
28.26 inHg
5℃
11/13/2020 10:48PM
HFDOT31


28.26 inHg - 5℃ 11/13/2020 11:11PM HFDOT31


28.17 inHg
7℃
11/14/2020 04:57AM HFDOT31

Sodium fluoroacetate

Pesticide Information Review

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Version History:

Version	Date Written	Change/Reason for Change
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 degradion 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 (absortion, 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 riflemen (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 (*Pica pica*) 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

Contents

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 $\mu g\ l^{-1}$ 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.

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 loses. 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, köaro 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 $C_2H_2FNaO_2$ (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).

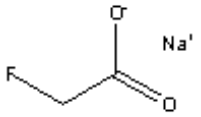

Figure 1. **The chemical structure of sodium fluoroacetate.**

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 contain 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 were 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 (Erlichman 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 ^{14}C-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 CO_2, 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 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.

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 0809SIS02).

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 µg 1080 m^{-3} (Wickham and Baynham, 2016).

Carrot

Thomas et al. (2004) subjected 12 g carrot baits containing 1.5 g kg^{-1} 1080 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 käpuka (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 herbfield 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 mouldly 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 CO_2. 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 (DT_{50}) 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 µg l^{-1} were found in 101 samples but most of these had less than 1 µg 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 µg l^{-1} (L. Booth, Landcare Research, pers. comm. 2016). All the positive samples were below the Ministry of Health maximum of 3.5 µg 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 µg 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 µg 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 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 m^2 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 µg 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 µg 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: käpuka (New Zealand broadleaf) (Ogilvie et al., 1998), käramuramu (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 käramuramu in the field, the maximum concentration of 1080 detected in the plants was 5 µg kg^{-1} of plant material. This concentration occurred 7 days after the bait was place beside the plants, and declined to 2.5 µg 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 µg 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 käramuramu 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 mg kg^{-1} day^{-1} a person would need to consume 0.7 - 1.4 tonnes of 1080-containing käramuramu 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 *Lemma 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 käpuka (NZ broadleaf) or ryegrass. The 1080 residues in the plants were near the Method Detection Limit (MDL) after 38 days in käpuka (NZ broadleaf) and 7 days in ryegrass.

Ogilvie et al. (2004) reported that after käramuramu 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 LD_{50} for sheep and less than a quarter of the LD_{50} 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 LD_{50}) 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
Arthropods			
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 ½ (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

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 µg kg^{-1}), the concentration of 1080 in the muscle of sheep sacrificed post-dosing reached a maximum of 111 µg kg^{-1} in 4 hours and declined exponentially thereafter. In the liver a maximum concentration of 38 µg 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 0.06 1- 0.75 µg g^{-1} in the heart, 0.058 - 0.72 µg g^{-1} in the skeletal muscle and 0.047 - 0.051 µg 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 µg 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 µg 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 µg g^{-1} at a 1080 dose of 1.59 mg kg^{-1} b.w., 0.70 µg g^{-1} at a dose of 2.00 mg kg^{-1} b.w., 0.84 µg g^{-1} at a dose of 2.52 mg kg^{-1} b.w. and 1.16 µg g^{-1} at a dose of 2.52 mg kg^{-1} b.w. In birds that died the day after being dosed the concentrations in the breast muscle were: 0.23 µg g^{-1} (1.59 mg kg^{-1} b.w. dose), 0.39 µg g^{-1} (2.00 mg kg^{-1} b.w. dose), 0.50 µg g^{-1} (2.52 mg kg^{-1} b.w. dose) and 0.64 µg g^{-1} (3.17 mg kg^{-1} b.w. dose).

Ants (*Huberia striata*) lethally poisoned with sugar water containing 1.5 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
Birds			
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/Kukupa	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
Marsupials			
Possum	Bone	0–0.01	1; 8; 9
	Liver	1.5–8.4	
	Muscle	0.003–2.3	
	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	8.7–35.9	
	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
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	
Goat	Muscle	0.36	21

Species	Sample Type	Residues (mg kg^{-1})	Reference
Chamois	Muscle	0.23	21
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
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 dectected 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 comparitively 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 that 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 loses. 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, köaro 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 (LD_{50}) range for each taxon?

The LD_{50} 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 (Eisenia fetida)	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 at el 2005.

Aquatic Invertebrates

Based on sub-lethal exposure trials, Suren and Bonnett (2006) suggest that the 1080 LC_{50} 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 LD_{50}'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% ± 4.6% (standard error of the mean) (N = 10) and 8.0% ± 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 equivalnet 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 LD_{50} 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 1.0g 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									
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 LD_{50} dose to >100 000 ants with a mean bodyweight of 2 mg each (Booth and Wickstrom, 1999).

Note: The LD_{50} 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 LD_{50} 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
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.

