneration has been reported as well as necrosis of individual or small groups of myocardial fibres (Schultz et al., 1982). Researchers in Australia noted macroscopic lesions in the heart of sheep, described as acute multifocal injury to the myocardium, after doses as low as $0.11 \text{ mg kg}^{-1} \text{ day}^{-1}$ for 3–7 days. A dose of 0.1 mg kg^{-1} is approximately equivalent to a 30-kg sheep eating one 4 g 0.08% 1080 possum bait. Mild cardiac histopathology at doses of $0.055 \text{ mg kg}^{-1} \text{ day}^{-1}$ has been reported, but the duration of treatment was not specified (Whittem and Murray, 1963).

O'Connor et al. (1999) orally administered groups of pregnant **ewes** with either single (0.25 mg kg^{-1}), or multiple (0.05 mg kg^{-1} over 3 consecutive days) doses of 1080 approximately two weeks prior to lambing as part of a trial on the toxicity of 1080 to pregnant ewes. The surviving ewes and their lambs were followed through to weaning. There were no differences in the ewe health, lambing percentages, lamb survival, or lamb growth rates between either of the 1080-dosed groups and a control ($0 \text{ mg 1080 kg}^{-1}$) group.

In a study of the long-term effects of 1080 in **sheep**, 21 ewes that survived acute 1080 poison and a control group of 23 animals were monitored for two years (Gooneratne et al., 2008). No adverse effects on general health or condition were observed in any of the animals. There was no increase in the incidence of infectious or metabolic diseases in the 1080-exposed animals compared to the control group. The ewes were mated in both years. There was no difference in lambing percentage, lamb survival or mean lamb birth mass between the groups in either year. At the end of the study 10 ewes from each group were euthanised and necropsied. Tissue samples of the heart, brain, kidney, liver, lung, skeletal muscle rumen, abomasums, duodenum and ovaries were collected for histopathology. There were no grossly visible pathological lesions in the 1080-exposed ewes. Histopathological lesions were restricted to the heart and brain. There were scattered foci of fibrous tissue in the muscle of the heart. One animal had small, focal lesions in several regions of the brain, indicating chronic neuronal degeneration. The significance of the heart and brain lesions is uncertain in light of the lack of apparent adverse effects on general health and reproductive performance.

Glial cells in the brain are particularly sensitive to fluorocitrate (Erliechman et al., 1998; Hulsman et al., 2000).

Feral animals

The results from three different, complementary tests (using laboratory rats and mice) indicate that 1080 is not mutagenic, and therefore unlikely to cause cancer. A developmental toxicity study in rats indicated that 1080 causes developmental defects in rats when pregnant females are exposed to relatively high doses (0.33 and 0.75 mg kg⁻¹) on a daily basis during the period of organogenesis (from days 6 through to 17 of gestation). The developmental abnormalities observed were mild skeletal effects: slightly curved forelimbs, and bent or 'wavy' ribs (Eason et al., 1999).

Spielmann et al. (1973) reported that 1080 at a dose just below the maternal LD₅₀ was not teratogenic to **rats**. The embryos in this study showed no macroscopic or skeletal abnormalities. This work involved only a single dose and the results contrast with the investigation by Eason et al. (1999) which followed current international guidelines that require dosing rats from day 6–17 of gestation at three dose levels. Eason et al. (1999) found the NOEL derived from their multi-dose study (0.1 mg kg⁻¹ day⁻¹) was 10-fold less than the single dose NOEL (1 mg kg⁻¹) reported by Spielmann et al. (1973).

Reduced testes weight, atrophy of seminiferous tubules and damaged spermatids has been reported in **rats** (Shinoda et al., 2000; Smith et al., 1977; Sullivan et al., 1979). Wolfe (1998) reported an increased heart weight in rats of both sexes, and decreased weight of testes/epididymides and abnormal sperm formation in male rats.

In the most recent exposure study in rats (Eason and Turck, 2002), the NOEL for rats administered 1080 via oral gavage for 90 days was 0.075 mg kg⁻¹ day⁻¹. This study confirmed that the epididymides, testes and heart are the target organs for 1080 sub-lethal effects, with severe hypospermia, severe degeneration of the seminiferous tubules and cardiomyopathy seen at doses of 0.25 mg kg⁻¹ day⁻¹.

Decreased body weight and food consumption in **mink** and **ferrets**, and impaired reproduction in mink has been reported following sub-lethal 1080 poisoning (Hornshaw et al., 1986).

In pen trials 1080 caused damage to the wing muscle in **mallard ducks** (Ataria et al., 2000) and reduced testes weight in **starlings** (Balcomb et al., 1983).

An Australian study of the sub-lethal effects of 1080 on the **shingleback lizard**, a decrease in plasma testosterone concentration in the study animals was reported and there was a suggestion of degeneration of seminiferous tubules in some individuals (Twigg et al., 1988).

Smith and Grosch (1976) studied the effects of 1080 on *Bracon hebetor*, a **parasitoid wasp** found in North America. They found egg production was disrupted after a sub-lethal dose. Inhibition of reproduction in a **nematode** species (Middendorf and Dusenbery, 1993) Metabolism and movement inhibited in *Haemonchus* **worms** (Ward and Huskisson, 1978).

Note: The information in this section includes studies with species not extant in New Zealand

4.2. Exposure

4.2.1. What species (individual animals) have been reported as non-target deaths in field operations with 1080?

Aerial and hand laid operations

Pets

Based on the EPA NZ annual 1080 reports, between 2007 and 2016, 34 **dogs** and 1 **cat** were reported to have died during aerial 1080 operations (Table 30).

This compares to 72 **dogs** and 1 **cat** confirmed as being killed during 1080 operations in the 7 years between 1986 and 1992 (Orr and Bentley, 1994), and the 254 **dogs** and 9 **cats** confirmed as being poisoned by 1080 in the 17 years between 1960 and 1976 (Rammell and Fleming, 1978).

Livestock

Based on the EPA NZ annual 1080 reports, between 2007 and 2016, 10+ **cattle**, 7+ **sheep**, 4 **horses**, 4 **pigs** and 1+ **farmed deer** were reported to have died during aerial 1080 operations (Table 29).

In the 7 years between 1986 and 1992 the following livestock were confirmed as being poisoned by 1080: 24 **cattle**, 37 **sheep**, 10 **deer**, 4 **pigs** and 1 **goat** (Orr and Bentley, 1994).

Rammell and Fleming (1978) reported 125 **cattle**, 2101 **sheep**, and 25 **fowl** were confirmed to have died during 1080 operations between 1960 and 1976.

Table 30. Pet and livestock deaths reported during aerial 1080 operations between 2007 and 2016 (Based on EPA NZ annual reports).

Species	Total Found Dead	No. of Operations
<i>Domestic animals</i>		
Dog	34	21
Cat	1	1
<i>Livestock</i>		
Cattle	10+	5
Sheep	7+	5
Horse	4	1
Pig	4	2
Farmed deer	1+	1

Honeybees from hives near the loading zone of an operation in Golden Bay in August 2002 were observed gathering the green dust from toxic RS5 cereal baits. This loading zone had been used on previous occasions for aerial 1080 operations using the same bait type and no similar observations were made (Pestlink 0203GDB13).

Honeybees were observed collecting bait material (0.15% 1080 RS5 cereal pellets) at a bait loading zone near Arthurs Pass in February 2022. The bees accessed the bait over a period of about 1 ½ hrs. Soon after the incident the beekeeper found dead bees outside the entrances of three hives. He estimated about 200 bees outside one hive and 20-30 outside the other two. Green material was observed in pollen cells in the brood frames in two of these hives in one further hive (Pattemore and Fale 2022).

A sample of green material from the corbicula ('pollen sac') of a bee captured at the loading site contained 1050.85 mg kg⁻¹ 1080 (Table 32), indicating it was predominantly the 1080 bait material. Two samples of the dead bees from the hives tested positive for 1080 (0.059 and 1.43 mg kg⁻¹). Two samples of the green material from hive brood frames tested positive for 1080 (76.7 and 195 mg kg⁻¹).

Based on the observations and information from the incident it was considered most likely the bees were foraging on the bait as a substitute for pollen, to use as a protein source. Bee ecologists consider this was due to the scarce floral resources in the area during the period leading up to the operation meaning the bees were highly motivated to find new sources of food. They concluded it highly unlikely that the bees were collecting bait material as a nectar substitute for honey making because pollen foraging bees (as the observations consisted of) do not bring nectar back to the colony or interact directly with honey cells, the bait material was dry, and conditions at the time suggest bees were pressured to seek alternative pollen sources rather than nectar sources.

To confirm this conclusion tests of honey from 27 samples extracted from 73 hives in the apriary found no traces of 1080 (MDL 0.002 mg kg⁻¹). This included a sample from the honey extracted from one of the affected hives (where 1080 was detected in material from brood frame cells) three days after the incident (Pattemore and Fale 2022).

AHB (2012) conducted trials to investigate the attractiveness of RS5 and Wanganui #7 pellets to honeybees. The bees were trained to visit wet and dry cereal baits coated with a sugar-syrup attractant. The attractiveness of the baits was determined by switching the sugar-coated bait with standard non-toxic baits. Within 10 minutes, the bees lost interest in the standard baits. When EDR coated pellets were used, bees continued to visit the baits for approximately 30 minutes after the sugar-coated baits had been switched with the EDR coated pellets. When 1080 cereal pellets were placed within 80 metres of hives, no bees were observed visiting or landing on the baits.

To test the risk of dust to honey bees, six hives were put out during an actual 1080 operation at Buller South. 1080 was not detected in honeybees, wax, nectar or pollen samples collected within 24 hours of the operation or when the monitoring

was repeated after 15 – 16 days. Additionally, there was no evidence of 1080 dust on flowers on which honeybees were observed foraging (AHB, 2012).

Feral animals

A review of **deer** (various species) mortality observed in 26 aerial 1080 operations which used **cereal pellets** without deer repellent between 1999 and 2019 found a wide range of mortality estimates. Operations were classified as having low (0 to 33% mortality), moderate (34 to 66%) or high (67 to 100%) impacts on deer populations with 42%, 38% and 20% in each respective class. Sowing rates at or below 1.5kg/ha more often resulted in low deer by-kill. Bait size (6 or 12 gram) did not explain variation. Deer mortality was suggested to be lower for operations at sites that had been treated within the previous five years (Morris et al., 2020).

A **red deer** kill of 43% was reported following application of **cereal pellets** at 10 kg ha⁻¹, July 1988 at North Pureora. Simultaneous carcass searches over the poisoned area confirmed the pellet-count result (Nugent et al., 2001). A red deer kill of 54% was reported following application at 3 kg ha⁻¹ June 1999 in the Orongorongo Valley (Nugent et al., 2001). A red deer kill of 5% was reported following application at 3 kg ha⁻¹ overall but sown in strips of 25 kg ha⁻¹, with pre-feeding June 1999 at Wainuiomata Valley (Nugent et al., 2001).

Fallow deer were monitored during an aerial 1080 operation in the Blue Mountains using **0.15% 1080 pellets** at 2 kg ha⁻¹ 12 days after prefeeding with non-toxic bait. All three radio tagged deer were killed and estimates using a range of data available (carcass searches, deer sightings and hunter kill records) led the authors to conclude a best guess kill of 67-75% (Nugent and Yockney, 2001).

By-kill of **white-tailed deer** was estimated for an August 2014 aerial 1080 operation covering 15,215ha of the Dart and Routeburn catchments using 1kg/ha 6 gram RS5 **0.15% cereal pellets** pre-fed 4 days earlier. Four 100 ha areas within the treatment block were searched over four days with a total of 190km of search effort. The search success rate was estimated at 78% using simulated carcasses (paper sacks) placed in the search areas beforehand and used to adjust the number of deer found dead. Overall the estimated mortality was 0.96 deer/km² but this method did not allow a population estimate to be determined (Pinney et al 2021).

A study of **red deer** mortality during **1080 carrot** operations (0.15%) in Pureora in 1994 resulted in kills of 30% and 31% following application at 15 kg ha⁻¹, with non-toxic pre-feeding, and 42% where no prefeed was used (Fraser et al., 1995). Deer faecal pellet densities in this study area declined by about 40% 15 months after poisoning but returned to pre-control levels a year later, and then apparently doubled over the ensuing two years (Coleman et al., 2000).

A **red deer** kill of 57% was reported following application of 0.09% **carrot baits**, with pre-feeding at 15 kg ha⁻¹, May 1996 at North Pureora (Sweetapple and Fraser, 1997). A red deer kill of 93% was reported following application in August 1997 of 0.08% **carrot bait** and at 15 kg ha⁻¹, with pre-feeding at Titiraupenga. In the same study using 0.15% bait at 15 kg ha⁻¹ (prefed) the reported kill was 92% (Fraser and Sweetapple, 2000).

During the 2017 TBfree aerial 1080 operation at Paemahi (Kaimanawa Forest Park), the impact of **EDR** deer repellent coated cereal pellets on **sika deer** was studied. The study involved pre- and post monitoring using camera traps in four 600 ha blocks, two within and two outside the operational area. 730 deer were sighted during the pre-monitoring and the deer density was estimated at 20 deer km⁻¹. There was a decline in deer sighted post control, however, the decline was highest in the two blocks outside the operational area. The reduction in deer sightings was attributed to a decline in deer activity in winter rather than as a result of the 1080 operation. 11 deer were found dead by searchers, giving a by-kill of 1.6 deer km⁻¹. This is equivalent to <10% of the deer population that was present (TBfree, 2017).

A trial comparing mortality rates of red deer between Pestex® DR (deer-repellent) and Pestex® (non deer-repellent) 1080 cereal pellet baits was conducted during possum control operations in the Clarence and Awatere valleys in winter 2019. Each block was treated with 1kg/ha of non-toxic bait (16mm, cinnamon lured) followed 17-20 days later by 2kg/ha toxic bait (16mm, cinnamon lured, 0.15% 1080) with one block of 13,280 hectares having the deer repellent Pestex® DR bait and the other block of 9,447 hectares the non deer repellent Pestex® bait for both prefeed and toxic phases. All of 11 radio collared deer that were present in the non deer repellent Pestex® treatment block at the time of 1080 bait application died (estimated kill rate 100%, 95% CI 74.1-100%). Nineteen of 30 radio collared deer that were present in the deer repellent Pestex® DR block died (63.3% kill; 95% CI = 43.9-79.5%). The estimated reduction in deer by-kill with Pestex® DR compared to standard Pestex® 1080 bait was 36% (95% CI = 13-60%) (Morriss et al 2019). The average weight of the deer killed in the deer repellent block was significantly lower than in the non repellent block reflecting that the population of deer there were more nutritionally limited, smaller, and potentially more vulnerable to poisoning through aerial 1080 operations than those in the standard bait block.

In the trial reported by Morriss et al (2019) there were incidental observations of dead **goats** (n=3) and **chamois** (n=1) in the block sown with Pestex (non-repellent) bait. The chamois and one goat were tested and found to contain 1080 residues in muscle tissue sampled. In the block sown with Pestex DR (repellent) bait three live chamois were seen and no dead chamois or goats were reported.

The effect of Prodeer Possum & Rat bait (deer-repellent 1080 cereal pellet manufactured by Orillion) on incidental red deer mortality was studied during a 54,188 hectare possum control operation at Molesworth and Muller stations in May and June 2021. Prefeed bait (Prodeer, cinnamon-lured, 6g pellets) was applied at 1.0kg/ha and toxic bait (Prodeer, cinnamon-lured, 0.15% 1080, 6g pellets) at 2kg/ha 19-21 days later. Of 39 radio-collared deer that were alive and present in the treatment area just before 1080 baiting, two died, indicating a deer kill of 5.1% (95% CI 0.9-18.7%) (Morriss et al 2021).

The impact of Prodeer 1080 bait on red deer and feral pigs was studied during a 5,395 hectare possum control operation at Willowflat Forest, Hawke's Bay, in October 2021. Prefeed (Prodeer non-toxic 6g pellets) was applied at 1.5kg/ha followed 13 days later by toxic bait (Prodeer, 0.15% 1080, 12g pellets) at 2kg/ha. Trail cameras were used to monitor deer and pig activity over 4 months before and 2 months after the poison operation at the poison treatment site and a nearby

unpoisoned block at Maungataniwha Forest. Deer visit rates per camera day increased by a similar amount in both the poisoned and unpoisoned blocks throughout the study period, probably in response to seasonal changes such as increased grass growth. There was no effect of poisoning on deer count per camera after accounting for the time+site effects, with an estimated increase in activity of 2% (95% CI = -5.5-10%) in the poisoned area. A few live deer were seen during deployment servicing and removal of cameras but no dead deer. A small number (1%) of deer observations on camera were of fallow deer. For pigs in the poisoned area there was a estimated decrease of 47% (95% CI=39-54%) in pig count per camera after accounting for time+site effects, however camera visitation rate of feral pigs progressively declined through the monitoring period (including over each 7 day period in the 4 months before the control) and it was not clear if the poison operation caused any bykill of pigs. No pig carcasses were observed incidentally during fieldwork in the poisoned area (Morriss and Gormley 2022).

The survival of tahr was assessed during two aerial applications of 1080 cereal pellets within a 8,659 ha treatment area in the Perth River valley in late autumn and winter of 2020. A first phase of bait applications took place in March-April with two applications of prefeed (each with 6g baits at 2kg/ha) applied 15 days apart before toxic bait (6g baits, 0.15% 1080 at 4kg/ha) was applied 10 and 11 days later. All baits in the initial phase were green-dyed Wanganui #7 with 0.3% orange lure. The second phase of applications took place in June with prefeed (6g baits at 1kg/ha) being applied 7 days apart before toxic bait (6g baits at 2kg/ha) was applied 27 and 28 days later. All baits in the second phase were green-dyed RS5 with 0.3% cinnamon lure. Tahr fitted with radio collars, a mix of female adults and juveniles of both sexes, were monitored before and after the bait applications. Based on locations of animals during searches, 11-15 were exposed to the first baiting phase and 8-14 were also exposed to the second baiting phase. All of these animals survived the poison baiting operations (Kerr 2020). In a trial of aerially applied 1080 carrot bait for tahr control, estimated tahr kill rates were 11%, 30% and 51% in blocks that received no prefeed, 1 prefeed, and 2 prefeed applications respectively (Douglas 1967). The baits used (chopped carrot pieces up to 200g, 0.14-0.36% 1080, green dyed) did not meet current standards for registered 1080 products.

Game birds

During an aerial 1080 operation in Rotoehu Forest in October 2004 (type of bait not stated), Fish and Game staff monitored **pheasant** crowing rates using five-minute counts in treated and untreated blocks. There was a healthy population throughout the forest and there was no discernible difference in the crowing rates between the blocks following the 1080 operation (McDougall, 2005).

Evans and Soulsby (1993) reported 27 **California Quail** died during three 1080 **carrot** (0.2 g 1080 kg⁻¹) rabbit control operations between 1985 and 1991. In all three operations, the deaths could be attributed to 1080 either through residue testing or observing carrot in the crop. The authors also reported **Chukar** being found dead following two other rabbit control operations using carrot (0.2 g 1080 kg⁻¹).

During an aerial 1080 rabbit control operation on Dovedale Station, Central Otago in August 1993, five **California quail** coveys were monitored inside (treatment coveys) and a further two outside (non-treatment coveys) the operational area. The operational area received two prefeeds of unscreened carrot bait 7 days apart. Seven days later unscreened green dyed toxic **carrot** ($0.2 \text{ g } 1080 \text{ kg}^{-1}$) was applied at a rate of 25 kg ha^{-1} . California quail survived inside the operational area in significant numbers. Following the operation, of the coveys inside the operational area, quail numbers remaining the same in two and dropped in one. The other two coveys in the treatment area could not be located. One non-treatment covey's numbers remained the same and the other one appeared to break up for breeding. Insufficient information was obtained to determine whether the change in covey sizes were as a result of non-location, breeding dispersal, emigration or poisoning (Evans and Soulsby, 1993).

Four **California quail** deaths were reported during two rabbit control operations using 1080 **oat** ($0.2 \text{ g } 1080 \text{ kg}^{-1}$) baits in the 1980-90's (Evans and Soulsby, 1993).

During a 1976 rabbit control operation near Lake Benmore using 1080 **oat** ($0.2 \text{ g } 1080 \text{ kg}^{-1}$) baits, **Canada geese** died after eating the bait. The birds contained up to 70g of the bait in their crops and gizzards (Anonymous, 1986).

Other birds

A number of other introduced bird species have been found dead during aerial 1080 operations (using carrot and cereal pellet baits). These include **blackbirds, thrush, chaffinch, dunnoek, goldfinch, redpoll, yellow hammer** and **hedge sparrows** (Morris et al., 2016; VPRD; Pestlink: 0304RAN08 ; Nugent et al., 2004; Rammell and Fleming, 1978).

Morris et al. (2016) reported that **blackbirds** comprised 80% of the introduced dead birds found during 15 aerial 1080 operations (cereal pellet and carrot) between 2003 and 2014. Furthermore, they reported that in two detailed studies conducted in the Hauhungaroa Ranges in 2011 and 2013, while blackbirds represented 3.2% and 1.9% of the overall live bird counts, they comprised 54% and 73% respectively of the dead birds found.

Bait station operations using 0.15% or 0.08% 1080 Pellets

Domestic and feral non-target deaths reported after the use of 1080 cereal pellets in bait stations are reported in Table 31. **Error! Reference source not found..**

Table 31. Feral and domestic non-target animal deaths reported during bait station operations using 0.15% 1080 pellets.

Species	Total Found Dead	No. of Operations Involved	No. of Cases Where Residues Confirmed	Sowing Rate (kg ha^{-1})	Ref.

Dog	2	1	1		1, 2
Cattle	16	1	2		3
Australasia n magpie	1	1	0		1

1 VPRD: 6461-1; 2 Pestlink: 0405WNG12; 3 VPRD: T2109.

Pestoff Professional 1080 Possum Paste (0.08 & 0.15%)

Honey bees were known to be attracted to 1080 paste baits (sometimes referred to as jam baits) used in pest control prior to 1995. In an operation using this formulation of bait, honey was sampled from hives within the estimated forage zone of the bait application. Samples from 3 honeycombs that were uncapped/semi capped 12 days after the operation had residues of 1080 at 0.003-0.015 mg kg⁻¹ (Lowe 1994). Changes in formulation of 'Pestoff Professional' possum paste since then have been found to be unattractive to bees (Morgan, 2000).

Cut apple bait

Honey bees offered this bait near their hive were seldom observed on the bait compared with control baits offered (Thomas et al., 2003).

4.2.2. For which species have residues of this pesticide been detected following 1080 operations?

Aerial and hand laid operations

1080 residue levels in domestic and feral animals found dead after 1080 operations are presented in Table 32.

Table 32. 1080 residue levels recorded in domestic and feral animals during pest control operations in New Zealand.

Species	Sample Type	Residues (mg kg ⁻¹)	Ref.
<i>Mammals</i>			
Cat	Muscle	0.06-1.24	1
	Stomach	0.36	
Dog	Muscle	0.014-0.41	1
	Stomach	0.028-0.7	
	Intestine	0.44	

Species	Sample Type	Residues (mg kg ⁻¹)	Ref.
	Vomit	1.07	
Cattle	Muscle	0.003-0.46	1
	Stomach	0.04-9.1	
Sheep	Muscle	0.021-0.3	1; 2
	Stomach	0.001-1.3	
Deer	Muscle	0.012-7.37	1; 3; 4; 5
	Stomach	8.7-35.9	
	Heart	0.85-8.12	
	Liver	0.75-4.05	
Deer - whitetail	Muscle	0.27-3.08	1
	Stomach	0.33-51	
Goat	Muscle	0.36	19
Chamois	Muscle	0.23	19
Pig	Muscle	0.03-0.21	1
	Stomach	56	
Birds			
Blackbird	Muscle	0.01-32.0	1; 3; 4; 6
Chaffinch	Muscle	0.14-5.80	1; 6
Dunnock	Muscle	0.28-1.75	6
Hedge Sparrow	Muscle	0.03	1
Thrush	Muscle	2.01	6
California Quail	Crop	18 - 76	7
Invertebrates			
Honeybee	2 whole animals	0-10.8	1
Honeybee	Pooled samples of bees	0.059-1.43	18
Honeybee	Corbicula ('pollen sac')	1050.85	1

Species	Sample Type	Residues (mg kg ⁻¹)	Ref.
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1 VPRD; 2 Parliamentary Commissioner for the Environment (1994); 3 Speedy (2003); 4 Nugent et al. (2004); 5 McIntosh and Staples (1959); 6 Morriss et al. (2016); 7 Evans and Soulsby (1993); 18 Pattemore and Fale (2022); 19 Morriss et al. (2019)

0.15% 1080 Pellets in bait stations

Muscle samples from 8 trout had no detectable 1080 following application in bait stations at 100g/station, approximately 1 station/ha, October 1997, Lake Rotoiti (VPRD T0543, T0642).

4.3. *Treatment*

4.3.1. Is there an effective treatment of 1080 poisoning that is practical to administer?

No antidotes for 1080 poisoning are currently available but research is continuing (Ataria et al., 1995; Cook et al., 2001; Diaz, 2018).

5. Human Health

The estimated lethal dose of 1080 in humans lies in the range of 0.7 and 10.0 mg kg⁻¹. Sodium monofluoroacetate (1080) is absorbed through the gastrointestinal tract or via the lungs if inhaled. Monofluoroacetate is not readily absorbed through intact skin, but it can be absorbed more readily through cuts and abrasions. The onset clinical signs usually range from 30 minutes to about 2-3 hours. Signs of poisoning include nausea, vomiting, and abdominal pain initially, followed by respiratory distress, anxiety, agitation, muscle spasms, stupor, seizures, and coma.

1080 is not a mutagen and is unlikely to be a carcinogen. It has sub-lethal effects on reproduction and is classified as a teratogen.

There is no effective antidote for 1080 poisoning in humans and any treatment given is largely symptomatic and supportive.

5.1. Toxicity

5.1.1. What is the oral MDL (mg kg⁻¹ b.w.)?

The oral MDL (Minimum Lethal Dose) for humans has been estimated at 0.6 mg kg⁻¹ (TERA 2006). The oral LD₅₀ is estimated at being between 0.7 and 10.0 mg kg⁻¹ (Chenoweth, 1949; Eisler, 1995; Kaye, 1970). Other authors cite lethal dose estimates lying between 2 and 10 mg/kg (Reyes 2020, Nishii et al 2012). Some suggest differences in LD₅₀ figures depending on how it is administered with intravenous injection yielding much lower figures than oral in monkeys (Nishii et al 2012).

However, from a public health perspective, it is more appropriate to use the minimum lethal dose (MLD) as the estimate of the acute toxicity in humans. In this review the lowest estimated MLD of 0.7 mg kg⁻¹ is used in the acute toxicity calculations.

5.1.2. How much bait would children and adults need to ingest for poisoning?

The information on bait consumption required for poisoning is presented in Table 33.

Table 33. Amount of 1080 bait needed to be ingested by a human to result in death based on the LD₅₀.

	MLD (mg kg ⁻¹)	Av. Weight (kg)	Amount of 0.8 g kg ⁻¹ 1080 Bait (g) for MDL	Amount of 1.5 g kg ⁻¹ 1080 Bait (g) for MDL
Child	0.6	15	11.25	6
Adolescent	0.6	30	22.5	12

Small adult	0.6	60	45	24
Large adult	0.6	90	67.5	36

5.1.3. What is the dermal MDL (mg kg⁻¹ b.w.)?

Monofluoroacetate is not readily absorbed through intact skin, but it can be absorbed more readily through cuts and abrasions. An MDL has not been estimated, but Fagerstone et al. (1994) estimated the dermal LD₅₀ at 300 mg kg⁻¹. Exposure guidelines (Threshold Limit Values, TLV) for 1080 have been set in USA, with a Time-weighted average (TLV-TWA) of 0.05 mg/m³ for skin exposure (Anon., 1991).

In New Zealand the Occupational Health and Safety Service (OSH) has set a Biological Exposure Index (BEI) of 15 µg l⁻¹ (0.015 ppm) for 1080 in human urine (Occupational Safety and Health Service, 2002).

5.1.4. Where the pesticide involves a gaseous form, what is the gaseous MDL (ppm in air)?

This is not applicable for 1080.

5.1.5. Where there is dust or mist associated 1080 use, what is the dust and mist MDL (ppm in air)?

There is no published information on the LC₅₀ for 1080 in dust or mist. A Biological Exposure Index (BEI) of 15 µg l⁻¹ (0.015 ppm) for 1080 has been set by Occupational Health and Safety Service (OSH) New Zealand (Occupational Safety and Health Service, 2002).

5.1.6. Is there evidence that 1080 may have mutagenic and/or carcinogenic properties? If known, what are the LOEL or NOEL values?

Three different complementary tests (Ames assay; mouse lymphoma assay; mouse micronucleus assay) indicate that 1080 is not a mutagen and is therefore unlikely to be a carcinogen (Eason et al., 1999). The latter test dosed mice with 0.75, 1.5, 3.0, 6.0 and 7.5 mg/kg of the published LD₅₀ dose for mice being 8.3 mg/kg (McIlroy 1982b).

5.1.7. Is there evidence that 1080 may have sub-lethal effects on reproduction or lactation, or is classified as a teratogen? If known, what are the LOEL or NOEL values for these reproductive and developmental effects?

1080 has sub-lethal effects on reproduction and is classified as a teratogen (de Meyer and de Plaen, 1964; Spielmann et al., 1973).

It is a male reproductive toxicant with effects on testes of mammals (Eason and Turck, 2002; Shinoda et al., 2000; Wolfe, 1998). In a 90 day study, Wolfe (1998) reported a decreased weight of testes and epididymides, and abnormal sperm formation in male rats. In a 90 day toxicology study of 1080, Eason and Turck (2002) reported hypospermia in the epididymides and degeneration of the seminiferous tubules of the testes of male rats dosed with 1080 at $0.25 \text{ mg kg}^{-1} \text{ day}^{-1}$. The NOEL for rats administered 1080 via oral gavage for 90 days was $0.075 \text{ mg kg}^{-1} \text{ day}^{-1}$.

Neither 1080 nor its active metabolite fluorocitrate bound to human androgen or alpha oestrogen receptors during in vitro assays (Tremblay et al., 2005). 1080 and fluorocitrate did not bind to sheep oestrogen receptors either (Tremblay et al., 2004). Therefore, while 1080 is a male reproductive toxicant, it is not considered an endocrine disruptor.

Sub-lethal doses of 1080 to pregnant rats alters skeletal development of rat fetuses (Eason et al., 1997; 1999). Teratogenic effects have been reported at $0.75 \text{ mg kg}^{-1} \text{ day}^{-1}$ (Eason et al., 1999) and the developmental NOEL is $0.1 \text{ mg kg}^{-1} \text{ day}^{-1}$.

5.1.8. Is there evidence that 1080 may have sub-lethal effects on target organs? If known, what are the LOEL or NOEL values for these effects?

Sub-lethal effects on target organs have been reported. Small testes and epididymis in male rats were observed following doses of 1080 at $0.25 \text{ mg kg}^{-1} \text{ day}^{-1}$, and these observations were corroborated by a reduction in the weight of the testes. 1080-related increases in heart weight were noted in both males and females at $0.25 \text{ mg kg}^{-1} \text{ day}^{-1}$ when compared with controls. The NOEL for rats administered 1080 via oral gavage for 90 days was $0.075 \text{ mg kg}^{-1} \text{ day}^{-1}$ (Eason and Turck, 2002).

Changes in testes in male rats and in heart weights in both sexes of rats were reported by Wolfe (1998). Based on these findings the NOEL for sodium fluoroacetate, when given orally to Sprague-Dawley rats for 13 weeks, was $0.05 \text{ mg kg}^{-1} \text{ day}^{-1}$ (Wolfe, 1998).

Rhesus monkeys given trace doses of 1080 were monitored for three months afterwards. No statistically significant changes in blood chemistry, liver enzymes or renal function were observed (Nishii et al 2012).

5.1.9. How rapid is the onset of toxicity for 1080 in humans?

The onset clinical signs usually ranges from 30 minutes to about 2-3 hours (Eason and Wickstrom, 2001), however, in one case of acute poisoning, onset of symptoms was described as within minutes (Williams, 1948). Relatively few cases of human poisoning (accidental or deliberate) have been reported in the literature. Liu et al (2020) provide information for 68 cases in China, of which 6 were fatal. A further 23 cases, 16 of which were fatal are reported in (Reyes et al 2020; Anon., 1992; Brockmann et al., 1955; Ellenhorn and Barceloux, 1988; Harrison et al., 1952; Trabes et al., 1983).

Poisoning symptoms experienced include nausea, vomiting, and abdominal pain initially, followed by respiratory distress, anxiety, agitation, muscle spasms, stupor, seizures, and coma. Hypotension (low blood pressure) is thought to be one of the more important predictors of mortality in 1080 intoxication (Chi et al., 1999; Chi et al., 1996). Liu et al (2020) identified a number of other blood parameters indicative of 1080 poisoning and/or patient survival.

5.2. Treatment

5.2.1. Is there an effective treatment or antidote for 1080 poisoning in humans?

There is no effective antidote for 1080 poisoning in humans. Treatment is largely symptomatic and supportive, with special attention focused on stabilising cardiac and central nervous system functions (Goncharov et al., 2006). Renal replacement therapy has also been used successfully (Reyes et al 2020) The success of the treatment is likely to depend on whether the dose was acute or sub-lethal.

There is ongoing research into antidotes for 1080 (e.g. Goncharov et al., 2006; Hoyos et al., 2018). Ethanol has been found to be useful antidotal therapy but could not be considered totally effective (Goncharov et al 2006; Liu et al 2020).

6. Operational

1080 is considered to have medium humaneness for possums, however there has been little formal research into the humaneness of 1080 on other target species. Most deaths of pest species occur 8 – 48 hours after ingestion of a lethal dose.

All the registered target species have relatively high susceptibility to 1080. The short latent period means that bait shyness can develop in animals receiving a sub-lethal dose. Mice exhibit a marked avoidance of 1080 which is likely to result in control operation failures.

The majority of pest control operations using 1080 have target pest kills of greater than 80%.

6.1. Animal Welfare

6.1.1. What are the animal welfare impacts of 1080 on the target pest?

1080 toxicosis generally has a characteristic 'lag time' in mammalian species, where following intake of a lethal dose, the animal will show no visible signs of poisoning for up to a number of hours, before beginning to display symptoms (Eason and Wickstrom, 2001). The onset clinical signs usually ranges from 30 minutes to about 2 - 3 hours with most deaths in mammals generally occurring 8 – 48 hours after ingestion of a lethal dose (Eason and Wickstrom, 2001). The severity of symptoms observed are difficult to evaluate (Littin et al 2009 ; Beausoleil & Mellor 2015) However an insight may be gained from testimony from people who have ingested 1080. They describe abdominal pain, agitation and vomiting (Chi et al 1996; Liu et al 2020)

Possums

Littin et al. (2009) reported that the onset of symptoms in eight unhandled lethally dosed possums occurred at 1 hour 50 minutes ($\pm 0:09$ s.e.m) with animals exhibiting abnormal appearances and postures. Seven of the animals showed retching, and three vomited starting at 2 hours 53 minutes. Lack of coordination began at 3 hours 37 minutes, after which possums spent most of the time until death lying, showing spasms and tremors. Five of the possums had seizures while lying prostrate. The mean time to death was 11 hours 26 minute ($\pm 1:55$ s.e.m).

In possums the animal welfare impacts of 1080 is described as intermediate when compared to other vertebrate toxic agents used to kill possums in New Zealand (Littin et al., 2009; MAFBNZ, 2010).

Rodents

Cook (1998) reported laboratory rats orally dosed with 1080 exhibited hypersensitivity to light and sound, an increased incidence of grooming or scratching of the abdomen, increased cage pacing and increased curled-but-awake posture. Five of the ten rats dosed with 1080 showed convulsive behaviour between 4 to 10 hours after the 1080 was administered.

McIlroy (1982b) reported that ship rats exhibited a 0.8 - 27.8 hour latent period and died 2.4 - 36.5 hours after a lethal dose of 1080 was administered. Norway rats had a 0.4 - 2.3 hour latent period and a 2.5 - 112.0 hour time to death. Mice had a 1.3 - 2.8 hour latent period and 2.2 - 68.3 hour time to death. In rats observed symptoms included animals initially appearing depressed, often sitting quietly hunched in a corner or lying on their side, back or stomach with their eyes partially closed: hypersensitivity to touch or sounds; and uncoordinated movement with unsteady balance. Respiration was initially very rapid, but became slower, shallower and more irregular until death occurred. Convulsions were commonly observed.

In rats the animal welfare impacts of 1080 is described as intermediate when compared to other vertebrate toxic agents used to kill rats in New Zealand (MAFBNZ, 2010).

Cats

The main poisoning symptoms in cats are lethargy and disorientation, which are unusual for carnivores and more closely resemble those seen in herbivores. Other symptoms include uncoordinated movements and occasional vocalisation (Eason and Frampton, 1991). Neurological signs associated with 1080 exposure are generally less severe in cats than in dogs (Eason and Wickstrom, 2001). McIlroy reported a latent period of 1.0 - 5.6 hours and time to death between 20.7 - 21.0 hours. In cats the animal welfare impacts of 1080 are described as intermediate when compared to other vertebrate toxic agents (MAFBNZ, 2010).

Rabbits

In rabbits the animal welfare impacts of 1080 are described as intermediate (MAFBNZ, 2010). The onset of symptoms has been reported as occurring between 1.1 - 10.1 hours after exposure to a lethal dose and death occurring after 3.0 - 44.3 hours (McIlroy, 1982a). Gooneratne et al. (1994) reported the time to death ranging from 1 to 7.5 hours in rabbits following a lethal dose. Lying prone, lethargy, respiratory distress, sensitivity to noise or disturbance and convulsions have been reported in poisoned rabbits (MAFBNZ, 2010; McIlroy, 1982a).

Wallabies

McIlroy (1982a) reported symptoms in poisoned wallabies included animals sitting hunched up; generally appearing non-alert, with shivering or shaking forelimbs and unsteady balance; convulsions and a white froth exuded from the mouth and nostrils. The latent period in Bennett's wallabies was <16.9 to 23.2 hours (7 wallabies observed), and the time to death was 8.9 - 38.9 hours (23 wallabies observed). For dama wallabies the time to death was 13.8 - 37.1 hours. MAFBNZ (2010) describe the overall animal welfare impacts of 1080 on wallabies as intermediate compared to other vertebrate toxic agents.

Deer

In general, herbivores experience cardiac failure, whereas carnivores experience central nervous system disturbances and convulsions then die of respiratory failure (Egeheze and Oehme, 1979).

Daniel (1966) reported that deer became lethargic and lay down quietly without any of the convulsions or leg-thrashing commonly reported in Canidae. He reported that deer died between 2 and 30 hours after eating a lethal dose.

6.2. Efficacy

6.2.1. Is 1080 effective on the target pest, based on the LD₅₀?

All the registered target species have relatively high susceptibility to 1080. The LD₅₀ values are presented in Table 34.

Table 34. Acute oral toxicity (LD₅₀ mg kg⁻¹) of 1080 to the target pests.

Target Pest	LD ₅₀ (mg kg ⁻¹)	Ref.
Cat	0.28	1
Deer not specified	0.50	2
Mule deer	0.27 – 0.90	3
House mouse	8.30	4
Brush-tailed possum	0.79 ^a	5
Rabbit	0.35	6
Ship rat	0.76	4
Laboratory rat	1.71	4
male	2.08 (95% CI 1.73, 2.49)	7
female	1.85 (95% CI 1.56, 2.19)	7
Norway rat (wild)	0.22-3.0	8
Stoat	0.49 (LD ₉₀ = 0.70)	9
Bennett's wallaby	0.21	10
Dama wallaby	0.27	6; 10

^a Ambient temperature may affect the acute toxicity of 1080 to possums, with increased toxicity at low temperatures (Veltman and Pinder, 2001).

1 Eason & Frampton(1991); 2 Rammell & Fleming (1978); 3 Tucker & Crabtree (1970); 4 McIlroy (1982b); 5 Bell (1972); 6 McIlroy (1982a); 7 (McCranor et al., 2019); 8 Chenoweth (1949); 9 Spurr (2000b); 10 Munday (1978).

6.2.2. How much bait does the target pest have to ingest in order to be poisoned, within what timeframe?

Target pests would have to eat at least the amounts given in Table 35 in one feeding session (at least three hours) to be likely to receive an acute lethal dose.

