Impacts of aerial application of 1080 on non-target native fauna

Review and priorities for research

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E.B. Spurr and R.G. Powlesland

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CONTENTS

Abstract

Sodium monofluoroacetate (1080) is used by the Department of Conservation (in cereal-based baits) and by Regional Councils (in carrot and cereal-based baits) during aerial poisoning operations for control of possums (*Trichosurus vulpecula*) in New Zealand. The impacts of these operations on non-target species of birds, bats, lizards, frogs and invertebrates are reviewed, and priorities for further research are recommended. A Research Co-ordinating Group should be established to implement these recommendations.

1. Introduction

Baits containing sodium monofluoroacetate (1080) are both used in aerial poisoning operations by the Department of Conservation (cereal-based baits only) and Regional Councils (carrot and cereal-based baits) to reduce the number of possums (*Trichosurus vulpecula*) in New Zealand. Carrots are cut into pieces ranging in size from <0.25 g to about 16 g (Batcheler 1982). Cereal-based baits range in size from <1 g to about 10 g (Morgan 1994). The concentration of 1080 in baits is generally either 0.08% or 0.15% by weight.

Concern has been expressed about the risks to birds and other non-target species from these 1080-poisoning operations. As a result of these concerns, baits are dyed green to make them less attractive to birds (Caithness & Williams 1971). Since 1978, carrots have been screened through a 16 mm grid to remove the "fines" or "chaff". Cereal-based baits are used in Department of Conservation operations because it is perceived that they kill fewer birds (Harrison 1978a, b; Spurr 1991). Since 1983, cinnamon oil has been added to both carrot and cereal-based baits, partly to mask the smell and taste of 1080 from possums and partly to repel birds (Spurr 1993). Application rates of carrot baits have declined from more than 30 kg/ha in the 1970s to about 12 kg/ha in the 1990s, and cereal-based baits from 10–20 kg/ha in the 1980s to 5–10 kg/ha in the 1990s (Morgan 1994; Spurr 1994a).

The last review of the impacts of 1080-poisoning operations on non-target species was carried out in 1993 (Spurr 1994a). Before that time, most non-target species research had been done on common birds, and almost none on threatened birds and bats, lizards, frogs and invertebrates. Most monitoring of bird populations had used the 5-minute count technique (after Dawson & Bull 1975). In the last three years, studies on several non-target species have been completed and others initiated, including some that have used new monitoring techniques such as radio-telemetry. The purpose of this paper is to review the present state of knowledge regarding the impacts of aerial 1080-poisoning operations on non-target species, to highlight the new information that has become available since the previous review, and to provide a list of priorities for further research.

2. Bait quality

Bait quality specifications have been prepared for both carrot and cereal-based baits to improve the effectiveness of possum control and reduce the risks to non-target species (Morgan 1994). The specifications relate to a variety of factors, such as bait size, 1080 concentration, colour, and lure content.

A series of checks and tests are undertaken by MAF Quality Management staff to ensure that cereal-based baits purchased by the Department of Conservation are within the specifications set down before they leave the bait factory. However, there are additional problems of poor handling during transport and loading into aircraft (aeroplanes or helicopters) that may further reduce bait quality, especially by increasing the amount of bait fragments and dust.

A protocol for assessing the quality of carrot baits before they are loaded into aircraft is currently being prepared. However, there are no protocols for assessing the quality of either carrot or cereal-based baits after they have been spread by aircraft. The extent to which baits are broken up in the aeroplane hopper or helicopter sowing bucket and as they descend through the forest canopy to the ground is unknown. Also, the amount of different bait types that is caught up in the forest canopy is unknown. In a preliminary trial using unscreened carrot baits containing a high proportion of small fragments, about half of the small fragments remained within the canopy of the forest, placing them within the feeding range of most species of small forest birds (Batcheler 1978).

The cinnamon oil that is added to baits to mask the smell of 1080 to possums and to repel birds has been shown to have only a limited repellency to birds (Spurr 1993). Alternative compounds are available that are known to be very repellent to birds and may make baits more target-specific (e.g., Spurr *et al*. 1995).

3. Monitoring techniques for non-target species

3.1 FIVE-MINUTE COUNTS OF BIRDS

This technique was developed for monitoring bird populations in New Zealand forests (Dawson & Bull 1975). It has been used extensively for monitoring impacts of 1080-poisoning operations on bird populations (e.g., Spurr 1981, 1988, 1991, 1994a; Warren 1984; Calder & Deuss 1985; Miller & Anderson 1992; Pierce & Montgomery 1992; Fanning 1994). Counts are influenced by both the numbers and conspicuousness of different species, as well as by other factors, such as observer bias, weather, time of day, and season. Thus, counts should be made in poisoned and non-poisoned areas at the same time (using two or more observers) and an equal number of times by each observer (by observers swapping between areas on different days). Unless a bird species is very abundant (>1 per count) and large numbers of counts are made (>100), the technique is considered suitable for detecting only large changes (>50%) in forest bird populations (Dawson 1981). For example, to detect a 10% change, 770 counts would be needed for a species with an average count of 1 bird per count.

We are aware of only one study that has attempted to relate the numbers detected by the 5-minute count technique to known numbers of a species (Gill 1980). In Gill's study, 5-minute counts of grey warblers (*Gerygone igata*) and robins (*Petroica australis)* varied in proportion to their densities. Thus, it can be assumed that where these species, at least, are monitored before and after a 1080-poisoning operation at treatment and non-treatment sites, the 5-minute counts at the two sites will vary similarly according to the number of birds present. This assumption has not been verified for other bird species.

Five-minute counts are suitable for monitoring long-term impacts at the population level but not short-term impacts on individual birds because individual territory-holders that die from 1080-poisoning may be quickly replaced by "floating" non-breeders (see below). This replacement can be detected from resighting or recapturing banded birds.

3.2 TERRITORY MAPPING AND ROLL-CALLING BIRDS

Territory mapping has been used in New Zealand for monitoring populations of some bird species such as falcons (*Falco novaeseelandiae*), fernbirds (*Bowdleria punctata*), and kokako (*Callaeas cinerea*) before and after 1080-poisoning operations (Calder & Deuss 1985; Innes & Williams 1990; Pierce & Montgomery 1992; Fanning 1994). Roll-calling, in conjunction with territory mapping, was developed especially for monitoring kokako (Innes & Williams 1990), and prescribes that only birds located on their territories at least once a week for three weeks before poisoning are monitored afterwards. Birds are generally not individually recognisable. In the absence of information to the contrary, the technique assumes that, after the initial roll call, birds recorded in territories during a subsequent roll call are the same birds as recorded in the same territories previously. Recent studies of banded kokako at Mapara Wildlife Management Reserve, however, have indicated that individuals that die or leave a territory can be replaced within a few days without it being apparent that they are new birds (I. Flux pers. comm.). Thus, like 5-minute counts, territory mapping is suitable for monitoring long-term impacts at the population level but not short-term impacts on individual birds.

3.3 BANDING BIRDS

Birds have been banded with numbered metal bands and/or unique combinations of coloured plastic bands, and then recaptured or resighted several times before and after 1080-poisoning operations to determine impacts on individual birds (e.g., Pierce & Montgomery 1992; Walker 1997; R.G. Powlesland unpubl. data). However, at present there are no protocols defining the number of birds that should be banded, the number of times banded birds should be relocated, and the methods by which they should be relocated. The technique assumes that birds that disappear have died from 1080-poisoning. Few dead banded birds have been found to enable confirmation of cause of death.

