Appendix F: Monitoring Effects on Target and Non-Target Species Following 1080 Operations

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Key points

- Relatively high mortalities of individual birds have occurred in the past, in particular with poorly prepared carrot bait at high sowing rates. The significant improvements in carrot bait preparation and application technology (eg, uptake of use of global positioning systems (GPSs) and improved bucket design) and lower sowing rates for control of possums have reduced the numbers of birds killed. There may still be issues with preparation to achieve consistent toxic loadings (eg, on carrot bait).
- Ongoing investigations into improving pest control strategies over time, (eg, Morgan et al 2006) may assist in reducing the frequency of applications, but may also result in ‘double-sowing’ in the initial ‘knockdown’ phase.
- There is no evidence of significant adverse effects on populations of any non-target species as a direct result of exposure to 1080, with the exception of some historical cases where unscreened carrot was used at very high sowing rates.
- There are clearly benefits to many native fauna from the use of 1080 over large areas of forest in reducing predation pressure, and in reducing competition for food, particularly at times of high vulnerability (eg, nesting, raising young).

- The indirect effects of the reduction in pest numbers (possum, rodents, and mustelids) on predation and the various interactions between the populations of these species may present a direct short-term risk to some threatened species depending on the timing and level of control operations. This is an area of active research (Tompkins and Veltman 2006). A Foundation for Research Science and Technology–funded research programme is under way to provide greater understanding of multiple pest dynamics (Ruscoe et al 2006).
- There are benefits to ecosystems from removing browsing pressure by using 1080 over large areas that would otherwise be inaccessible.
- Practices on land managed by DoC may differ from those used by other agencies for pest management elsewhere, for example, the use of oats and screening of carrot. Use of unscreened carrot, in rabbit control operations appears to disregard effects on non-native birds and other species.
- Lack of a central data collection agency for information on the poisoning of livestock and companion animals means the summary information presented in this appendix is tentative in terms of scope and number of animals affected. Notwithstanding the limited information available, it appears that the deaths of these animals are largely avoidable.
- No alternative to 1080 as an acute toxicant is available for the control of rodent and stoat irruptions. 1080, as a broad-spectrum acute toxicant, appears to be an effective tool for multiple species pest control, achieving significant reductions through primary and secondary poisoning.
- The availability of cat pellets is listed on Animal Control Products's website as being restricted to DoC only. There is no HSNO control to this effect.

F1 Overview

The applicants provided very brief results from the monitoring of effects on non-target native species in Section 4.1D of the application and in the context case studies (pp 63–68 of the application). The Agency has reviewed the primary source documents cited in the application, and has accessed some additional information to clarify the context for the results reported in the application (eg, the type of bait used and sowing rates).

The summary monitoring information presented below includes potential adverse effects on non-target species; operational monitoring with respect to pest indices, and outcome monitoring for species being protected. Given the volume of material available, it has not been possible to comprehensively review every monitoring report. Furthermore, much of the monitoring data presumably exists within various contractual operational reports and is not available to the Agency. The extent of that information is unknown. The Agency assumes the information reviewed below is likely to be representative of current investigations, and in some cases demonstrates an improvement in practice over time.

The applicant did not specifically discuss effects on non-native species (other than target species) in the environmental effects register. Only a small number of reports note effects on introduced birds. The Agency has attempted to source some additional information, which is summarised in the sections below.

The implications of the monitoring information reviewed below in terms of overall risks from substances containing 1080 to populations of non-target species are addressed in Appendix N. In some cases, the focus of the monitoring is on assessing the benefits from removing browsing or predation pressure by the use of 1080 to control pests and will be drawn on in section 7.5.

F1.1 Methods for monitoring pests and non-target species

A very brief overview of the various methods of monitoring target and non-target species is presented below to provide additional background to information noted in the remainder of the monitoring section.