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 prefed 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 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
Invertebrates					
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) Gouland 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: 0809GDB08; 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. Guillotel 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		[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

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 Gouland 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	14d	0		5[a]	1
1994 Gouland Downs	9	4c		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 riflemen 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**, **silvereye**, **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 monitoried 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 whio 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 indvidual 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 Gouland 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 prefed 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, köaro** 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** (*Helicopyche, Pycnocentrodes, and Pycnocentria*), **orthoclad midges**, and the **mayfly** *Deleatidum*. 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 aerially 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 form 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 aerially 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, silvereye** 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**, **silvereye** 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 LD_{50} 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 LD_{50} 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 (LD_{50} 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}	
Daphnia magna	350[g]	22

Mosquito larvae (*Anopheles quadrimaculatus*)	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 LD_{50} 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 EC_{50}

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 LD_{50} 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 (LC_{50} values) which is more relevant when assessing likely risks to fish from possum baits. To achieve the 96-hour LC_{50} 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 LD_{50} 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 LD_{50} 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 LD_{50} 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 LD_{50} 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 mg kg^{-1} 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 mg kg^{-1} 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 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 (Erlichman et al., 1998; Hulsmann 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 LD_{50} 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 seminferous 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 tubulies 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
Domestic animals		
Dog	34	21
Cat	1	1
Livestock		
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 (Morriss 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/km^2 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 signficantly lower than in the non repellent block reflecting that the population of deer there were more nutritionally limited, smaller, and potentially more vulnerable to poisoining 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 incidientally 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 intial 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 repectively (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.

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 g 1080 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 are 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 g 1080 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 g 1080 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**, **dunnock**, **goldfinch**, **redpoll**, **yellow hammer** and **hedge sparrows** (Morriss et al., 2016; VPRD; Pestlink: 0304RAN08 ; Nugent et al., 2004; Rammell and Fleming, 1978).

Morriss 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.

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
Australasian 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.
Mammals			
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	
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

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 LD_{50} 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 yeilding 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 LD_{50}.

	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 LD_{50} 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/m^3 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 LC_{50} 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 lymphona 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 cf 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 mg kg^{-1} day^{-1}. The NOEL for rats administered 1080 via oral gavage for 90 days was 0.075 mg kg^{-1} 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 foetuses (Eason et al., 1997; 1999). Teratogenic effects have been reported at 0.75 mg kg^{-1} day^{-1} (Eason et al., 1999) and the developmental NOEL is 0.1 mg kg^{-1} 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 mg kg^{-1} 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 mg kg^{-1} day^{-1} when compared with controls. The NOEL for rats administered 1080 via oral gavage for 90 days was 0.075 mg kg^{-1} 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 mg kg^{-1} 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 (±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 (±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 LD_{50} values are presented in Table 34.

Table 34. Acute oral toxicity (LD_{50} 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 LD_{50}.

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 the 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 the 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 absciss 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 abscissed. However, abscissed 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% (±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% (±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)	1718WHT01
88.6%	Cleddau BfoB, Sept 2017	1 (6g pellets)	2 (12g RS5 pellets, 16 days later)	1718TEA02
94.3%	Rotoehu Forest, Sept 2017	1.5 (6g pellets)	2.5 (12g #7 pellets, 8 days later)	1718TAU01
94.0%	Whareorino, Jul 2017	1.5 (6g pellets)	2 (12g #7 pellets, 14 days later)	1617MPT06
58.1% (est.)	Egmont NP, Dec 2016	1 (6g pellets)	2 (6g RS5 pellets, 59 days later)	1617TAR01
100%	Waitutu BfoB, Nov 2016	1 (6g pellets)	1 (12g RS5 pellets, 13 days later)	1617TEA01
85%	Tawarau Management Area, Oct 2016	1.5 (6g pellets)	1.5 (12g #7 pellets, 24 days later)	1617MPT01
98.1%	Abel Tasman BfoB, Aug 2016	1.5 (6g pellets)	3 (10g RS5 pellets, 25 days later)	1718MOT06
66.7%	Kia Wharite Project - Mangapurua Block, Whanganui, Oct 2015	0.5 (6g pellets)	0.5 (6g #7 pellets, 31	1516WHA01
91.1%	Mokaihaha Ecological Area, Rotorua, Aug 2015	2 (12g pellets)	2 (12g #7 pellets, 15 days later)	1516ROT02
78.9%	Rotoiti BfoB, Dec 2014	1 (6g pellets)	1 (6g RS5 pellets, 25 days later)	1415STA02
100%	Eglinton Valley BfoB, Dec 2014	1 (6g pellets)	1 (12g RS5 pellets, 48 days later)	1314TEA05
73.7%	Matukituki BfoB Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 26 days later)	1415WANo1
91.1%	Lower Holyford BfoB, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 38 days later)	1314TEA06
99.9%	Iris Burn BfoB, Sept 2014	1 (6g pellets)	2 (12g RS5 pellets, 8 days later)	1415TEA01