Table 35. Amount of bait a target pest needs to ingest to result in death based on LD₅₀.

Species	LD ₅₀ (mg kg ⁻¹)	Av. Weight Female (g)	Amount of 0.2g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 0.4g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 0.6g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 0.8g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 1.0g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 1.5g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 2.0g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 50g kg ⁻¹ Bait (g) for LD ₅₀	Amount of 100g kg ⁻¹ Bait (g) for LD ₅₀
Bennetts wallaby	0.21	11000		-		-	-	1.5	1.2	0.05	0.02
Cat	0.28	2500		-		-	0.7	-	-	-	-
Dama wallaby	0.27	4300		-		-	-	0.8	0.6	0.02	0.01
House Mouse	8.30	20				0.21		0.1			
Norway rat	0.22	220		-		0.06	-	0.03	-	-	-
Possum	0.8	3000		-	4.0	3.0	-	1.6	-	-	-
Rabbit	0.35	800	1.4	0.7	0.47	-	-	-	-	-	-
Red deer	0.5	80000		-		-	-	26.67	-	-	0.4
Ship rat	0.76	140				0.13		0.07	-	-	-

Palatability

Palatability of a bait will also influence whether the target pest will ingest a lethal dose.

Possums

Morgan (2004) reported that under field conditions double wax coated 1080 pellets left in Philproof bait stations had a 20% decline in palatability after 4 months.

Mice

Wild caught mice demonstrate marked avoidance of baits containing 1080 in pen studies (Fisher et al., 2009; Morriss et al., 2008). In paired choice tests (using toxic pellets and non-toxic rodent pellets), only 8% of mice died when offered 0.15% 1080 baits. Pellet type (Wanganui #7 or RS5), the presence or absence of green dye, the presence or absence of 0.3% cinnamon and bait size (2g and 12g) did not have any effect on the amount of toxic bait eaten by mice (Morriss et al., 2008). In similar paired choice tests, Fisher et al. (2009) reported that mice had a low acceptance of 0.08% and 0.15% 1080 pellets and mortality rates were similar (25%) for both concentrations of 1080. The authors also found that pre-feeding with non-toxic pellets did not improve the acceptance of 0.15% 1080 pellets by mice.

Based on the marked avoidance of 1080 by mice, O'Connor et al. (2005) recommended that 1080 should not be used for mouse control operations until new methods are developed to improve 1080 bait acceptance by mice.

Other factors

Parkes (1991) noted that when 10% 1080 gel with a carbopol carrier was applied to mahoe leaves, the baits had a maximum life of about 60 days because phytotoxicity caused most leaves to abscise within 46 days. When mahoe leaves were smeared with 10% 1080 gel in a petrolatum carrier, the baits could remain effective as baits for at least 110 days, after which time most leaves had abscised. However, abscised leaves could remain toxic to animals that eat leaf-fall for at least 300 days.

6.2.3. What is the latent period between bait ingestion and onset of symptoms?

The latent period is hours. Possums receiving a sub-lethal dose of 1080 have been known to develop bait shyness (O'Connor and Matthews, 1999; Ogilvie et al., 2000) and this can persist for at least three years (O'Connor and Matthews, 1999). Conditioned food aversion to diets containing 1080 has been reported in rats (Nachman and Hartley, 1975).

Note: A short latent period increases the likelihood of the target pest developing poison shyness.

6.2.4. What field evidence is there that this pesticide use causes a population decline of the target pest species at sites where it is used?

Possums

Aerially distributed 1080 cereal pellets

The percentage kills obtained during aerial operations using 0.15% 1080 cereal pellets between 2010 and 2017 are presented in Table 36. The mean percentage kill was 89.1% ($\pm 2.0\%$ s.e., $n=37$). The results for earlier operations are in Appendix 1.

The percentage kills obtained during aerial operations using 0.08% 1080 cereal pellets are presented in Table 37. For non-prefed aerial operations using 0.08% cereal pellets the mean kill was 69.1% ($\pm 10.4\%$ s.e., $n=10$). The mean kill for prefed aerial operations using 0.08% cereal pellets was 82.2% ($n=1$).

Table 36. The percentage possum kill for aerial operations using 0.15% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
95.6%	Willowflat Forest, Hawke's Bay, Oct 2021	1.5 (Prodeer, 6g pellets)	2 (Prodeer, 12g pellets, 13 days later)	Morriss and Gormley 2022
100%	Molesworth and Muller Stations, June 2021	0.8-1.0 (Prodeer, 6g pellets)	0.8-2 (Prodeer, 6g pellets, 19-21 days later)	Morriss et al 2021
98.6%	Upper Awatere South 2019	1 (Pestex®, 6g)	2 (Pestex®, 6g, 19-20 days later)	Morriss et al 2019
100%	Clarence West/Waiautoa 2019	1.0 (Pestex ®DR, 6g)	2 (Pestex ®DR, 6g, 17-18 days later)	Morriss et al 2019
100%	Otahu, Coromandel, Nov 2017	1.5 (6g pellets)	2 (12g #7 pellets, 21 days later)	1718HAU 01
100%	Hollyford BfoB, Oct 2017	1 (6g pellets)	2 (12g RS5 pellets, 13 days later)	1718TEA 01
97.5%	Papakai, Coromandel, Oct 2017	1.5 (6g pellets)	2 (12g #7 pellets, 19 days later)	1718WH T04

95.2%	Moehau, Coromandel, Oct 2017	1.5 (6g pellets)	2 (12g #7 pellets, 26-40 days later)	1718WH To1
88.6%	Cleddau BfoB, Sept 2017	1 (6g pellets)	2 (12g RS5 pellets, 16 days later)	1718TEA 02
94.3%	Rotoehu Forest, Sept 2017	1.5 (6g pellets)	2.5 (12g #7 pellets, 8 days later)	1718TAU 01
94.0%	Whareorino, Jul 2017	1.5 (6g pellets)	2 (12g #7 pellets, 14 days later)	1617MPT 06
58.1% (est.)	Egmont NP, Dec 2016	1 (6g pellets)	2 (6g RS5 pellets, 59 days later)	1617TAR 01
100%	Waitutu BfoB, Nov 2016	1 (6g pellets)	1 (12g RS5 pellets, 13 days later)	1617TEA 01
85%	Tawarau Management Area, Oct 2016	1.5 (6g pellets)	1.5 (12g #7 pellets, 24 days later)	1617MPT 01
98.1%	Abel Tasman BfoB, Aug 2016	1.5 (6g pellets)	3 (10g RS5 pellets, 25 days later)	1718MO To6
66.7%	Kia Wharite Project - Mangapurua Block, Whanganui, Oct 2015	0.5 (6g pellets)	0.5 (6g #7 pellets, 31)	1516WH A01
91.1%	Mokaihaha Ecological Area, Rotorua, Aug 2015	2 (12g pellets)	2 (12g #7 pellets, 15 days later)	1516ROT 02
78.9%	Rotoiti BfoB, Dec 2014	1 (6g pellets)	1 (6g RS5 pellets, 25 days later)	1415STA 02
100%	Eglinton Valley BfoB, Dec 2014	1 (6g pellets)	1 (12g RS5 pellets, 48 days later)	1314TEA 05
73.7%	Matukituki BfoB Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 26 days later)	1415WA No1
91.1%	Lower Holyford BfoB, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 38 days later)	1314TEA 06
99.9%	Iris Burn BfoB, Sept 2014	1 (6g pellets)	2 (12g RS5 pellets, 8 days later)	1415TEA 01

98.6%	Waitutu BfoB, Aug 2014	1 (12g pellets)	2 (12g RS5 pellets, 6 days later)	1314TEA 07
93.1%	Pirongia FP, Aug 2014	2 (6g pellets)	2 (12g RS5 pellets, 30 days later)	1415WAI 02
63.6%	Project Kaka, Tararuas, Dec 2013	1 (6g pellets)	1 (12g #7 pellets, 10 days later)	1314WRP 02
67.7%	South Hurunui, Dec 2013	1 (6g pellets)	2 (12g RS5 pellets, 21 days later)	1314WM K03
87.1%	Poulter Valley, Dec 2013	1 (6g pellets)	2 (12g RS5 pellets, 21 days later)	1314WM K03
79%	Mataketake block 2, Haast, Nov 2013	1 (6g pellets)	2 (12g RS5 pellets, 11 days later)	1314SWS
82%	Mataketake block 5, Haast, Nov 2013	1 (6g pellets)	2 (12g RS5 pellets, 11 days later)	1314SWS
80.8%	Tennyson Inlet Reserve - Mt Stanley, Nov 2013	1 (6g pellets)	1 (6g RS5 pellets, 13 days later)	1314SND 02
94.0%	Waitaanga, Oct 2013	1 (8g pellets)	2 (12g #7 pellets, 16 days later)	1314TAR 10
80.5%	Waitaanga, Oct 2013	1 (8g pellets)	1 (6g #7 pellets, 16 days later)	1314TAR 10
100%	Central Coromandel-Papakai, Jun 2013	2 (12g pellets)	2 (12g #7 pellets, Orange lure, 7 days later)	1314HA U02
100%	Moehau, Jun 2013	2 (12g pellets)	2 (12g #7 pellets, Orange lure, 6 days later)	1314HA U01
100%	Te Kopia SR, Dec 2012	2 (6g pellets)	2 (12g #7 pellets, 16 days later)	1213ROT 03
75.2%	Waipoua Forest, Sept 2011	1 (6g pellets)	2 (12g #7 pellets, 22 days later)	1112KAU 01
94.4%	Waihaha Ecological Area, May 2011	1.5 (12g pellets)	1.5 (12g #7 pellets, Orange lure, 19 days later)	1112MPT 05

95.3%	Project Kaka, Tararuas, Nov 2010	1.4 (6g pellets)	2 (12g #7 pellets, 16 days later)	11011PO N20
95.1%	Ruahine Corner, Oct 2010	1.1 (8g pellets)	2.03 (12g #7 pellets, 13 days later)	1011PNT 09
99.6%	Waitutu, Oct 2010	1 (12g pellets)	2 (12g RS5 pellets, 26 days later)	1011MR H03
100%	Tawarau, Aug 2010	2 (12g pellets)	2 (12g RS5 pellets, 33 days later)	1011MPT 02

Table 37. The percentage possum kill for aerial operations using 0.08% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
100%	Station Creek A Trial, Jul 2006	-	5 (12g #7 pellets)	Josh Kemp pers. comm.
82.2%	Station Creek B Trial, Jul 2006	2 (12g pellets)	5 (12g #7 pellets, 7 days later)	Josh Kemp pers. comm.
0%	Mapara, October 1992	-	8	Spurr (1993)
89%	Isolated Hill SR Nelson August 1992	-	4	Spurr (1993)
96%	Titirangi Reserve Wanganui June 1992	-	5	Spurr (1993)
50%	Puketi Forest Northland March 1992	-	5	Spurr (1993)
32%	Mapara October 1991	-	5	Spurr (1993)
91%	Whitecliffs Wanganui July 1991	-	6	Spurr (1993)
61%	Waipapa EA June 1991	-	10	Spurr (1993)
79%	Mapara September 1990	-	8	Spurr (1993)
93%	Rangitoto Island October 1990	-	12	Spurr (1993)

Aerially distributed 1080 carrots

The mean percentage possum kill for operations using 0.8 g kg⁻¹ 1080 carrots (Table 38) is 91.1% ($\pm 1.4\%$ s.e., n=7).

Table 39 lists aerial operations using 1.5 g kg⁻¹ 1080 carrots where the percentage kill could be calculated. The mean kill for these operations was 93.7% (n=4).

Table 38. The percentage possum kill for aerial operations using 0.8 g kg⁻¹ 1080 carrot.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
93.4%	Te Kopia SR, 11-25/7/2006	2 (6g baits)	5 (6g baits, 12 days later)	0607ROTo1
91.8%	Whirinaki Rata Block 30/8-8/9/2005	3	5 (8 days later)	0506RANo1
87.8%	Hunua Ranges, 7-8/9/2001	5	5	0203AKD13
86%	Otupaka EA, 17-18/05/2000	5	10 (6g baits)	0304RANo8
96.0%	Paeroa Range, 18/08/1999	5	10-15 (6g baits)	0304ROTo5
88.4%	Marokopa/Tawerau, 5/7/1998	5	5 (6g baits)	0203MPTo8
94.2%	Marokopa/Tawerau, 5/7/1998	5	10 (6g baits)	0203MPTo8

Table 39. The percentage possum kill for aerial operations using 1.5 g kg⁻¹ 1080 carrot.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
98.1%	Matakuhia, Tatarakina, July 2003	5	5 (6g baits)	Nugent et al. (2004)

96.3%	Wakeman's Block, Tataraakina, July 2003	5	5 (6g baits with EDR deer repellent)	Nugent et al. (2004)
86.6- 100%	Hampden, North Otago, 28/6/2002	2	2 (6g baits)	Lorigan et al. (2002)
92.5%	Lake Okataina SR, 27/7/1999	5	12 (6g baits)	0304ROTo4

1080 cereal pellets in bait stations

Table 40 contains the percentage possum kills for bait station operations using 0.15% 1080 cereal pellets. The mean kill for these operations was 93.3% ($\pm 1.9\%$ s.e., n=8).

Table 40. The percentage possum kill for 0.15% 1080 cereal pellets in bait stations.

Kill	Location	Method	Ref.
83.7%	Opuiki, Sept-Oct 2009	100 x 100 m grid, 2 prefeeds (600g per bait station), 1 toxic fill (300gbait per station)	0800TAU01
95%	Fox Valley, Apr-May 2008	100 x 200 m grid, 2 prefeeds (460g per bait station), 1 toxic fill (460g bait per station)	0809SWS04
88.9%	Fox Valley, July 2007	100 x 200 m grid, 2 prefeeds (500g per bait station), 1 toxic fill (500g bait per station)	0809SWS04
97.1%	Rotoehu EA, Oct-Nov 2007	1 bait station/ha, 2 prefeeds (1500g per bait station), 1 toxic fill (700g bait per station)	0708ROTo3
96.2%	Mokaihaha EA, Oct 2001	1 bait station/ha, 3 prefeeds, 1 toxic fill (1500g bait per station)	0304ROTo6
94.8%	Minganui Faces, Oct 1999	0.53 bait stations/ha, 3 prefeeds, 1 toxic fill (750g bait per station)	0304RAN12
100%	Kaharoa CA, Jan 1997	0.25 bait stations/ha, 3 prefeeds, 1 toxic fill (1000g bait per station)	0304ROTo9
90.6%	Minganui Faces, Nov 1996	0.53 bait stations/ha, 3 prefeeds, 1 toxic fill	0304RAN13

Handlaid 1080 cereal pellets

The mean percentage possum kill for operations using handlaid 0.15% 1080 cereal pellets (Table 41) is 88.8% ($\pm 4.7\%$ s.e., n=6).

Table 41. The percentage possum kill for operations using handlaid 0.15% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
91.7%	Stewart Island, Dec 07 – Jan 2008	No	Not specified	0809SISo2
100%	Colenso Basin, Ruahines, Sept-Oct 2007	2 (6g pellets)	1.5 (12g pellets, 31 days later)	0708PNT17
66.7%	Awarua, 3/3/2000		0.4 (8g pellets, traps and Feratox also used)	0203SWS30
90.6%	Fox Valley, 23/9/1999		0.5 (8g pellets, traps also used)	0203SWS34
94.6%	Abbey Rocks B, 2/6/1999		0.5 (6g pellets, traps also used)	0203SWS28
89.3%	Abbey Rocks C, 3/6/1999		0.5 (6g pellets, traps also used)	0203SWS28

1080 cereal pellets in bait bags

The percentage kills obtained following the use of 1080 cereal pellets in bait bags are presented in Table 42. The mean is 82.9%.

Table 42. The percentage possum kill for operations using 0.15% 1080 cereal pellets in bait bags.

Kill	Location	Method	Ref.
96%	Stewart Island, Oct-Nov 2008	20 x 100 m grid (not prefed)	0809SISo3
97.6%	Pegasus/Tin Range Oct-Nov 2004	Grid (not prefed)	0405SISo4
85% (Range: 68.8%-100%)	Paterson Inlet Blocks, Oct 2003	Bags put on recent sign (not prefed)	0304SIS19

~92.6%	Mt Anglem/Hananui, Oct-Nov 2003	4.3-5.3 bait bags/ha, 1 prefeed, 2 toxic bag placements (6g baits).	0304SIS20
53.1-73.2%	Warawara Forest Blocks, Mar-Jun 2003	Bags put on recent sign (not prefed)	0203KAI12

1080 paste in bait bags

See Table 43 for the percentage kill during operations using 0.15% 1080 paste in bait bags.

Table 43. The percentage possum kill for operations using 0.15% 1080 paste in bait bags.

Kill	Location	Method	Ref.
56.4%	Minganui Faces, Sept-Oct 2000	Bags placed on a 75m x 10m grid, not prefed.	0304RAN09

Handlaid 1080 paste

The mean percentage possum kill for operations using handlaid 0.15% 1080 paste under good weather conditions is 83.1% (n=5) (Table 44).

Table 44. The percentage possum kill for operations using handlaid 0.15% 1080 paste.

Kill	Location	Method	Ref.
~84%	Rangitikei Snail Area, Kaimanawa FP, 2000-2002	Prefed, set on recent sign.	0304RAN09
86.6%	Mortens, Canterbury	Spits 5-6m apart around forest edge, not prefed	Ross & Henderson (2003)
84.7%	Steventon, Canterbury	Spits 5-6m apart around forest edge, not prefed	Ross & Henderson (2003)
84% (Range : 50-96%)	9 sites around NZ (1996-98) - good weather conditions	Spits 5m apart around forest edge, prefed	Thomas & Morgan (1998)
34% (Range	4 sites (1997) - where rain washed out baits	Spits 5m apart around forest edge, prefed	Thomas & Morgan (1998)

: 0-59%)	or hot weather dried out the baits		
76% (Range : 68-93%)	9 sites around NZ (1996-98) – good weather conditions	Spits 5m apart around forest edge, not prefed	Thomas & Morgan (1998)
30% (Range : 11-46%)	4 sites (1997) where rain washed out baits or hot weather dried out baits.	Spits 5m apart around forest edge, not prefed	Thomas & Morgan (1998)

Rats

Aerially distributed 1080 cereal pellets

The percentage rat kills obtained during aerial operations using 0.15% 1080 cereal pellets between 2010 and 2015 are presented in Table 45. Based on this data, the mean kill for prefed operations is 93.0% (n=87). The results for earlier operations are presented in Appendix 1.

The percentage rat kill for the aerial operations using 0.08% cereal pellets is presented in Table 46.

Table 45. The percentage rat kill for aerial operations using 0.15% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
100%	Northern Ruahine BfoB, Nov 2017	2 (6g pellets)	2 (6g RS5 pellets, 25 days later)	1718PNT01
100%	Kahurangi West and Kahurangi North BfoB, Nov 2017	1.5 (6g pellets)	1.5 (6g RS5 pellets, 28 days later)	1718GDB01
100%	Hollyford BfoB, Oct 2017	1 (6g pellets)	2 (12g RS5 pellets, 13 days later)	1718TEA01
97.4%	Abel Tasman NP, Oct 2017	2 (6g pellets)	2 (6g RS5 pellets, 7 days later)	1718MOT09
95.2%	Moehau, Coromandel, Oct 2017	1.5 (6g pellets)	2 (12g #7 pellets, 26-40 days later)	1718WHT01

100%	Matemateaonga, Whanganui, Oct 2017	0.5 (6g pellets)	0.5 (6g RS5 pellets, 30 days later)	1718WHA01
97.4%	Waitotara, Whanganui, Oct 2017	0.5 (6g pellets)	0.5 (6g RS5 pellets, 30 days later)	1718WHA01
100%	East & West Matukituki BfoB, Oct 2017	1.5 (6g pellets)	1.5 (6g RS5 pellets, 9 days later)	1718CNO06
88.6%	Cleddau BfoB, Sept 2017	1 (6g pellets)	2 (12g RS5 pellets, 16 days later)	1718TEA02
96.4%	Rotoehu Forest, Sept 2017	1.5 (6g pellets)	2.5 (12g #7 pellets, 8 days later)	1718TAU01
95.7%	Whitecliffs/Parininihi, Sept 2017	3 (6g pellets)	3 (6g RS5 pellets, 29 days later)	1718TAR02
90.6%	Dart/Routeburn BfoB, Sept 2017	1.5 (6g pellets)	1.5 (6g RS5 pellets, 7 days later)	1718WAK01
100%	Whirinaki Te Pua a Tane BfoB, Sept 2017	1.5 (6g pellets, with EDR)	1.5 (6g RS5 pellets with EDR, 16 days later)	1718WHK01
100%	Whirinaki Te Pua a Tane BfoB, (EDR Block), Sept 2017	1.5 (6g pellets, no EDR)	1.5 (6g RS5 pellets no EDR, 16 days later)	1718WHK01
100%	Paparoa North BfoB, Oct 2017	1.5 (6g pellets)	3 (12g RS5 pellets, 9 days later)	1718BUL01
100%	ZIP Jackson Arawhata #1, Jul 2017	2 (6g pellets, 2 prefeeds 11 days apart, Orange lure)	4 (6g RS5 pellets, 19 days later, Orange lure)	1718SWS01
100%	Whareorino, Jul 2017	1.5 (6g pellets)	2 (12g #7 pellets, 14 days later)	1617MPT06

100%	Makarora-Wilkins BfoB, Feb 2017	1 (6g pellets)	1 (6g RS5 pellets, 7 days later)	1617CNO04
86.4%	Beresford Range (Catlins) BFOB Dec 2016	1 (6g pellets)	1 (6g RS5 pellets, 41 days later)	1617MRHo3
91.8%	Pukaha/Mt Bruce, Dec 2016	1 (6g pellets)	1 (6g RS5 pellets, 9 days later)	1617WRPo3
96.8%	Landsborough BfoB, Dec 2016	2 (6g pellets)	2 (6g RS5 pellets, 32 days later)	J. Kemp pers. comm, 1617SWSo4
85.4% (est.)	Egmont NP, Dec 2016	1 (6g pellets)	2 (6g RS5 pellets, 59 days later)	1617TAR01
97.4% (est.)	Waitutu BfoB, Nov 2016	1 (6g pellets)	1 (12g RS5 pellets, 13 days later)	J. Kemp pers. comm, 1617TEA01
94.1%	Te Maruia BfoB, Nov 2016	1 (6g pellets)	1 (6g RS5 pellets, 9 days later)	1617GRY01
100%	Waikaia Forest BfoB, Nov 2016	1 (6g pellets)	1 (6g RS5 pellets, 26 days later)	1617MRHo2
100%	Hawdon BfoB, Nov 2016	2 (6g pellets)	2 (6g RS5 pellets, 7 days later)	1617WMKo1
0%	Poulter BfoB, Nov 2016	2 (6g pellets)	2 (6g RS5 pellets, 7 days later)	1617WMKo1
99.5% (est.)	Wangapeka, Oct 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 38 days later)	J. Kemp pers. comm, 1617MOT01
100% (est.)	Clinton BfoB, Oct 2016	1 (6g pellets)	1 (6g RS5 pellets, 26 days later)	J. Kemp pers. comm, 1617TEA04
100%	Whareorino Frog Protection Area Oct 2016	1.5 (6g pellets)	1.5 (6g Whanganu i #7 pellets, 24 days later)	1617MPT01

84.9% (est.)	Dart-Caples BfoB, Oct 2016	1 (6g pellets)	1 (6g RS5 pellets, 29 days later)	J. Kemp pers. comm, 1617WAKo1
80.7% (est.)	Eglington Valley BfoB, Oct 2016	1 (6g pellets)	2 (12g RS5 pellets, 25 days later)	J. Kemp pers. comm, 1617TEA05
96.3% (est.)	Oparara BfoB D+E, Sept 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 10 - 13 days later)	J. Kemp pers. comm, 1617MOT01
88.7% (est.)	Oparara BfoB A, Sept 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 10 - 13 days later)	J. Kemp pers. comm, 1617MOT01
100% (est.)	Arthur-Sinbad BfoB, Sept 2016	1 (6g pellets)	2 (12g RS5 pellets, 42 days later)	J. Kemp pers. comm, 1617TEA02
100%	Okarito South, Sept 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 11 days later)	J. Kemp pers. comm, 1617SWS03
90.7% (est.)	Kepler BfoB, Sept 2016	1 (6g pellets)	2 (12g RS5 pellets, 12 days later)	J. Kemp pers. comm, 1617TEA03
99.1% (est.)	Haaast Kiwi Sanctuary BfoB, Aug 2016	1.5 (6g pellets)	3 (12g RS5 pellets, 11 days later)	J. Kemp pers. comm, 1617SWS01
100% (est.)	Arawhata BfoB, Aug 2016	1.5 (6g pellets)	3 (12g RS5 pellets, 11 days later)	J. Kemp pers. comm, 1617SWS01
100% (est.)	Abbey Rocks BfoB, Aug 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 12 days later)	J. Kemp pers. comm, 1617SWS02
100%	Waipapa Pureora BfoB Jul 2016	1 (6g pellets)	2 (12g #7 pellets, 24 days later)	1617MPT04
87.3%	Kia Wharite Project - Mangapurua Block, Whanganui, Oct 2015	0.5 (6g pellets)	0.5 (6g #7 pellets, 31	1516WHA01

100%	Mokaihaha Ecological Area, Rotorua, Aug 2015	2 (12g pellets)	2 (12g #7 pellets, 15 days later)	1516ROT02
97.9%	Mt Bruce/Pukaha, Wairarapa, Jul 2015	1 (12g pellets)	1 (12g #7 pellets, 12 days later)	1516WRP01
100%	South Branch Hurunui BfoB, Feb 2015	1.5 (6g pellets)	1.5 (6g RS5 pellets, 6 days later)	1314WMK04
100%	Poulter Valley BfoB, Feb 2015	1.5 (6g pellets)	1.5 (6g RS5 pellets, 6 days later)	1415WMK05
76.4%	Rotoiti BfoB, 170m flight path, Dec 2014	1 (6g pellets)	1 (6g RS5 pellets, 25 days later)	1415STA02
100%	Rotoiti BfoB, 150m flight path, Dec 2014	1 (6g pellets)	1.18 (6g RS5 pellets, 25 days later)	1415STA02
38.5%	Hawdon & Andrews Valleys BfoB, Dec 2014	1 (6g pellets)	1 (6g RS5 pellets, 8 days later)	1415WMK01
100%	Eglinton Valley BfoB, Dec 2014	1 (6g pellets)	1 (12g RS5 pellets, 48 days later)	1314TEA05
100%	Blue Mountains BfoB, Dec 2014	1 (6g pellets)	1.5 (6g RS5 pellets, 25 days later)	1314MRH03
100%	Abbey Rocks, Nov 2014	1 (6g pellets)	1 (6g RS5 pellets, 13 days later)	1314SWS06
100%	Landsborough/Clark BfoB, Nov 2014	1 (6g pellets)	1 (6g RS5 pellets, 15 days later)	1314SWS04
87.2%	Tennyson Inlet Reserve - Mt Stanley BfoB, Nov 2014	1 (6g pellets)	1 (6g RS5 pellets, 44 days later)	1314SND03
100%	Catlins BfoB, Nov 2014	1 (6g pellets)	1.1 (6g RS5 pellets, 15 days later)	1415MRH01
100%	Oparara BfoB Kahurangi NP, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 22 days later)	1415GDB04

77.1%	Pukaha Mt Bruce, Nov 2014	1 (6g pellets)	1 (6g RS5 pellets, 16 days later)	1415WRP04
100%	Mataraua/Waipoua, Nov 2014	1 (6g pellets)	2 (12g #7 pellets, 25 days later)	1415KAU02
96.2%	Cobb BfoB, Kahurangi NP, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 24 days later)	1415GDB02
100%	Lower Holyford BfoB, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 38 days later)	1314TEA06
100%	Clinton BfoB, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 24 days later) some EDR deer repellent used	1415TEA02
98.8%	Anatoki BfoB Kahurangi NP, Oct 2014	1 (6g pellets)	1 (6g RS5 pellets, 16 days later)	1415GDB01
60.9%	Goulard BfoB Kahurangi NP, Oct 2014	1 (6g pellets)	2 (12g RS5 pellets, 14 days later)	1314GDB01
77.5% Gibbs	Wangapeka BfoB Kahurangi NP, Oct 2014	1 (6g pellets)	1 (6g RS5 pellets, 14 days later)	1415MOT05
73.3% Fyfe	Wangapeka BfoB Kahurangi NP, Oct 2014	1 (6g pellets)	2 (12g RS5 pellets, 14 days later)	1415MOT05
38.8%	Te Maruia North BfoB Oct 2014	1 (6g pellets)	1 (6g RS5 pellets, 24 days later)	1314GRY03
100%	Iris Burn BfoB, Sept 2014	1 (6g pellets)	2 (12g RS5 pellets, 8 days later)	1415TEA01
100%	Kia Wharite - Matemateaonga & Waitotara, Sept 2014	0.5 (8g pellets)	0.5 (8g RS5 pellets, 9 days later)	1415WHA01
100%	Waitutu BfoB, Aug 2014	1 (12g pellets)	2 (12g RS5 pellets, 6 days later)	1314TEA07

96.8%	Waikaia BfoB Aug 2014	1 (6g pellets)	1 (6g RS5 pellets, 7 days later)	1314MRHo2
97.3%	Abel Tasman BfoB, Aug 2014	1 (6g pellets)	2 (12g RS5 pellets, 7 days later)	1415MOT01
91.7%	Tongariro Forest, Aug 2014	0.75 (6g pellets)	0.75 (6g RS5 pellets, 9 days later)	1415RUA01
91.7%	Dart, Routeburn, Caples BfoB, Aug 2014	1 (6g pellets)	1 (6g RS5 pellets, 5 days later)	1415WAK01
64.6%	Te Kauri, Pirongia FP, Aug 2014	2 (6g pellets)	2 (12g RS5 pellets, 30 days later)	1415WAI02
100%	Project Kaka, Tararua, Dec 2013	1 (6g pellets)	1 (12g #7 pellets, 10 days later)	1314WRP02
100%	Mataketake block 2, Haast, Nov 2013	1 (6g pellets)	2 (12g RS5 pellets, 11 days later)	1314SWS
100%	Mataketake block 5, Haast, Nov 2013	1 (6g pellets)	2 (12g RS5 pellets, 11 days later)	1314SWS
70.1%	Whitecliffs/Parininihi, Nov 2013	1 (8g pellets)	2 (12g #7 pellets, 47 days later)	1314TAR09
100%	Tennyson Inlet Reserve - Mt Stanley, Nov 2013	1 (6g pellets)	1 (6g RS5 pellets, 13 days later)	1314SND02
92.8% - 100%	Catlins Maclellan Forest, Aug 2013	0.75 (6g pellets)	1 (12g RS5 pellets, 9 days later)	1314COT02
97.5%	Moehau, Jun 2013	2 (12g pellets)	2 (12g #7 pellets, Orange lure, 6 days later)	1314HAU01
100%	Hawdon Valley, Athurs Pass NP, Dec 2013	1 (6g pellets)	2 (12g RS5 pellets, 15 days later)	1213WMK02

100%	Lewis Pass – Station Creek, Nov 2012	1 (6g pellets)	1 (6g RS5 pellets, 7 days later)	1213GRY02
95.8%	Tongariro Forest, Sept 2011	1.5 (6g pellets)	2 (12g #7 pellets, Orange lure+EDR, & cinnamon 20 days later)	1112RUA02
98.2%	Waipoua Forest, Sept 2011	1 (6g pellets)	2 (12g #7 pellets, 22 days later)	1112KAU01
97.3%	Waihaha Ecological Area, May 2011	1.5 (12g pellets)	1.5 (12g #7 pellets, Orange lure, 19 days later)	1112MPT05
94.7%	Project Kaka, Tararua, Nov 2010	1.4 (6g pellets)	2 (12g #7 pellets, 16 days later)	11011PON20

Table 46. The percentage rat kill for aerial operations using 0.08% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
100%	Whakapohai E, Jan 2007	5 (6g baits)	2 (12g #7 pellets, 5 days later)	J Kemp pers. comm.
12%	Station Creek A Trial, Jul 2006	-	5 (12g #7 pellets, 5 days later)	J Kemp pers. comm.
96.3%	Station Creek B Trial, Jul 2006	2 (12g pellets)	5 (12g #7 pellets, 7 days later)	J Kemp pers. comm.
<70%	Mapara, Oct 1992	-	8	Bradfield. (1993)
80%	Mapara, Oct 1991	-	8	Bradfield. (1993)
100%	Mapara, Sept 1990	-	8	Bradfield. (1993)

Handlaid 1080 cereal pellets

During the Rotoiti Battle for our Birds (BfoB) in December 2014 part of the operational area was handlaid with 0.15% 1080 pellets. The area was aerially prefed at 1 kg ha⁻¹ (6g pellets). 25 days later 6g RS5 toxic pellets were hand broadcast at 1 ha⁻¹. The operation achieved a 66.7% rat kill (Pestlink reference: 1415STA02).

A 61% rat kill was achieved at Beam Head, Northland, in October 2008 when 0.08% 1080 rodent pellets were laid in clusters 50 metres apart along an existing track system. The operational area was prefed at a rate of 1 kg ha⁻¹ and 30 days later the toxic bait was laid at a rate of 0.8 kg ha⁻¹ (Pestlink reference: 0809WNG05).

1080 cereal pellets in bait stations

Table 47 contains the percentage rat kills for bait station operations using 0.15% 1080 cereal pellets.

Table 47. The percentage rat kill for 0.15% 1080 cereal pellets in bait stations.

Kill	Location	Method	Ref.
59.5%	Aislabies Block, Kaharoa, Sept 2012	Bait stations 100m apart along ridges/spurs. 1 prefeed (1500g per bait station), 1 toxic fill (500g bait per station)	1213ROTo2
30.4%	Mataraua, Jan 2010	120 x 100 m bait station grid, 1 prefeed (200g per bait station), 1 toxic fill (100g bait per station)	0910KAU04
91.3%	Mataraua, Oct 2009	120 x 100 m bait station grid, 2 prefeeds (1000g per bait station), 1 toxic fill (500g bait per station)	0910KAU04
97.0%	Opuia, Sept-Oct 2009	100 x 100 m bait station grid, 2 prefeeds (600g per bait station), 1 toxic fill (300g bait per station)	0800TAU01
91.2%	Waipapa East, Waipapa EA, Aug 2000	150 x 150 m bait station grid, 2 prefeeds, 1 toxic fill	Matthew et al. (2004)
87.7%	Waipapa North, Waipapa EA, Aug 2000	150 x 150 m bait station grid, 2 prefeeds, 1 toxic fill	Matthew et al. (2004)
85.5%	Waipapa South, Waipapa EA, Aug 2000	150 x 150 m bait station grid, 2 prefeeds, 1 toxic fill	Matthew et al. (2004)
100%	Trounson Kauri Park, Nov 1996	100 x 100 m bait station grid, 4 prefeeds, 1 toxic fill	Gillies et al. (2003)

Mice

Aerially distributed 1080 cereal pellets

The percentage mice kills obtained during aerial operations using 0.15% 1080 cereal pellets are presented in Table 48. Based on this data, the mean kill for prefeed operations is 78.3% (n=26). The percentage mouse kill for the aerial operations using 0.08% cereal pellets is presented in Table 49.

Table 48. The percentage mouse kill for aerial operations using 0.15% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
96.6%	East & West Matukituki BfoB, Oct 2017	1.5 (6g pellets)	1.5 (6g RS5 pellets, 9 days later)	1718CNO06
57.7%	Makarora-Wilkins BfoB, Feb 2017	1 (6g pellets)	1 (6g RS5 pellets, 7 days later)	1617CNO04
98.5%	South Branch Hurunui, Feb 2017	2 (6g pellets)	2 (6 g RS5 pellets, 10 days later)	1617WMK02
99.8%	Landsborough BfoB, Dec 2016	2 (6g pellets)	2 (6g RS5 pellets, 32 days later)	J. Kemp pers. comm, 1617SWS04
50% (est.)	Clinton BfoB, Oct 2016	1 (6g pellets)	1 (6g RS5 pellets, 26 days later)	J. Kemp pers. comm, 1617TEA04
100% (est.)	Arthur-Sinbad BfoB, Sept 2016	1 (6g pellets)	2 (12g RS5 pellets, 42 days later)	J. Kemp pers. comm, 1617TEA02
0% (est.)	Kepler BfoB, Sept 2016	1 (6g pellets)	2 (12g RS5 pellets, 12 days later)	J. Kemp pers. comm, 1617TEA03
97.3% (est.)	Abbey Rocks BfoB, Aug 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 12 days later)	J. Kemp pers. comm, 1617SWS02

0% (est.)	Eglington Valley BfoB, Oct 2016	1 (6g pellets)	2 (12g RS5 pellets, 25 days later)	J. Kemp pers. comm, 1617TEA05
60%	Beresford Range (Catlins) BFOB Dec 2016	1 (6g pellets)	1 (6g RS5 pellets, 41 days later)	1617MRH03
66%	Poulter Valley BfoB, Feb 2015	1.5 (6g pellets)	1.5 (6 g RS5 pellets, 6 days later)	1415WMK051
100%	Abbey Rocks, Nov 2014	1 (6g pellets)	1 (6 g RS5 pellets, 13 days later)	1314SWS06
81.1%	Matukituki BfoB Nov 2014	1 (6g pellets)	2 (12 g RS5 pellets, 26 days later)	1415WAN01
82.5%	Clinton BfoB, Nov 2014	2 (6g pellets)	2 (12 g RS5 pellets, 24 days later)	1415TEA02
100%	Catlins BfoB, Nov 2014	1 (6g pellets)	1.1 (6 g RS5 pellets, 15 days later)	1415MRH01
72.7%	Iris Burn BfoB, Sept 2014	1 (6g pellets)	2 (12 g RS5 pellets, 8 days later)	1415TEA01
50.0%	Dart, Routeburn, Caples BfoB, Aug 2014	1 (6g pellets)	1 (6 g RS5 pellets, 5 days later)	1415WAK01
92.0%	Waikaia BfoB Aug 2014	1 (6g pellets)	1 (6 g RS5 pellets, 7 days later)	1314MRH02
93.4%	Poulter Valley, Oct 2008	1 (6g pellets)	2 (6g #7 pellets, 17 days later)	J Kemp pers. comm.
100%	Pihanga, Nov 07	2 (12g pellets)	2 (12g #7 pellets, 8 days later)	J Kemp pers. comm.
86.2%	Parapara 07C Trial, May 2007	-	3 (12g RS5 pellets)	J Kemp pers. comm.
37.3%	Parapara 07D Trial, May 2007	-	3 (12g #7 pellets)	J Kemp pers. comm.

97.0%	Parapara 07A Trial, May 2007	3 (6g pellets)	3 (12g RS5 pellets, 43 days later)	J Kemp pers. comm.
92.0%	Parapara 07B Trial, May 2007	3 (6g pellets)	3 (12g #7 pellets, 43 days later)	J Kemp pers. comm.
100%	Whakapohai A, Jan 2007	5 (6g pellets)	2 (12g #7 pellets, 5 days later)	J Kemp pers. comm.
66.7%	Whakapohai B, Jan 2007	2 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	J Kemp pers. comm.
96.4%	Whakapohai C, Jan 2007	2 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	J Kemp pers. comm.
86.0%	Whakapohai D, Jan 2007	1 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	J Kemp pers. comm.

Table 49. The percentage mouse kill for aerial operations using 0.08% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
58%	Whakapohai E, Jan 2007	5 (6g pellets)	2 (12g #7 pellets, 5 days later)	J Kemp pers. comm.

1080 cereal pellets in bait stations

Table 50 contains the percentage mouse kills for bait station operations using 0.15% 1080 cereal pellets.

Table 50. The percentage mouse kill for 0.15% 1080 cereal pellets in bait stations.

Kill	Location	Method	Ref.
94%	Trounson Kauri Park, Nov 1996	100 x 100 m bait station grid, 4 prefeeds, 1 toxic fill	Gillies et al. (2003)

Rabbits

The majority of rabbit operations have operational targets based on the Modified Mclean Rabbit Infestation Scale. The Mclean Scale is not suitable for estimating

a percent kill because it is not linearly related to rabbit population density. However, during aerial 1080 carrot field trials by Landcare Research in Otago and Hawkes Bay between 2011 and 2014, based on pre- and post-control spotlight counts of rabbits, kills of greater than 90% were achieved. These operations were prefed twice and the toxic carrot was either broadcast or strip sown. The actual sowing rate varied depending on the pre-control estimate of rabbit density (Latham et al., 2015).