F1.1.1 Possums

A standard trap-catch protocol for assessing possum population densities both before and after 1080 operations or any other form of control (eg, trapping and cyanide) has been developed and updated by the National Possum Control Agency (NPCA 2005). The data obtained from the application of the trapping protocol is used to calculate the residual trap catch index (RTCI). The protocol is used to assess the number of possums caught over a given number of trap nights. The ratio between the pre- and post-operational indices gives an estimate of the percent kill or percent survival. The RTCI has been in wide use since 1997 (Green 2003a, 2003b) and is not directly comparable with earlier possum density monitoring methods. The Agency notes that the older monitoring reports did not always make explicit mention of the actual technique used and acknowledges that there may be some uncertainty in the way the information has been reflected in the summarised information presented. Older methods are not directly comparable with the current RTCI.

Observations have been made that the RTCI may not be accurate at low possum densities. Further investigation was undertaken by Forsyth et al (2005) on farmland and in forest. The authors concluded that the RTCI is non-linear at high possum densities, with a decreased probability of capture and can vary seasonally. The probability of capture on farmland was lower in spring compared with winter and summer on farmland and with forest during summer. There was no evidence of seasonal variation within forest habitat. As the index is approximately linear at low abundance, and the seasonal bias small, the authors concluded that the RTCI is currently the best tool available for monitoring management actions. Whenever possible, use of the RTCI for comparative purposes should be conducted in the same season.

Target RTCI for improvements in vegetation condition and reductions in predation are discussed in the relevant monitoring sections (see sections F2.1.3 and F2.5.1).

F1.1.2 Rodents and mustelids

Tracking tunnels are used to monitor the relative abundance of rodents and mustelids before and after a pest control operation (Hasler et al undated; Blackwell et al 2002). The animal walks through a small tunnel and over an inked surface leaving footprints on removable card or paper for later analysis. Tracking rates are expressed as the proportion of tunnels with tracks. A standard tracking method has been developed for use by DoC (Gillies and Williams 2003).

Kill trapping is an alternative method of monitoring.

F1.1.3 Rabbits

Night-counts can be used to estimate percent kill after a control operation, to provide population trend data and to establish whether a control threshold has been reached. The Modified Maclean Scale is used to establish whether a control threshold has been reached, and can be used for trend monitoring, but is not suitable for assessing percent kill shortly after an operation due to the residual rabbit sign (NPCA 2006). The Modified Maclean Scale is based on faecal pellet heap density and fresh rabbit sign, with a rating (1–8) assigned on the basis of number of heaps in a given area, with 1 being no rabbits or sign of rabbits and 8 being the greatest density of rabbits or signs.

F1.1.4 Birds

A variety of methods is used for monitoring bird populations before and after pest control operations including: five-minute bird counts; marking and re-locating individuals; and roll-calls of individual birds.

Five-minute counts have been identified as not reliable for assessing population impacts after 1080 operations unless high mortality occurs (Atkinson et al 1995) and not reliable for rarer species (Warren 1984). A species' conspicuousness can vary significantly during the year and from month to month (Powlesland et al 1998). Marking of individual birds and subsequent re-location after an operation has been identified as being more reliable. An investigation of transect based methods as alternatives to banding tomtits (Westbrooke et al 2003) concluded that counting of territorial males along a transect provided relatively high precision for monitoring short-term impacts. Distance sampling techniques were identified for further consideration for monitoring longer term effects. Both techniques were considerably less resource intensive than banding individuals. Distance sampling involves measuring the distance a bird is from a defined transect or point, and is suitable for species that are relatively common and not affected by the presence of observers such as bellbird, grey warbler and tomtits (Hamilton 2004).

Specific monitoring protocols have been developed for robins (*Petroica australis*) to assess individual mortality, nesting success, and the time taken for a population to recover from impact (Powlesland 1997).

F1.1.5 Terrestrial invertebrates

A variety of monitoring methods have been used to assess effects of 1080 operations on invertebrates including: the occupation of artificial refuges; the mark and recapture of larger bodied invertebrates; the use of pitfall traps and manual observations of invertebrates on and under baits.

Artificial refuges may be occupied by a wide range of invertebrate species, including weta. However, immature weta are less likely to be found (Spurr and Berben 2004). Mark–recapture techniques allow the monitoring of the fate of individual invertebrates, and overall responses of populations (Spurr and Berben 2004) but are applicable only to larger bodied invertebrates.

Pitfall traps can be used to monitor abundance and activity of invertebrates, but the taxa found on baits may not be caught in pitfall traps in sufficient numbers for an assessment of impacts at a species level (Spurr et al 2002; Sherley et al 1999).