3.4 RADIO-TELEMETRY OF BIRDS

Radio-transmitters (with or without mortality sensors) enable individual birds to be located even after death. This technique has been used recently to monitor impacts of 1080-poisoning on some species of large birds, such as kiwi (*Apteryx* spp.), weka (*Gallirallus australis*), kaka (*Nestor meridionalis*), and blue duck (*Hymenolaimus malacorhynchos*)(Pierce & Montgomery 1992; Greene 1995; Walker 1997; J. Lyall pers. comm., H. Robertson pers. comm.). However, as with banding, there are no protocols defining the number of birds that should be radio-tagged, the number of times radio-tagged birds should be relocated, and the methods by which they should be relocated. The technique is useful because it enables dead birds to be found.

3.5 DEAD BIRDS

Confirmation of the presence of 1080, and by implication cause of death, can be obtained by submitting carcasses of dead birds (or other non-target species) for analysis of 1080 residues. Residues of 1080 in tissue samples can be detected by gas chromatography to a level of 0.0015 μg/g (G.R.G. Wright pers. comm.). Protocols are currently being developed covering the type and quantity of sample required, the method of handling, storage, and transport of samples, which laboratory they should be sent to, what analyses need to be carried out, and how to interpret the results (G.R.G. Wright pers. comm.). At present, there is also no national database to send the results to. It is important to note that failure to detect 1080 in a carcass does not necessarily imply an alternative cause of death. The 1080 may have been degraded if the carcass was two or three days old when collected.

3.6 OTHER SPECIES

There are currently no established techniques to adequately monitor the impact of 1080-poisoning on bats (Lloyd 1994). Ground-dwelling lizard populations may be monitored by pitfall trapping but the technique is not unbiassed, being affected by factors such as weather and lizard behaviour (Towns 1991). No suitable techniques are available for monitoring populations of arboreal lizards. Frog populations have been monitored by transect or area search techniques (McNaughton & Greene 1994; Greene *et al*. 1995) but the method could be improved by including a quantitative method of determining the area searched along transects (Greene *et al*. 1995). Ground-dwelling invertebrate populations have been monitored by pitfall trapping in poisoned and non-poisoned areas (Meads 1994; Spurr 1994b) but the technique has not been validated (Topping & Sunderland 1992).

4. Impacts on birds

If it is known that a species has eaten cereal-based baits containing brodifacoum, that information is included in this report to indicate that the species may eat cereal-based 1080 baits.

Brown kiwi (*Apteryx australis*)

Brown kiwi are known to have eaten cereal-based baits (Pierce & Montgomery 1992), but did not eat carrot baits even when starved for 24 hours in captivity (McLennan *et al*. 1992). Kiwi feed on soil invertebrates, and so may be at risk from secondary poisoning. However, the species has not been reported dead after any 1080-poisoning operations. Recently, there have been three radio-tracking studies carried out on brown kiwi. At Waipoua Forest in Northland, all five radio-tagged brown kiwi survived for at least three months after aerial application of Wanganui No. 7 cereal-based baits (5 kg/ha, 0.08% 1080) in September 1990 (Pierce & Montgomery 1992). At Rarewarewa in Northland, all 22 radio-tagged adult brown kiwi survived at least three months after being exposed to Wanganui No. 7 cereal-based baits (3 kg/ha, 0.15% 1080), and all 13 radio-tagged adult brown kiwi survived at least three months after being exposed to jam baits containing 0.15% 1080, in May 1995 (H.A. Robertson pers. comm.). At Tongariro Forest, central North Island, two radio-tagged brown kiwi survived for at least six months following a possum control operation using aerially spread screened carrot baits (10 kg/ha, 0.08% 1080) in June 1995 (C. Speedy pers. comm.).

Little spotted kiwi (*Apteryx owenii*)

Little spotted kiwi have been exposed to baits containing 1080 only once, to our knowledge. In August 1984, kiwi on the western cliffs of Kapiti Island were exposed to an aerial application of screened carrot baits (15 kg/ha, 0.15% 1080), but they were not monitored The species has been exposed to cereal-based baits containing brodifacoum at least twice. All nine radio-tagged little spotted kiwi survived a rodent eradication operation using aerially distributed cereal-based Talon 20P (15 kg/ha, 20 ppm brodifacoum) on Red Mercury Island in September 1992 (Robertson *et al*. 1993). However, one of nine radio-tagged little spotted kiwi died after two aerial applications of cereal-based Talon 7–20 (20 ppm brodifacoum) for rodent eradication on Kapiti Island in September and October 1996 (11 kg/ha and 6 kg/ha, respectively), and the cause of death was confirmed as brodifacoum poisoning (R. Empson pers. comm.). It is not known whether the bird died from primary or secondary poisoning. The result indicates that little spotted kiwi may be vulnerable to 1080-poisoning operations using cereal-based baits for possum control, although the bait sowing rate is likely to be lower than in brodifacoum-poisoning operations for rodent eradication.

Great spotted kiwi (*Apteryx haastii*)

Great spotted kiwi, like brown kiwi, have not been reported dead after any 1080-poisoning operations. There have been two radio-tracking studies of this species carried out recently. In August 1994, all eight radio-tagged kiwi survived at least 6.5 weeks, and five survived at least five months after aerial application of RS5 cereal-based baits (5 kg/ha, 0.15% 1080) on the Gouland Downs, Nelson (Walker 1997). In December 1994, all seven kiwi survived at least two months after aerial application of Wanganui No.7 cereal-based baits (5 kg/ha, 0.15% 1080) near Karamea, Westland (J. Lyall pers. comm.; C. Miller pers. comm. *in* Fraser *et al*. 1995).

Blue duck (*Hymenolaimus malacorhynchos*)

Blue ducks are unlikely to eat either carrot or cereal-based baits and their aquatic invertebrate prey is unlikely to be contaminated by 1080. However, blue ducks are potentially at risk from prey-switching by predators such as stoats (*Mustela erminea*) and cats (*Felis catus*) as a result of the drastic reduction in rodent numbers from aerial 1080-poisoning operations. Only two studies have been made to assess the impact of 1080-poisoning on this species. In December 1989, there was no reduction in visual counts of blue ducks in the Otira Valley after aerial application of RS5 cereal-based baits (6 kg/ha, 0.15% 1080) (C. Miller pers. comm.). In August 1994, all 19 radio-tagged blue ducks survived for at least four weeks after aerial application of carrot bait (15 kg/ha, 0.08% 1080) in Waihaha, Pureora Forest Park (Greene 1995).

Brown teal (*Anas aucklandica*)

Brown teal are not known to have been present during any aerial 1080-poisoning operations for possum control, but teal were found dead and considered poisoned after the aerial application of cereal-based Talon 20P (10 kg/ha, 20 ppm brodifacoum) for eradication of kiore (*Rattus exulans*) on Tiritiri Matangi Island in September 1993 (C.R. Veitch pers. comm. *in* Eason & Spurr 1995). Thus, brown teal are likely to be vulnerable to 1080-poisoning operations using cereal-based baits for possum control. It is not known if brown teal would eat carrot baits.

Australasian harrier (*Circus approximans*)

Harriers have been reported dead occasionally, presumably from secondary poisoning, after 1080-poisoning operations against rabbits (*Oryctolagus cuniculus*) (Batcheler 1978), though Pierce & Maloney (1989) found no evidence of dead harriers after 1080-poisoning of rabbits in their study. Harriers are known to enter forest and shrub habitats in order to feed on carrion (pers. obs.) so it is possible that they may be vulnerable to secondary poisoning after 1080-poisoning operations for possum control. However, 1080-poisoning is unlikely to kill many harriers. Harriers were seen feeding on possum and wallaby carcasses after aerial application of Wanganui No. 7 cereal-based baits (12 kg/ha, 0.08% 1080) on Rangitoto Island in October 1990, but none were found dead and 5-minute counts of harriers increased after the operation (Miller & Anderson 1992).