Wallabies

The percentage kill of wallabies using aerially distributed 1.5 g kg⁻¹ 1080 pellets is presented in Table 51, in Table 52 for 1.5 g kg⁻¹ 1080 carrots and in Table 53 for handlaid 5% and 10% 1080 gels.

Table 51. The percentage wallaby kill for aerially distributed 1.5 g kg⁻¹ 1080 pellets.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
96.9%	Rotoehu Forest, Sept 2017	1.5 (6g pellets)	2.5 (12g #7 pellets, 8 days later)	1718TAU01, & Commins (2017)

Table 52 The percentage wallaby kill for aerially distributed 1.5 g kg⁻¹ 1080 carrots.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
93.1%	Okataina SR, 1999 (Dama wallabies)	5	12	0304ROTo4

Table 53. The percentage wallaby kill for handlaid 5% and 10% 1080 gel.

Kill	Location	Method	Ref.
86.2%	Okataina SR, 1988 (Dama wallabies)	5-10 m x 50-100 m transects, 5 baited leaves/branch (5% 1080 gel)	Warburton (1990)
91.3%	Tasman Smith SR, Hunter hills, 1983 (Bennett's wallabies)	10 branches/ha, 25 baited leaves/branch (10% 1080 gel)	Warburton (1990)

Deer

The percentage kill of deer is presented in Table 54 for aerially distributed 1.5 g kg⁻¹ 1080 carrot is and in Table 55 for handlaid 10% 1080 gel.

Table 54. The percentage deer kill for aerially distributed 1.5 g kg⁻¹ 1080 carrots.

Kill	Location	Sowing Rate (kg ha ⁻¹)		Ref.
		Prefeed	Toxic	
92%	Titiraupunga, 1997	5	15	Fraser & Sweetapple (2000)
34%	Pureora, 1994	5	15	Fraser et al. (1995)
42%	Pureora, 1994	15	15	Fraser et al. (1995)

Table 55. The percentage deer kill for handlaid 10% 1080 gel.

Kill	Location	Method	Ref.
79%	Hauhangaroa Range, 1997	2 branches/ha, 10 baited leaves/branch	Sweetapple (1997)
80%+	Stewart Island, 1981	2.5 branches/ha, 20 baited leaves/branch	Nugent (1990)
100%	Stewart Island, 1981	5 branches/ha, 20 baited leaves/branch	Nugent (1990)

Goats

10% 1080 gel (100 g kg⁻¹ 1080), handlaid

The percentage kill of goats using handlaid 10% 1080 gel is presented in Table 56.

Table 56. The percentage kill of goats following the use of handlaid 10% 1080 gel.

Kill	Location	Method	Ref.
88%	Whitecliffs, Buller River, Jul 2007	2.2 branch/ha in preferred habitat, 10 - 20 baited leaves/branch	Anderson (2008)
87%	Motu River, Jan 1986	1 branch/ha in preferred habitat, 20 baited leaves/branch	Veltman & Parkes (2002)
97%	Motu River, March 1982	2.5 branches/ha, 20 baited leaves/branch	Parkes (1983)

Stoats (bykill)

Aerially distributed 1080 cereal pellets

The percentage by-kill of stoats during aerial 1080 operations is recorded in Table 57

Table 57. The percentage stoat bykill for aerial operations targetting rats, mice and possums with 0.15% 1080 cereal pellets.

Stoat Bykill	Location	Kill Of Target Pest			Ref.
		Possums	Rats	Mice	
100%	Rainbow Valley (OSPRI treatment) 2024		100%	93.8%	Griffin et al 2024
87.8%	Whirinaki Te Pua a Tane BfoB (EDR Block), Sept 2017		100%		1718WHK01
100%	Whirinaki Te Pua a Tane BfoB, Sept 2017		100%		1718WHK01
100%	Makarora-Wilkins BfoB, Feb 2017		100%	57.7%	1617CNO04
100%	Okarito South, Sept 2016		100%		1617SWS03
100%	Kia Wharite Project - Mangapurua Block, Whanganui, Oct 2015	66.7%	87.3%		1516WHA01
50.0%	Dart, Routeburn, Caples BfoB, Aug 2014		100%	100%	1314SWS06
100%	Catlins BfoB, Nov 2014		100%	100%	1415MRH01
100%	Tongariro Forest, Aug 2014		91.7%		1415RUA01
90%	Project Kaka, Tararuas, Dec 2013	63.6%	100%		1314WRP02
95.8%	Tongariro Forest, Sept 2011		95.8%		1112RUA02

Feral cats (bykill)

Aerially distributed 1080 cereal pellets

The percentage by-kill of feral cats during aerial 1080 operations is recorded in Table 58.

Table 58. The percentage feral cat bykill for aerial operations targetting rats, mice and possums with 0.15% 1080 cereal pellets.

Feral cat Bykill	Location	Kill Of Target Pest			Ref.
		Possums	Rats	Mice	
100%	Rainbow Valley (OSPRI treatment) 2024		100%	93.8%	Griffin et al 2024

7. Appendix 1

The efficacy data for possum and rat aerial 0.15% 1080 pellet operations that occurred before 2010 along with information about de-registered 1080 products (No Possums® 1080 gel) is stored in DOC-2534486.

8. Glossary of Terms

$\mu\text{g kg}^{-1}$, $\mu\text{g l}^{-1}$

See ppb.

$\mu\text{g g}^{-1}$, $\mu\text{g ml}^{-1}$

See ppm.

Absciss

Part of a plant breaking off naturally (e.g. leaves dying)

Aconitase

An enzyme occurring in many animal and plant tissues that accelerates the conversion of citric acid first into aconitic acid and then into isocitric acid.

Biological Exposure Index (BEI)

A reference value below which exposure to a substance will not create an unreasonable risk of disease or injury. BEIs are set by the American Conference of Governmental Industrial Hygienists (ACGIH).

Biosynthesis

The production of a chemical compound by a living organism.

b.w.

Body weight

Carcinogenic

The ability of a substance to cause cancer.

Citrate

A salt or ester of citric acid.

Cyanosis

Blueness of the skin and mucous membrane due to insufficient oxygen in the blood.

Defluorination

To remove fluorine

Endocardium

The lining of the interior surface of the heart chambers. The endocardium consists of a layer of endothelial cells and an underlying layer of connective tissue. a thin serous membrane lining the cavities of the heart.

Epicardium

The inner layer of the pericardium, a conical sac of fibrous tissue that surrounds the heart and the roots of the great blood vessels / the visceral part of the pericardium that closely envelops the heart

Epiglottis

The flap that covers the trachea during swallowing so that food does not enter the lungs.

Fluorocitrate

The toxic metabolite of fluoroacetate that causes inhibition of aconitase.

Gastrointestinal tract

The stomach and intestine as a functional unit

Glial cells

A supportive cell in the central nervous system. Glial cells do not conduct electrical impulses (as opposed to neurons, which do). The glial cells surround neurons and provide support for them and insulation between them.

Half-life

During each half life ($t_{1/2}$ or elimination half-life) 50% of the pesticide in the body at the beginning of that half-life is eliminated. The half-life is established in laboratory trials, and is used to predict the rate of elimination of a single dose of pesticide from the body and to estimate how long the disappearance of cumulative intakes of a pesticide from the body would take.

Hypotension

Abnormally low pressure of the blood -- called also low blood pressure

Intravenous

Administered into a vein.

LC₅₀

Lethal Concentration 50%. The calculated concentration of a gas/liquid that kills 50% of the test organisms

LD₅₀

Lethal Dose 50%. The estimated dose that kills 50% of the test organisms.

LOEL

Least Observable Effect Level. The lowest dose in a study in which there was an observed toxic or adverse effect

MLD

Minimum Lethal Dose. The smallest amount of a toxin required to kill and individual.

Mitochondrial aconitate hydratase

An iron-dependent enzyme that catalyzes conversion of citrate to cis-aconitate in the tricarboxylic acid cycle within the mitochondrion.

Metabolites

The breakdown of compounds resulting from the metabolism of a parent compound.

mg kg⁻¹, mg l⁻¹

See ppm.

mmol (mM)

millimole: a unit of metric measurement that is equal to one thousandth (10⁻³) of a mole. It is the amount of a substance that corresponds to its formula mass in milligrams. [mol l⁻¹] $\times$ [mL] = mmol.

Mutagenic

The ability of a substance to cause damage to DNA and produce alterations or loss of genes or chromosomes

NOEL

No Observable Effect Level. A dosage of a toxicant that fails to produce any discernible signs of toxicosis, which may include a lack of morphological, biochemical, or physiological change

Non-saponifiable lipids

Non-polar compounds that cannot be broken down by a simple hydrolytic reaction. They include steroids and hormones.

Oral

Given or taken through or by way of the mouth, as in an oral solution.

Phosphofructokinase

An enzyme that functions in carbohydrate metabolism and especially in glycolysis by catalysing the transfer of a second phosphate to fructose.

ppb

parts per billion. This concentration unit is equivalent to 1 μ g l⁻¹ in water (solution) or air and 1 μ g kg⁻¹ in solid samples (soil/sediments/biological tissue).

ppm

parts per million. This concentration unit is equivalent to 1 mg l⁻¹ (or μ g ml⁻¹) in water (i.e. solutions) or air and 1 mg kg⁻¹ (or μ g g⁻¹) in solid samples (i.e. soil/sediments/biological tissue).

Succinate dehydrogenase

An iron-containing flavoprotein enzyme that catalyses, often reversibly, the dehydrogenation of succinic acid to fumaric acid in the presence of a hydrogen acceptor and that is widely distributed especially in animal tissues, bacteria, and yeast -- called also succinic dehydrogenase.

Subepicardial

Under the serious membrane which covers the heart situated or occurring beneath the epicardium or between the epicardium and myocardium.

Teratogen

A compound that causes birth defects in a developing foetus.

Toxicosis

A pathological condition caused by the action of a poison or toxin.

Toxin

A natural occurring poison, e.g. 1080, cyanide.

Toxicant

A synthetic man-made poison, e.g. brodifacoum.

Trachea

The tube-like portion of the respiratory tract that connects the "voice box" (larynx) with the bronchial parts of the lungs. called also windpipe.

Tricarboxylic acid cycle

A sequence of reactions in the living organism in which oxidation of acetic acid or acetyl equivalent provides energy for storage in phosphate bonds - called also citric acid cycle, Krebs cycle.

Threshold Limit Values (TLV)

Recommended values for the highest level of exposure to airborne chemical concentrations in the workplace that does not produce adverse health effects. They are set by the American Conference of Governmental Industrial Hygienists (ACGIH).

Viscera

Body organs.

VPRD

Vertebrate Pesticide Residue Database. ([DOCDM-32812](#))

9. Common and Scientific Names of Species

Amphibians

Archeys frog	<i>Leiopelma archeyi</i>
American Bullfrog	<i>Rana catesbeiana</i>
Hochstetters frogs	<i>Leiopelma hochstetteri</i>
Leopard frog	<i>Rana pipiens</i>
South African clawed frog	<i>Xenopus laevis</i>
Spotted grass frog	<i>Limnodynastes tasmaniensis</i>

Aquatic invertebrates/Crustaceans

NZ cockle	<i>Austrovenus stutchburyi</i>
Daphnia	<i>Daphnia magna</i>
Koura	<i>Paranephrops planifrons</i>
Mussel (freshwater)	<i>Echyridella menziesii</i>
Mussel (green lipped marine)	<i>Perna canaliculus</i>

Birds

Australasian harrier	<i>Circus approximans</i>
Bellbird	<i>Anthornis melanura</i>
Blackbird	<i>Turdus merula</i>
Chaffinch	<i>Fringilla coelebs</i>
Chicken	<i>Gallus gallus</i>
Whio (Blue duck)	<i>Hymenolaimus malacorhynchos</i>
Duck (Grey)	<i>Anas superciliosa</i>
Duck (Mallard)	<i>Anas platyrhynchos</i>
Duck (Maned)	<i>Chenonetta jubatta</i>
Fantail	<i>Rhipidura fuliginosa</i>
Fernbird	<i>Bowdleria punctata</i>
European goldfinch	<i>Carduelis carduelis</i>
Grey warbler	<i>Gerygone igata</i>
Kaka	<i>Nestor meridionalis</i>

Kakariki	<i>Cyanoramphus</i> sp.
Kea	<i>Nestor notabilis</i>
Kereru / kukupa	<i>Hemiphaga novaeseelandiae</i>
Kiwi (Haast tokoeka)	<i>Apteryx australis</i> 'Haast'
Kiwi (NI brown)	<i>Apteryx mantelli</i>
Kiwi (Little spotted)	<i>Apteryx owenii</i>
Kiwi (Rowi)	<i>Apteryx rowi</i>
Kiwi (Great spotted)	<i>Apteryx haastii</i>
Kokako (NI)	<i>Callaeas cinerea wilsoni</i>
Magpie (Australian)	<i>Gymnorhina tibicen</i>
Magpie (Eurasian)	<i>Pica pica</i>
Morepork/ruru	<i>Ninox novaeseelandiae</i>
N.Z. Falcon	<i>Falco novaeseelandiae</i>
partridge (Chukar)	<i>Alectoris graeca</i>
Pheasant (Ring-necked)	<i>Phasianus colchicus</i>
Common pigeon	<i>Columba livia</i>
Quail (California)	<i>Callipepla californica</i>
Rifleman	<i>Acanthisitta chloris</i>
Robin (North Island)	<i>Petroica australis longipes</i>
Robin (South Island)	<i>Petroica australis australis</i>
Silvereye	<i>Zosterops lateralis</i>
Sparrow (Hedge)	<i>Prunella modularis</i>
Sparrow (House)	<i>Passer domesticus</i>
starlings	<i>Sturnus vulgaris</i>
Tomtit (NI)	<i>Petroica macrocephala toitoi</i>
Tomtit (SI)	<i>Petroica macrocephala macrocephala</i>
Tui	<i>Prosthemadera novaeseelandiae</i>
Weka	<i>Gallirallus australis</i>

Eutherian mammals

Bat (Short-tailed)	<i>Mystacina tuberculata</i>
Cat	<i>Felis catus</i>

Cattle	<i>Bos taurus</i>
Deer (red)	<i>Cervus elephus</i>
Deer (fallow)	<i>Dama dama</i>
Deer (mule)	<i>Odocoileus hemionus</i>
Deer (sika)	<i>Cervus nippon</i>
Dog	<i>Canis familiaris</i>
Ferret	<i>Mustela furo/ Mustela putorius</i>
Goat	<i>Capra hircus</i>
Horse	<i>Equus caballus</i>
Mink	<i>Mustela vison</i>
House mouse	<i>Mus musculus</i>
Pig	<i>Sus scrofa</i>
Rabbit	<i>Oryctolagus c. cuniculus</i>
Rat (Laboratory/Norway)	<i>Rattus norvegicus</i>
Rat (Ship/Brown)	<i>Rattus rattus</i>
Sheep	<i>Ovis aries</i>
Stoat	

Fish

longfin eels	<i>Anguilla dieffenbachia</i>
koaro	<i>Galaxias brevipinnis</i>
Harlequin fish	<i>Rasbora heteromorpha</i>
upland bullies	<i>Gobiomorphus breviceps</i>
Bluegill sunfish	<i>Lepomis macrochirus</i>
Trout (Rainbow)	<i>Oncorhynchus mykiss</i>

Marsupial mammals

Brushtail possum	<i>Trichosurus vulpecula</i>
Wallaby (Bennett's)	<i>Macropus rufogriseus</i>
Wallaby (Dama)	<i>Macropus eugenii</i>

Reptiles

Blotched blue-tongued lizard	<i>Tiliqua nigrolutea</i>
Common Skinks	<i>Oligosoma nigriplantare</i>
Gould's monitor	<i>Varanus gouldi</i>
Grand skink	<i>Oligosoma grande</i>
MacCann's skink	<i>Oligosoma maccanni</i>
Otago skink	<i>O. otagense</i>
Shingle-back lizard	<i>Tiliqua rugosa</i>

Terrestrial invertebrates

Cockroaches	<i>Blattidae</i>
Compost worms	<i>Eisenia fetida</i>
Honeybees	<i>Apis mellifera</i>
Housefly	<i>Musca domestica</i>
Leaf-veined slugs	<i>Athoracophorus bitentaculatus</i>
Wasp	<i>Vespula spp.</i>
Weta (bush)	<i>Hemideina broughi</i>
Weta (Cave)	<i>Pharmacus sp. and Isoplectron sp.</i>
Weta (tree)	<i>Hemideina spp.</i>
Weta (Auckland tree)	<i>Hemideina thoracica</i>
Weta (Wellington tree)	<i>Hemideina crassidens</i>

Plants

Broad bean	<i>Vicia faba</i>
box poison	<i>Gastrolobium parviflorum</i>
cabbage	<i>Brassica oleracea</i>
gifblaar	<i>Dichapetalum cymosum</i>
heart-leaf poison	<i>Gastrolobium bilobum</i>
kāpuka (New Zealand broadleaf)	<i>Griselinia littoralis</i>
kāramuramu	<i>Coprosma robusta</i>
lettuce	<i>Lactuca sativa</i>
Mahoe	<i>Melicytus ramiflorus</i>

peanut	<i>Archis hypogaeae</i>
perennial ryegrass	<i>Lolium perenne</i>
puha	<i>Sonchus</i> spp.
pikopiko	<i>Asplenium bulbiferum</i>
rat weed	<i>Palicourea margravii</i>
ratsbane	<i>Dichapetalum toxicarium</i>
sugar cane	<i>Saccharum</i> spp.

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1998 - 2025 Progress Report

Benefits of long-term predator control for forest bird populations in the Landsborough Valley, South Westland

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Terrestrial Biodiversity Unit, Department of Conservation, Christchurch
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Department of
Conservation
Te Papa Atawhai

**Te Kāwanatanga
o Aotearoa**
New Zealand Government

Summary

1. Long-term responses of forest bird populations to sustained use of aerial 1080, in conjunction with trapping, have been measured in the Landsborough Valley consistently over 28 years (since 1998).
2. This report briefly summarises the latest bird count trends following the November 2024 and 2025 monitoring sessions, which reflect management operations during the previous 12 months of each session.
3. Without effective predator control, all indigenous species were predicted to decline, and mohua were predicted to be locally extinct by now.
4. Mohua, the primary indicator of forest bird recovery, increased until 2023. The population then declined in 2024 following the late delivery of a mast-driven 1080 operation. In 2023, 479 mohua were counted in the c.350 ha study area, a drop down to 2010 levels. They recovered somewhat during 2025 to 2018 levels. Despite declines, mohua remain the most frequently counted species on the counts. At their lowest, there were only c.14 mohua left in that area (1991).
5. Upward trends in counts have been recorded for numerous species, although recovery has been gradual and long-term. Five species (mohua, brown creeper, fantail, kākā, yellow-crowned kākāriki) continue to project overall increases, whereas declines were more noticeable over the last two counts for five species that were mostly increasing previously (bellbird, tūī, rifleman, grey warbler, tomtit).
6. Counts for kea, NZ falcon, kererū, long-tailed cuckoo and shining cuckoo have remained low and more-or-less stable. Silvereyes and introduced birds generally have declined steadily through the monitoring period.
7. Overall, the number of indigenous birds have doubled since predator control commenced and appear to continue to increase despite recent declines in counts over the last two monitoring sessions.

Background

- i. Predator induced declines in forest birds are well documented in New Zealand.
- ii. The Landsborough Valley has one of the best remaining bird faunas in Westland, but it was suffering steady declines following predator irruptions in years following heavy beech seeding.
- iii. Predator control consisting of valley-wide stoat traps and periodic aerial 1080 drops to control possums and rats commenced in the late 1990s.
- iv. The response of the forest bird community to ongoing pest control has been monitored intensively since 1998, with occasional monitoring efforts since 1985.
- v. Mohua and kākā are the primary indicators of success of predator control operations in the valley. Mohua are vulnerable to impacts of rats and stoats and the species was predicted to go extinct without management, while kākā are vulnerable to possums and stoats.

- vi. The Landsborough bird count dataset is the Department of Conservation's longest dataset monitoring bird populations through repeated aerial 1080 drops. The value of long-term monitoring at this site is a showcase for demonstrating how native species and ecosystems can recover resulting from sustained predator control. We communicate the results widely through regular media stories, DOC's digital channels (website, social media) and the National Predator Control Programme annual report.

Purpose of the project

To measure the long-term responses of indigenous forest birds to sustained use of aerial 1080 in conjunction with trapping in the Landsborough Valley.

Methods

Pest control: Introduced mammalian pests have been controlled at the Landsborough since late 1994. Three techniques have been used: best practice trapping aimed at stoats; ground control (trapping and poisoning) aimed at brushtail possums; and aerial bait application using baits impregnated with the toxin sodium monoflouroacetate (1080) aimed at possums and, from 2009, rats and (through secondary poisoning) stoats.

Since formal bird counts commenced in the study area in 1998, consistent methods of pest control have been applied. Aerial applications of 1080-laced baits have been undertaken, largely following beech masts, in winter 1998 (7,340 ha), winter 2000 (3,750 ha), Spring 2004 (16,420 ha) spring 2009 (12,170 ha), winter 2014 (25,533 ha), winter 2016 (28,283 ha), spring 2019 (46,758 ha), spring 2024 (33,695 ha) and spring 2025 (54,521 ha).

Bird monitoring: Initially, bird monitoring involved recording how frequently birds occurred along 1-km line transects. However, we found that this method didn't provide enough power to detect changes in relative abundance, so we changed to a more intensive method involving point counts in 1998. From then on, standardised unbounded five minute point counts (Dawson 1981) have been undertaken annually (but excluding 1999–2001 and 2019 due to bad weather).

Counts are undertaken over 2-3 consecutive days by a team of 3 expert bird counters. All bird species seen and heard within 5-minute periods are counted at 112 stations. Counts were carried out between 0900 and 1500 h to avoid times of the day when conspicuousness of birds is most variable (dawn and dusk). Stations are at c.200-m intervals along a transect through habitats representative of the valley. The transect follows the forest edge from McKerrow Creek down to Fraser Creek, then turns inland and runs back up the valley, parallel with the edge but 200–500 m into the forest. One count per station was conducted, except for the central 65 stations, which were counted twice on each occasion (n = 177 counts).

Bird count analysis: **Graphs presented in this report are preliminary**, with trend lines derived from 3rd-order polynomial regression analyses aimed at visualising broad trends in the bird counts. Low-order polynomial regressions are suitable for describing non-linear trends in bird populations, which are apparent from exploratory data analysis. Final trend analyses will be more comprehensive and account for the influence of other influencing factors (e.g., weather).

O'Donnell & Hoare (2012) summarised and published the trends after the initial 12 years of monitoring (to 2009). In this analysis they averaged count data across stations within each year. Using linear modelling, they assessed linear population trends for each species. Models contained log-transformed mean counts as the response variable and year as the predictor variable were used in the published analysis.

Previous summary reports

Project report 2009: O'Donnell & Hoare (2012), NZ Journal of Ecology 36: 131-140¹.

Project report 2017: DOC-5510265.

Project report 2019: DOC-5729267.

Project report 2023: DOC-7635383.

Data

DOC File DOCDM-562615.

Results 2024-2025

Overall, the numbers of indigenous birds counted doubled over 26 years, then declined slightly over the last two monitoring sessions (Figure 1). Recent declines likely reflect the late delivery the 1080 operation following the 2023 beech mast, meaning that birds had reduced protection from predators from much of the 2024-2025 breeding season. Increases in indigenous species contrast with a steady decline in numbers of introduced species (Figure 2).

Mohua, the primary indicator of bird population recovery from predators, have increased overall since predator control commenced (Figure 3) and appear to have recovered from previous mast-driven population crashes, when there were only c.14 mohua left in the study area (1991).

In 2024, 359 mohua were counted, a large drop compared to 479 during the previous year and coinciding with the late delivery the 1080 operation post the 2023 beech mast. The number increased again to 433 in 2025, bringing the count up to a similar level similar to that recorded in 2018. Despite these drops, mohua continue to be the most frequently counted forest bird species on the counts.

Mohua and other species numbers dropped markedly following an unmanaged rat plague in 2010, and it took 7 years for numbers to recover from that population crash (Figure 3). In

¹ O'Donnell CFJ; Hoare J.M. 2012. Quantifying the benefits of long-term integrated pest control for forest bird populations in a New Zealand temperate rainforest. New Zealand Journal of Ecology 36: 131-140. **Link:** <http://newzealandecology.org/nzje/3022.pdf> or https://www.researchgate.net/publication/262565385_Quantifying_the_benefits_of_long-term_integrated_pest_control_for_forest_bird_populations_in_a_New_Zealand_temperate_rainforest_New_Zealand

contrast, even late delivery of the 1080 operation likely still benefitted mohua and other forest bird species, as noted by moderate recovery in count number during the 2025 count session.

Overall, upward trends in average numbers counted per five minutes have been recorded for 9 species up until 2023 (mohua, bellbird, brown creeper, fantail, tūi, rifleman, grey warbler, kākā, yellow-crowned kākāriki). Five of these maintained upward trends to 2025 (mohua, brown creeper, rifleman, kākā, and kākāriki; Figures 3 – 7). However, the remaining four species indicated apparent declines over the last two years following the last beech mast (bellbird, tūi, rifleman, grey warbler; Figures 8 - 11). In addition, tomtits also signalled a decline in the counts after fluctuating for many years (Figure 12).

Counts for kea, shining cuckoo, NZ falcon and kererū have remained low but apparently stable (or, if increasing, are doing so at a very slow rate) (Figures 13 – 16). Long-tailed cuckoo appears to be in a similar category. Shorter-time trend analyses indicated that the population was declining, but when adding recent counts it appears that counts have stabilised, albeit at a very low level (Figure 17).

All species were predicted to decline if predator control was ineffective (based on other studies). Species such as kākā, kea and kererū are highly mobile, moving among different food sources at landscape scales much larger than the Landsborough Valley. Therefore, they are still subject to threatening pressures at times of the year when they are outside of the valley.

Counts for silvereye are still declining (Figures 18). The reasons for this are unknown, however, the dramatic increase in larger, more aggressive honeyeaters (tūi, bellbird) may signal that silvereye are being outcompeted.