Investigations into video-monitoring invertebrates on baits indicate that the method records lower numbers and diversity of invertebrates as it cannot detect the presence of invertebrates, which may be under the baits, but may be useful for observations of large-bodied species (Wakelin 2000).

F1.1.6 Vegetation

A standardised Foliar Browse Index (FBI) developed by Landcare (Payton et al 1999) and used by DoC since the late 1990s (Green 2003a, 2003b) is based on the assessment and reassessment of permanently marked individual plants to determine trends in foliage cover, dieback, possum browsed leaves, possum stem use and flowering and fruiting. While useful for most species, the FBI has proven to be inadequate for monitoring northern (*Metrosideros robusta*) and southern rata (*M. umbellata*), as has an alternative method called ‘Rata View’ (Green 2003a, 2003b).

F1.1.7 Aquatic invertebrates

Kick-sampling is used to dislodge invertebrates from the bottom of stream riffles, which are then captured in nets and identified and counted (TRC 1993, 1994). Standard protocols for sampling macro-invertebrates have been developed that allow for comparison across agencies (Stark 2001) and were used in sampling streams at Haupiri Forest (Suren and Lambert 2002).

F2 Monitoring for effects of 1080 on non-target species

F2.1 Birds

Deaths of individual birds have been reported frequently after pest control operations, but generally do not give any indication of potential effects at a population level (eg, Powlesland et al 2000). Systematic searches for dead birds are not common practice, with other monitoring methods used to assess potential impacts at a population level. Results of recent monitoring of bird populations during aerial 1080 operations available to the Agency are summarised in Table F1. The level of detail in the reports is highly variable, with more recent studies generally using more refined monitoring techniques for birds at higher risk (see Appendix N for further discussion on the risks to birds), for example, radio-tracking and mark and recapture. Impacts of predation or removal of predation pressure have been noted where this information was included in the study report. In many cases, the conclusions that can be drawn from the monitoring are limited by lack of replication and/or a lack of suitable control (untreated) blocks.

A discussion on the ability of a population to recover from an impact such as may occur as a result of a 1080 operation is included in Appendix N.

One carrot operation in particular was reported to have had a significant impact on tomtits in Cone State Forest in 1977, with the population taking three years to recover and the brown creeper one year to recover (Spurr 1981, cited in Powlesland et al 2000). The carrot bait used was unscreened and sown at 30 kg/ha. Several carrot drops in the central North Island in 1976–77 resulted in a large number of dead birds (large areas systematically searched), primarily introduced birds (Harrison 1978). In one case, where the carrot was unscreened and undyed, 222 dead birds were found (30 native); in a series of three trials to evaluate the utility of screening the bait, all at a sowing rate of 40 kg/ha, 177 dead birds were found (143 native). No analyses for 1080 residues were undertaken on any of the birds found.

Reductions in sowing rates from the very high levels used in the early 1970s and 1980s for possum control and improvements in bait quality (eg, the screening of carrot bait to remove chaff and use of green dye) along with adoption of improved sowing technologies and use of global positioning systems have assisted in reducing impacts on birds.

The adequate screening of carrot removes small pieces that carry a much higher toxic loading than the larger baits based on surface coating (ie, a high surface to volume ratio) and may be more attractive to small birds.

However, it is evident from the information reviewed by the Agency that carrot bait may not always be prepared reliably; for example, inaccurate toxic loading (Clapperton et al 2005; Spurr et al 2002; Sweetapple and Fraser 1997), poor dye coverage (Green 1998), and poor screening to remove chaff (Powlesland et al 1999; Green 1998). The Agency does not have sufficient information to determine how frequently these problems may occur and what impacts they may have in terms of achieving pest control or on non-target species.

Different types of carrot cutter produce different qualities of bait, that is, a greater or lesser proportion of fine pieces (Batcheler 1996). The Agency notes that there does not appear to be a consistent industry standard, although the Agency does not have sufficient information to fully assess the matter, having only been provided with the standard operating procedure for one contractor used by the Animal Health Board (AHB) (further information from the applicants, 22 December 2006). DoC best practice for carrot operations has specific requirements for cutting and screening (chaff, pieces less than 0.5 g to be less than 1.5% by weight); bait size (6 g or larger to ensure a single bait is lethal to a possum); toxic loading 0.15% 1080 (0.08% loading acceptable only when sowing at more than 5 kg/ha); green dye; double lure (cinnamon or orange at 0.3% rather than 0.15%).