New Zealand falcon (*Falco novaeseelandiae*)

Falcons may be susceptible to secondary poisoning by eating poisoned birds or small mammals. However, no falcons have been found dead after 1080-poisoning operations. A single falcon territory was monitored during aerial application of Mapua cereal-based bait (7 kg/ha, 0.15% 1080) in Motere, Pureora Forest Park, in June 1984, and the territory was still occupied after the operation (Calder & Deuss 1985). Falcons inhabited two to three territories in the Mapara Wildlife Management Reserve during three consecutive annual possum control operations using Wanganui No.7 cereal-based baits (8 kg/ha, 0.08% 1080) in September 1990, October 1991, and October 1992, and no territories became unoccupied afterwards (I. Flux pers. comm.). At least three falcon territories were occupied throughout aerial application of screened carrot (15 kg/ha, 0.08% 1080) at Waihaha, Pureora Forest Park, in August 1994 (T. Greene pers. comm.). In all these cases, it is assumed that the territories remained occupied by the same birds, but it is possible that they were filled quickly by new birds after the death of the original occupants. There have been no studies of marked or radio-tagged birds.

Banded rail (*Rallus philippensis*)

Banded rails are not known to have been present during any aerial 1080-poisoning (or brodifacoum poisoning) operations. However, they feed on a wide variety of foods, including invertebrates, seeds and fruits (Williams 1985), and so we consider the species is likely to eat carrot and cereal-based baits if any are distributed in their habitat.

Weka (*Gallirallus australis*)

Weka are known to eat both carrot and cereal-based baits (Spurr 1993) and to scavenge on the carcasses of dead animals. They have been found dead occasionally after 1080-poisoning operations (Spurr 1994a). However, aerial application of screened carrot bait (20 kg/ha, 0.2% 1080) in the Copland Valley, Westland National Park, in 1986 had no detectable effect on 5-minute counts of the species (Spurr 1988). In August 1994, 24 radio-tagged weka were monitored during two possum control operations using RS5 cereal-based baits (5 kg/ha, 0.15% 1080) on the Gouland Downs, North-West Nelson, and Tennyson Inlet, Marlborough Sounds. One of these birds was subsequently found dead, and 1080 was present in its muscle tissue (Walker 1997). The remaining weka all survived for at least four weeks after the operations. A weka without a radio transmitter was found sick, and its droppings contained 1080. However, this bird subsequently recovered. Eight radio-tagged weka were monitored through aerial application of Wanganui No.7 cereal baits (5 kg/ha, 0.15% 1080) at Rotomanu, West Coast, in 1994, and all survived (C. Miller pers. comm.).

Spotless crake (*Porzana tabuensis*)

This species has not been found dead after aerial 1080-poisoning operations for possum control, but probably has seldom been exposed to such operations and impacts on its populations have not been monitored. However, one was found dead and considered poisoned after aerial distribution of cereal-based Talon 20P (10 kg/ha, 20 ppm brodifacoum) for rodent eradication on Tiritiri Matangi Island in September 1993 (C.R. Veitch pers. comm. *in* Eason & Spurr 1995). Thus, spotless crake may be vulnerable to 1080-poisoning operations using cereal-based baits for possum control. It is not known if spotless crake would eat carrot baits.

Marsh crake (*Porzana affinis*)

This species has not been found dead after 1080-poisoning or brodifacoum poisoning operations, but it has not been monitored either. Marsh crakes eat a variety of food types, such as aquatic insects, snails, crustaceans, small vertebrates and seeds (Marchant & Higgins 1993), and we suspect they would eat carrot and cereal-based baits too.

Pukeko (*Porphyrio porphyrio*)

Pukeko are known to eat both carrot and cereal-based baits, but are rarely found in areas subject to aerial 1080-poisoning operations for possum control. They have been found dead after 1080-poisoning operations for rabbit control (Batcheler 1978), but so far as we know they have not been monitored after 1080-poisoning operations for possum control. However, more than 90% of pukeko on Tiritiri Matangi Island died after aerial distribution of cereal-based Talon 20P (10 kg/ha, 20 ppm brodifacoum) for eradication of kiore in September 1993 (C.R. Veitch pers. comm. *in* Eason & Spurr 1995). Three years after poisoning, pukeko numbers have returned to pre-poison levels (B. Walters pers. comm.). Because of their good dispersal and reproductive capacities, pukeko are likely to recover rapidly from any reductions from 1080-poisoning.

Kereru (*Hemiphaga novaeseelandiae*)

Kereru are known to eat carrot baits (Lloyd & Hackwell 1993; Spurr 1994a), and may eat cereal-based baits although none of six ate cereal-based baits in a trial on Kapiti Island (R. Empson pers. comm.). Kereru obtain most food arboreally but they do forage on the ground. Thus, it is possible that kereru could encounter baits and bait fragments both in the canopy and on the ground. At least eight have been found dead incidentally after 1080-carrot operations (Spurr 1994a; Greene 1994; Marsh 1996; P. Sweetapple pers. comm.) but none that we know of after 1080-cereal operations. The one kereru submitted for 1080 analysis that was found dead after aerial application of screened carrot bait (15 kg/ha, 0.08% 1080) in the North Block of Pureora Forest Park in May–June 1996 tested positive for the toxin (M. Frank pers. comm.). There was no detectable effect of 14 aerial 1080-poisoning operations for possum control (nine using screened carrot, three using Wanganui No. 7 cereal bait, and two using Mapua cereal baits) on kereru populations monitored by 5-minute counts (Pierce & Montgomery 1992; Spurr 1994a). However, kereru have increased in abundance in Waipoua Forest since the aerial 1080-poisoning operation in 1990 (5 kg/ha, 0.08% 1080) and subsequent sustained ground control of possums (R.J. Pierce pers. comm.). To date there has been no attempt to monitor radio-tagged kereru during aerial 1080-poisoning operations.

Kaka (*Nestor meridionalis*)

Kaka are known to eat carrot and cereal-based baits (Lloyd & Hackwell 1993; Spurr 1993). One was found dead, and contained 1080 residues, after a possum-control operation using 1080 in unscreened carrot baits in 1977 (Spurr 1994a). Kaka have been monitored by 5-minute counts during five aerial 1080-poisoning operations; numbers were similar before and after three operations (two using screened carrot and one Mapua cereal bait), decreased two weeks after one operation (using screened carrot bait, 30 kg/ha, 0.08% 1080), and increased two weeks after another operation (using Mapua cereal bait, 7 kg/ha, 0.15% 1080) (Spurr 1994a). Radio-tagged kaka were monitored following aerial application of screened carrot bait (15 kg/ha, 0.08% 1080) in Waihaha, Pureora Forest Park in August 1994. All 21 kaka survived for at least one month after the operation (Greene 1995). However, four out of 20 radio-tagged kaka died after two aerial applications of cereal-based Talon 7–20 baits (20 ppm brodifacoum) on Kapiti Island in September and October 1996 (11 kg/ha and 6 kg/ha, respectively), and three were confirmed as dying from brodifacoum poisoning (R. Empson pers. comm.).

Kea (*Nestor notabilis*)

Kea are known to eat carrot baits (Spurr 1979, 1994a) and probably would eat cereal-based baits. Dead kea were found after a 1080-poisoning operation using unscreened carrot bait (30 kg/ha, 0.08% 1080) in the Dobson Valley in September–October 1964, and residues of 1080 were found in the carcasses (Douglas 1967). However, kea are only occasionally exposed to 1080 baits. Five-minute counts of kea were similar before and after two 1080-poisoning operations using screened carrot baits (20 kg/ha, 0.08% and 0.2% 1080, respectively) in Westland National Park in 1983 and 1986 (Spurr 1994a). No monitoring of individually marked or radio-tagged kea exposed to 1080 has been carried out.