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)	11011PON20
95.1%	Ruahine Corner, Oct 2010	1.1 (8g pellets)	2.03 (12g #7 pellets, 13 days later)	1011PNT09
99.6%	Waitutu, Oct 2010	1 (12g pellets)	2 (12g RS5 pellets, 26 days later)	1011MRH03
100%	Tawarau, Aug 2010	2 (12g pellets)	2 (12g RS5 pellets, 33 days later)	1011MPT02

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% (±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)	0607ROT01
91.8%	Whirinaki Rata Block 30/8-8/9/2005	3	5 (8 days later)	0506RAN01
87.8%	Hunua Ranges, 7-8/9/2001	5	5	0203AKD13
86%	Otupaka EA, 17-18/05/2000	5	10 (6g baits)	0304RAN08
96.0%	Paeroa Range, 18/08/1999	5	10-15 (6g baits)	0304ROT05
88.4%	Marokopa/Tawerau, 5/7/1998	5	5 (6g baits)	0203MPT08
94.2%	Marokopa/Tawerau, 5/7/1998	5	10 (6g baits)	0203MPT08

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, Tataraakina, 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)	0304ROT04

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% (±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%	Opuiaki, 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)	0708ROT03
96.2%	Mokaihaha EA, Oct 2001	1 bait station/ha, 3 prefeeds, 1 toxic fill (1500g bait per station)	0304ROT06
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)	0304ROT09
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% (±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	0809SIS02
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)	0809SIS03
97.6%	Pegasus/Tin Range Oct-Nov 2004	Grid (not prefed)	0405SIS04
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)	1617MRH03
91.8%	Pukaha/Mt Bruce, Dec 2016	1 (6g pellets)	1 (6g RS5 pellets, 9 days later)	1617WRP03
96.8%	Landsborough BfoB, Dec 2016	2 (6g pellets)	2 (6g RS5 pellets, 32 days later)	J. Kemp pers. comm, 1617SWS04
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)	1617MRH02
100%	Hawdon BfoB, Nov 2016	2 (6g pellets)	2 (6g RS5 pellets, 7 days later)	1617WMK01
0%	Poulter BfoB, Nov 2016	2 (6g pellets)	2 (6g RS5 pellets, 7 days later)	1617WMK01
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 Whanganui #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, 1617WAK01
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.)	Haast 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%	Gouland 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)	1314MRH02
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, Tararuas, 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 Maclennan 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, Tararuas, 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.
1.2%	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 arpart along ridges/spurs. 1 prefeed (1500g per bait station), 1 toxic fill (500g bait per station)	1213ROT02
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%	Opuiaki, 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 prefed 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	0304ROT04

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

µg kg^{-1}, **µg** l^{-1}

See ppb.

µg g^{-1}, **µg** 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 (t½ 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.

LC_{50}

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

LD_{50}

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}]x[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 µg l^{-1} in water (solution) or air and 1 µg kg^{-1} in solid samples (soil/sediments/biological tissue).

ppm

parts per million. This concentration unit is equivalent to 1 mg l^{-1} (or µg ml^{-1}) in water (i.e. solutions) or air and 1 mg kg^{-1} (or µg 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, Kreb 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	*Leiopelma archeyi*
American Bullfrog	*Rana catesbeiana*
Hochstetters frogs	*Leiopelma hochstetteri*
Leopard frog	*Rana pipiens*
South African clawed frog	*Xenopus laevis*
Spotted grass frog	*Limnodynastes tasmaniensis*

Aquatic invertebrates/Crustaceans

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

Birds

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

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

Eutherian mammals

Bat (Short-tailed)	*Mystacina tuberculata*
Cat	*Felis catus*

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

Fish

longfin eels	*Anguilla dieffenbachia*
koaro	*Galaxias brevipinnis*
Harlequin fish	*Rasbara heteromorpha*
upland bullies	*Gobiomorphus breviceps*
Bluegill sunfish	*Lepomis macrochirus*
Trout (Rainbow)	*Oncorhynchus mykiss*

Marsupial mammals

Brushtail possum	*Trichosurus vulpecula*
Wallaby (Bennett's)	*Macropus rufogriseus*
Wallaby (Dama)	*Macropus eugenii*

Reptiles

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

Terrestrial invertebrates

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

Plants

Broad bean	*Vicia faba*
box poison	*Gastrolobium parviflorum*
cabbage	*Brassica oleracea*
gifblaar	*Dichapetalum cymosum*
heart-leaf poison	*Gastrolobium bilobum*
käpuka (New Zealand broadleaf)	*Griselinia littoralis*
käramuramu	*Coprosma robusta*
lettuce	*Lactuca sativa*
Mahoe	*Melicytus ramiflorus*

peanut	*Archis hypogeae*
perennial ryegrass	*Lolium perenne*
puha	*Sonchus* spp.
pikopiko	*Asplenium bulbiferum*
rat weed	*Palicourea margravii*
ratsbane	*Dichapetalum toxicarium*
sugar cane	*Saccharum spp.*

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