The Agency notes that birds that feed on invertebrates may be affected by secondary poisoning (from consuming invertebrates containing 1080 residues) or primary poisoning (from direct ingestion of bait) or both. This is discussed further in Appendix N.

F2.1.1 Effects on game birds: rabbit control operations

The Agency is unaware of information on the effects of 1080 operations on game birds, particularly after rabbit control. The applicants provided further information on the use of carrot bait from the Otago Regional Council (further information from applicants, 22 December 2006) that indicates that this council does not screen carrot bait used for rabbit control. The sowing rates for rabbit control (10 to more than 40 kg/ha at 0.02% 1080) are much greater than that used for possum control, resulting in a significantly larger number of baits being available for ingestion by target and non-target species. The rationale given for not screening the bait is two-fold. Firstly, a large population of rabbits needs to be exposed to a large number of baits, and secondly, "native birds which could be deemed at risk, are not usually present in the type of country where rabbit control takes place". *Pest Rabbits: Monitoring and Control* (NPCA 2006, p 19) also has a similar statement.

Treated oats are also used for rabbit control and their use on land under DoC management is not allowed due to the high risks to non-target native species (further information from applicants, 22 December 2006).

F2.1.2 Birds vulnerable to secondary poisoning from feeding on animal carcasses

Moreporks, *Ninox novaeseelandiae*, are not known to eat vegetation, so the poisoning of these birds is most likely to be secondary from the consumption of poisoned rodents (Spurr and Powlesland 1997) and invertebrates (Lloyd and McQueen 2000). Dead birds have been reported following 1080 operations and the morepork has been flagged as a high priority for further research to determine longer term impacts, including from indirect effects due to loss of prey (Spurr and Powlesland 1997; Greene 1998).

Harrier hawks have been observed feeding on carcasses of poisoned possums (Spurr and Anderson 2004) and weka, while kea have been known to feed on poisoned thar (Douglas 1967).

Table F1: Monitoring for effects on birds from possum control operations using 1080 in New Zealand

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
Kereru/kukupa, *Hemiphaga novaeseelandiae*	Possum/ship rat Ground-based Three pre-feeds cereal bait 0.15% 1080 1 kg/bait station for one week, then replaced with brodifacoum for the next two years and cyanide Feratox in cholecalciferol paste for two years (Trapping for mustelids)	Motatau Forest, Northland (350 ha) October 1997–2001 Control (untreated 300 ha) Okaroro, Northland	**Birds** Five-minute bird counts and 30-minute display counts (abundance) Radio-transmitters (nesting success) **Pests** RTCI for possums Tracking tunnels for rats	Ship rat tracking declined to zero after 1080 operation and remained <4% until three months after final bait station fill with brodifacoum in Aug 1999. Rates increased with use of cyanide/cholecalciferol. RTCI dropped from 26% to 12% after the 1080 operation (initial knockdown), and subsequently stayed below 7%. Significant increase in five-minute counts: more than trebled compared with control site. Maximum number of display flights increased from 11 (August before pest control) to 33 in October 2000. All nests (13) failed due to predation before commencement of pest control (Sept 1996 – Oct 1997). Some ongoing predation managed by intensive trapping around nest trees after initial pest control started. In 1998–99 when possum and rat indices both low (<4%), all (seven) nests fledged young. An increase in ship rat numbers (tracking rate 34%) in 2000–01 resulted in rat predation of 11 out of 16 nests. Counts of chaffinches, eastern rosellas, mynas and tui also increased relative to control site. Counts of grey warblers, pheasants and silvereyes increased at the control site relative to the treated site. No significant difference in fantails, kingfisher, shining cuckoo or tomtit between treated and untreated blocks. No poison-related mortalities reported in any non-target species	Innes et al 2004