Kakariki (*Cyanoramphus novaezelandiae* and *C. auriceps*)

Captive kakariki ate carrot and cereal-based baits (Spurr 1993). No kakariki have been found dead after 1080-poisoning operations (Spurr 1994a), but one was found dead (containing traces of brodifacoum) after aerial application of cereal-based Talon 20P (containing 20 ppm brodifacoum) for eradication of kiore on Lady Alice Island in October 1994 (Ogilvie *et al.* in press). Populations exposed to possum-control operations using 1080 have been monitored by 5-minute counts on four occasions (two where the bait was screened carrot and two Mapua cereal bait), and there was no detectable impact on the number of kakariki counted (Spurr 1991). No kakariki populations have been monitored by following radio-tagged birds during a 1080-poisoning operation.

Long-tailed cuckoo (*Eudynamys taitensis*)

Long-tailed cuckoos are present from about September to February, when few 1080-poisoning operations occur. No attempt has been made to monitor this species during 1080-poisoning operations.

Shining cuckoo (*Chrysococcyx lucidus*)

Shining cuckoos are present from about September to February, when few 1080-poisoning operations occur. No attempt has been made to monitor this species during 1080-poisoning operations.

Morepork (*Ninox novaeseelandiae*)

Moreporks have been found dead after 1080-poisoning operations using carrot and cereal-based baits (Warren 1984; Spurr 1991; M. Frank pers. comm.; C. Speedy pers. comm.). Presumably the birds died from secondary poisoning because they are not known to eat vegetable matter. One morepork found dead after the 1080-poisoning operation using screened carrot baits (15 kg/ha, 0.08% 1080) on the Rangitoto Range in May–June 1996 contained residues of 1080 (M. Frank pers. comm.). Moreporks were monitored by 10-minute counts during a 1080-poisoning operation using Wanganui No.7 cereal-based baits (5 kg/ha, 0.08% 1080) at Waipoua Forest in September 1990, and the numbers counted were not affected by the operation (Pierce & Montgomery 1992). All seven radio-tagged morepork were alive five days after two 1080-poisoning operations using Wanganui No.7 cereal-based baits in Nelson and Marlborough in 1994 (Walker 1997). One transmitter then fell off, but the six remaining radio-tagged birds were all alive one month after the operations. Of six radio-tagged moreporks exposed to aerial application of screened carrot bait (15 kg/ha, 0.08% 1080) for possum control at Pureora Forest Park in September 1996, one was found dead one month later, probably having died a week previously. Analysis of muscle tissue from this bird revealed 1080 was present. Of the remaining five moreporks, four were still alive two months after the 1080 operation, and the fifth had lost its transmitter (R.G. Powlesland unpubl. data). Two dead moreporks were handed in and a further six were reported dead following aerial application of Wanganui No.7 cereal-based baits (5 kg/ha, 0.08% 1080) in Mangamingi Ecological Area, Tongariro–Taupo Conservancy, in September 1995. The one bird analysed tested positive for 1080 (C. Speedy pers. comm.).

Rifleman (*Acanthisitta chloris*)

Riflemen have been found dead after several 1080-poisoning operations (Harrison 1978a, b; Spurr 1991), all using carrot baits. Five riflemen found dead after aerial application of screened carrot bait (15 kg/ha, 0.08% 1080) in Waihaha, Pureora Forest Park, in August 1994 all contained residues of the poison (P. Sweetapple pers. comm.). No food remains were found in any of the birds and so it is not known whether they died of primary or secondary poisoning. Riflemen have been monitored by 5-minute counts during 13 aerial 1080-poisoning operations (nine using screened carrot, two using Wanganui No. 7 cereal bait, and two Mapua cereal bait), and overall there was no detectable impact on the number of riflemen counted 2–8 weeks afterwards (Spurr 1991).

No rifleman populations have been monitored by following individually marked birds before and after a 1080-poisoning operation.

Fernbird (*Bowdleria punctata*)

This species has not been found dead after 1080-possum control operations (Spurr 1991). Fourteen fernbirds, including two banded birds, were located before and five weeks after an aerial 1080-poisoning operation using Wanganui No. 7 cereal-based baits (5 kg/ha, 0.08% 1080) at Waipoua Forest in September 1990 (Pierce & Montgomery 1992). Nine fernbirds were banded in the five months before a 1080-poisoning operation using RS5 cereal-based baits (5 kg/ha, 0.15% 1080) on the Gouland Downs in August 1994, and five were relocated in the two weeks afterwards (Walker 1997). However, it is not known if the four missing birds died of 1080-poisoning, died naturally, or moved out of the study area because a roll call of birds was not made immediately before the operation. Concern that fernbirds may be killed during 1080-poisoning operations stems, in part, from the impact of a Talon 20P (20 ppm brodifacoum in cereal bait) operation on banded birds at Waituna wetlands near Invercargill in October 1994 (Ranum *et al*. 1994). The baits for this operation were spread at 37.5 kg/ha, instead of the expected 15 kg/ha. Fifteen of 18 banded birds disappeared from the treatment area, but the same number of unbanded birds (n=43) was present in the non-treatment area two months after the operation (Ranum *et al*. 1994). It is not known whether the birds died from primary or secondary poisoning. No dead birds were found.

Whitehead (*Mohoua albicilla*)

Whiteheads have been seen eating carrot baits (Spurr 1979), and have been found dead after 1080-poisoning operations, especially those using unscreened carrot baits containing a high proportion of small fragments or chaff before 1978 (Harrison 1978a, b; Spurr 1991). However, despite modifications to carrot baits (removal of chaff and addition of cinnamon in an attempt to repels birds), whiteheads are still found dead occasionally after possum-control operations (Spurr 1994a). It is assumed that they died from 1080-poisoning, though none of the carcasses were tested for 1080 residues. It is not known if the birds died from primary or secondary poisoning. Whitehead populations have been monitored by 5-minute counts during 18 aerial 1080-poisoning operations (11 using screened carrot, five using Wanganui No. 7 cereal bait, and two Mapua cereal bait), and overall there was no detectable impact on the number of birds counted 2–8 weeks afterwards (Spurr 1991). No whitehead populations have been monitored by following individually marked birds before and after a 1080-poisoning operation.

Yellowhead (*Mohoua ochrocephala*)

Yellowheads are rarely exposed to aerial 1080 possum-control operations, and we are unaware of any monitoring of impacts on their populations.

Brown creeper (*Mohoua novaeseelandiae*)

Brown creepers have not been found dead after aerial 1080 possum-control operations. Five-minute counts of brown creepers declined (by about 60%)

following aerial application of unscreened carrot (30 kg/ha, 0.06% 1080) for possum control in Cone State Forest, Southland, in September 1977, but returned to pre-poison levels one year later (Spurr 1981). However, similar fluctuations in counts of brown creepers have been observed in non-poisoned populations. Five-minute counts of brown creepers were similar one year before and one year after two 1080-poisoning operations using screened carrot baits (20 kg/ha, 0.08% and 0.2% 1080) in Westland National Park in 1983 and 1986 (Spurr 1988). No brown creeper populations have been monitored by following individually marked birds before and after a 1080-poisoning operation.

Grey warbler (*Gerygone igata*)

Grey warblers have been found dead occasionally after 1080-poisoning operations, all using carrot baits (Harrison 1978a, b; Spurr 1991, 1994a). It is assumed that they died from 1080-poisoning, though none of the carcasses were analysed for 1080 residues. It is not known if the birds died from primary or secondary poisoning. Grey warbler populations have been monitored by 5-minute counts during 20 aerial 1080-poisoning operations (13 using screened carrot, five using Wanganui No. 7 cereal bait, and two Mapua cereal bait), and overall there was no detectable impact on the number of birds counted 2–8 weeks afterwards (Spurr 1991). No grey warbler populations have been monitored by following individually marked birds before and after a 1080-poisoning operation.