Figure 1 - Total indigenous birds - Landsborough Valley

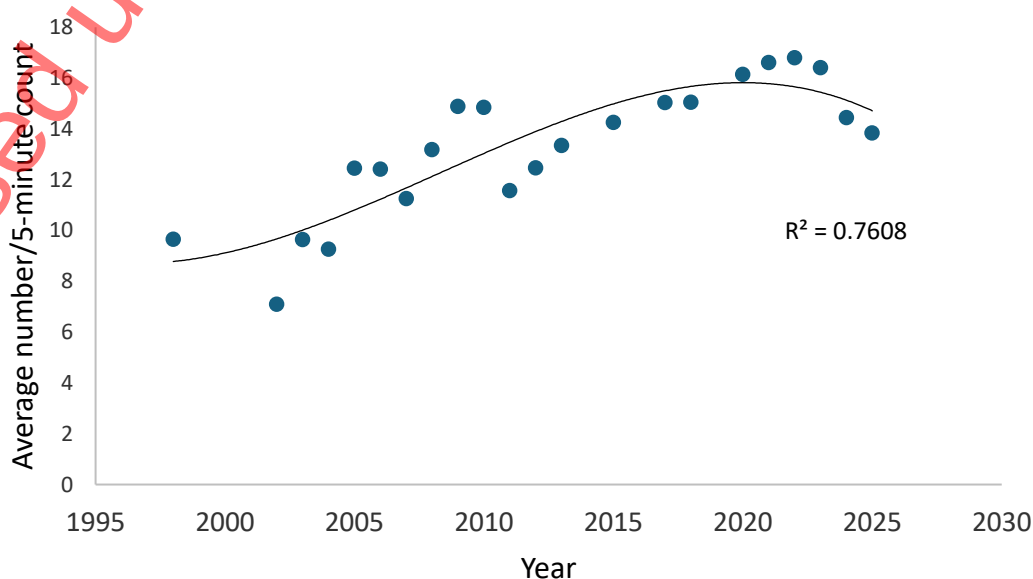


Figure 2 - Total introduced birds -Landsborough Valley

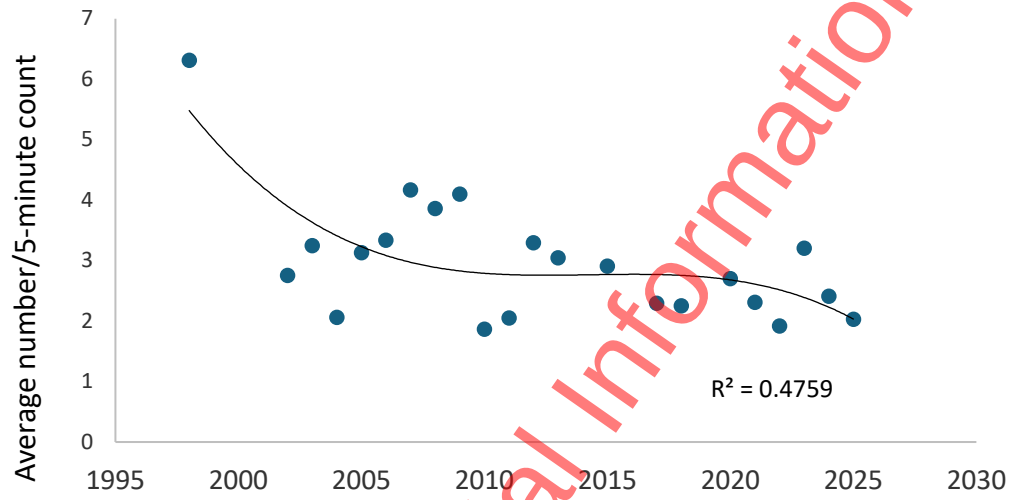


Figure 3 - Mohua trends - Landsborough Valley

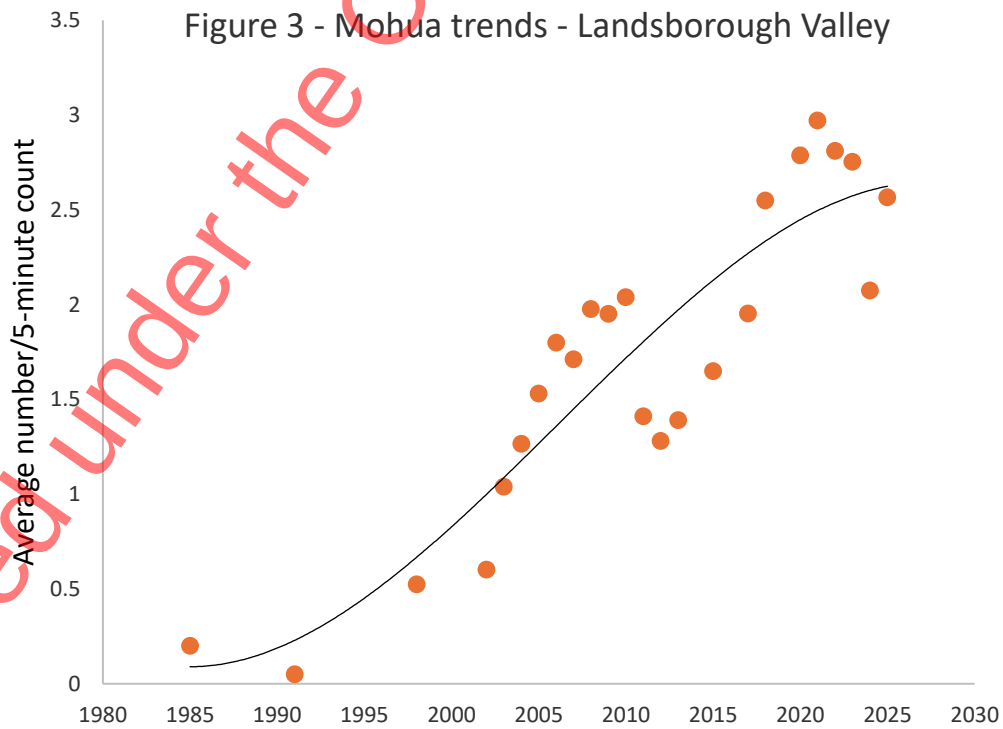


Figure 4 - Brown creeper trends - Landsborough Valley

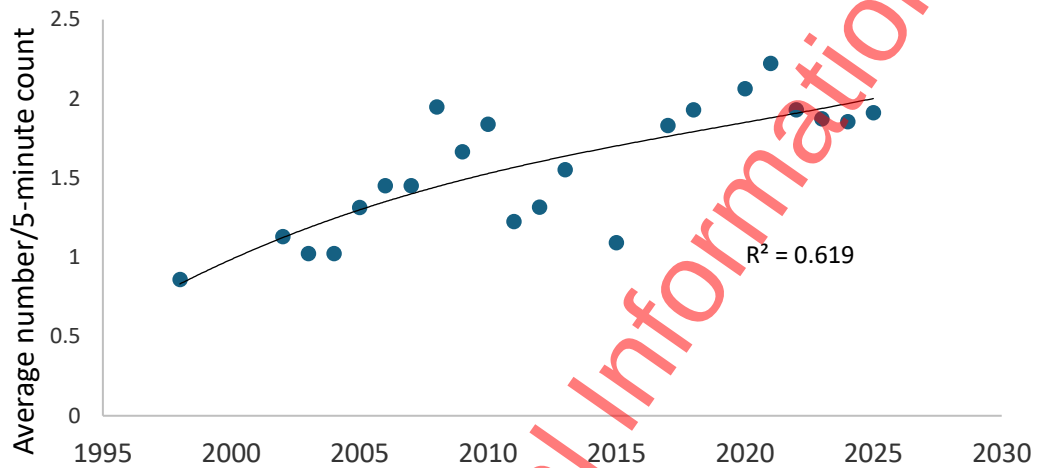


Figure 5 - Fantail trends - Landsborough Valley

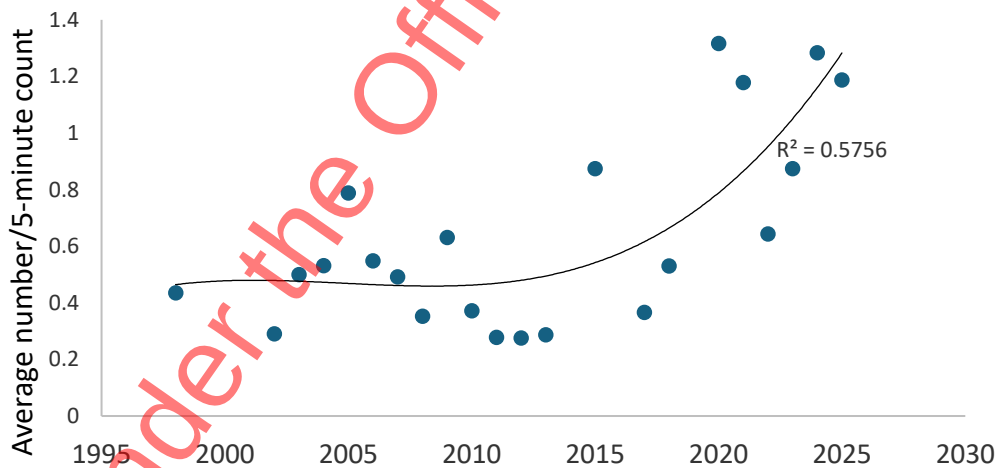


Figure 6 - Kākā trends - Landsborough Valley

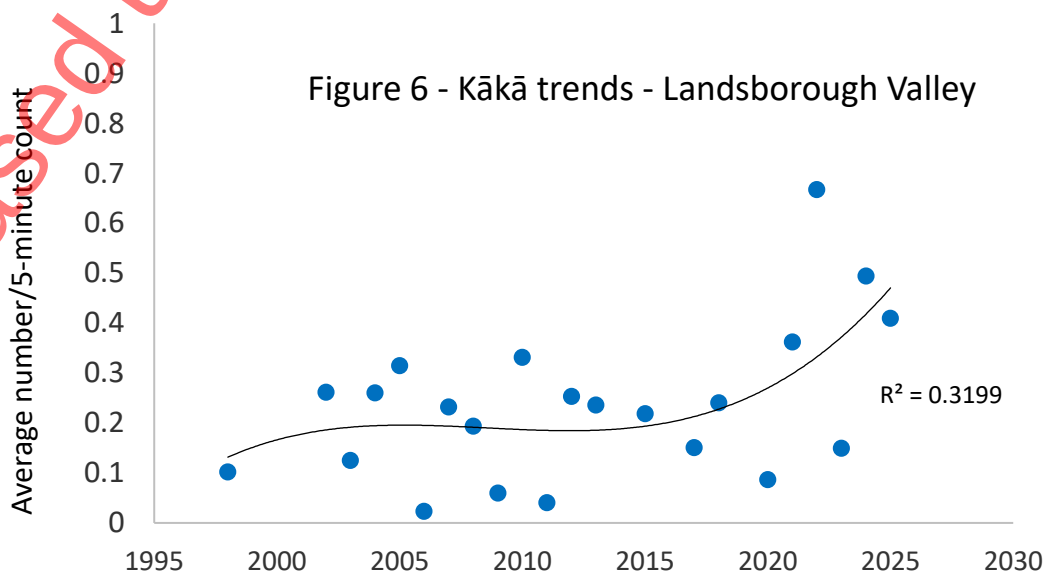


Figure 7. Kākāriki trends - Landsborough Valley

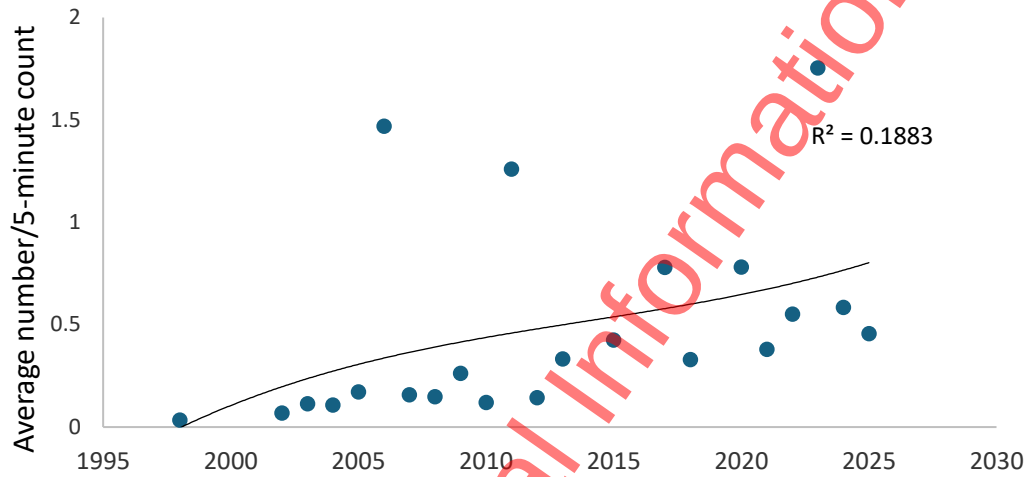


Figure 8 - Bellbird trends - Landsborough Valley

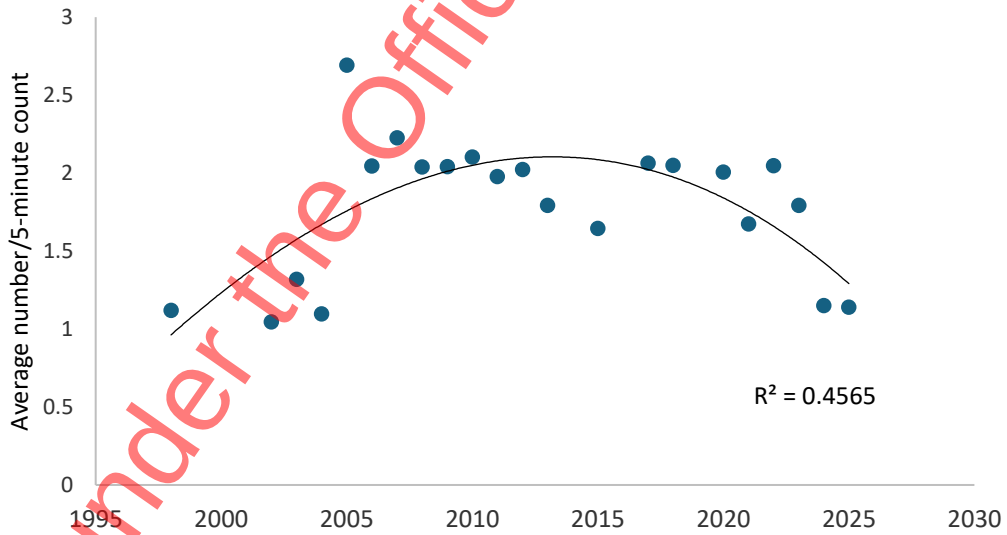


Figure 9 - Tui trends - Landsborough Valley

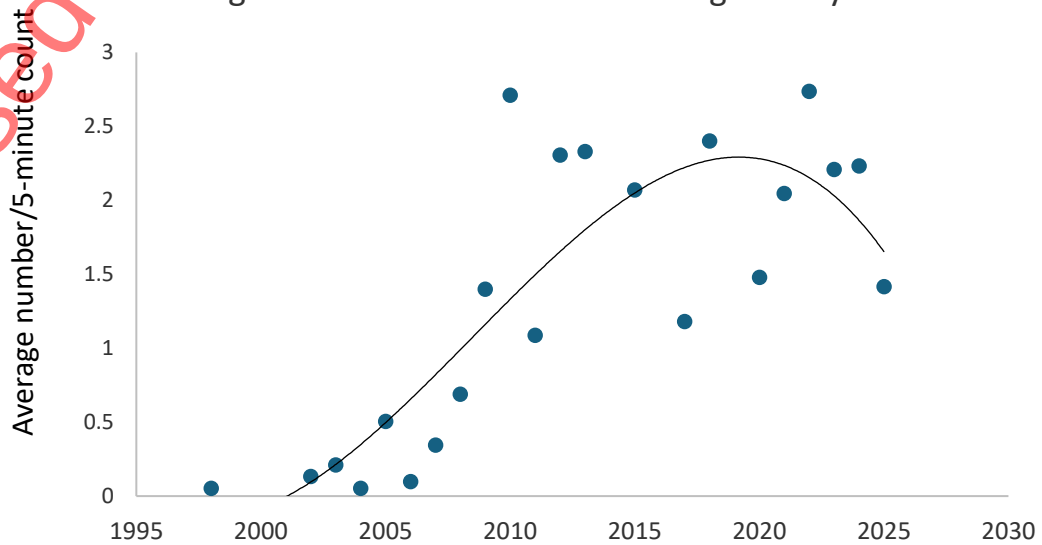


Figure 10. Rifleman trends - Landsborough Valley

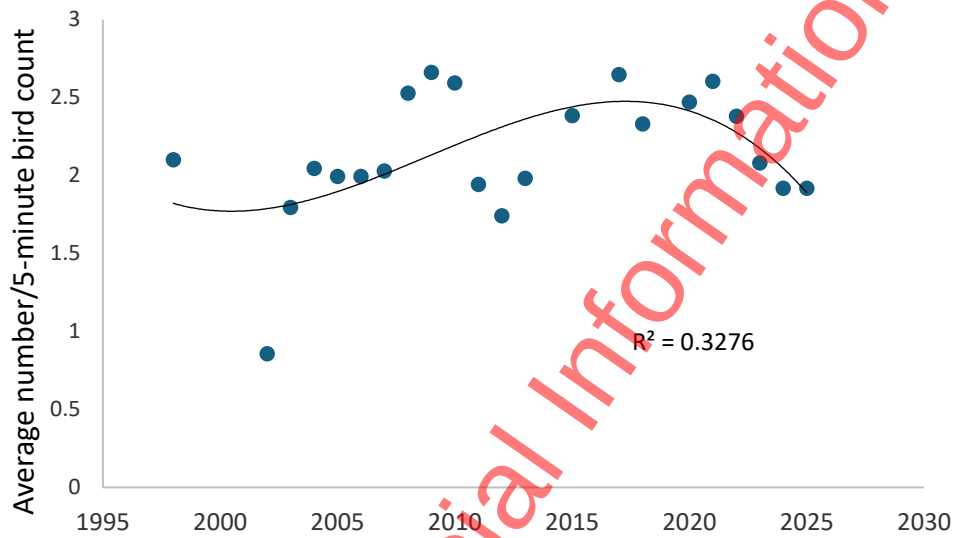


Figure 11 - Grey warbler trends - Landsborough Valley

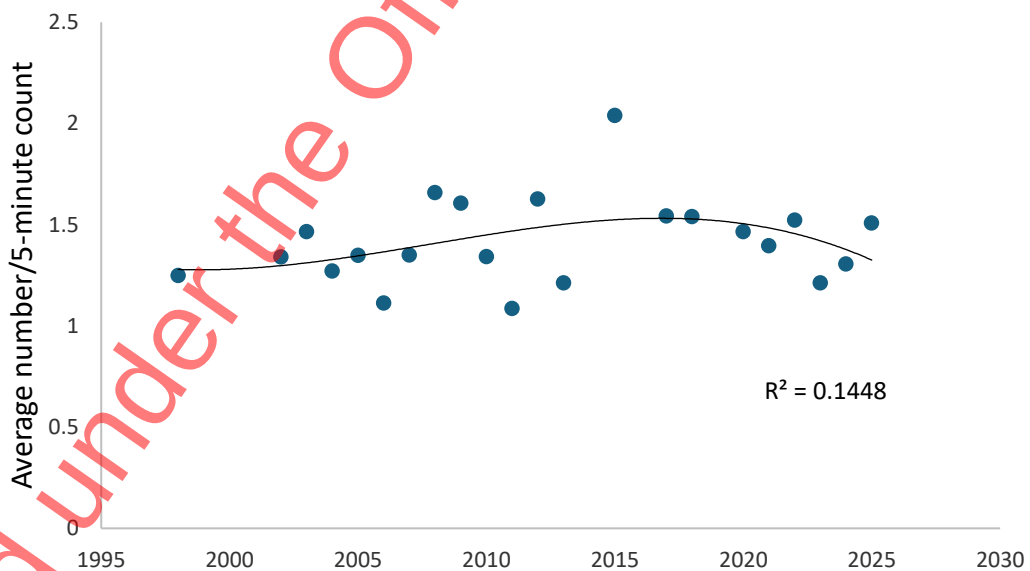


Figure 12 - Tomtit trends - Landsborough Valley

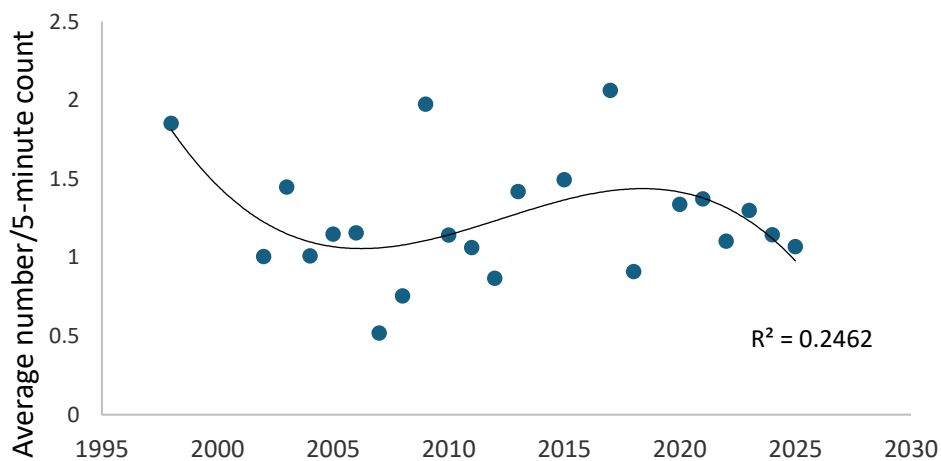


Figure 13 - Kea trends - Landsborough Valley

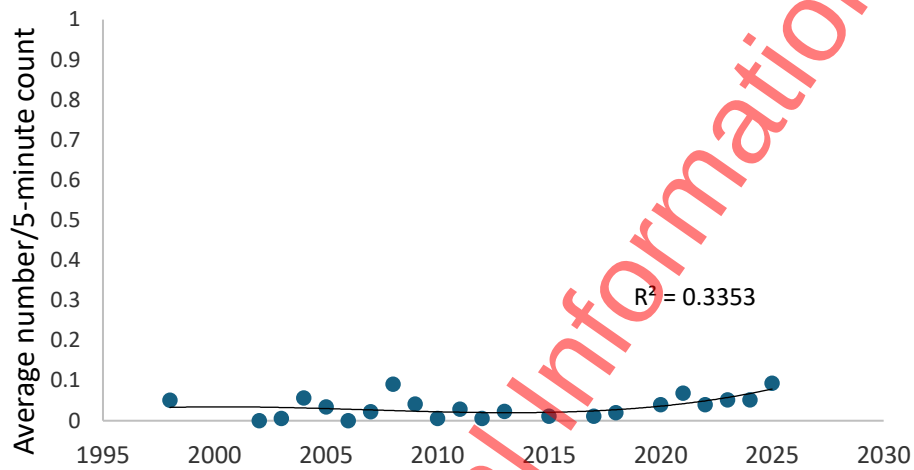


Figure 14. Shining cuckoo trends - Landsborough Valley

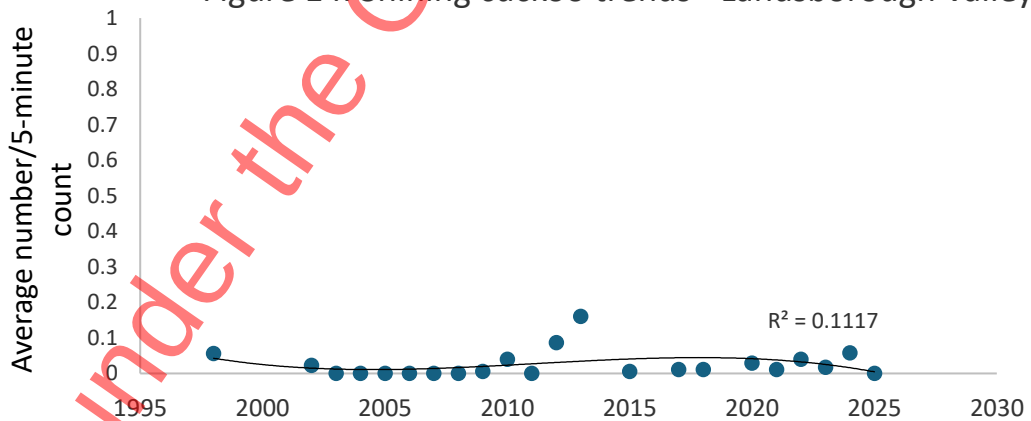


Figure 15 - NZ Falcon trends - Landsborough Valley

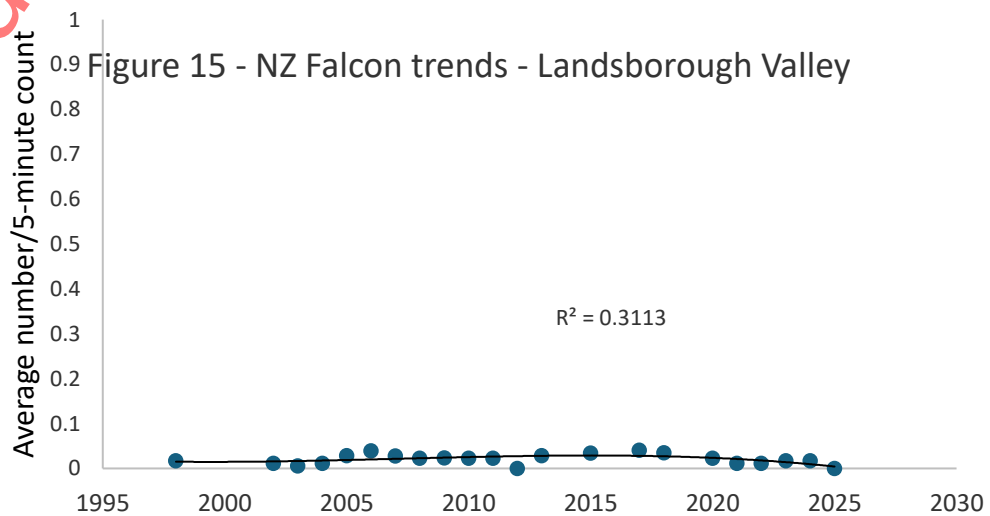


Figure 16 - Kereru trends - Landsborough Valley

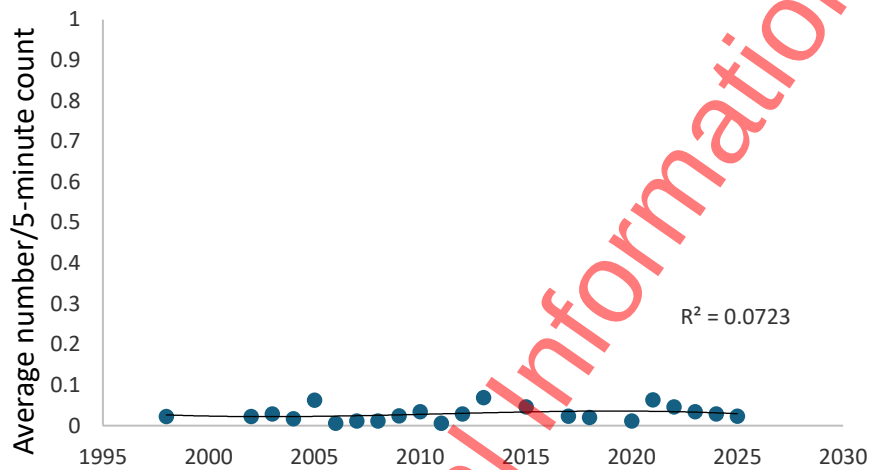


Figure 17 - Long-tailed cuckoo trends - Landsborough Valley

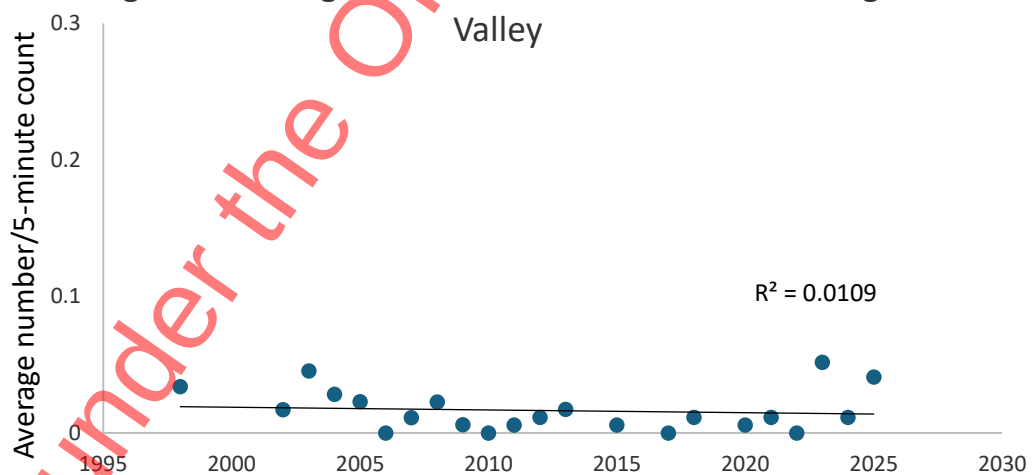
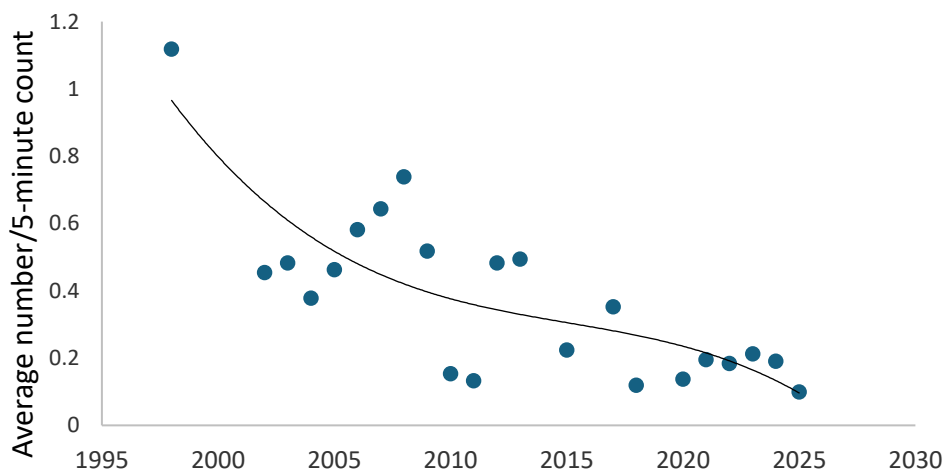


Figure 18 - Silvereye trends - Landsborough Valley



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Dart-Caples Outcome Plan

2022 – 2030



National Predator Control Programme

Site Outcome Plan No. 11



Department of
Conservation
Te Papa Atawhai

New Zealand Government

National Predator Control Programme

Dart-Caples Site Outcome Plan 2022 – 2030

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1 Purpose

The National Predator Control Programme (NPCP) will carry out ongoing predator control in the Wakatipu District for the conservation of mohua, rock wren, kea, long-tailed bats, whio and native vegetation values. The purpose of this Outcome Plan is to:

1. Describe the biodiversity values at the site and desired long-term outcomes
2. Describe a management regime designed to achieve the outcomes
3. Describe a measurement regime by which to gauge achievement
4. Inform national site prioritisation by determining treatment frequency
5. Inform technical advice and operational decision making at site
6. Assist with communications about this site

2 Summary

Key managed species [^]	Mohua
Rationale	Mohua (forest dwelling) are the most rat-sensitive of all the managed species at this site. The scale, methods and return times required to protect Mohua will protect other rat-limited species* and some stoat-limited species. Rock wren (alpine dwelling) are primarily stoat-limited but are also very sensitive to rats when rats colonise the alpine zone.
Key pests	Stoats and ship rats
1080 frequency	Approximately every three years but determined by rat response to beech masting. From 0 to 2 treatments may be required each mast event. Treatment should be dependent on TAG advice based on rat tracking rates. Extreme rat irruption (i.e. starting from >25% tracking rate <u>per line</u> in August Year 0): • Nov pre-seedfall <u>AND</u> • Feb-March (16 months later following seed germination)** Normal rat irruption (i.e. starting from <25% tracking <u>per line</u> in August of Year 0): immediately following beech seed germination (November-December Year 1 ideal)
1080 timing	Dependent on TAG advice based on rat tracking rates and timing of seed availability. Baiting will try to be avoided during a beech-seed food glut.
1080 scale	20,000 to 80,000 ha depending on rodent dynamics
Bait stations scale	Currently 400 ha though 1000+ha (forest) proposed, 100m x 75m, 10% rat density trigger, toxin Pindone***
Stoat trapping scale	4000+ha (forest) + 2000+ha (alpine), 100m x 800m, double-set DOC 150 (or AT220), Oct - March annually, Erayz dried rabbit meat & hen egg***

[^]Key benefit species = species that NPCP use to prioritise management sites nationally and require outcome monitoring.

*Secondary benefit species = other threatened plant and animal species that should also benefit from NPCP management.

**A precautionary approach to deal with high magnitude rat irruptions (such as happened in 2019)

***Toxins may change with development of new compounds and lures.

3 Biodiversity values at risk

Species	Scientific Name	NZ Threat Classification (2021)	Target predators (other predators)
Key benefit species			
Long-tailed bat	<i>Chalinolobus tuberculatus</i>	Nationally Critical	Ship rat, stoat (weasel, feral cat)
Rock wren*	<i>Xenicus gilviventris rineyi</i>	Nationally Endangered	Ship rat, stoat (weasel, feral cat)
Kea	<i>Nestor notabilis</i>	Nationally Endangered	Stoat (feral cat, ferret)
Whio	<i>Hymenolaimus malacorhynchus</i>	Nationally Vulnerable	Stoat
Mohua	<i>Mohoua ochrocephala</i>	At Risk – Declining ⁺	Ship rat, stoat
Secondary benefit species			
South Island kākā	<i>Nestor meridionalis meridionalis</i>	Nationally Vulnerable	Possum, stoat
Yellow mistletoe	<i>Alepis flavida</i>	At Risk – Declining	Possum (Ship rat, stoat - avian pollinators affected)
Red mistletoe	<i>Peraxilla tetrapetala</i>	At Risk – Declining	Possum (Ship rat, stoat - avian pollinators affected)
Crimson mistletoe	<i>Peraxilla colensoi</i>	At Risk – Declining	Possum (Ship rat, stoat - avian pollinators affected)
Yellow-crowned kākāriki	<i>Cyanoramphus auriceps</i>	At Risk – Declining	Ship rat, stoat (feral cat)

* see Appendix 4 Graph

⁺ Mohua suffered severe decline in Dart-Caples during 2019-20 mast and are considered to be “Regionally Critical” at this site. **Note:** Other species at this site that may be considered in future as applicable for NPCP status: black-billed gull; wrybill, black-fronted tern, SIPO, karearea, *Carmichaelia* sp., banded dotterel, alpine/forest lizards, giant scree weta (*Deinacrida connectans*).

Table 1. Dart-Caples NPCP species.

4 Species Distribution (see Map 1)

Rock wren are present in low scrubby vegetation, cliffs and boulder fields above the treeline and their numbers appear to be declining.

Long-tailed bats are present in the lower Dart and Caples.

Kea are present in Dart and Caples Valleys in both forest and alpine habitats.

Whio are present in the large tributaries of the Dart and their numbers have increased in response to stoat trapping. They are rarely present on the Dart River as its milky glacial water is unsuitable for whio and the invertebrates they eat.

Mohua are widespread in the Dart and Caples Valleys with greatest densities in red beech-dominated forests on valley floors. Their numbers have declined dramatically over the last 10 years. Up until 2012 the Dart-Caples mohua population was one of the 3 largest and was regarded as the key to the survival of the species on the mainland. It no longer warrants this status. The Dart/Caples has a mosaic of red beech at low altitudes in the valley floors and silver and mountain beech elsewhere (See map 2 Vegetation in Dart Valley EMU). Beech trees mast approximately every 4 years at this site.

5 Species ecology and predator vulnerability

Mohua are vulnerable year-round to **stoats** and **rats** as mohua both nest and roost in tree holes. During the spring of a seed year, when rats have seed to eat during the mohua breeding season, mohua can tolerate rat tracking rates up to 30%. When the seed germinates, predation increases dramatically.

Rock wren are thought to be most vulnerable to **stoats** when nesting (October to January), but as they roost in holes they may suffer from catastrophic winter predation. Episodic outbreaks of **rats** and **cats** in the alpine zone possibly impact heavily on rock wren.

Long-tailed bats are vulnerable to **ship rats**, **stoats** and **cats** year-round, and may be particularly vulnerable in late spring/early summer when females are pregnant or carrying young.

Kea eggs and nestlings are vulnerable to **stoats** August – March, but in normal years nesting success is about 40%. In stoat irruption years, nest success is <5%. Adults and juveniles are vulnerable to stoats and feral **cats** whilst foraging on the ground. Predation on adults and juveniles is particularly acute during post-mast years, after rodents have crashed.

Whio are vulnerable to **stoats** when nesting (September to November). They are also vulnerable to **stoats**, **ferrets** and **cats** when moulting where they may inhabit small waterways for a few weeks (Feb/March).

Mistletoe species (Red, Yellow & Crimson) are vulnerable to **possum** browse year-round. **Ship rats** and **stoats** may reduce common avian pollinators to such low levels that it may affect mistletoe pollination rates and subsequent seed production and dispersal.

Kaka are vulnerable to **stoats** and **possums** when nesting in mature tree holes (October to March during seed-masting events). Juveniles are also vulnerable to **stoats**, **ferrets** and **cats** for up to a week post-fledging as they spend most time on or close to the ground during this period.

Yellow-crowned kakariki also nest in holes from October to March during beech seed-masting events. However, as they nest in smaller holes than kaka nests and so therefore may be less vulnerable to possums, but vulnerable to **stoats** and **ship rats**. Juveniles are less vulnerable than kaka post-fledging.

Arboreal lizards are vulnerable year-round to **ship rats** and **stoats**.

Ground-dwelling lizards (riverbeds, forests, screes and alpine areas) are vulnerable year-round to **rats, stoats, weasels, mice, cats** and **hedgehogs**.

Threatened invertebrates are likely to be vulnerable to **rats, mustelids, mice, cats** and **hedgehogs** year-round (or mainly spring/summer).

Braided river birds – wrybill, black-billed gull, South Island Pied Oystercatcher, banded dotterel, black-fronted tern nest on open areas of the Dart River. Greater numbers of these species nest downstream of the current treatment area, which could be extended to include these nesting areas. These birds are vulnerable to **rats, stoats, ferrets, cats, hedgehogs** and **black-backed gulls** during August to December.

6 Target predator dynamics

Rodent populations are highly irruptive in the Dart-Caples. When resources are scarce, there are usually close to no rats or mice in these forests or alpine areas (usually 0% overnight TT index). Following a beech flowering, rodent populations rapidly increase so by the following spring there are high numbers of rats and/or mice. When there's a full mast, rodents increase at the same rate regardless of whether it's a 'normal mast' or a 'mega mast'. Therefore, peak rodent abundance at the end of the irruption hinges on pre-mast rodent abundance. Pre-mast rat tracking of >5% (August of Year 0) generates an extreme rat irruption that requires more than one rat control intervention for mohua to persist.

When all beech seed is consumed (or germinates – usually mid-late spring) rodent breeding slows and stops. However, it takes 9-12 months for tracking rates to return to near zero. Mouse tracking usually crashes between May and August of the post-mast year, whereas rat tracking usually crashes between August to November in the post-mast year. Mouse irruptions usually go all the way to treeline and into alpine ecosystems, especially if snow tussocks have seeded. Extreme rat irruptions can push up into the alpine zone. Rats in the alpine zone is a rare event that needs to be carefully managed. Rats in the alpine zone spell disaster for rock wren populations.

Stoats respond to rat and mouse populations. When rats increase following a mast, female stoats produce up to 13 young in their annual litter with a high survival of young the following spring. This results in a high number of stoats the following summer. Mouse irruptions invariably penetrate alpine ecosystems and can be exacerbated and generated by tussock masting. Mice in the alpine zone can help sustain stoat populations in alpine areas. Stoat secondary poisoning rates are determined by kill rates of rodents. Mice tend to survive aerial 1080 operations performed during their growth phase of a mast response, so are not an effective vector in those circumstances. Moderate-high numbers of surviving rodents leads to poor stoat kill rates. The abundance of rodent vectors is less important than the percentage kill of the rodents present. It is better to have few rodents (i.e. less stoat vectors) and kill them all, than have lots of rodents (i.e. more stoat vectors) and leave survivors.

Possums breed comparatively slowly (1-2 young per year/female) and do not seem to respond to masts. However, they have no predators and so can steadily increase over several years following control. They can be found throughout these forests and often in scrubby vegetation of alpine margins, with some even able to survive in alpine ecosystems.

7 Outcome targets (See Table 3 for detail)

1. The mean number of mohua detected on transects has increased to **1.5 groups per km** by 2030
2. The mean number of rock wren is **>1/transect** in the Harris Basin by 2030
3. Kea hourly encounter probability has **increased by 5%** by 2030 (e.g. from 20% to 25%)
4. The whio population has reached **50 pairs** by 2030
5. For long-tailed bats, there is currently no cost-effective outcome monitoring method

8 Result targets (See Table 3 for detail)

1. Rat 1-night tracking index never exceeds 30% post-beech seed germination in mohua habitat.
2. Rat 21-night tracking does not exceed 5% in rock wren alpine habitat.
3. Mustelid 21-night tracking is <5% in half of all summers across the site.
4. Possum 3-night wax tag index remains below 5% at all times.

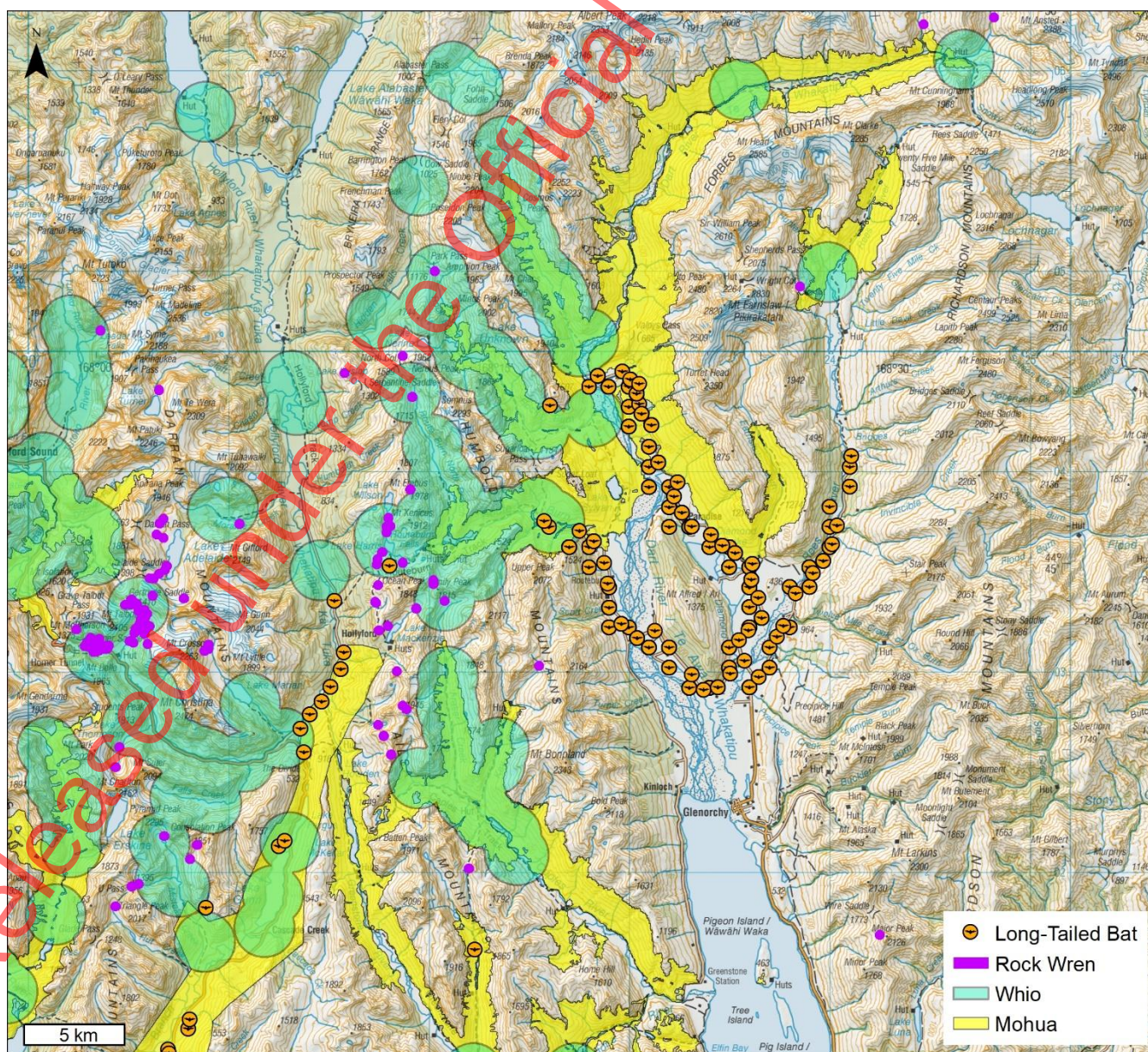
9 Monitoring methods (See Table 3 for detail)

Method	Purpose
Temperature modelling	Predicts beech mass seeding events
Annual beech seed snipping	Confirms mast and estimates magnitude (by Feb)
Annual beech rain	Confirms mast and estimates magnitude (by May)
Snow tussock seed counts	Predicts tussock seed events
Mohua transect counts	Provides number of mohua groups per km of transect
Rock wren abundance index	Measures rock wren encounter rate per transect
Kea Survey Tool https://survey.keadatabase.nz/	Provides hourly encounter probability rate

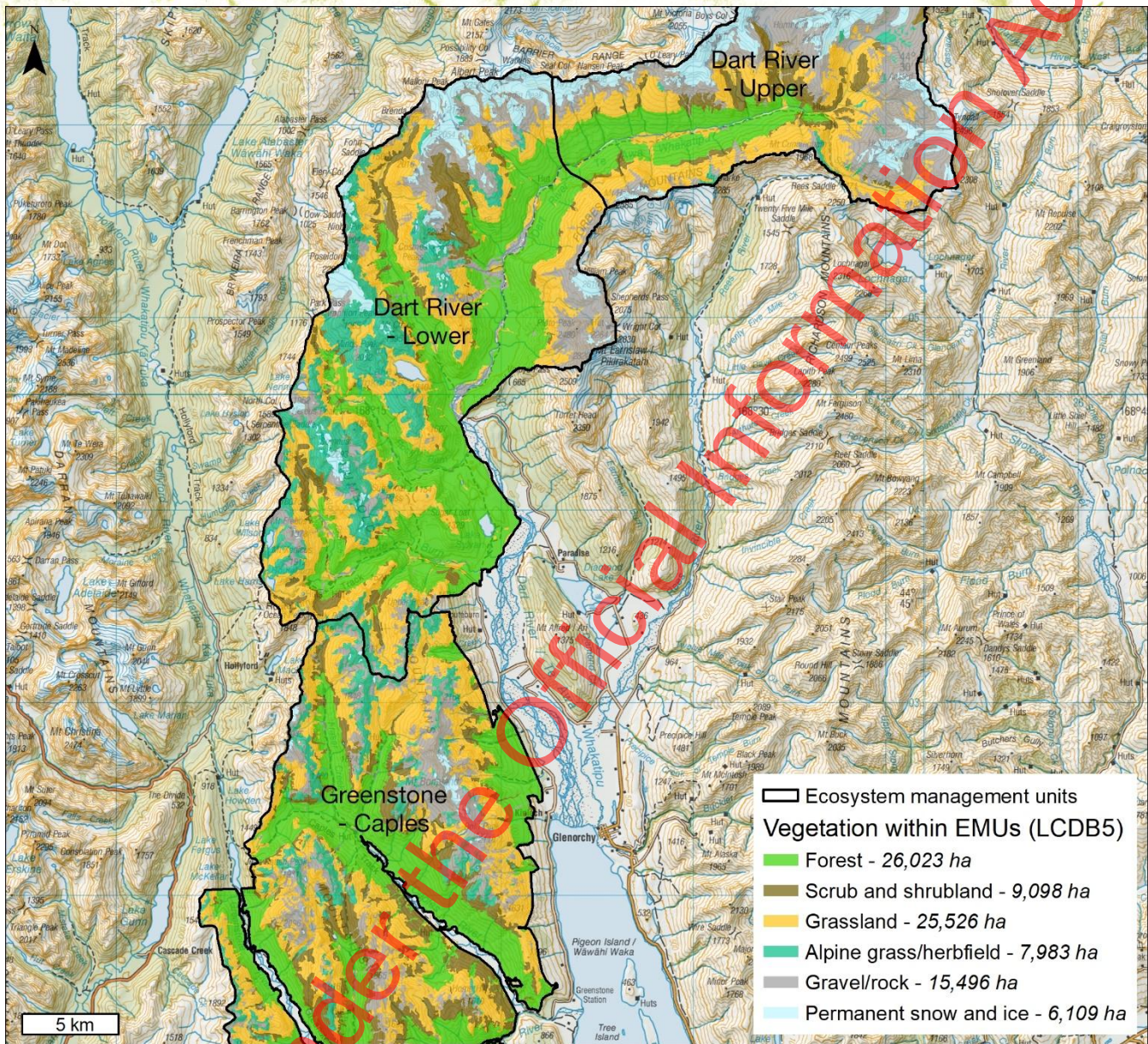
Whio census	Provides population size estimate
5 -minute bird counts	Measures forest bird relative abundance and population trends
1-night tracking tunnel index	Measures rat relative abundance
21-night tracking tunnel index	Measures rat and mustelid relative abundance
3-night wax tag index	Measures possum relative abundance

The NPCP monitoring plan proposes continued monitoring of mohua and extensive monitoring of mammals using cameras and vegetation using plots in both the Dart & Caples Valley ([DOC-6218676](#)). The detailed design of monitoring in the Dart-Caples will be described in a separate monitoring plan.

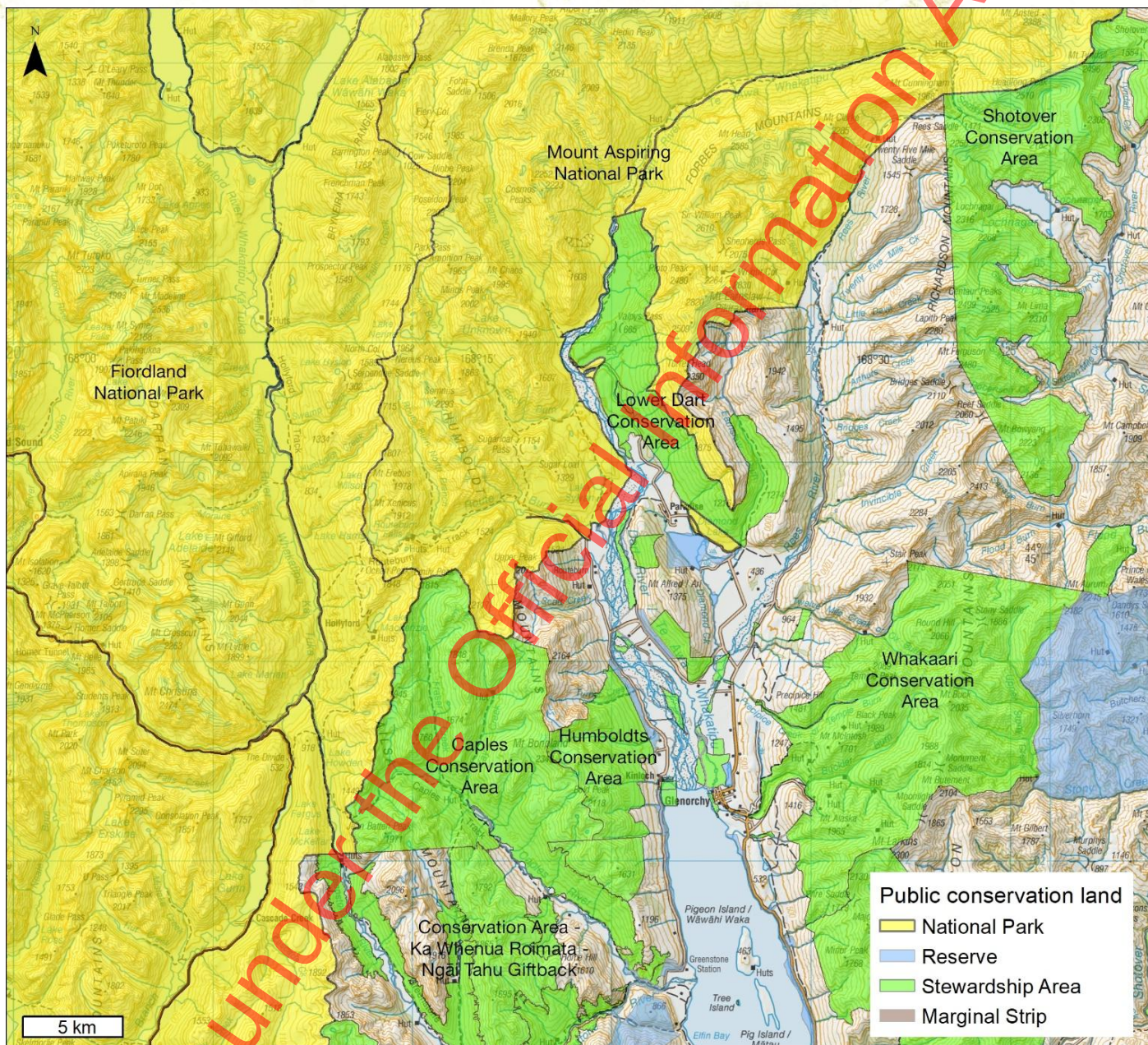
10 Species distribution and habitat type



Map 1. Distribution of NPCP species in Dart-Caples



Map 2. Vegetation in Dart-Caples EMU's



Map 3. Land status in Dart and Caples Valleys

11 Predator control methods

Aerial 1080

Targeting effective multi-pest control of ship rats, possums and achieving secondary kill of stoats. Large-scale operation of approx. 65,000 ha roughly rectangular, including alpine areas, and timed to achieve moderate to high recruitment rates and high adult survival of mohua, rock wren and kea. This is applied across at least two cohorts/breeding seasons that should occur by 2030 as well as protecting other managed and benefit species. Operations will follow best practice and TAG advice.