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
Kereru Kaka, *Nestor meridionalis*	Possum (secondary: rats) Aerial 5 kg/ha pre-feed 10 kg/ha screened carrot at 0.08% (6–8 g baits), chaff <0.2%	Whirinaki Forest Park (2250 ha treated Otupaka; 3,000 ha control untreated Oriuwaka) May 2000	**Birds** Re-location of birds Banding before operation and radio-transmitters attached to all kereru, female kaka and some male kaka. Male kaka not radio-tagged were marked with coloured leg-flags **Pests** RTCI for possums Tracking tunnels for rats and mustelids	RCTI dropped from 27–33% pre-operation to 4.4% post operation (June 2000) rising to 9.5% in February 2002. In the non-treatment area, RCTI dropped from 30.8% in February 2001 to 11.5% in February 2002, with no significant differences between treatment and control by Feb 2002. Decline in control block due to possum poisoning and trapping for fur by people not involved in the study. Tunnel tracking for rats declined from 43% to 5% in the treatment area immediately after the operation and remained at $\leq$11% for the next 21 months then increased to 32% by May 2002 (no significant difference from control area at May 2002) Mustelid indices were low (<10%) for both treatment and control and did not differ significantly during the study. **1080-related mortality of kaka and kereru** None of the radio-tagged kaka died in either the treatment or control area in the two weeks following the operation. All radio-tagged kereru survived in the treatment area, one died in the control area, cause not stated. **Nesting success** Kaka and kereru nesting is linked with mast fruiting in podocarps, which is inherently variable. There was ongoing predation of both kaka and kereru nests (egg, nestlings, fledglings and one incubating female kaka). The RCTI achieved (4.4%) was below that recommended for protection of kokako, and close to that recommended for protection of kereru. The authors commented that the treatment area may have been too small to realise significant gains from the 1080 operation.	Powlesland et al 2003

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
Kaka	Possum Aerial 0.08% carrot at 15 kg/ha	Waihaha, Pureora Forest August 1994	**Birds** 21 radio-tagged birds (18♂)	Contact with one bird lost before the 1080 operation; all other birds successfully monitored after the operation Issues with preparation of carrot bait included poor uptake of dye in some batches; and adjustment screen to reduce number of small particles passing through Dead birds noted included four kereru, two blackbirds, four riflemen, one grey warbler and seven tomtits, but no analysis for 1080 residues. Snow fell soon after the poison drop and may have contributed to the deaths of the smaller birds.	Greene 1998
Kea, *Nestor notabilis*	Thar Aerial 0.17% unscreened carrot bait; green dyed	Dobson Valley, Sept/Oct 1964		Four dead kea found; two analysed for 1080 residues one positive the other 'doubtful' (also eight dead gulls *Larus dominicanus*, one analysed for 1080 and found positive) One kea observed feeding on toxic carrot; kea may also have fed on poisoned thar carcasses (one thar observed with viscera removed)	Douglas 1967
	0.08% screened carrot at 20 kg/ha (1983) 0.2% screened carrot at 20 kg/ha (1986)	Westland National Park Two operations 1983 and 1986	**Birds** Five-minute call counts	Counts similar before and after both operations	Spurr 1994
Tomtit, *Petroica macrocephala toitoi*	Possum Aerial One pre-feed 12 g cereal baits 0.15% 1080 at 3 kg/ha Nine nights without rain after the drop	Tongariro Forest (~20,000 ha) September 2001	**Birds** Banding of 15 male tomtits in treatment and control areas Distance sampling (population density) Territorial male counts **Pests** RTCI for possums	RTCI 5% pre-operation; 0.1% post-operation Sighting of banded birds 14/15 in treatment area; 15/15 in control area Distance sampling 3% reduction in average density: not significantly different from the control area Territorial male counts, no significant differences	Westbrooke et al 2003