Fantail (*Rhipidura fuliginosa*)

Fantails have been found dead after 1080-poisoning operations (Spurr 1991, 1994a), all using carrot baits. It is assumed that they died from 1080-poisoning, though none of the carcasses were tested for 1080 residues. It is not known if they died from primary or secondary poisoning. Fantail populations have been monitored by 5-minute counts during 20 aerial 1080-poisoning operations (13 using screened carrot, five using Wanganui No. 7 cereal bait, and two Mapua cereal bait), and overall there was no detectable impact on the number of birds counted 2–8 weeks afterwards (Spurr 1991). No fantail populations have been monitored by following individually marked birds before and after a 1080-poisoning operation.

New Zealand tomtit (*Petroica macrocephala*)

Tomtits have been found dead after 1080-poisoning operations for possum control, especially in the 1970s when the poison was applied in unscreened carrot bait (Harrison 1978a, b; Spurr 1981, 1991). In one operation using unscreened carrot bait (30 kg/ha, 0.06% 1080), in Cone State Forest, Southland, in September 1977, no tomtits were seen or heard two weeks afterwards (Spurr 1981). Two were found dead. Five-minute counts of tomtits in this forest took three years to return to pre-poison levels. Although various measures have been taken to reduce the attractiveness of carrot baits to birds (removal of chaff and addition of cinnamon in an attempt to repels birds), dead tomtits are still found after 1080-poisoning operations using both carrot and cereal-based baits. For example, dead tomtits (number unknown) were found after aerial application of Wanganui No. 7 cereal-based baits (5 kg/ha, 0.15% 1080) in the Hunua Ranges in

June 1994 (J. Fanning pers. comm.). Two dead tomtits were found incidentally following aerial application of screened carrot bait (15 kg/ha, 0.08%1080) at Waihaha, Pureora Forest Park in August 1994, and both contained residues of 1080 (P. Sweetapple pers. comm.). Landcare Research staff working in the area immediately after the poison operation did not see or hear any live tomtits (Nugent *et al*. 1996). Similarly, no tomtits were seen or heard in the Tahae block of Pureora Forest Park for the first fortnight after aerial application of screened carrot bait (15 kg/ha, 0.08% 1080) in September 1996 (R.G. Powlesland unpubl. data). Prior to the operation five birds, including two banded individuals, would regularly approach observers for mealworms. None of these birds appeared after the poison operation. Two tomtits were found dead and both contained residues of 1080. Thus, it seems that tomtit mortality remains high (>25%) as a result of 1080-possum control operations, especially those using carrot baits. However, populations appear to be able to recover from this mortality. Tomtit populations have been monitored by 5-minute counts during 20 aerial 1080-poisoning operations (13 using screened carrots, five using Wanganui No. 7 cereal baits, and two Mapua cereal baits), and overall numbers were similar before and 2–8 weeks afterwards (Spurr 1991).

New Zealand robin (*Petroica australis*)

Robins are known to eat carrot and cereal-based baits, and have been found dead after 1080-poisoning operations to control possums, especially in the 1970s when the poison was applied in unscreened carrot bait (Harrison 1978a, b; Spurr 1991, 1994a). Although baits have since been modified by screening out small pieces and the addition of cinnamon oil, robins still eat baits and are still found dead after 1080-poisoning operations. A North Island robin (*P. a. longipes*) on Kapiti Island was seen flying off with a non-toxic carrot bait in May 1993 (Lloyd & Hackwell 1993), and a South Island robin (*P. a.* australis) at Maruia Creek was seen pecking at a Talon 20P cereal-based bait containing 20 ppm brodifacoum (K. Brown pers. comm.). In trials on Kapiti Island in March and July 1993, 56% of 34 North Island robins ate non-toxic green-dyed Wanganui No. 7 cereal-based bait (R. Empson pers. comm.). After aerial application of Talon 7–20 cereal-based bait (containing 20 ppm brodifacoum) for rodent eradication on Kapiti Island in September and October 1996, 30% of 37 colour-banded robins disappeared from a coastal site, and 64% of 42 colour-banded robins disappeared from a site near the summit of the island (R. Empson pers. comm.). All 13 colour-banded robins with territories away from public tracks at the coastal site survived. This suggests that the robins adjacent to public tracks were more likely to sample novel foods.

Colour-banded robins have been monitored through two 1080-poisoning operations. Two colour-banded South Island robins both survived at least one month after an aerial application of RS5 cereal-based baits (5 kg/ha, 0.15% 1080) on the Gouland Downs, North-west Nelson, in August 1994 (Walker 1997). Twelve of 22 colour-banded North Island robins (55%) disappeared within two weeks of aerial application of screened carrot bait (15 kg/ha, 0.08% 1080) in the Tahae block, Pureora Forest Park, in September 1996 (R.G. Powlesland unpubl. data). Two that were found dead both contained residues of 1080. At this stage it is not known whether the robins died from primary or secondary poisoning.

All 24 colour-banded robins in the non-poison area were alive two months after the 1080-poisoning operation.

Robin populations have been monitored by 5-minute counts during 11 aerial 1080-poisoning operations (six using screened carrots, three using Wanganui No. 7 cereal baits, and two using Mapua cereal baits), and numbers were similar before and 2–8 weeks after nine operations; in one operation using Wanganui No. 7 baits they decreased, and in one using screened carrot baits they increased (Spurr 1994a).

Silvereye (*Zosterops lateralis*)

Silvereyes have been seen eating carrot baits (Spurr 1979), and have been found dead after 1080-poisoning operations, all using unscreened carrot baits (Harrison 1978a, b; Spurr 1991). It is assumed that they died from 1080-poisoning, though none of the carcasses were analysed for 1080 residues. It is not known if they died from primary or secondary poisoning. Silvereye populations have been monitored by 5-minute counts during 20 aerial 1080-poisoning operations (13 using screened carrot, five using Wanganui No. 7 cereal bait, and two Mapua cereal bait), and overall there was no detectable impact on the number of birds counted 2–8 weeks afterwards (Spurr 1991). No silvereye populations have been monitored by following individually marked birds before and after a 1080 operation.

Bellbird (*Anthornis melanura*)

No bellbirds have been reported dead following 1080-poisoning operations for possum control using carrot or cereal-based baits, though one was found dead after a 1080 operation using jam baits (Spurr 1994a). Bellbird populations have been monitored by 5-minute counts during 13 aerial 1080-poisoning operations (nine using screened carrots, two using Wanganui No. 7 cereal baits, and two using Mapua cereal baits), and overall numbers were similar before and 2–8 weeks afterwards (Spurr 1991). No bellbird populations have been monitored by following individually marked birds before and after a 1080 operation.

Tui (*Prosthemadera novaeseelandiae*)

One tui was found dead after aerial application of screened carrot bait (15 kg/ha, 0.15% 1080) for eradication of possums on Kapiti Island in 1984 (Sherley 1992). Tui populations have been monitored by 5-minute counts during 11 aerial 1080-poisoning operations (seven using screened carrots, two using Wanganui No. 7 cereal baits, and two using Mapua cereal baits), and overall numbers were similar before and 2–8 weeks afterwards (Spurr 1991). No tui populations have been monitored by following individually marked birds before and after a 1080 operation.