The frequency of operations will be determined by beech mast events with aerial 1080 applied when required to manage rat and stoat irruptions and achieve the respective result targets. The timing may need to be in the early stage of, or prior to, seed set and/or may need to occur post-germination in late spring to meet the result target of ensuring rats do not exceed 30% tracking post-germination. This is because 1080 operations may not be consistently highly effective for controlling rat populations when lots of beech seed (food glut) is available.

TAG advice closer to the time will consider current rodent abundances, mast conditions, and operational considerations/constraints to advise on a seasonal timing to aim for. Possums should be sufficiently suppressed with 1080 operations every 3-4 years on average, due to their low fecundity.

[Note: previous aerial 1080 programme of 11-19,000 ha forest-only operations performed during food gluts has not achieved a good conservation outcome for mohua]

Bait Station network

Targeting ship rats. Currently 400ha in Dart Valley at 100 x 100m spacing targeting ship rats for mohua protection. This needs to be increased to a minimum of 1000 ha in Dart Valley at the highest known density mohua population. Bait station methods including spacing should be reviewed. Bait stations should be activated whenever rat tracking >10% overnight RTI. Bait stations will also be more effective at times of natural food scarcity (i.e., they don't work well in a beech forest full of seed).

Stoat trap network

Stoat traps lines are located in the main waterways in both Dart and Caples Valley's and on Routeburn Great Walk, embedded within the larger aerial 1080 area. A 4000+ ha "square-shaped" area surrounding the bait station network in the Dart Valley, and 2000+ ha in a high-density rock wren area also (e.g. Harris Basin), should be developed. Annual reviews should occur to determine if trapping is sufficient and cost-effective to achieve outcomes. Stoat traps should be operated year-round in all years where snow conditions allow. Service intervals will be informed by season, predator abundance, trap occupancy, and lure-life.

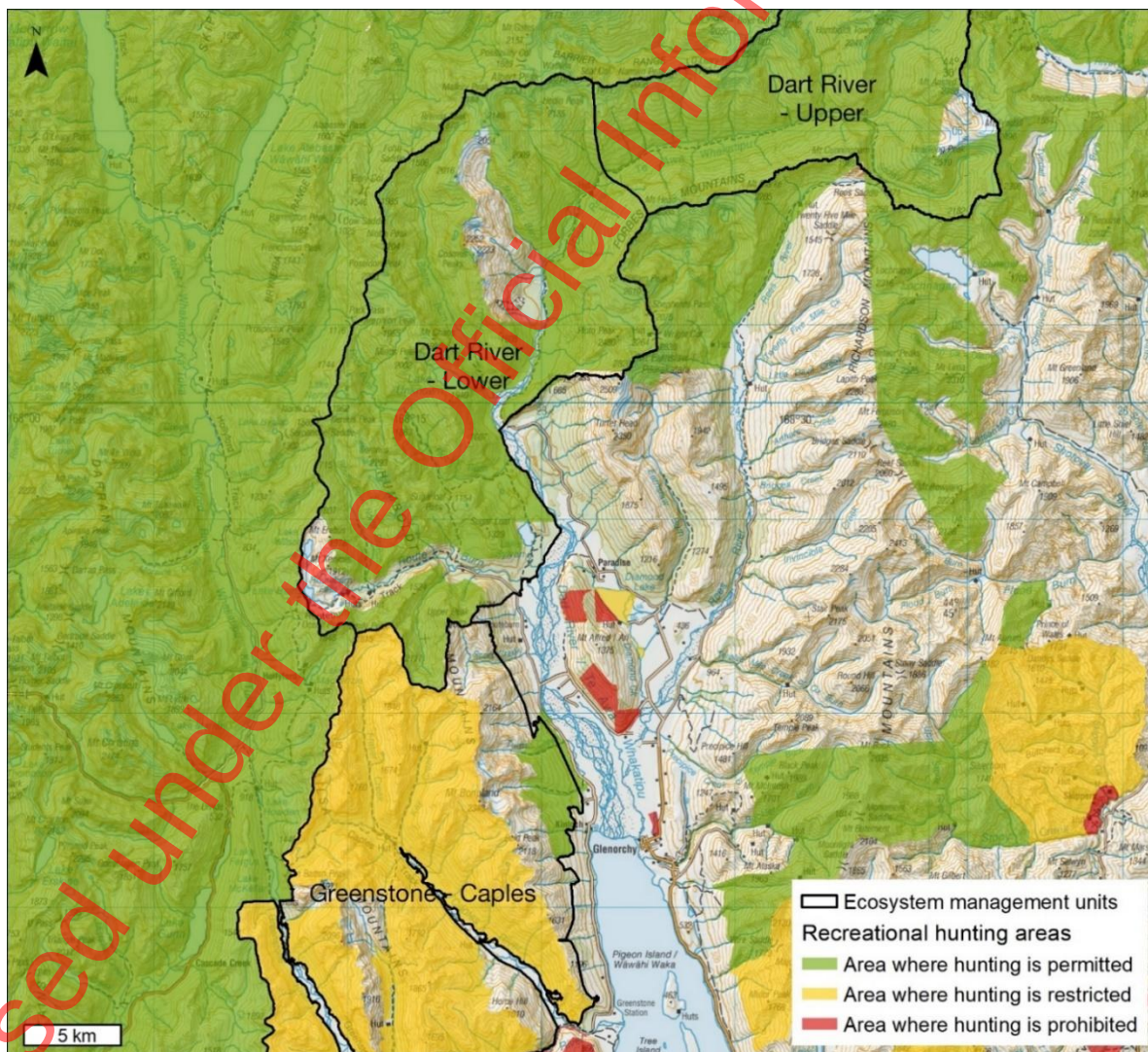
Feral cat control

Work in progress, but not part of NPCP. This is likely to be more effective on braided river areas for ground-nesting birds, with perhaps an opportunity for community groups to substantially contribute.

12 Site-specific issues and constraints

- **Beech forest** habitat is long and narrow up several side branches of the Dart River. As possums and stoats can often be found above the bush line, having aerial 1080 control only within forest habitat only means a high risk of reinvasion. There is a need to treat a more "square-shaped" block with a lower perimeter to area ratio and include large alpine areas adjoining the beech-forested valleys.

- **Deer** have a high recreational value in Dart-Caples, with the only mainland population of **white-tailed deer** in the Dart Valley, and five balloted Recreational Hunting Areas over 18,000ha established for **fallow deer** in the Caples/Greenstone area (Map 4). Balloted blocks operate from 1 April – 30 September. Any aerial 1080 treatment during the white-tailed rut (mid-April to early June) may be contentious due to recreational hunting values. There has been pressure by hunting advocates to use deer repellent in 1080 baits to minimise impacts on deer, but the impact on native species is largely unknown. If an exemption to use deer repellent is granted it needs to comply with the Kea Code of Practice. Kea survivorship through the operation may need to be monitored, requiring a significant time investment for both pre-planning and implementation.



Map 3. Deer RHA classification in Dart and Caples Valleys

- Effects of **mast intensity** on rat-irruption magnitude, and the effect on threatened species, is sometimes unpredictable e.g. a partial mast in 2011 was not expected to generate a damaging rat irruption, so no rat control was performed. However, a damaging rat irruption did eventuate, and this significantly impacted mohua. Rat tracking indices increased to 70% and mohua suffered a serious decline.
- The **Routeburn Great Walk** constrains the aerial 1080 operational season from 1 May to 31 October outside the Great Walk season. If operations occur during the Great Walk season (1 November – 30 April) a large exclusion is likely to apply around the Routeburn track, potentially

compromising the effectiveness of the operation. However, it may be possible to still undertake operations during the Great Walk period if MOH is consulted early to discuss.

- Aerial operations cannot be undertaken in National Parks within **school holidays** (approx. 20 Dec - 31 Jan) without special MOH permission.
- **Kea Code of Practice** has additional performance standards apply over part of the current operation due to it being within 40km of identified scavenging sites in Fiordland National Park. There is also a risk the operational area could become more scrounge-affected in future. Huts on the Routeburn track and campervan parks at the Routeburn road-end can quickly turn into scrounge sites if pro-active measures are not taken. The status of the operation under the current version of the aerial 1080 in kea habitat Code of Practice should be checked during the planning stages of the operation and advice sought from the Landscape Threats Advice Team.
- **Snow** in winter and spring can be problematic for aerial and ground operations.
- **LINZ** manages significant areas of the Dart riverbed, and permission is needed to treat this area.
- The **braided riverbed** of the Dart River has not been aerially treated in the past, creating **significant gaps** in the coverage of aerial operations. Likewise, there are many coverage gaps on the **forest-river margin**, as there has been a non-treatment buffer imposed in previous operations. This provides a refuge for pests, particularly rats and possums that may not move far during the time the 1080 bait is still toxic, which act as a source to reinvade forests.
- **Mice** have reached very high densities in some post-mast years. This also could lead to an increase in **weasel** densities which can breed twice per year, so can increase markedly (i.e. more than stoats) during the summer period.
- Rat and mouse **carrying capacity** during inter-mast periods may be increasing over time due to climate change and improvements in forest condition. This is concerning because higher inter-mast density gets amplified to higher-magnitude irruptions during mast years.
- Queenstown residents can be somewhat **more litigious** than other areas of New Zealand, so particular care may be required to keep the community informed of operations.
- The Dart and Caples are non-continuous with different species and pressures, so treating them as **two separate treatment sites** should be considered.

13 Mast prediction and measurement

This monitoring is performed on a regional or national scale by national teams within DOC. Temperature modelling is used to predict beech mast events. Annual **seed rain** collection is vital for confirming beech masting and may help predict irruption intensity. **Seed snipping** from helicopters may also be used in some years. Remote sensing (satellite) monitoring occurs, and a model of NZ-wide beech forest flowering has been developed (but not for each beech species yet). Seed counts for **snow tussocks** are also carried out each summer.

14 Information gaps & uncertainties

There are many gaps in our complete understanding of the ecology at this site including:

- Variable response of rats, stoats & mice to similar levels of beech seed in different years, and at different parts of this site
- How tussock masting affects predator numbers in alpine and forest habitats
- Effect of aerial 1080 exclusion areas on the ability of pests to reinvade
- Likelihood of predators living in alpine zone to avoid being poisoned by aerial 1080 applied in forested habitat only.
- Distribution of threatened species (including roost sites of LT-bats)
- Sex ratio and genetic diversity of threatened species
- Insufficient (or overly expensive) monitoring methods for some threatened species
- How to control mice and weasels when they increase over summer
- Likely carrying capacity of threatened species at this site
- Unknown level of habituation of kea through interaction with humans and their belongings (including food)
- Baseline kea (and kaka) relative abundance
- Effect of management on lizards, threatened invertebrates and braided river birds

15 Research underway

No current research programmes are underway at this site. Research that should occur includes testing the efficacy and outcomes of an experimental two-stage aerial 1080 approach (suggested in this document) in extreme mast years and understanding at finer resolution the response of pests to partial masts, when it is uncertain whether an aerial 1080 operation is required or not. The suitability of trail cameras as a cost-effective animal pest monitoring method at this site also needs verifying.

16 Review and reporting

Annual reporting of methods and results at site are to be collated and inserted into the NPCP annual report.

This document will be reviewed annually by Queenstown staff and the NPCP TA

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Table 2. Dart-Caples treatment variables (also see Dart-Caples NPCP Aerial Operation Decision Tree [DOC-6865931](#))

Key benefit species	Secondary benefit species	Main predators	Secondary predators	Control method	Area controlled	Return time	Timing*	Block prescription**
Mohua [most sensitive forest species]		Rats, possums	Stoats	Aerial 1080	All forested areas	Each 'normal or more' beech mast event	Normal irruption: Spring-summer ideal (Nov - Mar) Extreme Irruption: Nov pre-seed-fall, repeated March 16 months later	<u>Aerial 1080:</u> - Entire block - Nov to March or Nov Yr0 AND March Yr2 <u>Bait stations:</u> 1000+ ha highest density mohua popⁿ in beech forest - Annual (trigger: rats >10% 1-night RTI Nov) - Oct - May <u>Trapping (stoats):</u> 4000+ ha (forest) surrounding bait station area 2000+ ha (alpine) - Annual - Oct - March
				Bait stations - rats	1000+ ha forest	Annual	Oct - May	
				Trapping stoats	4000+ ha forest	Annual	Sept - March	
Rock wren [most sensitive alpine species]		Rats, stoats	Cats, weasels	Aerial 1080	All alpine areas	Each beech and/or tussock mast event	Early spring	
				Trapping stoats (& cats)	2000+ ha alpine	Annual	Oct - Feb	
LT-bats		Rats, stoats	Cats, weasels?	Aerial 1080	All forested areas	Each beech mast event	Spring	
				Bait stations - rats	1000+ ha forest	Annual	Nov - Jan	
				Trapping stoats	4000+ ha forest	Annual	Oct - Jan	
Kea		Stoats	Cats	Aerial 1080	Entire block	Each beech mast event	Post-mast autumn	
Whio		Stoats	Cats	Aerial 1080	All forested areas	Each beech mast event	Early spring	
				Trapping	River margins	Annual – except when major spring floods occur	May not be required	
	Mistletoe	Possums	Rats, stoats*** (avian pollinators)	Aerial 1080	All beech forest	3-yearly	Any time	
	Kaka	Stoats, possums	Cats, ferrets	Aerial 1080	All forested areas + lower alpine	Each beech mast event	Pre-mast Spring	
				Trapping stoats	2000+ ha forest	Annual	Oct - March	
	Yellow-crowned kakariki	Rats, stoats	Cats, weasels?	Aerial 1080	All forested areas	Each beech mast event	Spring	
				Trapping stoats	2000+ ha forest	Annual	Oct - Feb	

* Timing adapted & communicated on an annual basis, **Block prescription based on the needs of the benefit species most sensitive to rats, stoats and possums. ***Prey on avian pollinators

Table 3. Dart-Caples Result & Outcome Monitoring details						
Key benefit species	Outcome monitoring method	Monitoring Frequency & timing	2030 Outcome targets	Main predators	Result monitoring method	Result target
Mohua	Mohua forest transects	Annual – October	Achieve 2012 levels (anticipated through two mast events)	Rats	1-night Tracking Tunnels	<1% following acute control; <5% during breeding season; <10% non-breeding season
					Trail Cameras	Unknown (<1% detection?)
				Stoats	21-night Tracking Tunnels	<1% following acute control; <5% during breeding season
					Trail Cameras	Unknown (<1% detection?)
			Possums	3-night wax-tag index	<20% at any time (= c.5% RTC)	
Rock wren	20 x 250m transects	Biannual - February	Mean >1 rock wren/transect in Harris Basin; Non-T in Scott Basin	Rats	21-night alpine TT's	<1% following acute control; <5% during breeding season
				Stoats/ weasels	21-night alpine Tracking Tunnels	0% following acute control; <1% during breeding season
				Cats	Trail Cameras	Unknown – under development
LT-bats	n/a	n/a	No cost-effective method	Rats	1-night Tracking Tunnels	<1% following acute control; <5% during breeding season; <10% non-breeding season
				Stoats/ weasels	21-night Tracking Tunnels	<1% following acute control; <5% during breeding season
				Cats	Trail Cameras	Unknown – under development
Kea	Kea Survey Tool (hourly presence/absence)	Ongoing, all field workers and other community persons	Hourly encounter probability increased by 5% (absolute) over baseline	Stoats	21-night Tracking Tunnels	<1% following acute control; <5% during breeding season
				Cats	Trail Cameras	Unknown – under development
Whio	Walk-through of rivers with dog	3-yearly; March or Sept	50 pairs	Stoats	21-night Tracking Tunnels	<1% following acute control; <5% during breeding season
				Cats	Trail Cameras	Unknown – under development
Secondary benefit species*						
Mistletoe	Browse score of known plants	3-yearly; flowering period (Dec-Jan)	<5% plants browsed	Possums	3-night wax-tag index	<20% at any time (= c.5% RTC)
	Pollination rates		>90% flowers pollinated	Rats	1-night Tracking Tunnels	<20% spring/summer
	Recruitment		Population increasing	Stoats	21-night Tracking Tunnels	<10% spring/summer
Kākā	Mohua forest transects/distance sampling? Bird recorders?	Annual – October	Population trend increasing	Stoats	21-night Tracking Tunnels	<5% during breeding season
				Possums	3-night wax-tag index	<20%

	5-MBC	Annual – October		Cats/Ferrets	Trail Cameras	Unknown – under development
Yellow-crowned kākāriki	Mohua forest transects/distance sampling? Bird recorders?	Annual – October	Population trend increasing	Rats	1-night Tracking Tunnels	<10%? during breeding
				Stoats/ weasels	21-night Tracking Tunnels	<5% during breeding
				Cats	Trail Cameras	Unknown – under development
Forest birds	5-MBC Bird recorders	Annual – October	Mean 'Species Richness' and 'Density' per station increasing	Rats, stoats, possums, cats	n/a	n/a

- Not funded by NPCP

Appendix 1 – Key resources Dart-Caples biodiversity results and outcomes

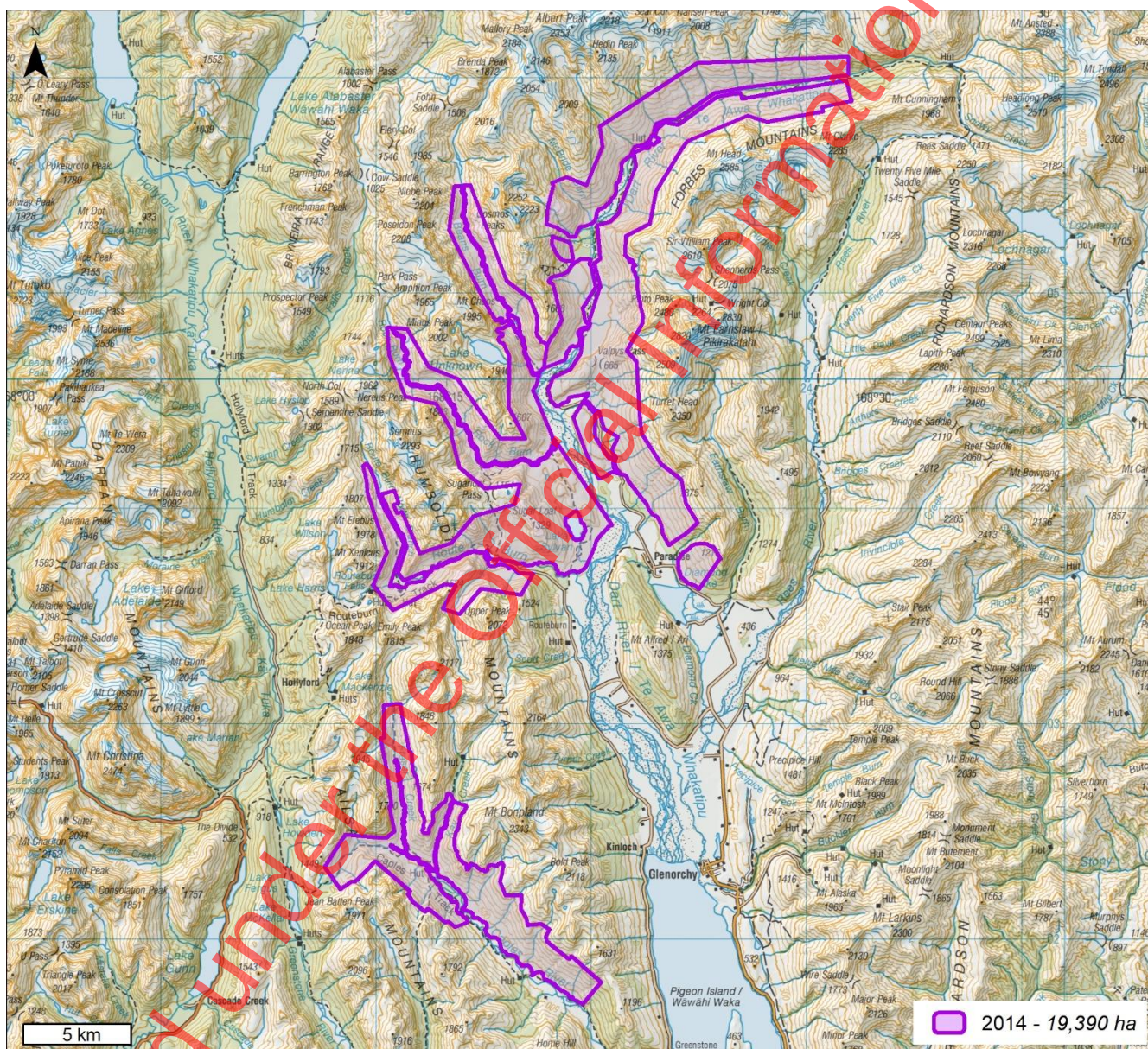
Year	Title	Author	DOC reference	Note
1999-2021	Treatment history of Dart-Caples	-	DOCDM-6635600	Spreadsheet
1999-2016	Wakatipu Predator Monitoring	-	DOCDM-93834	Data
2016-2021	Tracking Tunnel Report PRO	-	DOC-5383503	Report
2005-07				
2005	Dart Caples TT data	Fraser Maddigan	OLDDM-553154	Data
2005-06	Mohua report	Barry Lawrence	OLDDM-572896	Report
2006-07	Dart-Caples Annual Report	Barry Lawrence	DOCDM-128337	Report
2007-08	Operation Ark Dart Annual Report	Ray Molloy	DOCDM-317010	Report
2008-09	Operation Ark Dart Annual Report	Ray Molloy	DOCDM-464282	Report
2009-2010	Dart-Caples Annual Report	Barry Lawrence	DOCDM-633552	Report
2010	Dart report	Barry Lawrence	DOCDM-546827	Report
2014-15	Biodiversity protection in upper Wakatipu basin	Edward Waite	DOC-2313104	Report
2015-16	Biodiversity protection in upper Wakatipu basin	Chris Hankin	DOC-2896100	Report
2016-17	Biodiversity protection in upper Wakatipu basin	Sarah Keeble	DOC-5390630	Report
2020	Dart Bait Stations Operational plan	Sarah Keeble	DOC-6176951	Plan

Appendix 2 – Management history

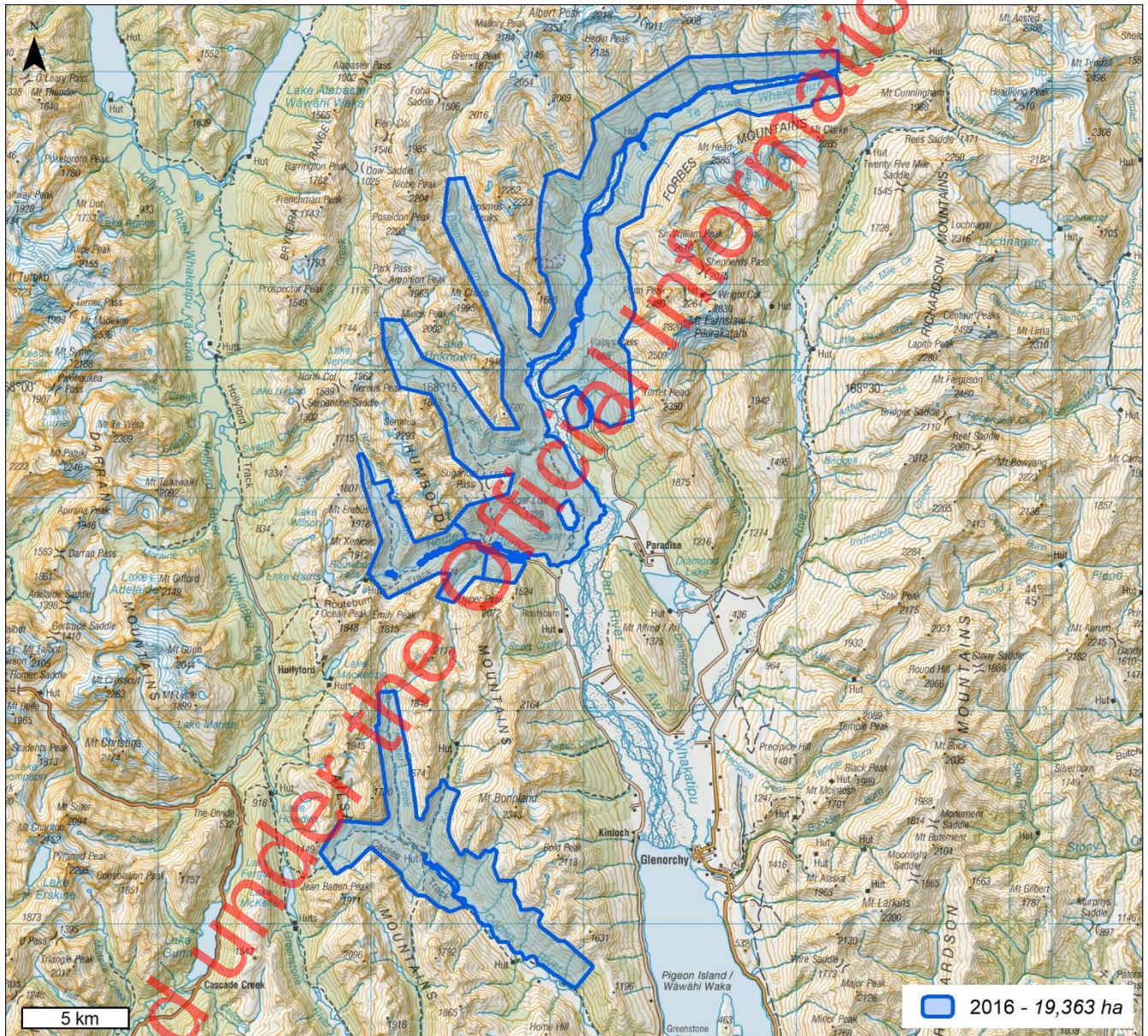
A more detailed history of management at this site is at [DOC-6635600](#)

Year	Method	ha	Number of items	Services/annum
1999	Bait stations	?	?	?
2006	Aerial 1080	?	n/a	n/a
2006-07	Bait stations	?	?	
2009	Aerial 1080	6667	n/a	n/a
2012-21	Stoat trapping (ss DOC 150, Routeburn)	n/a (145km)	1451	3-5?
2014	Aerial 1080	19,430	n/a	n/a
2016 (Sept)	Aerial 1080	19,400	n/a	n/a
2016-17	Stoat trapping expansion (ss DOC 150, Harris Basin, Routeburn)	?	?	3-5
2017 (Sept)	Aerial 1080	11,051	n/a	n/a
2019 (July)	Bait stations (Dart)	?	?	
2019 (Sept)	Aerial 1080	14,340	n/a	n/a
2020 (July)	Bait stations (pindone) @ Surveyors (Dart Valley)	400	400?	
2022 (June)	Bait stations (pindone) @ Surveyors (Dart Valley)	400	800 (100 x 50m)	
2022 (Dec)	Aerial 1080	41,000	n/a	n/a

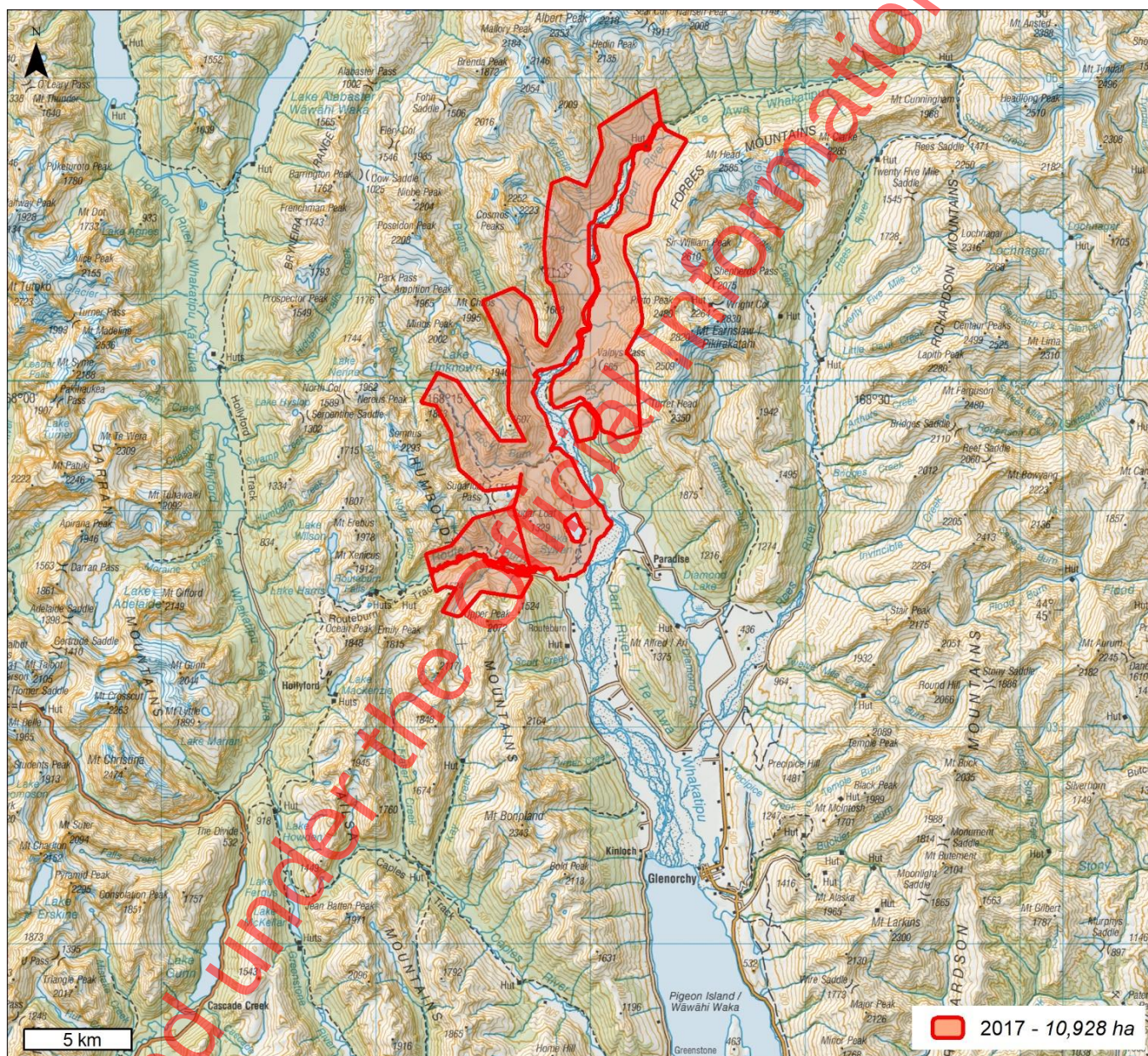
Table 4. Animal pest treatment at Dart-Caples [ss = single-set; ? = unsure]



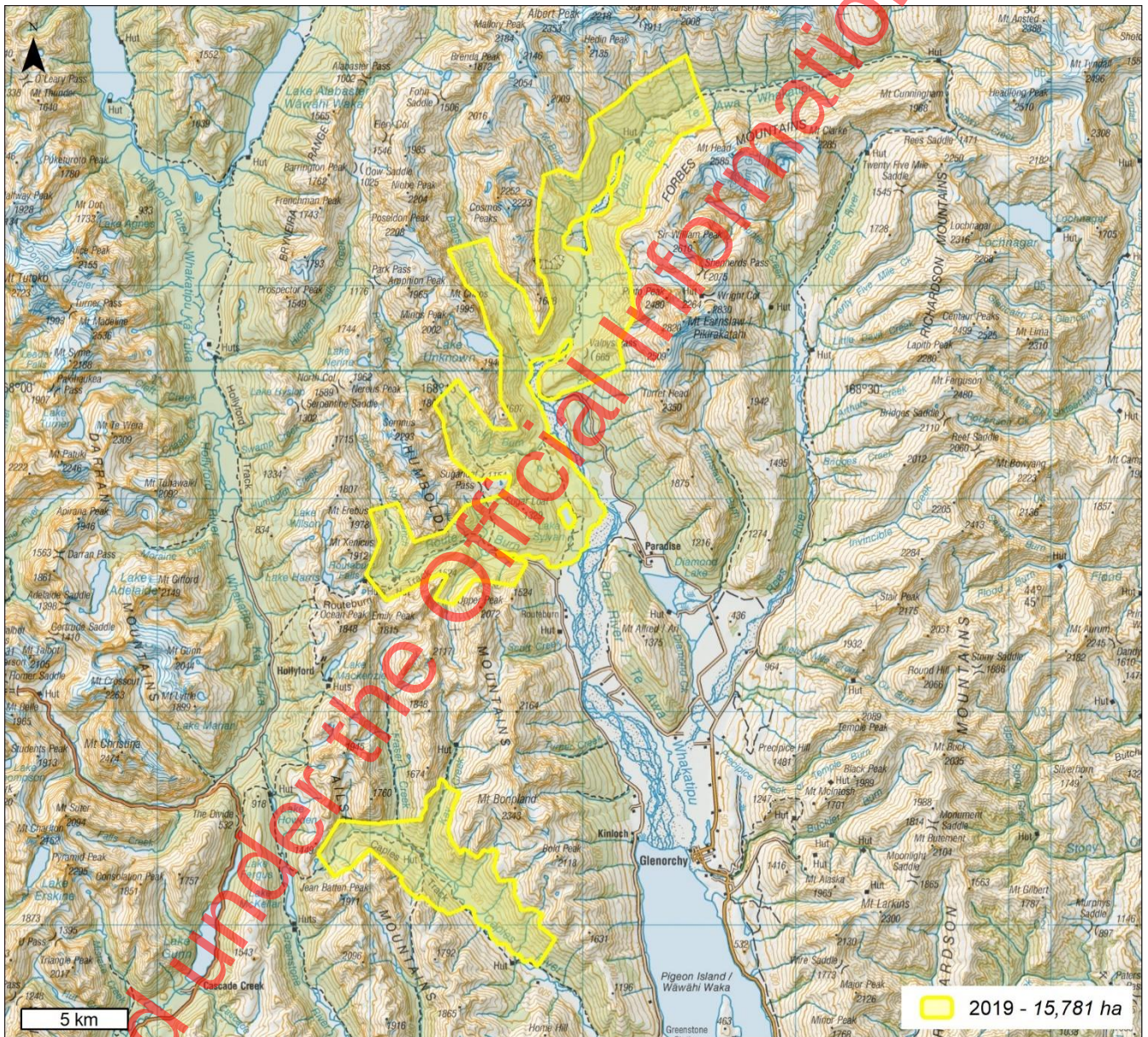
Map 4. 2014 aerial 1080 operational boundary



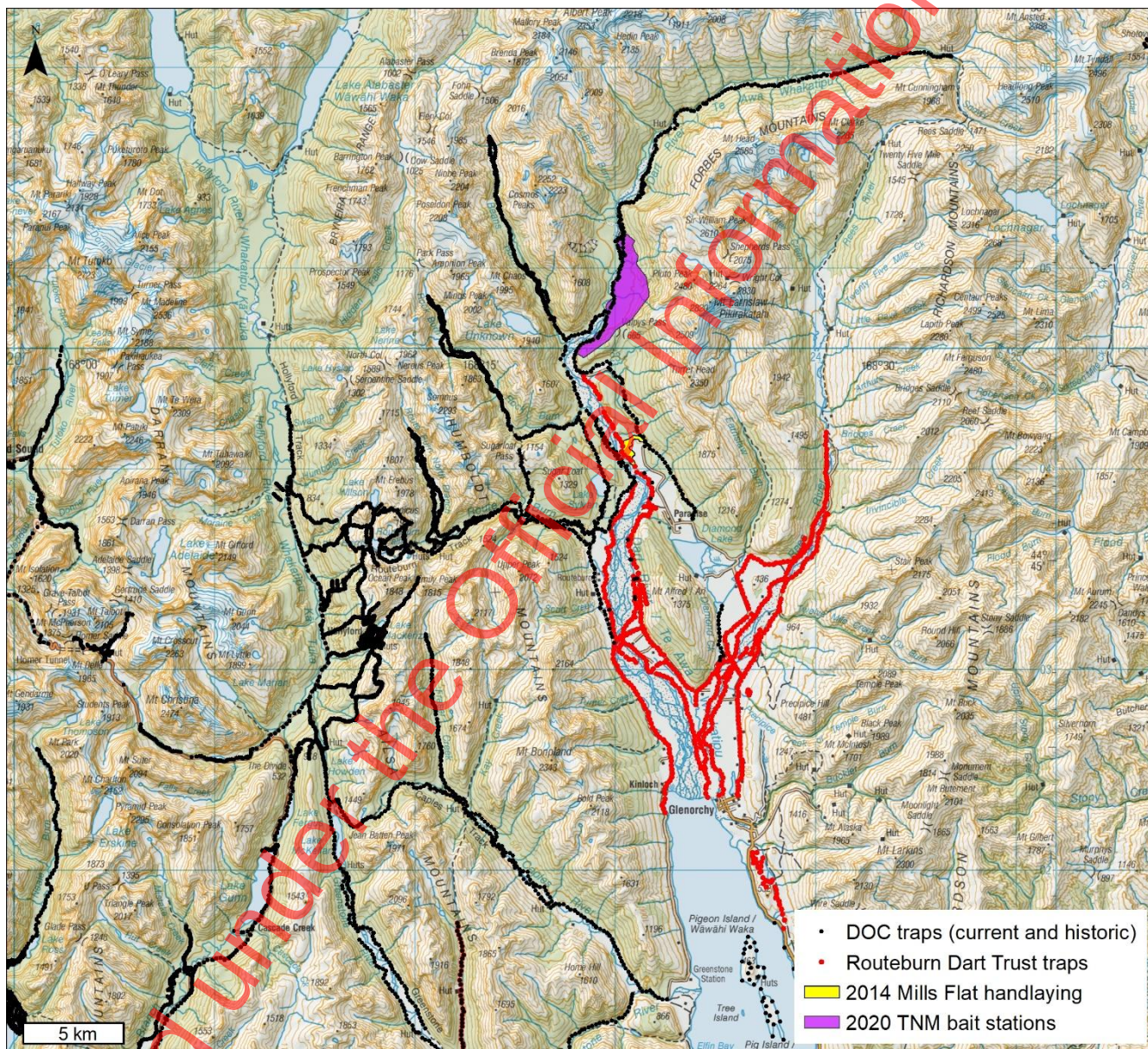
Map 5. 2016 aerial 1080 operational boundary