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
	Possum/rats Aerial Carrot (1997) one pre-feed 0.08% 1080 at 10 kg/ha (bait checked and contained <0.2% chaff) 9.5 mm rain 3–4 days after drop, 100 mm within a month Cereal (1998) no pre-feed 0.08% Wanganui No 7 cereal bait at 5 kg/ha	Pureora Forest, August 1997 (Waimanoa study area 8577 ha) and 1998 (Long Ridge study area 200 ha) (non-treatment control block – Tahae (100 ha) in both 1997 and 1998 Tahae had been treated in 1996)	Each study area comprised ~300 ha within a larger block, but only ~100 ha of each was regularly searched for tomtits **Birds** Banded after being accustomed to hand-feeding with mealworms. Monitored every day or second day for a fortnight after poison drop Nests visited by following banded males Analysis of dead birds for 1080 residues in muscle **Pests** RTCI for possums Tracking tunnels for rats	**1997 carrot** Banded tomtits seen 14 before, 3 after (3 before and after in control block) RTCI 23.7% before operation; 0.2% after operation Tunnel tracks 44% before; 0% in Sept/Oct 1997, rising to 7% by Feb 1998, late in the nesting season No dead banded tomtits found, three dead un-banded tomtits found. Concentrations of 1080 in muscle tissue of each bird were 1.9, 1.5 and 1.3 mg/kg. No bait fragments found in dead birds, but tomtits known to regurgitate pellets of indigestible food and may do the same with toxic food. Four of five nests in the treatment area were successful (one failed due to predation) compared with four of six nests in the control block (one failed due to predation., the other for unknown reasons); the difference in nesting success between blocks was not significantly different One year after operation: fewer tomtits seen in treatment block compared to before the operation but only a small proportion of the population banded making assessment more difficult. The following season, pairs reared two and sometimes three broods in a season (mean four chicks/brood) indicating a high likelihood of population recovery. **1998 cereal** Banded tomtits seen 14 before and after (16 before and after in control block) RTCI 9.7% before operation; 2.5% after operation Tunnel tracks 46% before; 9% after	Powlesland et al 2000

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
	Possum Aerial 2 kg/ha carrot at 0.15% 1080	Hampden, Otago (6500 ha) July 2002 Non-treated control at Moeraki	**Birds** Distance sampling: once pre-operation, and three times post-operation (summer and winter 2003; summer 2004)	No adverse effect on population density after the operation; increased tomtit density after first breeding season but declined in the later survey periods to below the pre-operation levels. A severe winter in 2003 followed by a wet and windy summer may have contributed. Significant damage occurred to plantation forest at the treatment site during the storm and was followed by harvesting, which may also have affected the bird surveys by reducing habitat and creating significant noise. At control site, tomtit density decreased after the first monitored season and continued to decline. No dead birds found during monitoring, though apparently deer stalkers in the area had made claims to the contrary.	Hamilton 2004
	Possum Aerial unscreened carrot 0.06% at 30 kg/ha	Cone State Forest, Southland 1977	**Birds** Five-minute counts	High mortality, three years for population to recover	Spurr 1981 cited in Powlesland et al 2000
	Possum Aerial 3 kg/ha pre-feed 3 kg/ha carrot at 0.08% 1080	Kokomoka Forest May 2003	**Birds** Counting of territorial males on transects within a month of the operation **Pests** RTCI for possums	Significant differences in tomtit counts between cereal and carrot operations (as also seen in the Tongariro 2001 result above). Decreases in male tomtit numbers after operations with carrot, point estimates were 47% at Kokomoka, 20% at Mohaka, 15% at Waimanoa Small increases in average counts after operations with cereal baits; point estimates were 10% at Pureora (3% Tongariro based on re-analysis of data)	Westbrooke and Powlesland 2005
	Possum Aerial 5 kg/ha pre-feed 5 kg/ha carrot at 0.08% 1080	Mohaka forest May 2003			