Kokako (*Callaeas cinerea*)

One kokako was found dead after a 1080-poisoning operation using cereal-based baits for possum control and fishmeal baits for cat control in Rotoehu Forest in October 1994, and the carcass contained residues of 1080 (H. Speed pers. comm.). However, of 319 kokako monitored by territory mapping and roll-calling during ten 1080-poisoning operations using cereal-based baits, only three or four birds disappeared (Pierce & Montgomery 1992; Fanning 1994; P. Bradfield, W. Fleury, J. Innes, H. Speed pers. comm. *in* Spurr 1994a). None of 44 kokako monitored by territory mapping and roll-calling during two 1080-poisoning operations using screened carrot baits have disappeared (H. Speed pers. comm. *in* Spurr 1994a; Marsh 1996). Recent studies of banded kokako at Mapara Wildlife Management Reserve have indicated that kokako that die or leave a territory can be replaced within a few days (I. Flux pers. comm.). However, there have been no losses of 47 banded kokako at Mapara in 1990 (n=6), 1991 (15) and 1992 (26) following 1080-poisoning operations with cereal-based baits (I. Flux pers. comm.).

Saddleback (*Philesturnus carunculatus*)

Saddlebacks are restricted to offshore islands, and have never been exposed to aerial 1080-poisoning operations for possum control. However, they are known to eat carrot and cereal-based baits (Spurr 1993). In trials on Kapiti Island in March and July 1993, 27% of 11 saddlebacks ate non-toxic green-dyed Wanganui No. 7 cereal-based bait (R. Empson pers. comm.). Saddlebacks have been found dead after aerial distribution of cereal-based Talon 20P baits (containing 20 ppm brodifacoum) for rodent and rabbit eradication, and the carcasses contained residues of the poison (Eason & Spurr 1995). Thus, saddlebacks would be at risk from 1080-poisoning if they were present in treated areas.

Other bird species

A number of other bird species, such as takahe (*Porphyrio mantelli*), kakapo (*Strigops habroptilus*), kingfisher (*Halcyon sancta*), rock wren (*Xenicus gilviventris*), New Zealand pipit (*Anthus novaeseelandiae*), stitchbird (*Notiomystis cincta*), southern black-backed gull (*Larus dominicanus*), paradise shelduck (*Tadorna variegata*), and grey duck (*Anas superciliosa*), may or may not have been exposed to 1080-poisoning operations. Impacts on their populations are unknown.

5. Impacts on bats

Short-tailed bat (*Mystacina tuberculata*)

Short-tailed bats are primarily insectivorous and unlikely to eat carrot or cereal-based baits used in 1080-poisoning operations for possum control (Eckroyd 1993; Lloyd 1994) but may suffer from secondary poisoning by eating invertebrates that have eaten baits (Lloyd 1994). No dead short-tailed bats have been reported following 1080-poisoning operations (Spurr 1994a) but even if bats did die from 1080-poisoning their carcasses would be very difficult to find. A study to evaluate the risk of 1080-poisoning operations to short-tailed bats commenced in beech forest near Ohakune in October 1994 (B. Lloyd & S. McQueen pers. comm.).

Long-tailed bat (*Chalinolobus tuberculatus*)

Long-tailed bats are considered entirely insectivorous and forage in flight, mainly within and above the canopy, on flying invertebrates (C.F.J. O'Donnell pers. comm.). Therefore, the species is at risk only from secondary poisoning, and this risk is considered minimal. Long-tailed bat populations have not been monitored during any 1080-poisoning operations.

6. Impacts on lizards

Several species of skinks and geckos live in New Zealand forests where 1080 possum-control operations have been carried out, but the impacts on their populations have never been monitored. New Zealand lizards are predominantly insectivorous and so could be at risk from secondary poisoning. However, they also eat soft fruit, honeydew and nectar, and so may eat carrot and cereal-based baits which contain sugars. Captive McCann's skinks (*Oligosoma maccanni*) ate non-toxic RS5 and AgTech cereal-based baits, especially when the baits were wet, but the level of consumption was probably insufficient for the animals to have received a lethal dose had the baits been toxic (Freeman *et al.* 1996). No dead lizards have been found after 1080-poisoning operations (Spurr 1994a).

7. Impacts on frogs

Hochstetter's frog (*Leiopelma hochstetteri*) and Archey's frog (*L. archeyi*)

Frogs are not known to eat carrot or cereal-based baits but, being insectivorous, could be at risk from secondary poisoning. Two recent studies have assessed the impact of 1080 possum-control operations on native frogs. In June 1994, Hockstetter's frogs were monitored at three sites before and after aerial application of Wanganui No. 7 cereal-based baits (5 kg/ha, 0.08% and 0.15% 1080) in the Hunua Range, near Auckland (McNaughton & Greene 1994). There was no evidence that the population or individual frogs were affected by the 1080-poisoning operation. One frog found dead immediately after the operation tested negative for the presence of 1080. Two of the three sites were re-surveyed one year later, and frog numbers were similar to those found in the 1994 survey (Greene *et al*. 1995). A second study, in June 1995, found no evidence of any major impact of aerial application of Wanganui No. 7 cereal-based baits (5 kg/ha, 0.15% 1080) on Archey's and Hochstetter's frogs at a site on the Coromandel Peninsula (A. Perfect & B. Bell, pers. comm.). These results are in agreement with the international literature indicating that amphibians, in general, are fairly tolerant of 1080 (Spurr 1994a).

8. Impacts on invertebrates

Various invertebrate species have been seen feeding on carrot and cereal-based baits containing 1080 and on carcasses of animals poisoned by 1080 (Spurr 1994b). Invertebrates are prone to 1080-poisoning (Notman 1989; Hutcheson 1989) and residues of 1080 have been found in invertebrates collected after 1080-poisoning operations (Eason *et al*. 1991, 1993; Pierce & Montgomery 1992). A short-term reduction in the total number of invertebrates, especially beetles and collembolans, caught in pitfall traps was claimed after a 1080-poisoning operation using Wanganui No. 7 cereal-based baits (5 kg/ha, 0.08% 1080) in Whitecliffs Conservation Area in July 1991 (Meads 1994) but the study was flawed because bait density within one metre of the pitfall traps was ten times higher than usual and the non-treatment area may have been contaminated by 1080. No impacts were detected in the numbers of amphipods, ants, beetles, collembolans, millipedes, mites, slugs, snails, spiders, or cave weta caught in pitfall traps after two 1080-poisoning operations using Wanganui No. 7 cereal-based baits (5 kg/ha, 0.08% 1080), at Puketi Forest Park in March 1992 and Titirangi Scenic Reserve in June 1992 (Spurr 1994b). To date, too few studies have been carried out to make a general statement about the likely impact of 1080-poisoning operations on invertebrate populations (Spurr 1994a, b). However, several studies are in progress. The species of invertebrates that consume and/or come in contact with carrot and cereal-based baits on the ground are being identified in podocarp–beech forest near Ohakune (G. Sherley, M. Wakelin & J. McCartney pers. comm.) and in rata–kamahi forest in Westland (E.B. Spurr unpubl. data). The impact of 1080-poisoning on invertebrate populations is being determined in beech forest near Ohakune (B. Lloyd & S. McQueen pers. comm.), in podocarp–beech forest near Ohakune (G. Sherley pers. comm.), and in a range of sites throughout New Zealand (E.B. Spurr unpubl. data). Ground-dwelling invertebrate numbers were monitored by pitfall trapping before and after aerial application of carrot bait (15 kg/ha, 0.08% 1080) at Waihaha in August 1994 but the results are not yet available (P. Aspin pers. comm.).