Map 6. 2017 aerial 1080 operational boundary

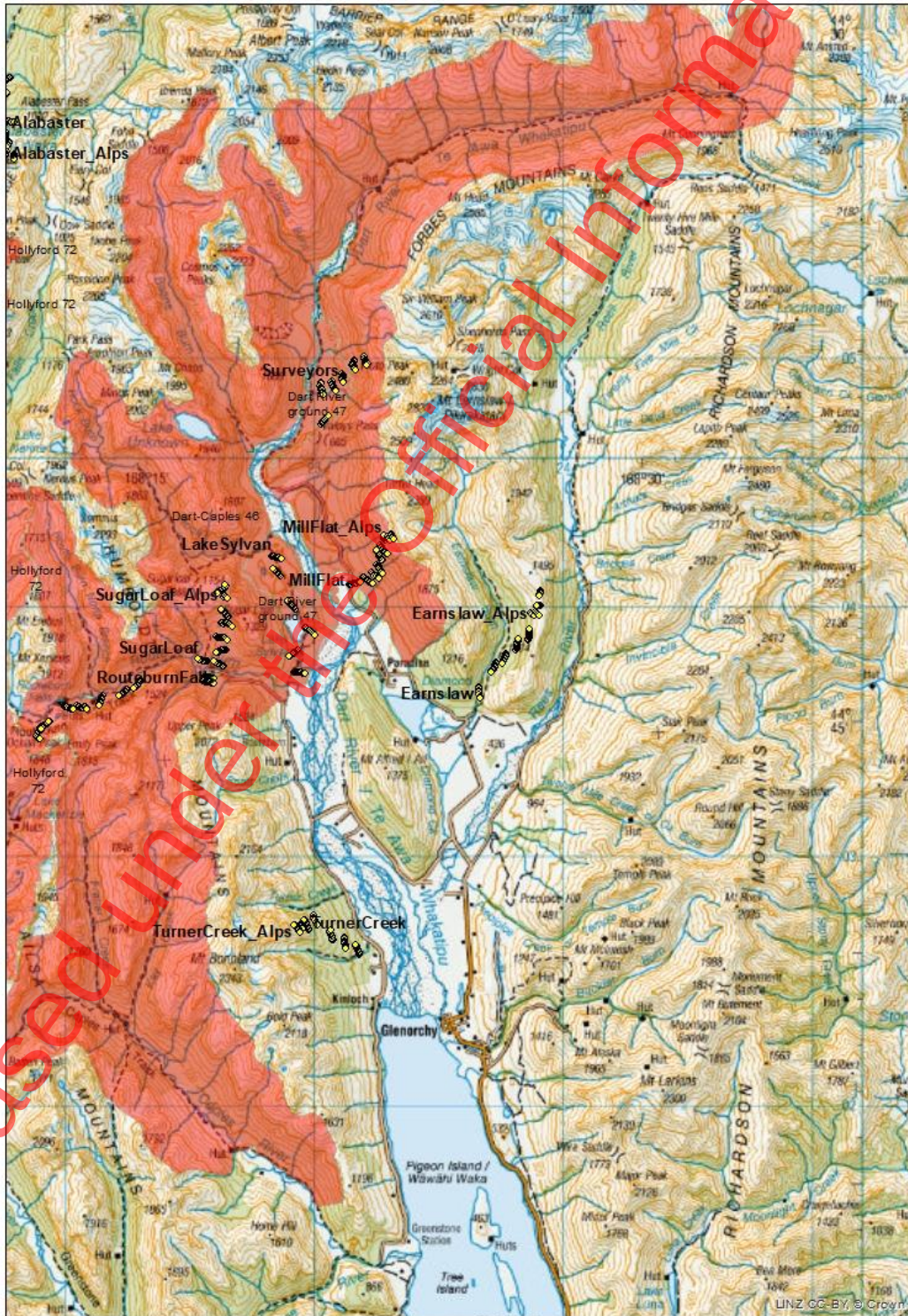


Map 7. 2019 aerial 1080 operational boundary



Map 8. Dart-Caples ground treatment (as at 2021)

Appendix 3 – Result monitoring



Map 10: Location of Tracking Tunnel lines in Dart-Caples Operational Area

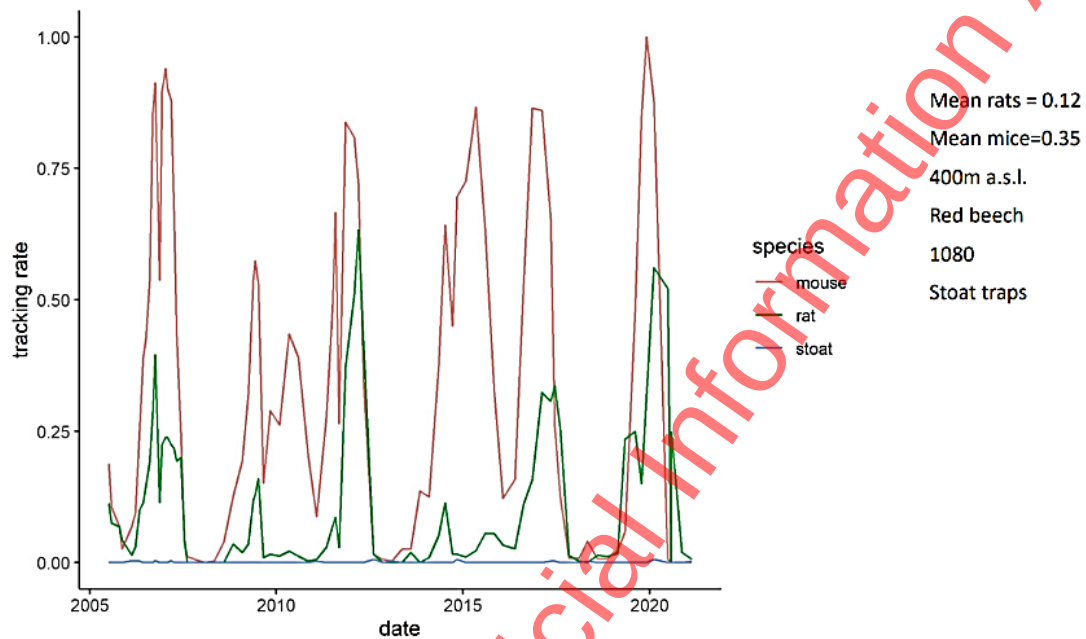


Fig. 1a. Dart overnight Tracking Tunnel results

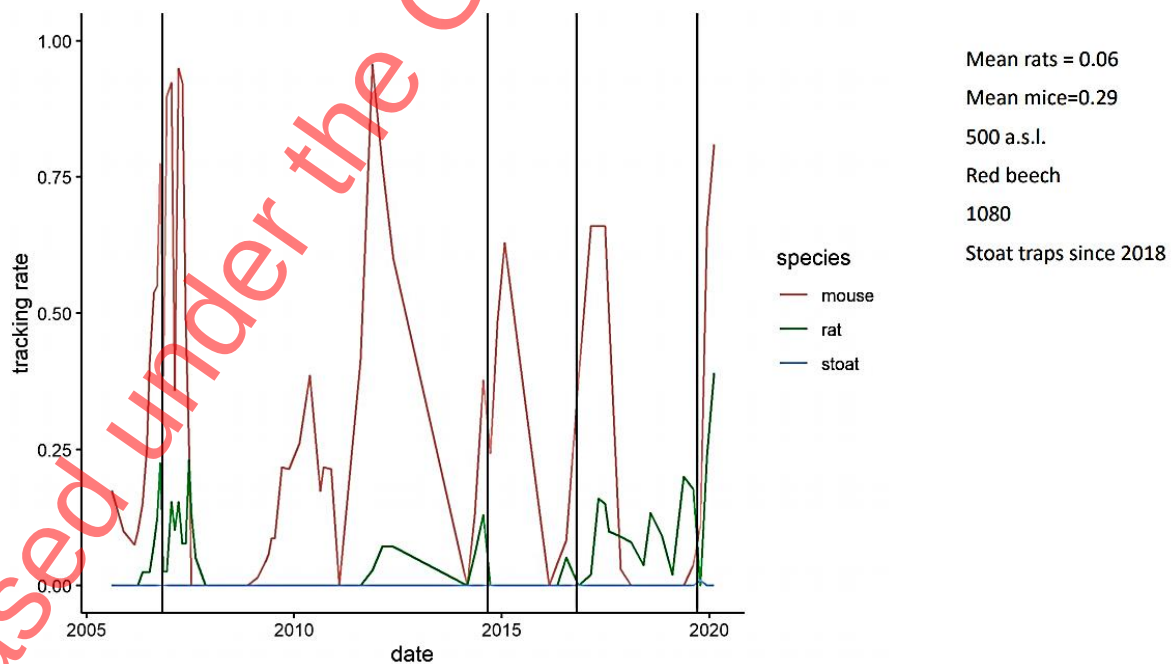


Fig. 1b. Caples overnight Tracking Tunnel Results

Appendix 4 – Outcome monitoring

a. Methods

Year	Mohua	Rock Wren	Whio	5MBC	Kea
2000/01	October 1km transects, 4 repeats with >30min between repeated transects: 10 @Dart 10 @ Caples	-	-	-	-
2007/08		-	Dart watershed surveys with dogs	-	-
2010/11		-	-	4 repeats/yr at start & end of each mohua transect: 30 stations @ Routeburn 26 stations @ Dart 20 stations @ Caples	-
2012/13	15 (or 19?) transects @ Dart	-	-		-
2014/15	14 transects @Caples	-	-		-
2015/16		30 x 250m transects repeated 4x each within 1 week in Feb @ Harris Basin	-		-
2016/17	0 transects @ Caples		-		-
2019/20			Dart watershed surveys with dogs		Kea Survey Tool started. 1 hour submitted.
2020/21	11 transects @Greenstone		Dart watershed surveys with dogs (not whole watershed)	22 stations @ Greenstone	234 hours submitted
2021/22			-		91 hours submitted
2022/23			-		207 hours submitted

Table 6. Outcome Monitoring Methods over time. Any change from the initial method is indicated when it occurred in subsequent years; a “-” indicates no survey was performed that year.

b. Results

Mohua (most sensitive NPCP species of Dart-Caples forest ecosystems)

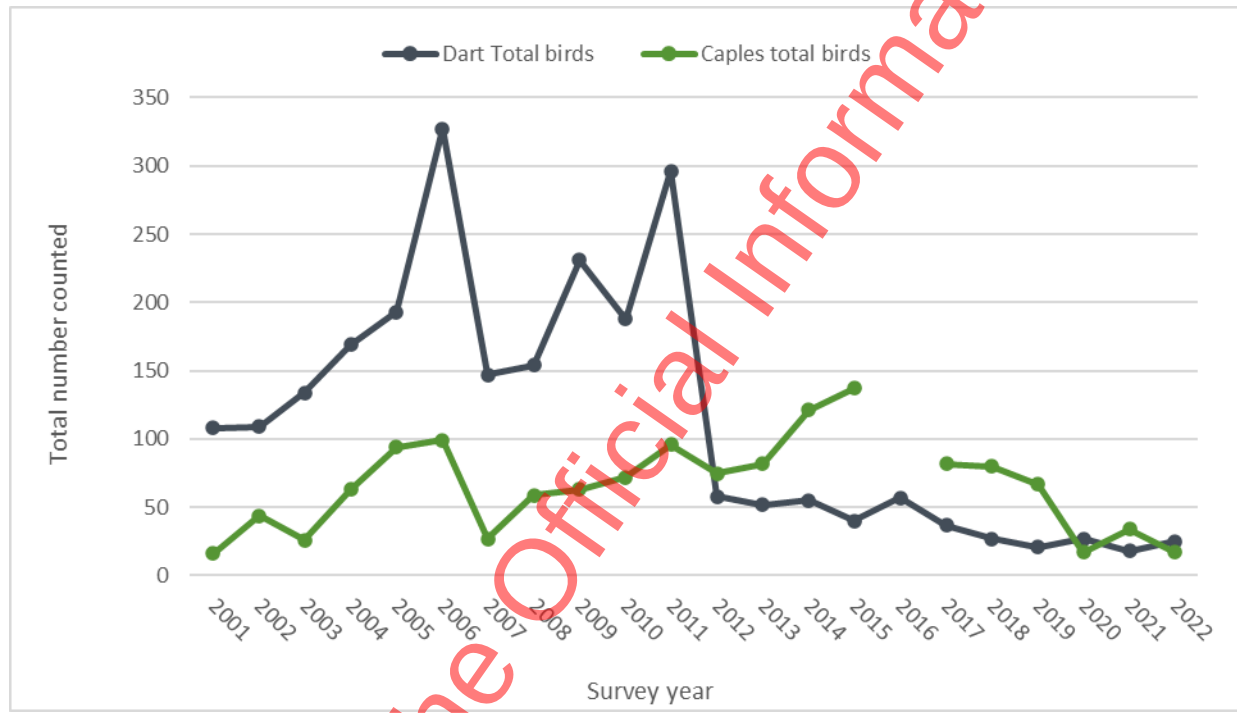


Fig. 2. Mohua counts at Dart and Caples valleys (on ten original 1km transects)

Rock Wren (most sensitive NPCP species of Dart-Caples alpine ecosystems)

Year	Mean Rock Wrens/ transect	
	Harris Basin (Treatment)	Scott Basin (Non-treatment)
2014-15	0.55	-
2015-16	0.79	-
2016-17	0.76	-
2017-18	1.34	-
2018-19	1.05	-
2019-20	1.14	0.44
2020-21	0.63	0.01
2021-22	0.77	-
2022-23	0.63	0.28

Table 7. Rock Wren counts at Harris & Scott Basins

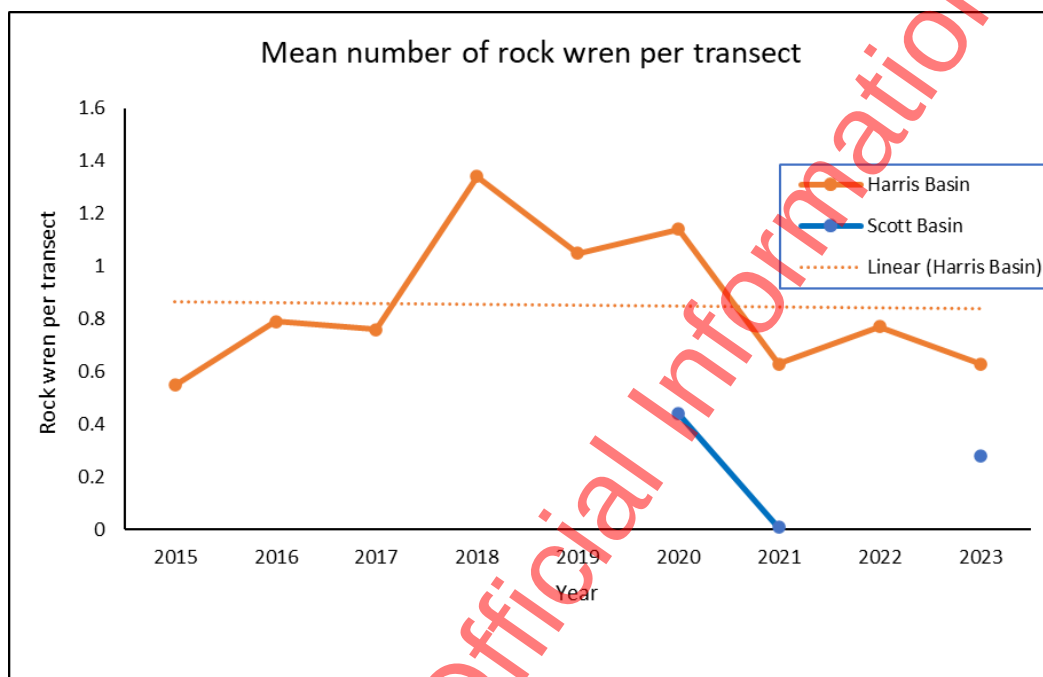


Fig. 3 Rock wren per transect at Harris Basin (Treatment area) and Scott Basin (Non-treatment area).

Other species

See DOCDM-6750828

[END]

Tiakina Nga Manu summary report from 1 July 2014 to 30 June 2021

s9(2)(g)(ii) - December 2021

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EXECUTIVE SUMMARY

- Tiakina Nga Manu (TNM) is the Department of Conservation's (DOCs) landscape predator control program. TNM was initiated in 2014 as a response to rat and stoat irruptions caused by beech masting.
- The goal of Tiakina Nga Manu (TNM) is to protect threatened native birds, animals and plants from rats, stoats, and possums.
- Orange-fronted parakeet, kiwi, mohua, long-tailed bats, short-tailed bats, whio, kea, rock wren, kokako, powelliphanta snail and lizard populations are managed by TNM at sites throughout New Zealand.
- A wide range of native biodiversity benefits from TNM management including the prevention of canopy collapse at some sites.
- TNM use aerial 1080 on a landscape scale (e.g., 30,000ha) supplemented with smaller scale more intensive ground-based control (e.g., bait stations and trapping).
- Between 1 July 2014 and 30 June 2021 TNM carried out 78 aerial 1080 operations.
- Percentage rat kill was variable between operations and years with poorer results in mast years
- Research has clearly shown the benefits of TNM pest control to populations of native species. However, species vulnerable to stoats (e.g., whio) respond better to predator control than species sensitive to both stoats and rats (e.g., orange-fronted parakeet and mohua).
- TNM best practice methods for predator control using aerial 1080 is effective and continuing to improve.
- Further improvements in bait palatability, bait application timing, and the frequency of treatment are required to better protect species at site.
- Modeling is underway to identify a sustainable program of work linked to well defined outcomes at site.

1. CONTEXT

Tiakina Nga Manu (TNM) is the Department of Conservation's (DOCs) landscape predator control program. TNM was initiated in 2014 as a response to rat and stoat irruptions caused by beech masting. The goal of Tiakina Nga Manu (TNM) is to protect threatened native birds, animals and plants from rats, stoats, and possums. Orange-fronted parakeet, kiwi, mohua, long-tailed bats, short-tailed bats, whio, kea, rock wren, kokako, powelliphanta snail and lizard populations are managed by TNM at sites throughout New Zealand. TNM use aerial 1080 on a landscape scale (e.g., 30,000ha) supplemented with smaller scale more intensive ground-based control (e.g., bait stations and trapping).

Beech mast-initiated rat and stoat plagues (King 1983, King & Moller 1997) and the impacts of introduced predators (rats, stoats, and possums) on native biodiversity is well known (King 1984, Innes et. al. 2010, Montague 2000). Aerially applied 1080 has been used since the 1960s, to control possums as vectors of bovine tuberculosis and to prevent forest canopy collapse in forest types vulnerable to possum browse. Possums were first shown to prey on birds in 1993 (Brown et. al. 1993). However, it was not until the 1990's that the effectiveness of 1080 at controlling rats at large scales was described (Innes et. al. 1995). While the effectiveness of 1080 at killing stoats through secondary poisoning was first identified in 1999 (Murphy et. al. 1999).

When DOC was formed in 1987, it inherited the aerial 1080 possum control operations lead previously by the New Zealand Forest Service. DOC prioritized the protection of native plant and animal communities from possums on Crown Land in its national possum control plan 1993 – 2002 (DOC 1994). Meanwhile, the National Priority Pool Fund was established to finance targeted possum control by DOC. The local extinction of mohua on Mount Stokes during a 1999/2000 mast event raised awareness of the impact of predator eruptions linked to beech seed mast events (Gaze 2001).

The New Zealand Biodiversity Strategy written in 2000 further reinforced the need for biodiversity protection and Government provided an extra \$54 million (DOC 2000). The South Island Beech Forest Advisory Group formed in 2002. It was research focused and subsequently morphed into the more applied Operation Ark. Operation Ark began in June 2004 to protect bats, whio, mohua and orange-fronted parakeet from rats, stoats, and possums at 10 South Island sites using both ground-based tools and aerial 1080 (Elliott & Suggate 2007). In 2009, Operation Ark morphed into the South Island Pest Response Group (SIPRG). While funding sources changed the goal of this group remained the same as Operation Ark.

SIPRG morphed into Battle for our Birds in response to the 2014 beech mast event. The 2014 beech mast response was reviewed resulting in a more structured national response (Cox 2015). Accordingly, the scale of the DOC landscape predator control program and budget increased in time to face the next challenge of the 2016 beech mast. Save Our Iconic Kiwi (SOIK) is a separate program aimed at protecting kiwi from predators. It commenced in 2018 with TNM managing aerial 1080 operations on SOIK's behalf to protect Northern and Southern Tokoeka and Roroa (Great spotted kiwi). Battle for our Birds was renamed Tiakina Nga Manu in 2019 following a change in Government.

The intensity of mast seeding varies by site and year. In addition to the two major events of 2014 and 2016, 2019 was even bigger with intense seeding everywhere. Another beech mast is predicted for Southwest New Zealand in 2022. Other trees mast (e.g., rimu) but little is known about their triggers and impacts on pest abundance (Harper 2005). Evidence of the benefits to bird communities from long-term integrated pest control has continued to grow (Brown & Ulrich 2005, O'Donnell et. al. 2012, Brown et. al. 2015). The Parliamentary Commissioner for the Environment reviewed 1080 use in 2011 (Wright 2011) and called for increased use to protect native biodiversity. BFOB/TNM landscape scale pest control using 1080 in beech forests was described by Elliott and Kemp (2016).

1.1 Purpose of this document

The purpose of this document is to provide a summary of TNM's program of work from 1 July 2014 to 30 June 2021. While this report has been written for everyone interested in the TNM program, the prime audience is operational staff.

2. WHAT WE ARE TRYING TO PROTECT

2.1 Goal of Tiakina Nga Manu

The goal of Tiakina Nga Manu is to protect threatened native birds, and other animals and plants from rats, stoats, and possums (Rutledge 2021).

2.2 Biodiversity values TNM aim to protect

TNM aim to protect populations of “managed threatened species” (species that TNM use to prioritize management sites nationally). TNM also protect a wide range of ecosystem values and “benefit species” (other native plant and animal species that benefit indirectly from TNM management) and prevent canopy collapse.

2.3 Managed threatened species vulnerability

Orange-fronted parakeet and Mohua are vulnerable to rat and stoat predation all year. Both species are year-round users of tree cavities for roosting and, seasonally, for nesting. These cavities are commonly found on main tree trunks where they are easily located by predators searching for den sites and hunting for food. Both species are even more vulnerable when nesting as females spend nearly 100% of their time on the nest. Mohua nest October to February, OFK December to March most years, but all year round in mast years.

Kiwi chicks are vulnerable to stoat and feral cat predation until they reach 1200gms at 6 months old. Their key period of vulnerability is from November to August, each year.

Kea eggs and nestlings are vulnerable to stoats from August – March. In normal years nesting success is about 40%. While foraging on the ground, adults and juveniles are vulnerable to stoats and feral cats year-round when rodents are scarce. When rodents are common, predation on kea is rare. In stoat eruption years the second half of the post-mast year and the year after that, nest success drops to <5%.

Rock wren are widely thought to be most vulnerable to stoats when nesting (October to January), but like mohua and parakeets they roost in holes and may suffer from catastrophic wintertime predation. Episodic outbreaks of rats, weasels and feral cats in the alpine zone possibly impact heavily on rock wren.

Long-tailed and Short-tailed bats are vulnerable to stoats, rats, cats, and possums. Both species roost in tree cavities year-round. During the breeding season (November to February) the females congregate in roosts to raise their young. Bats are likely to be vulnerable to predators all year, but the effects of predation may be more pronounced during the breeding season when they are roosting in larger numbers.

Whio adults and eggs are vulnerable during nesting (August to January) to stoats. Adults are also vulnerable to stoat predation while molting in riverbank crevices.

Kokako females (incubating eggs), and eggs and chicks are vulnerable to rat, stoat, and possum predation from November to February.

Powelliphanta snails are preyed on by possums year-round particularly at high altitude poor soil fertility sites. Elsewhere rats prey on them year-round.

Lizards that are arboreal are vulnerable to rat predation year-round.

2.4 Additional benefits from TNM management

A wide range of native biodiversity (plant and animal) is vulnerable to predation by rats, stoats, and possums so benefits from control aimed at protecting the ‘managed threatened species’.

Forests (particularly southern rata, kamahi, and northern hardwood and coastal) are vulnerable to canopy collapse from possum browse.

2.5 Tiakina Nga Manu sites

Figure 1: Map of TNM 2021 management sites

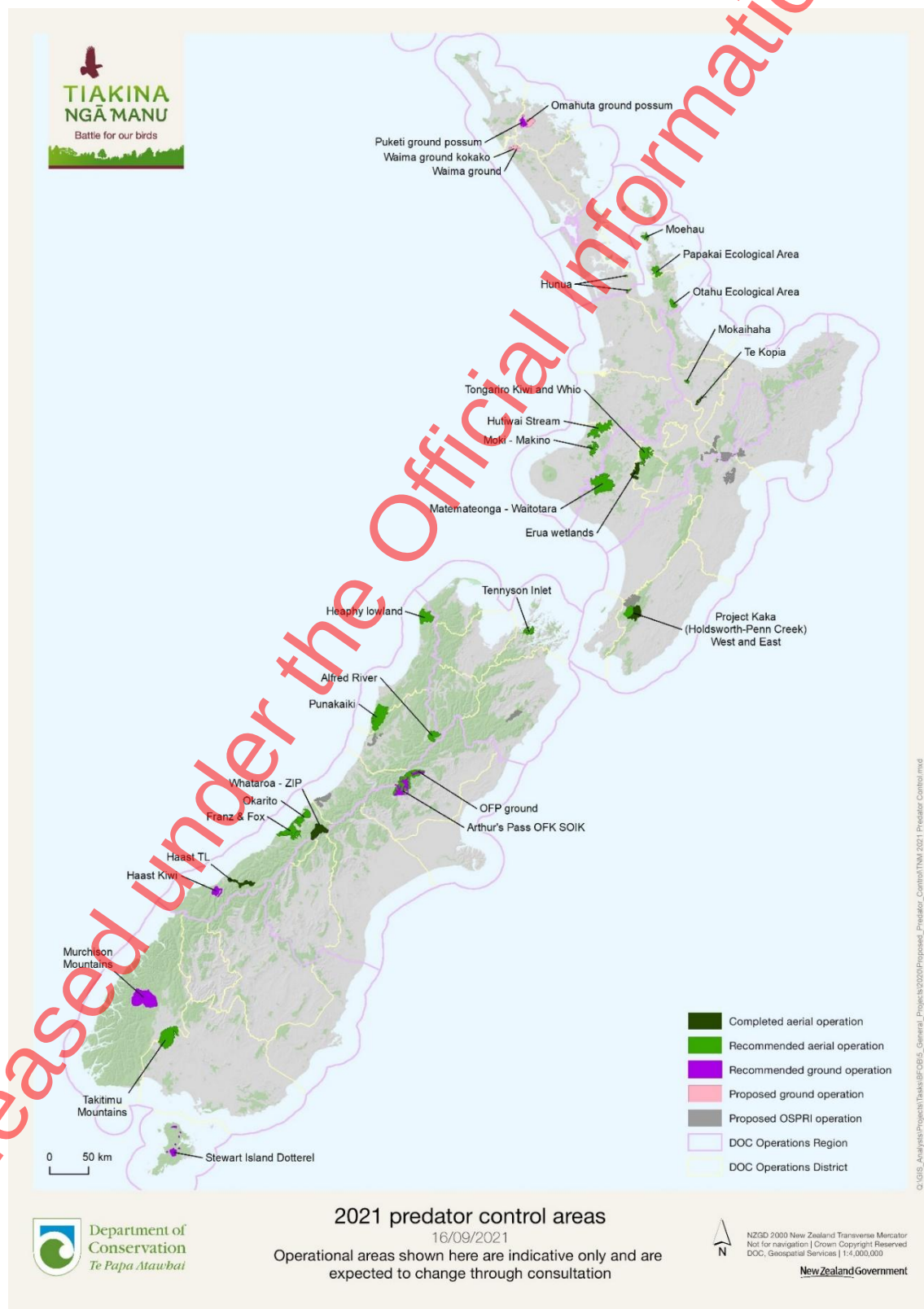
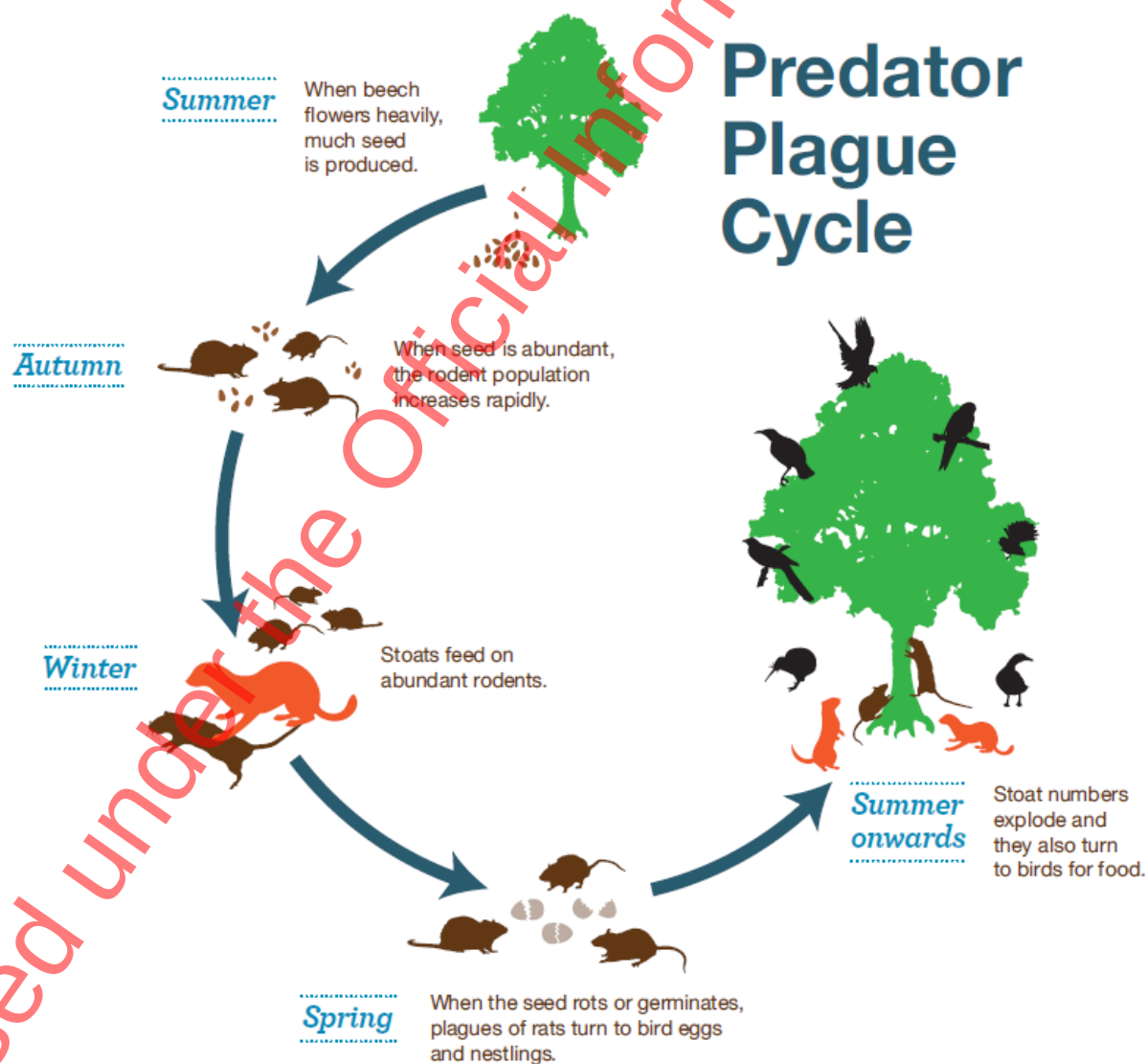


Figure 1 shows the proposed TNM work for the 2021/22 year. It illustrates the distribution and scale of TNM predator control effort.

3. ECOLOGICAL COMPLEXITY

3.1 Masting dynamics

Figure 2: Predator response to masting



3.2 Mast frequency and intensity

Mast intensity varies through space and time. They do not occur every year and their intensity can vary with geographic location. Masts can be characterized as partial, full, or mega dependent on their intensity and scale. The figure below illustrates variation through time. It is derived from the DOC seed-rain database, which stores seed fall data recorded from seed-rain traps located in forests across New Zealand. The figure shows the mean number of Mountain, Hard, Red and Silver Beech seeds collected in seed-rain traps divided by their catching area. Seed-rain exceeding 1000 seeds m^{-2} is often associated with rodent irruptions.

Figure 3: Mast intensity between 1969 and 2000 for mountain, hard, red, and silver beech.

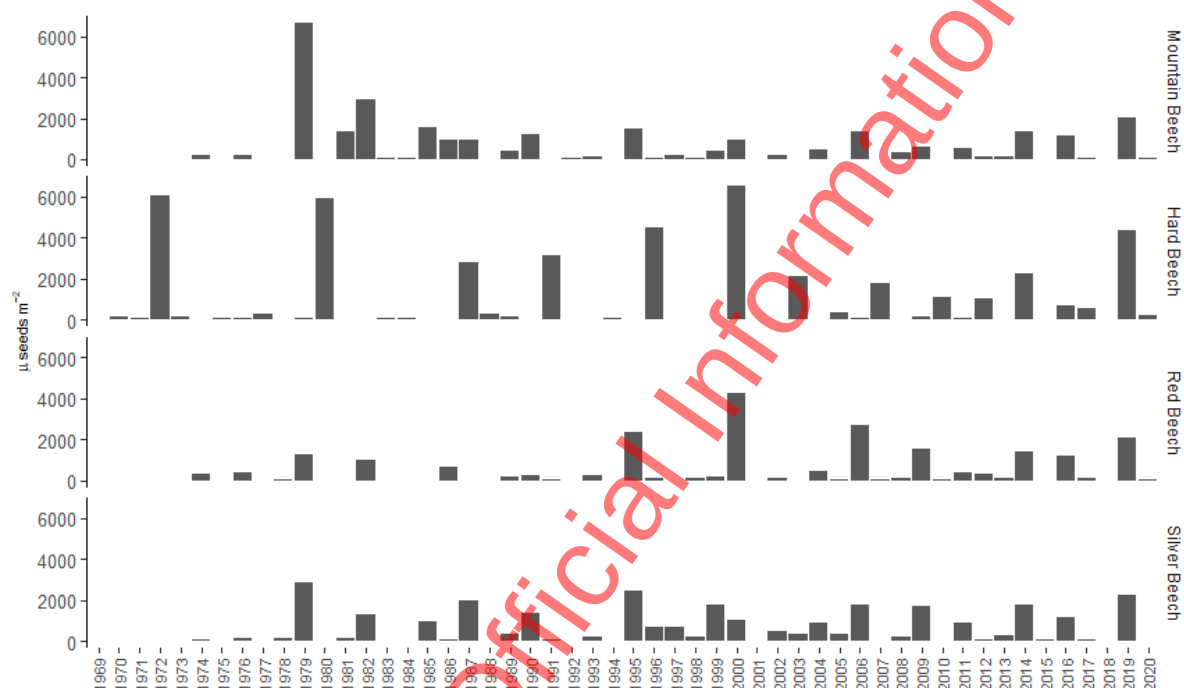


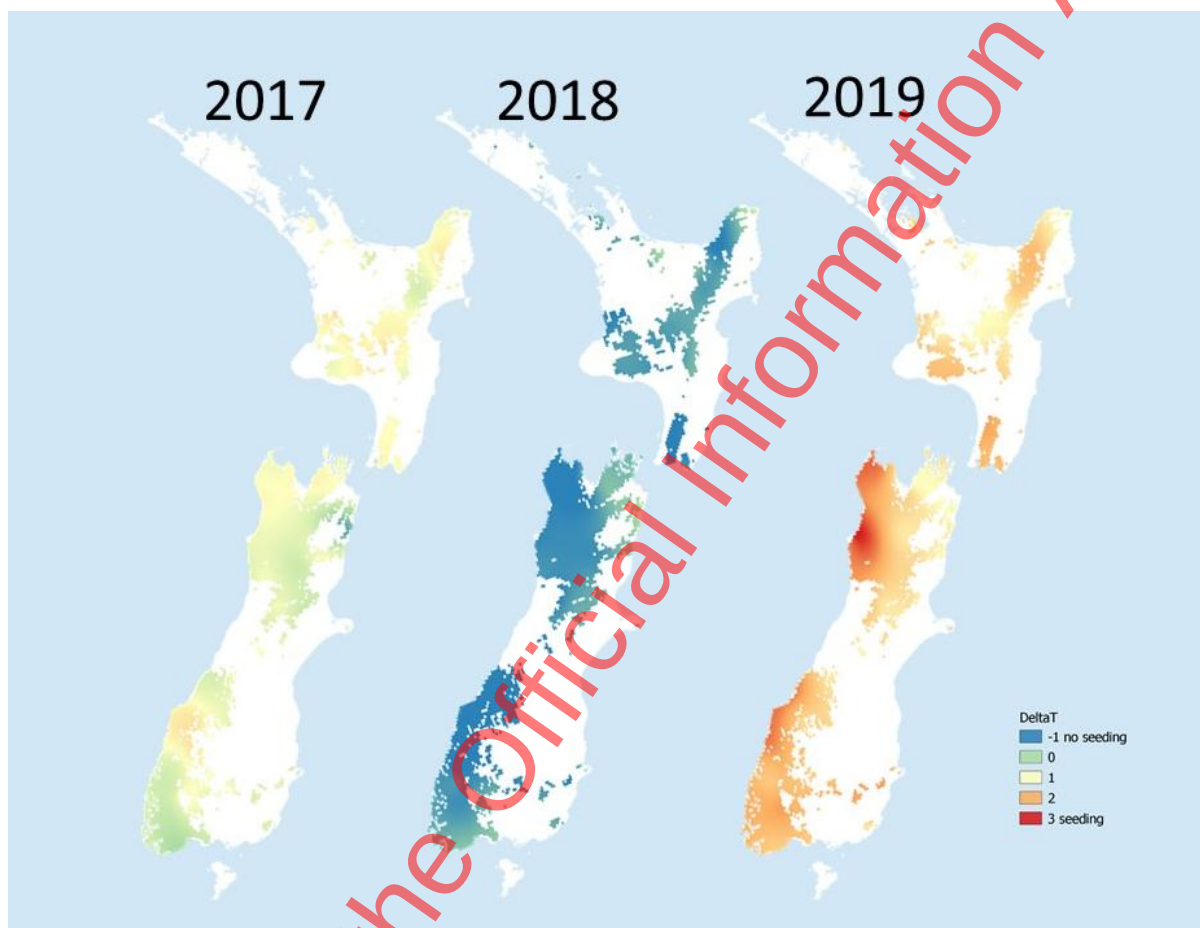
Figure 3 illustrates the variability in beech seed masting by year and beech species.

3.3 Mast prediction

Predicting beech mast events early and accurately is critical to priority setting and operational planning. Temperature modelling (estimating Delta T) using NIWA climate data is carried each March to predict beech October/November flowering. Anecdotal field observations are also used to find flowers and pollen at different sites. Annual seed snipping (removal of beech and rimu branch tips) from the outer canopy is carried out in February/March to estimate mast magnitude. Seed rain collection in February/March/April is processed in June/August and used to confirm masts for beech. Rimu tree climbing is used to detect fruiting and fruiting tips that produce in the following year. Tussock seed flower per plant are counted in summer (January/February/March), along transects, each with 20 marked tussock plants of species dominant at site.

Figure 4: Predicted mast intensity using Delta T modelling

This figure shows variation in beech seeding predictions for the years 2017, 2018 and 2019. A Delta T of 1 or greater results in masting. In 2019 heavy beech seed masting occurred throughout beech forests nationwide. The coloured key on the right reflects the likelihood and intensity of masting. The most intense masting is red and occurred at Kahurangi in 2019.



3.4 Pest ecology

In mast seeding forest systems, **rodent** populations can be highly irruptive. When resources are scarce, there are usually close to no rats or mice present in beech forests and alpine areas (usually 0% tracking). Following a beech flowering, rodent populations rapidly increase and if resources are plentiful can continue breeding all winter, meaning the next spring there are high numbers of rats and/or mice. When there's a full mast, rodents increase at the same rate, regardless of whether it's a 'full mast' or a 'mega mast'. Therefore, peak rodent abundance at the end of the irruption hinges on pre-mast rodent abundance.

When beech seed is consumed (or germinates – usually mid-late spring) then rodent breeding slows and stops. But it takes nine-twelve months for tracking rates to return to near zero. Mouse tracking usually crashes between May and August of the post mast year, whereas rat tracking usually crashes between August to November in the post mast year.

Mouse irruptions usually go all the way to tree line and into alpine ecosystems, especially if snow tussocks have seeded. High magnitude rat irruptions can push up into the alpine zone. Rats in the alpine zone ARE a rare event that we should attempt to prevent at managed sites.

However, different forest types have different soil fertility, drainage and vegetation communities resulting in different pest dynamics. For example, productive mixed broadleaf podocarp forests can maintain high rat abundance (>50% tracking). In northern mixed broadleaf podocarp forests where food sources are more stable year-round ship rat abundance can reach 12 rats per hectare. Rat abundance is higher in these forests where possums have been controlled due to reduced competition for food (Sweetapple & Nugent 2007).

Rat reinvasion rates after treatment can be high depending on treatment area shape and size, natural barriers to dispersal, operational efficacy (including presence of exclusion zones) and dispersal pressure outside the operational area (Innes & Russell 2021). Mice numbers are normally suppressed by rats but can reach very high abundance when rats and other predators are absent or when released from predation pressure (e.g., post high rat kill in a 1080 operation). Mice kills in 1080 operations are variable especially in mast years. High numbers of mice can also result in high weasel numbers with the risk that rats, and stoats are replaced by mice and weasels (Murphy & Nathan 2021).

Stoats have large home ranges between 70 and 220 ha in beech forest. Male home ranges overlay several smaller female home ranges. While stoats only breed once each year, the number of young born is closely related to food availability with up to 13 young in mast years. Young are born in spring and disperse in summer (December to January). Stoats are vulnerable to secondary poisoning from eating poisoned rats, mice, and possums. 1080 secondary poisoning is less effective when many rodents survive poison baiting. Stoat reinvasion rates can be high if operations are poorly timed relative to juvenile stoat dispersal (King & Veale 2021). Without management stoats increase at the end of the mast seed year, regardless of which rodent species have irrupted, and take two years to return to low levels.