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
	Possum Aerial 3 kg/ha pre-feed 3 kg/ha carrot at 0.08% 1080	Pureora Forest (Waimanoa) 2003			
	Possum Aerial 2 kg/ha pre-feed 2 kg/ha cereal bait at 0.08% 1080	Pureora Forest (Mt Pureora) 2003			
Robin, *Petroica australis longipes*)	Possum Aerial 7 kg/ha pre-feed 15 kg/ha screened carrot at 0.08% 1080 Operation in two stages: first stage wastage from carrot screening was 23% by weight compared to 9.9% by weight for the second stage, suggesting a higher proportion of chaff was not removed but was distributed with the bait	Pureora Forest September 1996 Tahae (control block Waimanoa)	**Birds** Territory mapping of banded and unbanded birds Monitoring of banded birds which would approach for food **Pests** RTCI possums Tunnel tracking rats	Twelve of 28 robins disappeared from the treatment area after the operation (32/32 were observed the control block) based on territory mapping. Of the birds that disappeared, most did so within three days of the operation Three banded birds were found dead and contained 1080 residues 0.37, 0.83, and 3.8 mg/kg muscle. Autopsy of one the most recently dead bird revealed an empty alimentary tract from the beak to the gizzard; invertebrate fragments were found in the gizzard. Robins are known to regurgitate pellets of indigestible food and have been observed to regurgitate mealworms coated in cinnamon oil Twelve of 22 robins disappeared from the treatment area based on monitoring of banded birds seeking food (24/24 were seen in the control area) *Nesting success in the 1996/97 breeding season* Four of 35 nests fledged chicks in the control block (mean 0.4 chicks/pair); four adult females lost to predation; 13/18 nests fledged chicks in the treatment block (mean 3.7 chicks/pair) One year after the operation: Control block: 33 birds compared with 32 pre-treatment	Powlesland et al 1999

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
				Treatment block: 36 birds compared with 16 post-operation and 28 pre-operation indicating recovery from impact **Possums** Treatment block pre-operation October 1995 RTCI 6.2%; none post operation Control block RTCI 8.9% in October 1995; 14% in October 1996 **Rats** Sept 1996 – February 1997 (robin breeding season) 89–95% reduction in treatment area compared with essentially no change in the control block (~60% of tunnels with prints)	
	Possum Aerial 5 kg/ha pre-feed 10 kg/ha screened carrot at 0.08% 1080 (<0.2% chaff)	Pureora Forest October 1997 Waimanoa (Control block – the above Tahae area treated in 1996)		Three of 35 birds disappeared based on territory mapping in the treatment area compared with one in 49 in the control Three of 31 banded birds disappeared in the treatment block based on monitoring of birds seeking food (one in 42 disappeared in the control block) Nesting success in 1997/98 season: Control block: 23 pairs monitored 20/67 nests fledged chicks (mean 1.5/pair); seven adults disappeared Treatment block: 10 pairs monitored 20/30 nests fledged chicks (mean 3.8 /pair) 2 adults lost Numbers in June 1998 Treatment block: 46 birds compared with 32 post-operation and 35 pre-operation Control block: 65 birds compared with 49 Aug 1997, 48 October 1997 **Possums** Treatment block pre-operation RTCI 23.7.%; 0.8 post operation	

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
				Rats Treatment block: pre-operation 44% tunnels tracked Control block: 58% tunnels tracked	
Rifleman, *Acanthisitta chloris*	Aerial 0.08% screened carrot at 15 kg/ha	Waihaha, Pureora Forest, August 1994.		Five birds found dead after the operation, all contained 1080 residues. Stomachs were empty so it wasn't possible to determine primary or secondary poisoning.	P. Sweetapple *personal communication* In Spurr and Powlesland 1997.
	13 aerial operations Nine screened carrot, Two Wanganui No 7 cereal bait Two Mapua cereal bait		**Birds** Five-minute counts	Overall, no measurable impact on numbers of birds 2–8 weeks after the operations	Spurr 1991. In Spurr and Powlesland 1997.
Fernbird, *Bowdleria punctata*	Possum Aerial 0.08% Wanganui No 7 cereal bait (8 g) dyed green + cinnamon lure at 5 kg/ha	Waipoua Forest Spring 1990	**Birds** Visual sighting both and after operation of 14 birds, and two birds of these banded.	All birds re-located five weeks after operation.	Pierce and Montgomery 1992,
	Aerial 0.15% RS5 cereal bait at 5 kg/ha	Gouland Downs, North-West Nelson August 1994	**Birds** Nine birds banded before the operation. No roll call taken immediately before the operation.	Five birds re-located in the two weeks after the operation. The fate of the missing birds was unknown.	Walker 1997
Whitehead, *Mohoua albicilla*	18 aerial operations 11 screened carrot, 5 Wanganui No 7 cereal bait 2 Mapua cereal bait		**Birds** 5-minute counts	No detectable impacts on the numbers of birds 2–8 weeks after the operations.	Spurr 1991