9. Priorities for further research

9.1 BAIT QUALITY

The highest priority for research on improving bait quality is to develop a protocol for measuring bait quality after baits have been spread by aircraft. This should be complemented by research to determine whether auger-fed sowing equipment damages baits and increases the fragment content after baits have been loaded into the hopper or sowing bucket. Research is also needed to determine whether bait quality can be improved at the time of production; e.g., by washing carrot baits to remove small fragments created during the cutting process, then drying them before spraying on the toxin, and by improving the handling qualities of cereal-based baits during transport and loading into aircraft. Further studies are needed to determine the fate of carrot and cereal-based baits aerially spread over forests. For example, how much bait and what sized baits are caught up in the canopy? What proportion of baits are eaten by possums and what proportion by non-target species? Further research is also needed on bird repellents for possum baits, such as has been initiated for rodent baits (Spurr *et al*. 1995).

9.2 MONITORING TECHNIQUES

The highest priority for research on improving monitoring techniques is to develop validated techniques for measuring the long-term population trends (upwards and downwards) of all non-target wildlife species. Five-minute counts of birds, pitfall trap catches of ground-dwelling lizards and invertebrates, and transect or area counts of frogs are assumed to represent an index of population numbers but this assumption has not been validated for any of these measures. Validated techniques also need to be developed for bats and for arboreal lizards and invertebrates. Without validated techniques we cannot properly assess the impacts, especially long-term impacts, of 1080-poisoning operations for possum control on non-target species.

Protocols are needed for using current techniques for measuring impacts of 1080-poisoning on non-target species. For example, for mark–capture–recapture, resighting, or radio-telemetry studies, the number of animals to be marked, the number of times they should be relocated, and the methods by which they should be relocated need to be established for each species. BACI (before, after, control, impact) experiments could be used to monitor the impacts of poison operations on a few invertebrate species known to feed on baits. The data sought should be the number of invertebrates per bait and the percentage of baits with invertebrates on non-toxic baits before and after a poison operation in treatment and non-treatment blocks. One concern expressed about the present robin research at Pureora Forest Park is that monitoring the birds by way of training them to feed on mealworms may pre-condition them to eat dyed carrot and/or cereal-based baits. This possibility needs to be investigated.

Techniques are required urgently to determine whether animals die of primary or secondary poisoning. It should be possible to tag large-bodied animals with mortality-sensing transmitters so that any that die following a 1080-operation can be found within a few hours of death.

9.3 IMPACTS ON NON-TARGET SPECIES

Non-target species classified as low priority for further research are either those that are unlikely to be regularly exposed to aerial 1080 possum-control operations (Table 1) or those for which sufficient monitoring has been carried out to be reasonably confident that such operations are likely to have no, or

TABLE 1. SUMMARY OF DATA ON NON-TARGET SPECIES EXPOSED TO 1080 POISONING FOR POSSUM CONTROL.

SPECIES	EXPOSED TO 1080	EAT BAITS		FOUND DEAD AFTER		RESIDUES OF 1080	RISK OF SECONDARY POISONING	POPULATION IMPACT	RISK OF NON-RECOVERY
		Carrot	Cereal	Carrot	Cereal				
Brown kiwi	++	?	+	–	–	–	?	–	+++
Great spotted kiwi	++	?	?	–	–	–	?	–	+++
Little spotted kiwi	+	?	?	–	–(1)	–	?	–	+++
Bue duck	++	–	–	–	–	–	?	–	+++
Brown teal	?	?	+	–	–(1)	–	?	–	+++
Harrier	+++	–	–	+	?	?	+	–	+
Falcon	++	–	–	–	–	–	+	–	++
Banded rail	?	?	?	–	–	–	?	–	+++
Weka	++	++	++	?	+	+	+	–	++
Spotless crake	?	?	+	–	–(1)	–	?	–	+++
Marsh crake	?	?	?	–	–	–	?	–	+++
Pukeko	++	++	++	?	–(1)	–	?	–	+
Kereru	+++	+	?	+	–	+	–	–	++
Kaka	++	++	++	+	–	+	?	–	+++
Kea	++	++	++	+	–	+	?	–	+++
Kakariki	++	++	++	–	–	–	–	–	++
Long-tailed cuckoo	+	–	–	–	–	–	?	–	++
Shining cuckoo	+	–	–	–	–	–	?	–	++
Morepork	+++	–	–	++	+	+	+	–	++
Rifleman	+++	?	?	++	?	+	?	–	++
Fernbird	++	?	?	–	–	–	?	–	+++
Brown creeper	++	?	?	–	–	–	?	–	++
Whitehead	+++	++	?	++	?	?	?	–	++
Yellowhead	+	?	?	–	–	–	?	–	+++
Grey warbler	+++	?	?	+	?	?	?	–	+
Fantail	+++	?	?	+	?	?	?	–	+
Tit	+++	++	++	++	+	+	?	+	+
Robin	++	++	++	++	?	+	?	?	++
Silvereye	+++	++	+?	+	?	?	?	–	+
Bellbird	+++	?	?	–	–	–	?	–	+
Tui	++	?	?	+	–	–	?	–	+
Kokako	+	+	+	–	+	+	–	–	+++
Saddleback	?	+	+	–	–	–	–	–	+++
Short-tailed bat	++	–	–	–	–	–	?	–	+++
Long-tailed bat	++	–	–	–	–	–	?	–	+++
Lizards	+++	++	++	–	–	–	?	–	+++
Frogs	+	–	–	–	–	–	?	–	+++
Invertebrates	+++	++	++	–	–	–	?	–	+

– = never or none; + = rarely or low; ++ = occasionally or medium; +++ = frequently or high; ? = uncertain;
(1) = Found dead after brodifacoum poisoning, but not after 1080-poisoning operations.

minimal impact on the species. However, if the opportunity is available to readily monitor the mortality of marked individuals of low priority species following a 1080-poisoning operation then it would be useful to do so. Species classified as high priority are either those for which there is no or insufficient information to assess the impact of 1080-poisoning operations on their populations, or those for which the little information available indicates that some mortality of the species has occurred (Table 1). In either case, further research needs to be carried out to produce robust data on the impacts of 1080-poisoning operations on these species. Category A species are the highest priority for conservation action and category B species are second priority for conservation action (Molloy & Davis 1994).

Kiwi — Low priority for further research on impacts of 1080-cereal bait operations because no impacts have been observed on 22 radio-tagged North Island brown kiwi (a category A species) and 15 radio-tagged great spotted kiwi (category B). There is a high priority to collect data on impacts of 1080-carrot operations because only two radio-tagged North Island brown kiwi have been monitored through such an operation.

Blue duck — Low priority for this category B species because of results to date and because 1080 is unlikely to impact directly on the species in its aquatic habitat.

Brown teal — Low priority because the species is very unlikely to be exposed to aerial 1080 possum-control operations.

Australasian harrier — Low priority because there are few reports of harriers being found dead after 1080-poisoning operations, even those targeting rabbits in open habitats, and the species is widespread and not known to be in decline.

New Zealand falcon — High priority for this category B species because there is very little information available about the impact of 1080-poisoning operations on falcon populations.

Banded rail — Low priority because it is unlikely to be exposed to 1080 possum-control operations.

Weka — High priority because this category B species eats baits and scavenges dead possums, and so is susceptible to both primary and secondary poisoning, and weka have been monitored adequately by radio-telemetry during just one operation.

Spotless crake and marsh crake — Low priority because these species are very unlikely to be exposed to 1080 possum control operations.

Pukeko — Low priority given the species' nation-wide distribution, high productivity and good dispersal, and the small area of pukeko habitat likely to be exposed to aerial 1080 operations.

Kereru — High priority for this category B species because some dead birds have been found after 1080-poisoning operations, some populations have declined from a variety of factors (such as introduced predators and competitors), and there has been no attempt to quantify the mortality of tagged kereru during a 1080 operation.

Kaka — High priority for this category B species because its distribution on North and South Islands is restricted, it eats baits, and it has been monitored only once using radio-tagged birds during a 1080-operation.