Weasels can breed three times a year averaging 4.5 young per litter. Weasels like stoats are vulnerable to successful rodent poisoning (King & Murphy 2021). However, weasels can reach high numbers following mice increases in response to successful rat control.

Possums breed comparatively slowly (1-2 young per year/female) and do not seem to respond to masts because they are less fecund. However, they are long-lived, have few predators, and so can steadily increase over several years following control. Possums can reach densities of 25/ha in mixed broadleaf podocarp forests (average of 10-12/ha) but less in beech forest (0.5 to 5/ha). Consequently, operational return times to maintain possums at low abundance are significantly longer than for other pests (Cowan & Glen 2021). Possums can be found throughout forests and often in scrubby vegetation of alpine margins, with some even able to survive in alpine ecosystems.

Cats have large home ranges and occur in forests containing rats. Where rodents are less abundant cats and **ferrets** can “invade” after crashes in rabbits on adjoining farmland putting kiwi and other biodiversity at risk.

Pests are part of complex food webs with complex ecological consequences resulting from pest control (Innes & Barker 1999). Unexpected consequences of control can include competitive and predator release (Ruscoe et.al. 2011). Understanding of how pests respond to control in the medium to long-term through reduced predation and competition is critical to management timing and method to achieve meaningful ecological outcomes.

4. TECHNICAL COMPLEXITY

4.1 Pest control

Historic changes in best practice

Aerial 1080 best practice has changed significantly in the last 50 years. For example, cereal pellets have largely replaced carrot baits and sowing rates have reduced on average through time from 20kg/ha in the 70s to 10kg/ha in the 80s to 5kg/ha in the 90s to <2kg/ha today (Green 2003). Though first developed in the early 90s, GPS guidance equipment became much more prominent in the early 2000's following the shutdown of 'selective availability' accuracy interface by USA owners in 2000. Prefeeding was identified as important in the late 90's (Moss et. al. 1998) but was not universally adopted until the mid-2000's (Kemp 2009). Bucket technology has evolved through time from 1980 on (Garden et. al. 2019, Morgan 2004).

Possum susceptibility to 1080 results in 1999 (Henderson et.al. 1999, Frampton et. al. 1999, O'Connor & Matthews 1999) initiated change to maximize possum kill and minimize bait shyness. Including, change in bait recipe (to increase bait palatability), 1080 concentration (standard use of 0.15% 1080 rather than 0.08%), bait size (6gm/16mm to 12g/20mm baits) and increased cinnamon lure from 0.1 and 0.15% to 0.2% and 0.3% (to aid bait longevity due to high cinnamon dissipation rates). Cinnamon dissipates quicker from 6g baits than 12g baits (Morgan 2012).

Historically, most research effort was spent on improving the efficacy of possum control. However, possum driven changes in best practice did not necessarily improve rat kill efficacy. For example, rats and mice are averse to cinnamon concentrations greater than 0.1% and use of 6g baits results in twice the number of baits at the same sowing rates. While possums remain a target pest, for TNM rodents are the key target pest. Rats and mice prey on native biodiversity, and act as vectors for stoat control through secondary poisoning. Possums are controlled as a by-product of rodent control operations because rodents require more frequent control than possums.

TNM best practice control methods

The main control methods that TNM use are the aerial application of 1080 and bait stations with different toxins targeting rodents, and possums, and stoats, through secondary poisoning, and kill trapping targeting stoats.

TNM aerial 1080 current best practice when targeting rats is to use 6gm/16mm baits sown at 1.5kg/ha prefeed and 1.5kg/ha toxic with 0.15% 1080 and 0.15% cinnamon. Toxic bait is dropped 5-30 days after non-toxic prefeed, with swaths overlapping by 20% (DOC 2021). Best practice is derived from analysis of the TNM aerial 1080 operations database. Three other documents provide guidance - on bucket calibration (DOC-2651373), managing air operations (DOC-2651365) and managing loading sites (DOCDM-1560571). Trials aimed at determining optimum 1080 concentrations, bait type, cinnamon concentrations and other 1080 masks are proposed to further refine aerial 1080 best practice. Rat control using bait stations is guided by DOC best practice (DOCDM-29380) and stoat trapping is guided by DOC best practice (DOCDM-29448).

Aerial 1080 operations best practice improvements

Timing of treatment is critical to effectively protect native species, when they are most vulnerable (e.g., over the breeding season). But different species breed and are vulnerable at different times each year and in different years. Timing many large operations precisely is problematic as bad weather and logistics can adversely affect the program timing.

Because rodents can be more difficult to control when food is abundant, improvements in bait palatability maybe required to improve percentage kills. The frequency of treatment needed to keep pests low enough to benefit some native species is unknown. Even effective control does not last with some rodent and stoat populations re-establishing relatively quickly. We have more to learn if we are to improve aerial 1080 efficacy.

Constraints on aerial 1080 operations

There are many factors that constrain aerial 1080 operations. Weather has a major influence. Fine weather is needed because 1080 quickly leaches from bait in wet weather and snow can limit where bait is sown, and wind can interfere with accurate sowing. Contractor capacity (helicopter and project management companies) is an issue when weather windows are few and operations many. Bait supply, storage and transport capacity is limited. Crown Public Health Units acting under the Ministry of Health (MOH) often prevent sowing of toxic bait over school holidays, public holiday weekends and great walks, and can require exclusion zones around huts, tracks, and waterways. Adjoining landowners can restrict and/or deny access to helicopter loading sites. The kea code of practice (DOC-5889535) also limits where and when operations are carried out to maximize the benefit and minimize the risk to kea.

5. MANAGEMENT RESULTS AND OUTCOMES

5.1 Pest control results and biodiversity outcomes

The number of hectares treated aerially with 1080 by DOC has increased significantly since 2014 when BFOB/TNM was initiated. Over the 14 years from 2000 to 2013 DOC treated about 122,000ha per annum while in the last seven years TNM has treated about 433,430ha per annum (3.5 times as much per annum). However, the number of operations carried out by TNM annually is variable, primarily driven by beech mast events.

Table 1: Number of TNM aerial 1080 operations between 1 June 2014 and 30 June 2021, hectares and rat kill results

Year	Number of operations	Hectares	% rat kill >97%
2014/15	32	644,553	74% (n=19)
2015/16	5	93,019	100% (n=1)
2016/17	32	760,567	56% (n=18)
2017/18	23	422,729	100% (n=7)
2018/19	16	243,709	50% (n=2)
2019/20	25	626,202	70% (n=20)
2020/21	11	243,228	100% (n=1)

Note: The number of operations where percentage rat kill is known is less than the total number of operations because data was not collected at all sites and sometimes the data that was collected was confounded.

Of the 80 separate operations analysed between 2014/15 and 2020/21 43% were treated once, 32% twice, 18% three times, 2% four times, 4% five times and 1 six times. There was also considerable variation in the size of each operation at the same site.

Table 2: TNM supported ground-based control operations in 2020/21

Site	Hectares	Purpose	Pest	Method
Omahuta	4,000	Protect short-tailed bats	Stoat and feral cats	Double set DOC 200 traps 200 x 200m and SA 2 cat traps 400 x 400m
Puketi	2,000	Maintain forest health	Possum	Cyanide and leg-hold trapping
Waima	440	Kokako nest protection	Rats, stoats, and possums	Bait stations 100 x 50m, Diphacinone, Double set DOC 200 traps
Haast	7,570	Protect Haast kiwi	Stoats	Double set DOC 200 traps
Murchison Mountains	52,985	Protect Takahe	Stoats	Double set DOC 150 traps
Arthurs Pass	5,671	Protect orange-fronted parakeet	Stoats	Trap upgrade to Double set DOC 200 traps
Stewart Island	5,382	Protect Stewart Island Dotterel	Feral cats and rats	1080 fishmeal, live catch, and opportunistic shooting, and brodifacoum

While TNM is mainly focused on aerial 1080 operations ground based control is also supported. Table 2 above shows where ground-based control was carried out in 2020/21.

TNM pest control results

Of the key pests, most effort is put into monitoring rats pre and post treatment. The rat % kill results are also variable with many unable to achieve at least a 97% kill particularly in mast years (See Table 1 above). Mustelid (it is not possible to distinguish between stoat and weasel footprints) monitoring is different. Tracking is measured after treatment and compared with non-treatment sites. Mustelid tracking is normally zero after treatment but where tracking is present it is often weasels (confirmed through trapping at site). Weasels breed quicker than stoats and feed on the mice that have survived treatment. Possum monitoring is seldom carried out, but pre-treatment monitoring can trigger treatment.

TNM biodiversity outcomes

Much work has shown the benefits of pest control to native biodiversity (Innes et. al. 2010, Brown et. al. 2015). Long term studies have shown the benefits of repeated aerial 1080 operations for North Island kiwi (Robertson et. al. 2019) and aerial 1080 combined with ground control for a range of other species including mohua, bats and kaka (O'Donnell & Hoare 2012, O'Donnell et. al. 2017, Greene & Thurley in press).

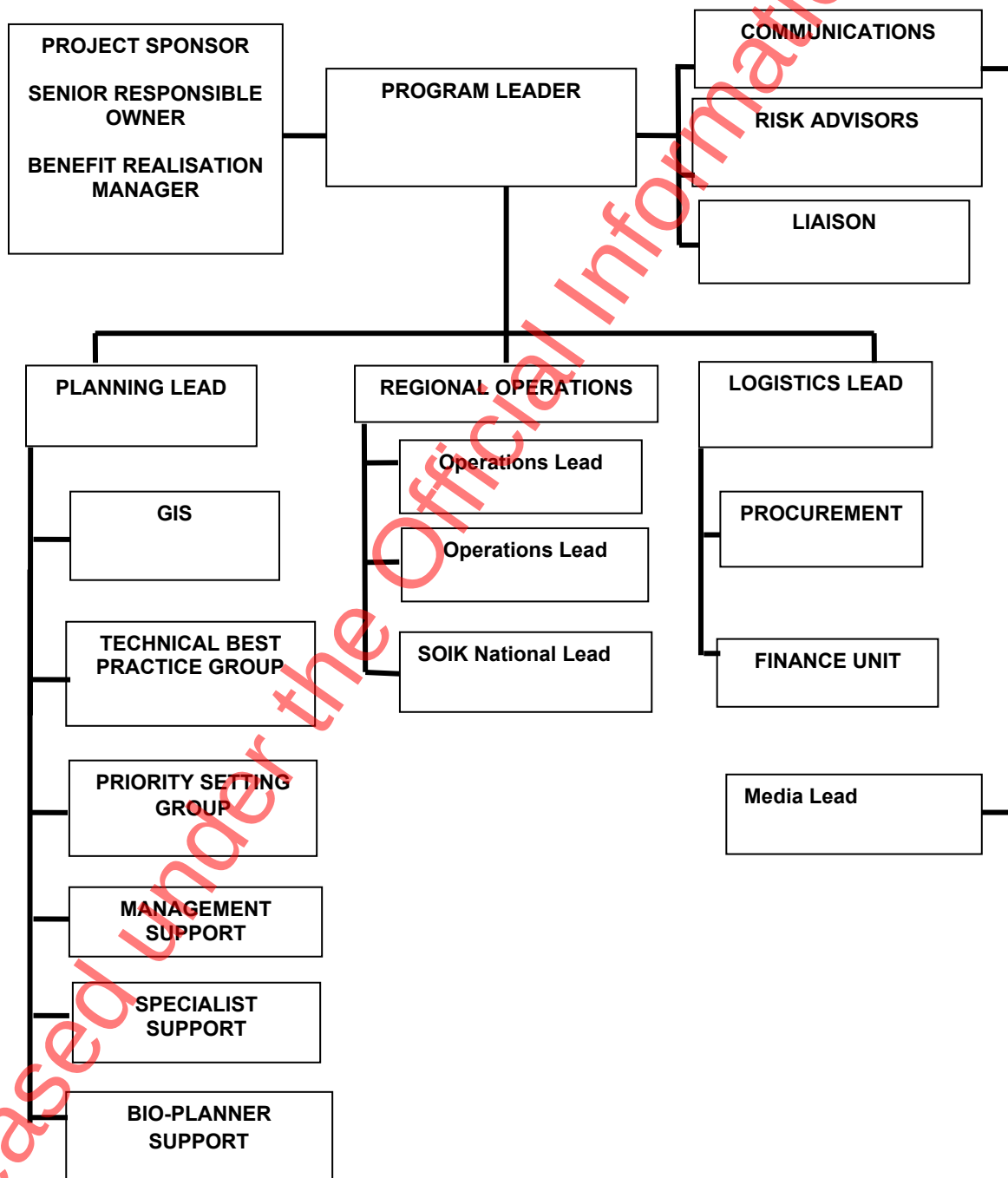
Published work linked to TNM management has shown benefits to kea (Kemp et. al. 2018, Kemp et. al. 2019), weka (Tinnemans et. al. 2019), and robins (Bell et. al. 2021). Currently unpublished work shows benefit to kea (Kemp et. al. in press), whio (Steffens et. al. in press), kaka (Elliott et. al. in press, Greene et. al. in prep.), rock wren (Rawlence et. al. in prep.), rifleman (Kilner et. al. in prep.), morepork (Malham et. al. in prep.), great spotted kiwi (McDonald et. al. in prep.), bats (Thurley et.

al. in prep.), whio (Malham et. al. in prep.), mohua (Elliott, et. al. in prep.) and forest birds (Elliott, et. al. in prep., Greene et. al. in prep.).

Species vulnerable to stoats (e.g., whio) respond better to predator control than species vulnerable to stoats and rats (e.g., orange-fronted parakeet and mohua). For example, a Kahurangi whio survey currently underway has found more than five times as many whio pairs (n=314) compared with a survey carried out 20 years ago (n=58) yet less than half the area previously surveyed has been re-surveyed. Whio in Kahurangi National Park have benefited from repeated 1080 operations integrated with ground-based stoat trapping (Jason Malham pers. comm.).

6. MANAGEMENT STRUCTURE

Figure 5: TNM management structure



TNM is a large-scale program of work that is structured using a Coordinated Incident Management System (CIMS) approach (Govt., 2020). Roles and responsibilities are described in Table 3 below.

6.1 Roles and responsibilities

Table 3: TNM Roles and responsibilities

Role	Responsibility
Governance	Support TNM accessing resources and managing barriers
Responsible manager	Responsible for ensuring the program achieves its goal
Benefit manager	Ensure biodiversity technical advice is available
Program leader	Manage the TNM program
Communications	Provide communications and engagement support for TNM
Risk advisor	Identify and minimize or eliminate program, operational and staff risks to the Department. Regional leads manage human safety risks
Liaison	Manage communications with external stakeholders
Planning lead	Coordinate TNM planning by liaising with operational, science, planning, communication, security, health and safety and management teams across the country. To help identify and manage risk, make best use of available resources, and help improve DOC systems and standards
GIS	Provide geospatial support to the TNM program
Best practice TAG	Maintain and update best practice and provide operational and strategic advice
Priority TAG	Determine annual site management priorities for the TNM program
Management support	Provide management support for the TNM program
Regional leads	Coordinate and support the delivery of the regions TNM program
SOIK lead	Manage the save our iconic kiwi protection program
Logistics lead	Provide logistics support for the TNM program to ensure the availability of helicopters and bait
Procurement	Establish and manage contract managers for operations, aircraft, security and bait manufacture and storage facilities.
Finance	Tracks the TNM finances and provides forecasts

7. MANAGEMENT APPROACH

7.1 Community engagement and social license

TNM's partners

DOC has a responsibility to work closely with iwi as part of the Treaty of Waitangi. Given our similar goals "to protect nature" DOC desires to develop close partnerships with iwi. Guidance on engagement with iwi (DOC-6290966) and a 4-year Communications and Engagement strategy (DOC-6315626) and guide (DOC-6598934) are available resources that outline the approaches to be used.

OSPRI through its subsidiary company TB Free NZ, undertakes aerial 1080 on private land and some Public Conservation Land to control vectors of bovine TB and thereby minimize the disease in stock which in turn protects access to agricultural export markets. Where timing and location offer opportunities for synergies DOC cooperates with OSPRI to simplify logistics and/or increase the scale of control undertaken.

DOC's legal responsibility to consult and notify

Consultation with iwi and/or hapu, owners in and adjacent to proposed treatment sites, all grazing license holders is compulsory and is supported with a communications plan. Consultation is a stage in the decision-making process, with DOC keeping an open mind about the final operational plan for a site.

Notification in contrast is about informing local community, stakeholders, visitors, and users about the forthcoming pest control operation. Notification is strongly regulated for operations on public land, and this is covered by DOC's standard procedures (see DOCDM-1488532).

Engagement and communication

Engagement involves active participation and codesign with community, Treaty Partners, and public voices. TNM is a subset of DOC's wider approach to engage New Zealanders with nature. TNM aims to develop partnerships at place – to strengthen awareness of, and participation in co-decision making, on how to protect native wildlife and the places they live.

OIA's

Official Information Act (1982) requests are requests made by members of the New Zealand public to a Government Department. The intention is to promote openness and transparency and enable greater public participation in government. TNM has received many OIA's (2015/16 = 15, 2016/17 = 58, 2017/18 = 112, 2018/19 = 217, 2019/20 = 182, 2020/21 = 127) reflecting a keen public interest in the use of aerial 1080.

7. 2 Management cycle

Figure 6: Theoretical management cycle

This management cycle (based on the Deming Cycle) illustrates the key components of managing a program of work.



Below the key components of the TNM management cycle are described.

7.3 Planning

TNM strategic planning

The draft Tiakina Nga Manu Strategy Document 2021-2031 (Rutledge 2021) describes TNM's strategic direction for the next 10 years. It describes the primary goal of TNM as "to ensure sufficient populations of threatened species are protected until we achieve Predator Free Aotearoa New Zealand". The strategy provides a framework for four-year and operational planning.

Four-year planning

Four-year plans are produced annually to identify the landscape scale predator control operations planned by the Department of Conservation across New Zealand and estimate their indicative funding. These plans provide a basis for consultation, and improved coordination with other groups. They also improve DOC's operational efficiency through better forward planning and coordination.

Site based operational planning

Every pest control operation both ground and aerial require an operational plan as part of DOC's standard operating procedures (DOCDM-1488532). Operational planners must have the appropriate training and plans are peer reviewed, readiness checked, assessed as part of the DOC permissions process, and a proportion are audited for compliance during implementation (see DOCDM-1562274).

Permissions

Operations may require landowner and/or occupier consent, resource consent, DOC permission and Public Health permission (see DOCDM-1475279).

Site-based outcome planning

Outcome plans identify biodiversity values at site, long-term desired outcomes, the management required to achieve those outcomes and how outcomes will be measured. This process can provide clarity on the scale and intensity (e.g., expansion of ground-based control) needed to achieve outcomes. It also informs the sizing of the TNM program of work. Outcome plans connect the ecology of pest and threatened species management with optimum control design and methodology whilst informing financial planning.

To date TNM have two draft outcome plans, one for Arthurs Pass (DOC-6431817) and for Dart-Caples (DOC-6762693). Further plans are being developed for Kahurangi.

Choosing sites for management annually

The TNM site prioritization TAG meets annually in March to determine priority sites for treatment in the next operational year. Mast predictions (see above) strongly influence priorities. Sites are scored on the values at site and urgency of treatment needed to protect those values. In mast years, urgency is determined by the intensity of mast and risk of management species decline. In non-mast years, urgency is determined by the time since last treatment relative to the need of the most sensitive management species (DOC-6406152).

Sizing the program to ensure management achieves desired outcomes

Determining the optimum program size within the constraints of the TNM budget is not straight forward. Until now the TNM 1080 program has been planned on a year-by-year basis. A key

unknown is the frequency of mast events and even the optimal return times to protect different management species at different sites is uncertain. A draft sizing of the TNM program has been carried out (DOC-6407164) with a comprehensive model due in December 2021. There will always be a challenge within program long term planning to forecast what is necessary to achieve and sustain outcomes at as many sites as we can, keep program overheads low, fill vital information gaps and collect, manage, and report information adequately to ensure quality management.

Technical advice to support detailed planning

The Best Practice TAG is responsible for the continuous improvement of best practice. This is achieved through analysis of the TNM operational database where correlations between different variables (e.g., sowing rate, time between prefeed and toxic) and rat kill results are sought. In addition, the TAG recommends large scale field trials and other applied research (e.g., palatability pen trials) to better inform best practice. Also, DOC threats scientists (on the TAG) lead research into the biodiversity outcomes of pest management. While best practice acts as a guide additional support is often required around the optimum timing, scale, and intensity of treatment at a particular site. The TAG has a role in answering specific site-based questions from operations, in a timely manner to support planning.

7.4 Implementation

Operational delivery

Priority projects are allocated funds and Operations Managers are asked to nominate site leads, usually from within their district staff. Ideally this is done through a formal task assignment from the Operations Manager. Operations managers and their Regional directors thereafter hold the accountability for delivering the project with support from the national TNM team. This support comes in a variety of forms:

- Training for site leads
- Supply contracts for some of the goods and services required (e.g., bait, helicopters, security, storage)
- Planning support from Regional and National TNM leads, sometimes contracted planning support
- In-house mapping services from the national GIS team
- Monitoring support
- TNM Technical Advisory Group support for questions and problem solving.
- National resources and expertise for communications

Like all animal pest management in DOC, standard operating procedures provide standards for planning, consulting, communicating and safely carrying out the work. Projects using vertebrate pesticides are given specific authorisation through a DOC permission process where site specific performance standards can be applied to manage risks. A proportion (10%) of these permissions are audited for compliance with standards.

Site lead role

The site lead has the critical role of program managing the operation. This includes planning the work, allocating jobs, coordinating the team, maintaining standards, assessing, and managing risks, ensuring the operation runs to time and budget, deal with changes, and ensure expected outcomes and benefits are delivered.

Training

The “operational planning for animal pest operations course” is a prerequisite for the “aerial baiting for landscape predator control course”.

7.5 Monitoring

Monitoring pest control results

Tracking tunnels have been established throughout TNM sites to measure rat, mouse, and stoat population trends and the efficacy of treatments. A 1-night tracking tunnel index is used to measure rodent relative abundance when it is moderate to high and a 21-night tracking tunnel index for rodents (when at low abundance) and stoats. A 7-night wax tag index is used to measure possum relative abundance. There is also a proposal to use lured cameras to monitor rodents, stoats, possums, and hedgehog relative abundance (DOC-6218676).

Monitor biodiversity outcomes

Outcome monitoring is part of the research to determine the benefits of pest control (see above). In addition, DOC District staff have carried out outcome monitoring to determine population trends. This work has been compiled (DOC-6547896) but is yet to be analyzed. Also, a TNM outcome monitoring program has been developed but not implemented (DOC-6218676). This proposed program includes, vegetation monitoring, intensive monitoring of the effect of pest control on a few key native species, and extensive measures of change in abundance of a range of native species at management and non-management sites.

7.6 Reporting

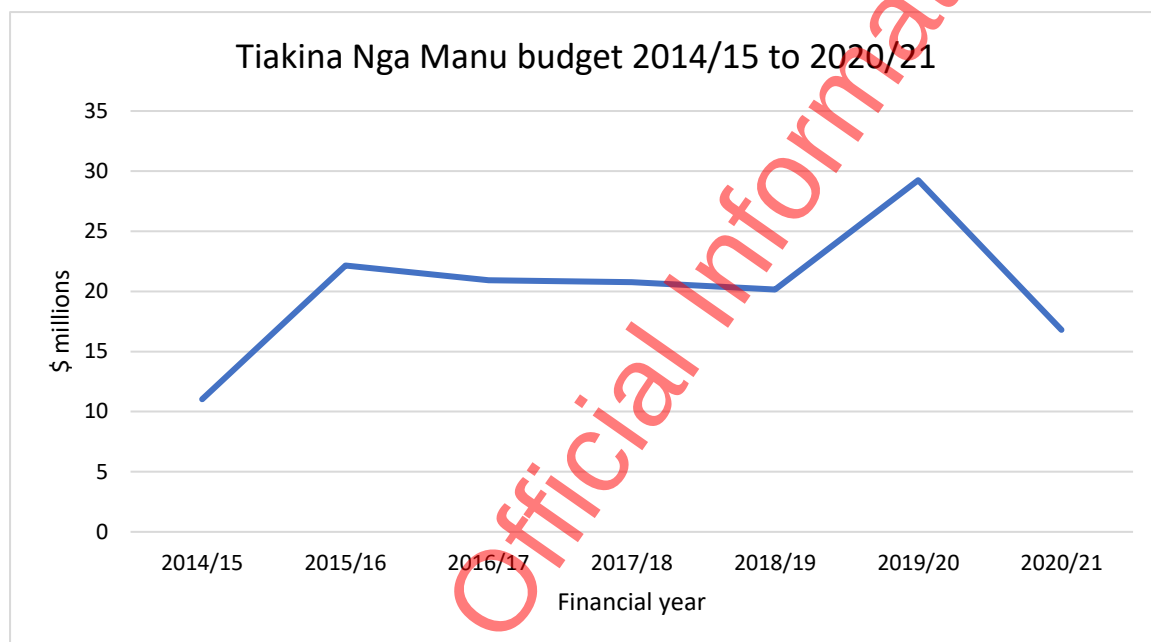
Each operation is expected to produce a report which is lodged in DOC’s Pestlink database. This summary report aims to summarize seven years’ work providing a platform for subsequent annual TNM reports. It is envisaged that annual reports would not repeat the information provided in this report but rather state where TNM worked, summarize treatment and monitoring effort and pest and biodiversity outcome results from the sites (as they become available).

7.7 Review

The TNM program has only been comprehensively reviewed once, soon after its creation. TNM was reviewed following the 2014 beech mast response, resulting in a more structured national response (Cox 2015). Though not a formal review, the program was looked at in detail as part of the strategic planning process (Rutledge 2021).

7.8 Budget

Figure 7: Graph of annual budget 1 June 2014 to 30 June 2021



The TNM budget has averaged \$20,155k per annum but varied annually from \$11,031k in 2014/15 to \$29,246k in 2019/20.

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Timing of mast-response aerial 1080 in upland masting ecosystems

DOCCM-7083017

National Predator Control Programme Best Practise TAG

13/07/2022

Summary

- Percent kills of rodents are highest when their populations are not growing rapidly.
- Rodents in growing populations are food satiated and difficult to train onto novel foods, and pups-in-the-den may miss prefeeding.
- Suboptimal rodent kills translate to suboptimal mustelid kills.
- Species outcomes are compromised by these problems.
- This guideline explains how to time mast-triggered aerial 1080 baiting so as to avoid these problems.

Background

Footprint tracking data from 109 aerial 1080 operations indicates that rodent kill rates are negatively correlated with population growth rate (*see Kemp et al when published*). This is consistent with a food-satiation hypothesis, which predicts that the process by which novel-foods (e.g., cinnamon cereal pellets) become accepted as safe takes longer in the presence of copious natural food (e.g. mast/seed). Food-satiated rodents can afford a more cautious novel-food testing process than hungry rodents. There may also be pups in the den that miss out on prefeeding and therefore survive the 1080 baiting. Untrained rodents have higher survival chances during 1080 baiting operations.

Poor rodent kills appear to translate to poor mustelid kills. Stoats, weasels and feral cats prefer mice over rats and they prefer live prey. Therefore, aerial 1080 operations that leave many live mice and/or rats are likely to be relatively unsuccessful against mustelids.

We need to respond to predator irruptions in masting ecosystems, but these findings suggest that baiting should be undertaken outside of mast-induced population growth periods. This document describes an approach to mast-triggered baiting in masting ecosystems that avoids mast/seed periods.

Rodent and stoat dynamics in upland masting ecosystems

In upland masting ecosystems, such as pure beech forests and snow tussock grasslands, cold intermast winters typically suppress rodent populations to low density. Rat tracking rates are often suppressed to <5%. Mice hang on slightly better than rats, but are also often suppressed to <5% tracking. In mast years, however, rodent populations grow rapidly and in what is known as an 'irruption', fuelled by abundant per-capita food supply (Fig. 1).

When rodents are scarce for a couple of years in a row, stoats also decrease to moderate densities. But stoat density increases dramatically after rodent irruptions, just about the same time as the rodent irruption peaks (Fig 1).

Extreme rat irruptions sometimes happen and these are terribly devastating for native wildlife. Extreme rat irruptions unfold when masting happens over a *primed* rat population (Fig. 2). Priming of rat populations

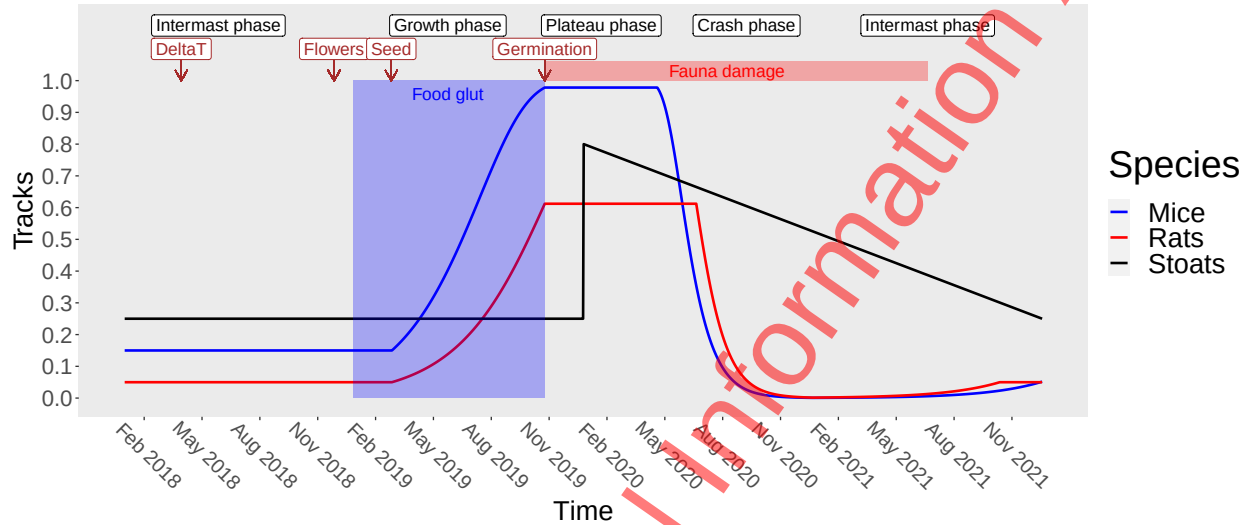


Figure 1: Typical rat, mouse and stoat irruption cascade in an unmanaged upland masting ecosystem.

in upland masting ecosystems happens for reasons like 1) a warm winter, 2) two mast years in a row, 3) mesopredator release due to pest control operations. When rats have an extreme irruption, mice are typically suppressed by the rats and play a lesser role in the irruption cascade.

It is important to understand that, once there is a 'full mast' (i.e., >4000 seeds/m²) seedfall intensity is not the main determinant of rodent irruption magnitude. The main determinant is the rodent density at the start of the seedfall year. After that, it makes little difference if there's 4000 seeds per m² or 10,000. They can only eat 4,000 of them anyway.

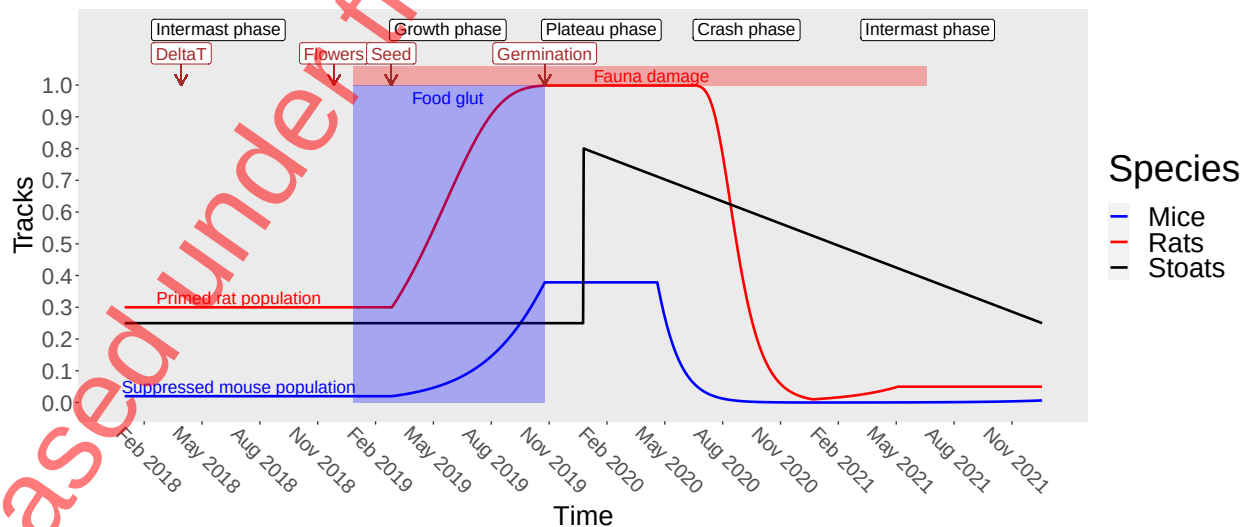


Figure 2: An extreme rat irruption, and suppressed mouse irruption, in an upland masting ecosystem, resulting from primed inter-mast rats.

Rat populations in lowland masting ecosystems, such as mixed rimu-beech forests, are almost always primed because winters are inherently warm. But in upland masting ecosystems, pre-elevation of rats is much rarer. Extreme rat irruptions happened across the South Island in 2000 and again 2019. The 2000 extreme irruptions were the result of two mast years in a row. The 2019 extreme irruptions were because of a warm winter

in 2018. The priming was slightly exacerbated in many managed sites by mesopredator release, from stoat trapping and/or aerial 1080 in the preceding years.

Damage to vulnerable fauna during irruption cascades

In typical upland irruptions, damage to rat-sensitive fauna primarily occurs after seed germination, during the plateau and crash phases (Fig. 1). Compounding the post-germination rat problem is the peak-year stoat cohort, which arrives within a couple of months of seed germination. The collective damage from rats and stoats to vulnerable fauna like mohua and bats during the plateau and crash phases is severe. Otherwise, vulnerable fauna thrive during cold intermast phases and they continue to thrive during the growth phase of a typical upland irruption cascade (Elliott & Kemp unpublished mohua data from Dart Valley, 2011 breeding season).

In extreme rat irruptions, severe damage to rat-sensitive species starts during the growth phase and continues through the crash phase (Dilks et al. 2003, Peter Gaze unpublished report from Mt Stokes DOCDM-300320; Elliott & Kemp unpublished mohua data from Catlins, 2006 breeding season). In warmer masting ecosystems, where intermast rat densities commonly exceed 30% (making extreme rat irruptions the norm) rat sensitive species are mostly already extinct (e.g. Oparara Basin, South Okarito Forest).

Rats penetrate the alpine zone during extreme irruptions and do massive damage to species like rock-wren, alpine lizards and alpine weta. This is exacerbated if snow tussocks mast synchronously with beech. Typically, only mice and stoats are present in the alpine zone.

Food satiation and timing of poison operations

As outlined above, analysis of rat kill data from 109 aerial 1080 operations between 2006 and 2020 links control success with food satiation (or absence thereof), via a link with population growth rates (Kemp & Elliott 2022, unpublished report to TNM TAG). High population growth rates manifest during the seed year food glut period, and this is when successful rat control is most compromised. The key recommendation from this analysis is to avoid baiting when abundant seed is readily available to rodents.

Exactly when to bait during the plateau phase depends on vulnerable fauna species and treatment block characteristics (i.e., shape, size, natural barriers, and implementation of other ground based tools). Baiting as soon as possible after germination is recommended where rat-vulnerable fauna are top priority (Fig. 3).

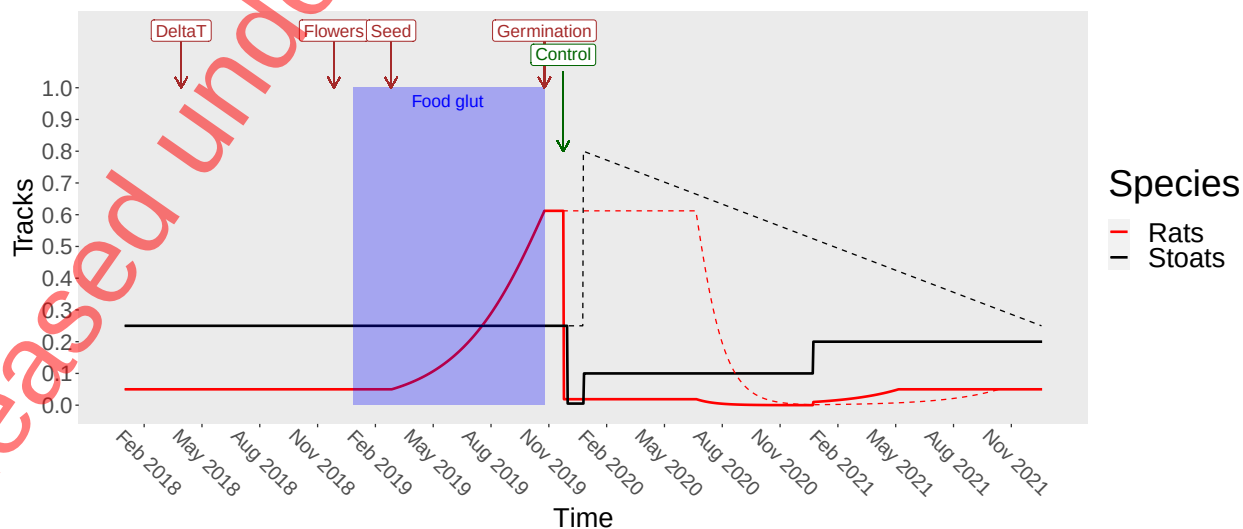


Figure 3: A post-germination poison operation over a typical upland rat irruption. This operation is timed to minimise rat damage, but is subject to immediate stoat reinvasion pressure. Dashed lines indicate untreated populations, as in Figure 1.

Baiting before the peak year cohort of stoat arrives (i.e., as shown in Fig. 3) has a drawback for stoat-vulnerable species, because stoat reinvasion will commence almost immediately. Mitigation of stoat reinvasion can be achieved via 1) treating very large areas (i.e., buffering), 2) making use of natural geographic barriers, and 3) extensive stoat trapping.

Baiting later in the plateau phase might better protect some stoat-limited species, because stoat invasion pressure reduces after March. After March, most juvenile stoats have settled down for the winter. Peak dispersal is from January to March. Damage during the dispersal phase (i.e. January-March) may be incurred (stoat trapping during this period can help), but the stoat control should last a lot longer (Fig. 4).

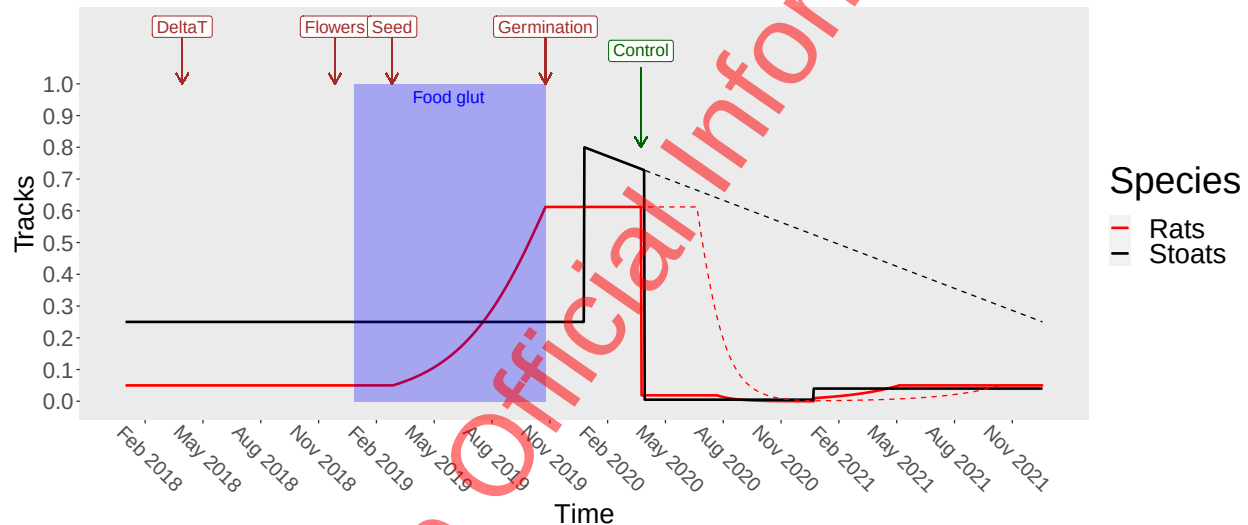


Figure 4: Example of a slightly later post-germination control pulse over a typical upland rat irruption. This timing is a good idea where stoat sensitive values are a priority, especially for smaller blocks. Dashed lines indicate untreated populations, as in Figure 1.