Kea — High priority for this category B species because, although kea are infrequently exposed to 1080 operations, they have been found dead after at least one operation using carrot baits and no quantitative monitoring of populations containing marked birds has been carried out.

Kakariki — Low priority because no dead kakariki have been found, although there have been no studies on the impacts of 1080-poisoning using radio-tagged birds.

Long-tailed cuckoo — Low priority because most 1080 possum control operations occur when this cuckoo is absent from New Zealand.

Shining cuckoo — Low priority because most 1080 possum control operations occur when this cuckoo is absent from New Zealand.

Morepork — High priority because dead moreporks have been found after 1080 possum control operations, some of the birds tested have contained 1080, and there have been only two studies using radio-tagged birds to quantify the impact of such mortality on morepork populations.

Rifleman — High priority because dead riflemen have been found after 1080 possum control operations, some of the dead birds have contained 1080, and no quantitative monitoring of marked birds has been carried out during 1080 possum control operations.

Fernbird — High priority because of the possible vulnerability of this species to 1080 possum control operations, as evident from the Waituna wetlands result.

Whitehead — High priority because many dead whiteheads were found after operations using unscreened carrot baits, and many forests inhabited by whiteheads are subject to regular aerial 1080 possum control operations.

Yellowhead — High priority for this category B species because, although it has a restricted distribution and is very rarely exposed to 1080 possum control operations, impacts on populations of marked birds have not been monitored.

Brown creeper — Low priority because no brown creepers have been found dead after aerial 1080-poisoning operations, the species is widespread, occupies a variety of habitats, and disperses readily.

Grey warbler — Low priority because few grey warblers have been found dead after aerial 1080-poisoning operations since carrot baits have been screened, the species is widespread, occupies a variety of habitats, and disperses readily.

Fantail — Low priority because few fantails have been found dead after 1080-poisoning operations since carrot baits have been screened, the species is widespread, occupies a variety of habitats, and disperses readily.

New Zealand tomtit — High priority because dead tomtits have invariably been found when forests inhabited by this species have been exposed to aerial 1080 possum-control operations, carcasses have tested positive for 1080, and there has been a marked decline in the populations immediately following some 1080 carrot operations.

New Zealand robin — High priority because robins have been found dead, carcasses have tested positive for 1080, and population mortality was 55% in one sample of marked birds. Information is needed on the impacts of carrot and cereal 1080 operations on more samples of marked birds.

Bellbird — Low priority because there is no evidence of any impact of 1080 possum-control operations on populations of this species.

Tui — Low priority because only one dead tui has been found after 1080 possum-control operations and there is no evidence of any impact of 1080 possum-control operations on populations of this species.

Kokako — Low priority for this category B species because results to date indicate no impact on populations. However, if a population containing banded birds is subjected to an aerial 1080 possum-control operation then it should be monitored to determine individual survival.

Short-tailed bat — High priority for further research on this category A species at a variety of sites and habitat types because there is only one study underway.

Long-tailed bat — High priority for this category B species because the species' diet has not been quantified and there is no information on the impact of 1080 operations on populations of this species.

Lizards — High priority because the little research to date indicates that they may feed directly on baits, and there has been no monitoring of the impacts of 1080-poisoning on their populations.

Frogs — Low priority because results from the two studies to date indicate no impact on populations, and the restricted distribution of Leiopelma frogs (category B species) means that most populations are rarely exposed to aerial 1080 possum-control operations. However, if a population is subjected to an aerial 1080 possum-control operation then it should be monitored to determine individual and population impacts.

Invertebrates — High priority because although studies are underway to determine the impacts of aerial 1080 operations on litter invertebrates, there are many studies of individual species needed, such as on Powelliphanta snails and the life-stages of macro-fauna that live in the soil. Also, there is a high priority for research on the likelihood of invertebrates that have eaten baits or carcasses of poisoned animals causing secondary poisoning of insectivorous birds, bats, lizards and frogs, and potential flow-on effects along the food chain.

The highest priorities for further research were determined by ranking the high priority species above (from highest to lowest) according to whether they: (a) are frequently, occasionally or rarely exposed to 1080-poisoning operations, (b) are known or likely to eat 1080 carrot and/or cereal-based baits, (c) have been found dead after aerial 1080-poisoning operations, (d) have had 1080 detected in dead specimens, (e) are likely to die from secondary poisoning, and/or (f) have a high, medium or low risk of non-recovery from population decline (Table 2). Using these criteria, the highest priority species for further research are the kereru and kaka.

10. Discussion

The lack of standard, validated methods for monitoring wildlife species has hindered assessment of the impacts of 1080-poisoning for possum control on non-target populations. Initial measurements of bird populations using 5-minute counts (e.g., Spurr 1981, 1988, 1991, 1994a; Warren 1984; Calder & Deuss 1985; Miller & Anderson 1992; Pierce & Montgomery 1992; Fanning 1994) found no evidence of any population impacts from 1080-poisoning. However, 5-minute counts have not been adequately validated. Recent studies using individually marked birds have revealed some mortality (R.G. Powlesland unpubl. data), but the significance of this to the population has not yet been determined. There is an urgent need for research to validate methods for monitoring population numbers of all non-target species.

Most monitoring of the impacts of 1080-poisoning on non-target species to date has been short-term. It has generally been assumed that the benefits of 1080-poisoning outweigh the risks to non-target species (Spurr 1991). This assumption needs verifying. Research is needed urgently on determining the long-term impacts (whether costs or benefits) of 1080-poisoning for possum control on wildlife.

TABLE 2. APPROXIMATE ORDER OF PRIORITY FOR FURTHER RESEARCH ON THE EFFECTS OF 1080 POISONING FOR POSSUM CONTROL ON HIGH PRIORITY NON-TARGET SPECIES.

SPECIES	EXPOSED TO 1080	EAT BAITS	FOUND DEAD	1080 RESIDUES	RISK OF SECONDARY POISONING	RISK OF NON-RECOVERY
Kereru	frequently	yes	yes	yes	no	high
Kaka	frequently	yes	yes	yes	no?	high
Invertebrates	frequently	yes	yes	yes	yes	low?
Robin	frequently	yes	yes	yes	yes?	medium
Tomtit	frequently	yes	yes	yes	yes?	low
Rifleman	frequently	yes?	yes	yes	yes?	medium
Kea	occasionally	yes	yes	yes	yes?	high
Morepork	frequently	no	yes	yes	yes	medium
Lizards	frequently	yes	no	–	yes?	high
Weka	occasionally	yes	yes	yes	yes	medium
Kiwi	occasionally	yes	no	–	yes?	high
Whitehead	frequently	yes	yes	?	yes	medium
Fernbird	occasionally	yes?	no	–	yes	high
Yellowhead	rarely	no?	no	–	yes	high
Short-tailed bat	occasionally	no	no	–	yes?	high
Long-tailed bat	occasionally	no	no	–	yes?	high?
Falcon	occasionally	no	no	–	yes?	medium

Research is needed to investigate the impact of sowing the baits on bait quality. This includes determining to what extent the various bait types are fragmented by loading machinery, auger-fed sowing equipment, and impact with the forest. The development of protocols for such research are a high priority. Also, while some research has been (Caithness & Williams 1971, Harrison 1978b, McLennan *et al*. 1992, Spurr *et al*. 1995) and is being (L. Hartley pers. comm.) carried out to reduce the attractiveness and palatability of baits to non-target species, especially birds, further research is required.

In order to make best use of the limited resources, and ensure that non-target species research is initiated and comprehensively co-ordinated, a Research Co-ordinating Group should be established, comprising representatives from the Department of Conservation (Science & Research and Conservancies), Landcare Research, and Universities.

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