Two control pulses for extreme irruptions

When an extreme irruption is predicted, a first pulse of control is needed during the pre-irruption spring, before the mast food glut starts (Fig. 5). Initial preparations for these operations will be triggered on the basis of DeltaT (i.e., weather-based prediction). Final preparations will be on the basis of winter-time rodent surveys during the pre-mast year. The thresholds for proceeding will vary from place to place depending on the threat-level to the vulnerable fauna.

A second pulse may then be needed 15-18 months later, during the autumn of the post-mast year. Whether or not a second operation is required will depend on the size, shape and success of the initial treatment, and on the threat level to vulnerable fauna. Triggering of the second operation will be on the basis of rodent and mustelid relative abundance during the mast year.

The two pulses of control two operations can be different, in terms of size, shape and method.

In places where rat-vulnerable fauna are a priority, it is vital that we are ready to respond to extreme rat irruptions. There is not much point responding to lots of typical irruptions and then failing to respond to extreme irruptions. In recent history, extreme irruptions in upland masting ecosystems happened in 1999-2001, and again in 2018-2021. The required frequency may increase in the future, with warming climate and with improving ecosystem productivity due to management (i.e., mesopredator release). Responding to extreme irruptions is at least as important as responding to the typical irruptions that happen every few years.

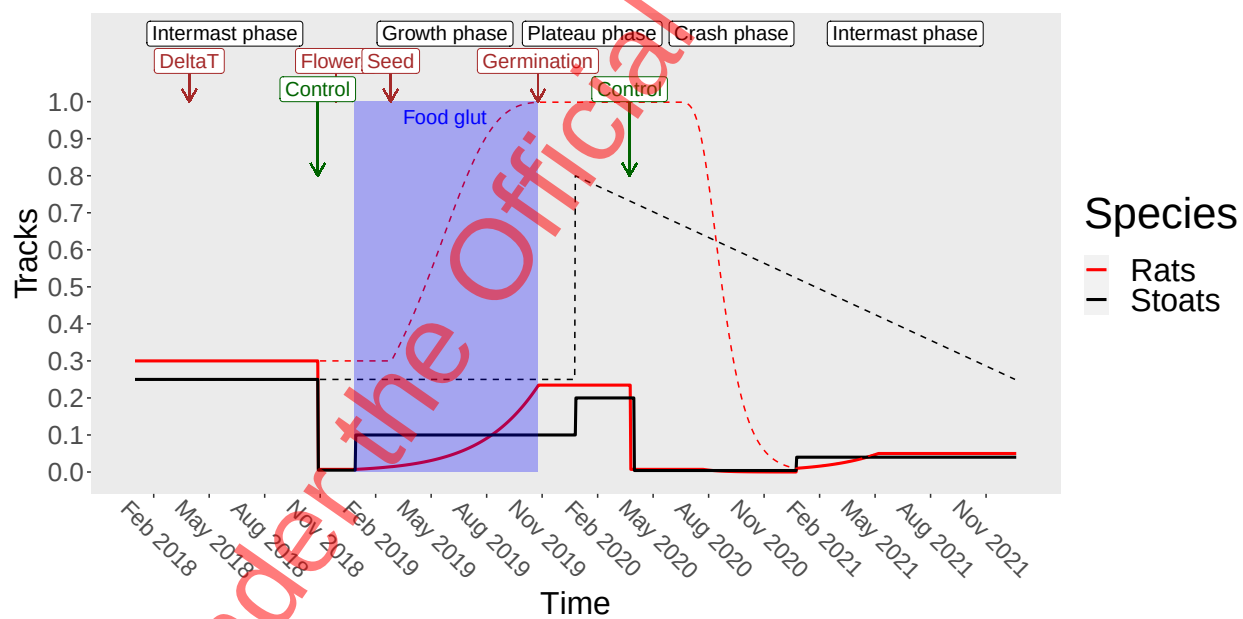


Figure 5: How two pulses of control can be used to manage an extreme rat irruption in an upland masting ecosystem. Dashed lines indicate untreated populations as in Figure 2.

Improving and maintaining efficacy of aerial poison baiting for rat control

V12 25/8/2020

Summary

Aerial poison baiting is the main tool to control predators impacting on some threatened species. Some recent operations have failed to achieve high rat kills despite good baiting practices. These failures may indicate a trend in declining efficacy of the tool against rats. We need to take steps to understand and address this issue before vulnerable species become extinct. This document discusses what we think we know about it, the probable explanations and recommends actions to avoid, mitigate and better understand the issues. We identify and explore three potential root causes of occasional poor results,

- 1) learned aversions persisting from one operation to the next
- 2) bad combinations of environmental and operational factors, and
- 3) development of heritable behavioural and/or physiological resistance to a repeatedly used tool (cinnamon-cereal 1080 pellets).

Key recommendations include

- Improving current systems to capture, analyse and use results
- Improving longer term planning of operations with an emphasis on outcomes and contingencies,
- Investing in a research and development programme to improve and maintain efficacy of aerial poisoning as a rat control tool. An initial list of proposed projects is given.

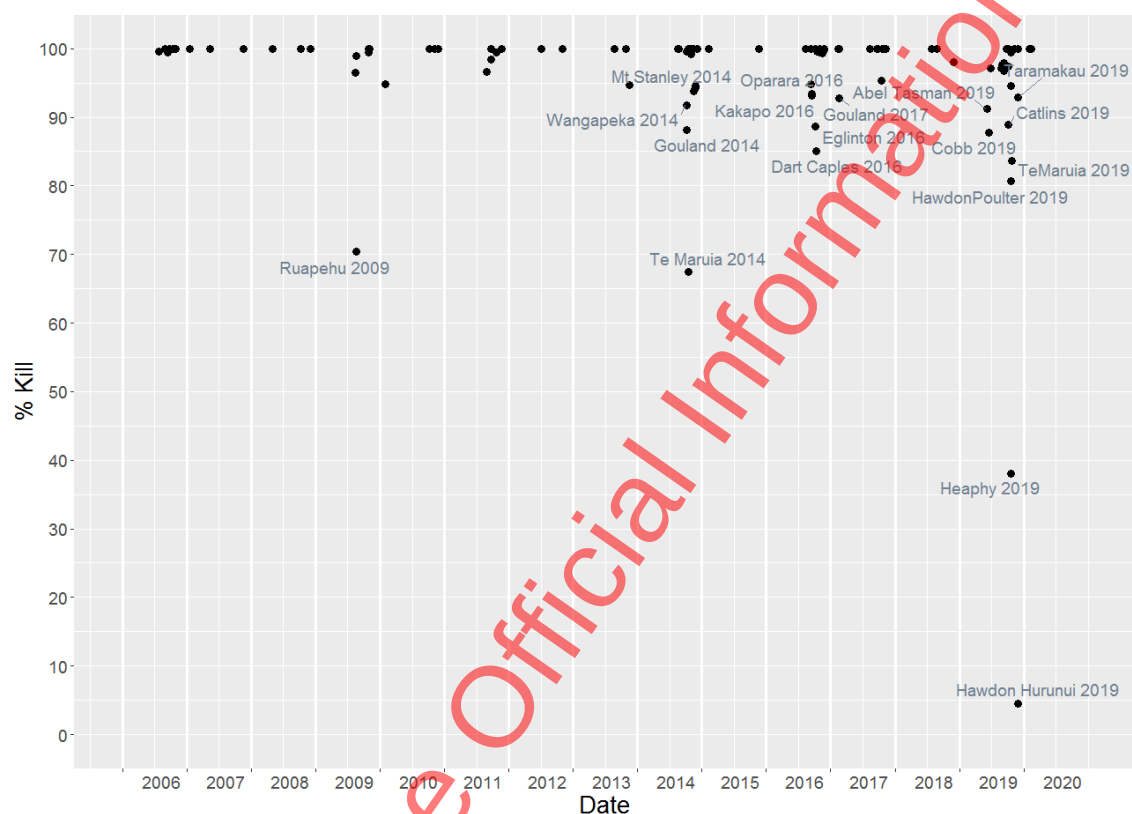
Introduction

The Tiakina Nga Manu programme (TNM) aims to prevent threatened species from going extinct due to predation from possums, rats and mustelids. For many species this means large scale control of these pests in response to periodic mast seeding events. The only practical tool currently available to achieve this is aerially applied 1080 poison baits. The bait used almost exclusively is a cereal pellet lured with cinnamon. Best practice guidelines help deliver high quality operations. Aerial baiting with cinnamon-lured cereal pellets laced with 1080 generally achieves high kills of rats, stoats and possums.

Occasionally the kill rate is insufficient to protect threatened species despite meeting or exceeding best practice (Fig 1). When other factors are accounted for, a strong correlation appears in the rodent footprint tracking data between the number of previous aerial 1080 operations at the site and the latest rat kill result (Fig. 2).

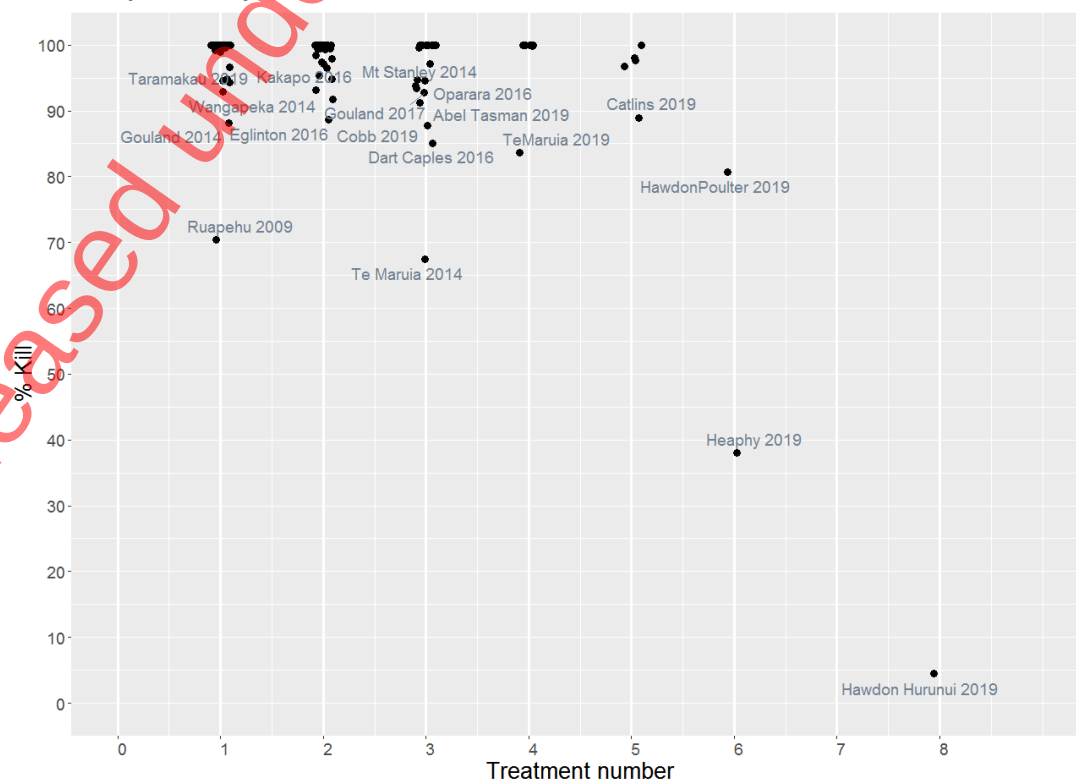
This document discusses the probable explanations for this and recommends actions to avoid, mitigate and better understand the issues. We want to base guidance for 1080 use patterns on robust information about the persistence of learned aversions and the development of 1080 resistance.

Fig 1. Percent kills of rats at prefed aerial 1080 operations from 2006 to 2020 (n=109),



Note: Calculated from tracking tunnel data collected within 180 days prior and 70 days post 1080. Operations where kills were <95% are labelled.

Fig 2. Percent kills of rats at 1080 operations (n=114) plotted against the number of times the site had been previously treated with 1080.



Note: Treatment number is a simplistic summary of 1080 history, taking no account of the frequency of operations or the ecological context/s at the site over the years. Changes in Site boundaries mean 'Treatment Number' for a given operation is a mean of various treatment numbers for all treated tracking tunnel lines.

What makes for poor kills?

Here we present three potential causes of poor rat kills with more detailed explanations provided in Appendix 1.

- 1) **Learned aversions** from one operation persisting in the population until the subsequent operation (learned bait shyness, conditioned aversion).
- 2) **Bad timing** - combinations of environmental and operational factors making rats particularly hard to control at times (e.g. food competition, small home ranges, pre-occupied breeding).
- 3) **Heritable resistance** to a repeatedly used method (cinnamon-lured cereal 1080).

We have intentionally omitted baiting practices and technology from this list. While these have varied historically, and cost-cutting changes to baiting practices probably contributed to some poor kills in 2014 and 2016, we consider the 2020 version of our best practice (DOC-2749355) fit for purpose. Some poor kills in 2019 resulted from baiting practices exceeding current best practice (e.g., bait swathes overlapping by 50%).

Although light on data, we also discounted interference or competition for bait by possums because we believe possum populations are low at these sites following repeated treatments. We also have examples of high rat kills in some sites with higher possum populations.

A combination of these causes is likely. Understanding the relative importance of each and therefore changes required to improve rat kills in the future is challenging with currently available data. We can confidently predict heritable resistance of some kind arising at some point if we continue to repeatedly use the same control tool. Have we got it now? How long before it becomes a significant contributor to operational failure?

In the meantime we must get better at timing operations (within the constraints already imposed on operational timing) and contingency planning for operations compelled to go ahead (to avoid extinctions) at sub-optimal times or in the face of learned aversion or heritable resistance.

What we think we know now

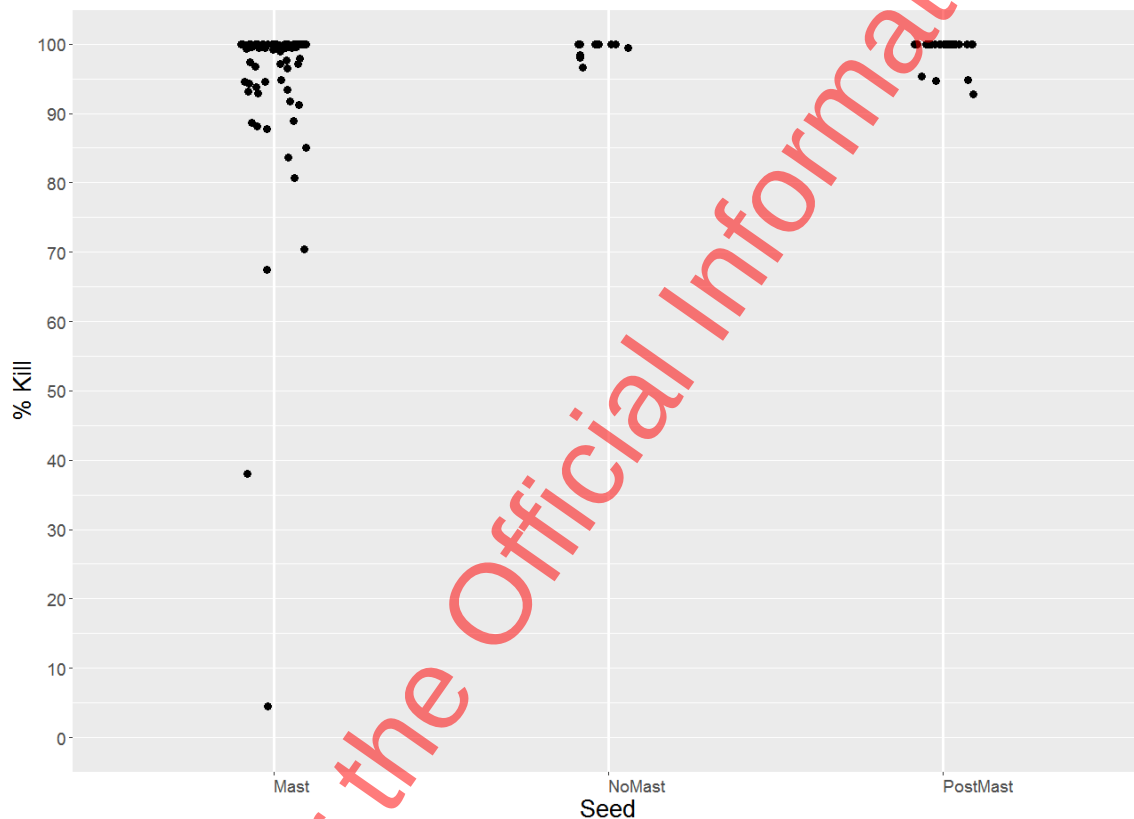
We think learned aversion has played a role in some poor kills but not all of them. Rat population index does not correlate well with poor results. We have examples of very high rat densities getting excellent kills and others with low to moderate densities getting poor results despite similar operational specifications (Fig 3).

Fig 3. Percent kills of rats plotted against mean rat tracking rate at the time of aerial 1080 operations (n=109) between 2006 and 2020.



Bad timing may explain some operations. The presence of mast seed (available to rats) at the time of baiting does look like an important factor (Fig. 4). We speculate rapid population growth rate at the time of baiting serves as a proxy for how much food is available to rats, perhaps thereby enabling poor kills to be predicted and avoided by changing the timing. This could work where we understand the mast cycle well but not at other (non-masting) sites because we could not infer population growth rate and measurement would be too cumbersome to provide the lead in time required for planning of operations. This theory requires further analyses.

Fig 4. Percent kills of rats plotted against a simple categorization of mast conditions at the site at the time of aerial 1080 operations (n=109).



Note: 'NoMast' = either not masting that year or seed germinated and not available to rodents.

We can attribute the poorest rat kill on record, Hawdon/Hurunui 2019 (Fig 1) to simple learned aversion. Only 6 weeks had passed since the previous operation, (Hawdon-Poulter 2019¹), which recorded a relatively poor kill rate of c.65%. The rats surviving the second operation, almost certainly survivors of the first operation, had probably learned to avoid the baits.

What explains the poor Hawdon/Poulter 2019 result? It occurred in mast conditions with rats breeding, the six-week interval between prefeed and toxic baiting may have allowed a cohort of rats to emerge after prefeed had disappeared; the site had been treated with this method five times before. We can guess bad timing, but we cannot rule out heritable resistance.

We think simple learned aversion did not contribute to the poor kill at Heaphy 2019. While this operation occurred 11 months after the previous operation (rats can live this long) most of the rats present in the 2019 operation were born after the 2018 operation: (2018 post-op rat index 8% ; 2019 pre-op index 78%). Unless aversion-trained rats teach naïve rats, we can discount learned aversion. Again we had rats breeding in mast conditions, a long interval between prefeed and toxic

¹ Over time the naming of operations, the shifting boundaries and variation in which tracking tunnels are relevant to results remain ongoing aggravations to quality analyses of kill results

baiting, and five previous treatments. While we can rule out learned aversion and suggest bad timing, we cannot rule out heritable resistance of some kind.

DOC is currently investing in formal statistical analysis of this dataset to control for sample size, confounded factors and learned aversions. We support continuation of this investment (see Management Recommendations). We also recommend investigation of potential mechanisms by which heritable 1080 resistance might arise and options to combat it (see Aerial baiting research programme).

Management recommendations

Below is the collective TAG advice on what we should do about this situation, given what we currently know. Although provided in a pragmatic order, we have not set priorities among them as we believe all are necessary.

- 1. Adhere to (or exceed) best practice for bait sowing.**

Rationale: This will minimise poor results resulting from avoidable mistakes and eliminate the perception of operational failures confounding other causes we need to isolate and learn from.

- 2. Monitor results of operations well**

Rationale: This will ensure we act on the best available information about our kill results.

- 3. Report operations comprehensively**

Rationale: We need to know exactly what we did and relate results to these variables in analyses.

- 4. Dedicate more science capacity to analyses and adopt recommendations arising as fast as practicable.**

Rationale: Our current system is not very responsive with delays between results coming in and lessons emerging. With timely analyses we could better support management decisions on operations with data we already collect.

- 5. Develop outcome-based plans for each site being managed to guide control design (including timing), monitoring and identify contingencies.**

Rationale: Identifying the optimal timing and scale of operation to achieve clearly defined outcomes involves careful consideration of multiple site factors. This is better done on a site by site basis than through more general rules in our best practice. In some sites, alternative ground-based contingencies may be appropriate to have in place to prevent extinctions while we have

no aerially-delivered alternative to operate at large scale. Well defined outcomes provide TNM programme planning, monitoring and reporting advantages.

6. Invest in the aerial baiting research programme outlined below.

Rationale: This research aims to better understand the issue of declining efficacy of aerial 1080 and develop solutions.

7. Review results of this research programme regularly and adopt recommendations.

Rationale: Consider the identified research a cohesive programme requiring ongoing review of progress and results to plot future direction and give best value for money.

Aerial baiting research programme

Here we identify projects to help our understanding of the issues and make a start on solutions we know will eventually be required but take time to become operational. We traded the plausibility of each theoretical mechanism identified in Appendix 1 against the cost of the project and the value of the implications. Thus, our set of initial projects are a subset of many possible projects. We consider these either fundamental to progressing (or eliminating) others, or requiring an early start to be ready in time.

The numbering in this list does not imply a priority order, we have already eliminated discretionary projects or those not offering value for money.

1. Measure rat life-expectancy, post-1080
2. Test the efficacy of orange lure against cinnamon in field operations.
3. Statistical modelling of factors affecting rat kills
4. Measure success of future cinnamon cereal 1080 operations in contexts of food scarcity
5. Quantify relationship between treatment history and 1080 tolerance
6. Quantify relationship between treatment history and heritable avoidance behaviours
7. Seek and register a third non-1080 aerial tool
8. Field test aerial pindone

1. Measure rat life-expectancy, post-1080

Background

This is a fundamental building block for much of the other proposed research because without it we cannot rule out learned aversion as a contributor to poor efficacy, and we cannot avoid baiting regimes and experimental designs compromised by learned aversion.

We aim to measure life expectancy after a 1080 operation, not to calculate rat longevity from birth. While an obvious management response to learned aversion is to 'wait them out' by having an arbitrary rule for minimum interval between operations- this compromises sites experiencing multiple mast years or containing threatened species requiring more frequent predator suppression.

We see more value in knowing how long learned aversion might last and more risk in assuming a figure.

Question

How long can ship rats surviving control operations live in the wild? / How long can learned aversion persist?

Methods

Existing data

Estimate rat survival rates using the Maruia Rat Density project dataset collected using six-weekly surveys over an 18-month rat irruption (February 2014 -November 2015).

Field study

Two components in priority order.

Monitor survival of rats marked after 1080 operations and estimate their survival and longevity. This would involve catching some rats at a recently treated site, marking them and then checking on their survivorship at regular intervals until a predetermined proportion had died.

Calibrate tooth wear of NZ ship rats against age and use to measure age structure with respect to food pulses and mesopredator release from 1080 drops.

Catch a large number of the recognisably juvenile rats and tag, using the same methods as above at one or several sites. At regular intervals check on their survival and kill some to measure their tooth wear. Calibrate tooth wear against age and use this to measure more widely age structure with respect to food pulses and mesopredator release after 1080 drops.

2. Test the efficacy of orange lure against cinnamon in field operations

Background

We from know a lot about the ability of cinnamon to mask 1080 to possums but the same experiments have not occurred with ship rats. Excellent rat kills with cinnamon lured baits is achievable (Fig 1), but we have some lab evidence for cinnamon above 0.1% to affect non-toxic bait uptake by rats (R Henderson pers comm).

The original development of 1080 masking for possums screened a range of flavours (Morgan 2004). Among them orange performed very well but seldom used because cinnamon was less expensive. If we found orange a more effective 1080 mask for rats it may provide a readily available solution to situations where cinnamon may not work - either from bad timing or populations genetically selected to avoid cinnamon.

Questions

Does orange lure effectively mask 1080 for rats?

Is it more acceptable than cinnamon in sub-optimal conditions?

When applying orange lured baits what non-target issues arise?

Methods

A series of comparative field trials of the two lure types with stringent non-target monitoring.

A desktop study of past use of orange lured baits.

3. Statistical modelling of factors affecting rat kills

Background

If environmental factors, learned aversion and past baiting practices explain all of the poor kills and treatment history is unimportant, the urgency for solutions to heritable resistance would much reduce (but still could not be ignored). Support for an effect of treatment history would increase the urgency of need for research into mechanisms and solutions.

If this analysis confirms treatment history as important, it will also underpin prediction of risk for future operations, especially if site factors could be isolated. This would be critical for the other proposed projects.

Question

What factors best explain variation in kills?

Hypothesis

Factors other than treatment history explain variation in kill rates better.

Methods

Model factors affecting kills at numerous 1080 operations using the tracking tunnel database. Include various expressions of treatment history, such as number of treatments and frequency of treatment. Control for simple learned aversion (factor for time-since-last-treatment). Control for confounded factors and allow for interactions and natural 'catastrophes' such as extreme winters which would potentially negate a treatment history effect.

Requires rodent tracking tunnel surveys pre and post operation on adequate numbers of transects within 6 weeks of operations. Helped by minimising loss of sample size from tracking tunnel lines not receiving aerial bait (eg., around block edges); a streamlined survey databasing system and a streamlined system for processing of GIS flight data.

This work requires dedicated science capacity.

4. Measure success of more cinnamon cereal 1080 operations in contexts of food scarcity

Background

Although part of 3 above, we have an opportunity to see if timing alone can overcome other factors affecting efficacy for our main control tool.

Questions

Does 1080 work better in post mast years?

Hypothesis

Good kill rates occur when rats are hungry, regardless of treatment history etc.

Methods

Ensure as many non-mast winter operations as possible proceed, with good monitoring of rat kills using tracking tunnels.

5. Quantify relationship between treatment history and 1080 tolerance

Background

Demonstration of a relationship in lab would clearly establish a mechanism and eliminate about 50% of possible solutions, leaving only alternative poisons and/or biocontrol. Absence of a relationship eliminates a mechanism entirely.

Question

Are rats getting more physiologically tolerant of 1080?

Hypothesis

1080 susceptibility in rats relates to 1080 history.

Methods

Live capture rats from a spectrum of sites from low risk to high risk. Measure responses to various 1080 doses delivered by oral gavage. Model death rates and/or LD50 as a function of 1080 history.

Phase 1 sample from extremes only. If significant difference found between highest and lowest risk sites, then repeat with a range of sites from across the spectrum. Sample immediately prior to 1080 operations wherever possible to establish relationship between LD50 and % kill.

Would we want to breed and test offspring?

AEC approval needs to be obtained and a contractor with laboratory might cost a lot.

6. Quantify relationship between treatment history and heritable avoidance behaviours

Background

Repeated control operations might allow rats who either avoid some characteristics of the baits or are generally more neophobic to survive and pass on those traits. Humphries et al (2000) found heritable cereal aversion in mice populations with repeated poisoning using cereal bait. Oliver et al (1982) found rabbit populations subjected to repeated 1080 operations to have higher neophobia. Identification of problem bait characteristics might provide simple short-medium term solutions.

Questions

Is acceptance of cinnamon and cereal related to 1080 history?

Is neophobia related to 1080 history?

Methods

Field trials

Introduce new foods on feed trays, with cameras. Compare neophobia and avoidances along predicted risk spectrum.

- Put up cameras and feeding stations in areas with various 1080 histories. Offer baits with various ingredient combinations and other foods, compare bait take at high and low risk sites. This should identify any problematic components.
- Offer new and familiar foods in the food trays and compare if it takes those in higher risk areas longer to take the new foods. This should identify if there is higher neophobia at high risk sites.

Lab trials

Bring rats from across the risk spectrum into captivity. Allow to breed.

- Offer baits with various ingredient combinations and other foods, compare bait take
- Offer new and familiar foods and compare consumption
- Differentiate heritable avoidance/neophobia from cultural transmission by removing offspring from their parents before weaning, if the offspring still avoid baits/new foods the avoidance is heritable

7. Seek and register a third non-1080 aerial tool

Background

An effective alternative toxin to 1080 to reset the 'resistance clock' would bring relief to the TNM programme. We don't know if pindone cereal pellets will successfully do this, or whether they are a practical solution. Therefore, we need to identify a pathway to identify and register another aerial pesticide use, if required.

Question

What is the best candidate bait + toxin combination that could be trialled and registered as an alternative to 1080 cereal pellets and pindone cereal pellets?

What data/information is required for a new/extended registration to allow aerial application to control rats (and possums)?

Will it allow a subsequent return to aerial 1080?

Methods

A literature review will identify and propose an alternative bait + toxin for aerial application with favourable costs and benefits relative to 1080 and pindone cereal pellets.

A scoping exercise will plan the project pathway (including field trials) required to achieve registration of a proposed new aerial-application pesticide use.

Final design would depend on the findings from research project six as these will determine whether a change in bait matrix is also required.

Following registration for aerial application, further refinement of methodology and information gathering would need to occur, similar to the method description for testing pindone.

Other design and registration considerations are:

- can cost effectively aerially treat large (e.g. 20,000 ha) operational areas;
- achieve >95% rat (and possum) kills;
- avoid causing problematic levels of aversion or resistance in residual rat populations;
- present acceptably low risk to populations of native non-targets

8. Field test aerial pindone

Background

Pindone pellets are currently registered for aerial application to control rats. This gives it a huge time advantage on other alternatives to 1080 if the urgency for alternatives turns out to be high. However, this method has only been used and reported on once (Innes et al 1995). This operation applied the bait once at 10 kg/ha and achieved a 98% reduction in ship rat tracking index. However, the current label directions require sowing rates of “4 to 5kg/ha applied twice one week apart”.

As a first-generation anticoagulant, rats are more vulnerable to pindone if they feed continuously on the bait for about 10 days (LD50 drops by two orders of magnitude). Interruptions to feeding (due to insufficient quantity or longevity of bait) can lead to survival unless an acute dose (about 50 grams per day) is eaten.

Before we can test the utility of this tool to control rat populations at sites where 1080 has lost effectiveness, we need certainty we have the application prescription optimised.

Use of aerial pindone in forest has questions about non-target risks which need answers before deploying the tool over large areas or vulnerable populations of potential non-target species.

Pindone pellets are essentially the same cereal bait type used for aerial 1080 so we need confidence (from experiments identified in 6 above) rats in sites with diminished 1080 effectiveness are not averse to eating cereal bait.

Despite the current registration advantage of pindone pellets over any other alternative poison to 1080 for aerial application, the investment in answering the questions outlined below would need justification by the desktop exercise outlined in 7 above confirming this was our best option.

In deciding on our best option, we also need to understand the urgency and scale at which the (alternative) tool may be deployed. This requires results from the research outlined in 1 to 6.

Demonstrated effectiveness of an alternative toxin and proving it could successfully ‘reset the clock’ and enable a return to successful 1080 operations would bring tangible relief to the TNM programme. However we would remain vigilant for problems arising through other mechanisms.

Questions

Can aerial pindone achieve very high rat kills on naïve rats following current label conditions?

Can changes to current aerial pindone application practices improve rat kills?

What are the non-target risks of using aerial pindone?

Can a toxin switch eliminate heritable resistance in a population?

Methods

Field test aerial pindone as per current practice and label directions.

Concurrently test variations in application rates and frequencies in experimental blocks

Apply the perfected technique at sites where we have demonstrated (non-learned aversion) problems and measure results. Following up at this site with another (well measured) 1080 operation when the need arises.

Future research by management

We can consider three of our eight recommended projects (numbers 3, 4, & 8) 'Research by Management' projects (RBM). Research by Management in this context means measuring kill rates at real operations, with tailored baiting specifications and sufficient monitoring to answer questions. RBM can use special blocks embedded within larger operations, or simply as large operations with tailored specifications. In a sense, all aerial 1080 operations are RBM operations because every operation is unique whether we like it or not.

We hope the initial suite of projects will enable testing priority potential solutions using RBM at a landscape scale. Therefore, we will need to maintain a willingness within our staff and management to undertake Research by Management (RBM) when warranted.

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See DOC-6364589 for PDF copies

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Appendix 1 Detailed discussion of mechanisms for reduced efficacy

Learned aversions

Learned aversions are not heritable, they result from individual rats surviving sub-lethal dosing in one operation. If the individual survives until the next operation their learned aversion may protect them from poisoning. When assessing the kill achieved by a 1080 operation, we should first consider the likelihood of simple learned aversions contributing to survival. This likelihood is a function of the time since previous treatment, the number of rats surviving the previous treatment and then surviving the interval between operations, the repopulation dynamics following the first operation (i.e. were survivors swamped by naïve re-invader rats?) and the propensity for bait shy rats to teach naïve rats to also avoid baits (B. Galef, 1977).

Knowledge gaps

Two of the factors required for estimating the likely contribution of learned aversions to poor kills are data deficient: 1) rat life expectancy in post-1080 environments and 2) the propensity for bait shy rats to teach naïve rats to also avoid baits. The literature gives us a steer on both, but not the confidence required by DOC in the context of the current biodiversity crisis, the TNM programme of work and PF2050 goals.

There is little field data on ship rat lifespans in NZ forests. Daniel (1972) found males living no more than 11 months and females 17 months in forest at Orongorongo. However, favourable environmental conditions after large scale control operations could contribute to increased longevity for surviving rats. Assessing rat age in the field using tooth-wear (the usual approach) requires verification against the reference (lab) study of Karnaukhova (1971) to know if they wear at the same rate. If we assume the teeth are basically the same as in the lab, then rats might actually live up to four and half years.

In general, we expect high juvenile mortality in the first six months of their lives, after which survival probably increases to create a long-tailed distribution of life-expectancy, with most adults reaching two-three years of age or more. Survivorship and its corollary, life expectancy, probably increase with food pulses and mesopredator releases from things like aerial 1080 drops.

If simple learned aversions are a minor contributor to the poor kills on record, one or both of the other two causes (bad combinations, heritable resistance) must be happening.

Possible solutions

- 1) We can minimise simple learned aversion by minimising the opportunities for sub-lethally dosing animals through strict adherence to best practice baiting and avoidance of environmental conditions under which even the best operations may fail.
- 2) We can overcome learned aversion by choosing intervals between 1080 operations which are longer than survivors live (provided cultural transmission is limited).

Bad Timing

We tightly control most aspects of aerial baiting with a well-developed best-practice and legal framework. However, we cannot control several critical environmental factors, including pest density, alternative foods, home-range size, breeding activity, and weather.

The weather affects intervals between prefeed and toxic baiting (PFI), bait longevity in the field and ambient temperature after baiting. However, none of these weather-related factors seem obviously related to rat kill rate.

With several uncontrollable factors potentially affecting rat kills, sometimes the worst will happen. Hypothetically a well-planned operation might result in a poor kill if done:

- while rats are all breeding, &/or
- with a long prefeed interval, & or
- with gaps in bait coverage (prefeed or poison) due to turbulent winds and high-altitude sowing.

Additionally, sampling error on tracking tunnel surveys will sometimes underestimate kills, making a kill appear worse than in reality.

Delays in the timing of operations can come from a range of sources and push baiting into sub-optimal times. The dilemma for managers then becomes whether to wait for a better time and risk significant loss of threatened species to predation in the meantime, or to go ahead anyway and risk creating further problems with bait avoidance and an inadequate result.

Knowledge gaps

Not enough thought has gone into timing operations at sites to achieve clearly stated outcomes. Without this outcome focus the timing of operations become more heavily influenced by logistical and financial planning. We could do better if we knew what was critical to protect at each site; what timing is optimal to achieve this protection; and what contingencies (both ground based and aerially delivered) should be made available if ideal timing cannot be realistically achieved.

Possible solutions

- 1) This theory suggests aerial 1080 will occasionally produce poor results and the solution is to focus on identifying and avoiding bad timing and
- 2) Building contingency plans for critical sites in case an aerial 1080 kill is poor due to bad timing.

Development of 1080-resistant populations

As time passes, priority sites are repeatedly treated with aerial 1080. Pest management theory predicts repeated use of a single tool to lead to an eventual loss of efficacy due to selection for genes which help individuals survive the tool. The rate of efficacy decline will vary with patterns of use, reinvasion context, and natural catastrophes which eliminate the 'gene pool'. Sometimes these factors might combine to preclude efficacy decline, but others might speed its development.

DOC's extensive tracking tunnel dataset enables us to test for a link between treatment history and kill rate. Excluding the HawdonHurunui2019 operation, which we attributed to learned aversion there is an apparent relationship between number of prior treatments and kill rate (Fig 2).

Mechanisms of resistance

To prevent and remedy heritable 1080 resistance, we need to understand underlying mechanisms and rank their relative importance. Here, we identify four different mechanisms, all are plausible

and none can be discounted on the basis of current knowledge.

Increased neophobia

We know rats are cautious neophiles. They investigate but test novel foods for safety before accepting them as 'safe-familiar'. Rats usually have a big meal every 3-4 hours. They will have a nibble of novel foods as part of a meal, then wait 3-4 hours. If they feel well after one or more nibble tests, then the novel food becomes safe-familiar and is eaten in larger amounts in future meals (this is the basis for prefeeding aerial 1080 operations).

We don't know how many nibble tests of cinnamon cereal prefeed rats undertake. Perhaps it varies with things like food supply and parasite load. However, there is probably heritable variation for selection to act on, in which case we expect neophobia to increase over time.

Possible solutions

An extreme neophobia scenario resulting from repeated selection for this mechanism is serious because it may protect rats from all control tools, including traps, bait stations, and other aerial baits.

- 1) More (prolonged) prefeeding may overcome the variation among rats testing,
- 2) Switching to slow acting poisons may disconnect the association made between the bait and illness
- 3) Biocontrol (if it were available) may act on the population by a completely different mechanism

Increased physiological tolerance of 1080

Physiological tolerance has evolved among browsing mammals where 1080 occurs naturally in plants. They can eat lots and not die – they have high LD50s.

Howard et al. (1973) applied moderate selection pressure for 1080 tolerance to laboratory bred Norway rats. The resultant LD50 in this line-bred population was 1.8 times higher than the starting population after four generations.

Possible Solutions

- 1) Toxin switching should expose these animals to a toxicant they are still highly vulnerable to. If an effective kill can be achieved this will eliminate those 'tolerant genes' in the population, allowing a return to 1080 at the site (sometimes referred to as 'resetting the clock').
- 2) Biocontrol (if it were available) may act on the population by a completely different mechanism

Increased avoidance of certain tastes, smells and textures

This mechanism is about selection for avoidance of bait characteristics.

DOC best practice is to use cinnamon-lure in cereal pellets with 0.15% 1080 and we don't vary these parameters (beyond uncontrolled dissipation of cinnamon in storage, which we don't measure).

Heritable aversion to all cereal-based foods has been demonstrated in mice (Humphries et al., 2000) and we see no reason why it wouldn't happen here with rats. It could also happen for cinnamon lure, we have some lab evidence that higher concentrations of cinnamon do affect rodent bait uptake.

This is not about selection for ability to detect these things, it's about selecting for those avoiding it because they don't like how it looks, tastes, smells or feels, whether it is harmless or not.

Possible Solutions

- 1) Switching lures may overcome an aversion to cinnamon
- 2) Switching bait matrix may overcome an aversion to the current cereal pellet.

Improved poison detection ability

We know 1080 poisoning symptoms appear within half an hour or so. To die, an animal must eat a lethal dose in one rapidly consumed meal. Resistance could therefore arise through selecting for:

- physiological traits that result in animals feeling sick earlier and not finishing 'the meal' before a lethal dose is ingested.
- genes causing animals to respond quicker to feeling sick (a sort of hypochondria) and not finishing 'the meal'.
- never eating large meals leading to sublethal doses

These three examples all involve 'post-ingestion' detection of poison.

Pre-ingestion detection mechanisms might also be acting to increase resistance, through taste and smell of 1080.

Possible Solutions

- 1) Switching to slow acting poisons may disconnect the association made between the bait and illness
- 2) Biocontrol (if it were available) may act on the population by a completely different mechanism