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
				Whiteheads still occasionally found dead after 1080 operations even with improvements in preparation of bait (screening to remove chaff and addition of cinnamon) though none had been tested for 1080 residues.	Spurr 1994a
Brown creeper, *Mouhoua novaeseelandiae*	0.06% unscreened carrot at 30 kg/ha	Cone State Forest, Southland Sept 1977	**Birds** Five-minute counts	60% decline in bird counts after the operation, returning to pre-operational levels one year later.	Spurr 1981
	0.08% screened carrot at 20 kg/ha (1983) 0.2% screened carrot at 20 kg/ha (1986)	Westland National Park Two operations 1983 and 1986	**Birds** Five-minute counts	Counts were similar one year before and one year after each of the two operations	Spurr 1994
Yellowhead, *Mouhoua ochrocephala*	Possum Aerial 0.15% RS5 cereal 3 kg/ha, dyed green, cinnamon lured; no pre-feed	Catlins State Forest Winter 1999	Birds 30-minute search (presence absence) in 1 km grid squares and five-minute counts in each grid square	Monitoring occurred yearly over the five-year period October 1998 – November 2002 No significant changes in mohua presence immediately after the 1080 operation. Author noted deficiencies in the sampling after the operation compared to that before Significant decline in 2001 following irruption of predators after a beech mast year	Ross 2006
Grey warbler, *Gerygone igata* Fantail, *Rhipidura fuliginosa* Silvereye, *Zosterops lateralis*	20 aerial operations 13 screened carrot, 5 Wanganui No 7 cereal bait 2 Mapua cereal bait			No detectable impacts on the numbers of birds 2–8 weeks after the operations.	Spurr 1991a
				Silvereyes, fantails and grey warblers have been found dead after 1080 carrot operations; but no analyses undertaken for 1080 residues	Harrison 1978; Spurr 1991
Bellbird, *Anthornis melanura*	'Jam' bait			One bird found dead	Spurr 1994

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
Tui, *Prosthemadera novaeseelandiae*	Possum Aerial 0.15% screened carrot at 15 kg/ha	Kapiti Island 1984		One dead bird found	Sherley 1992 (cited in application)
Kakariki, *Cyanoramphus novaezelandiae* and *C. auriceps*	Two with screened carrot Two with Mapua cereal bait		**Birds** Five-minute call counts	No detectable impact on number of counts	Spurr 1991a
				None found dead after 1080 operations but have been found dead after use of brodifacoum (Talon 20P) cereal baits.	Spurr and Powlesland 1997
North Island brown kiwi, *Apteryx australis*	Possum Aerial 0.08% Wanganui No 7 cereal bait (8 g) dyed green + cinnamon lure at 5 kg/ha	Waipoua Forest Spring 1990	**Birds** Seven radio-tagged and re-located at 10-day intervals after 1080 operation for three months. Two transmitters fell off soon after operation; and additional male found: Six = total number monitored Larger sample monitored by call counts.	Three of four radio-tagged pairs were found nesting during the poisoning period, all three nests failed; two nests eggs disappeared; one abandoned; one infertile. One pair renested. Call counts lower immediately before poisoning operation; and high after (about three times higher than in control block)	Pierce and Montgomery 1992

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
	Possum Hand broadcast 0.08% Wanganui No 7 cereal bait (8 g) at 3 kg/ha Ground 'Jam' paste baits'0.08% Both green-dyed and cinnamon lured	Rarewarewa, Northland May 1995 Hand-baiting over 33 ha; paste baits over 14 ha	**Birds** 35 radio-tagged (22 in area with cereal bait; 13 in area with paste baits)	All radio-tagged kiwi survived for at least three months after 1080 operation; one radio-tagged juvenile was found dead (killed by a predator) about 2.5 months after baiting Bodyweights of adult birds in the treatment areas were no different to those outside the treatment (to test the theory that kiwi may starve due to impacts of 1080 on invertebrates) Six abandoned eggs were tested for 1080 residues and were negative Thirty-three radio-tagged birds known to have survived one year after the operation.	Robertson et al 1999
	Possum Aerial 0.08% screened carrot at 10 kg/ha	Tongariro Forest, June 1995	**Birds** Two radio-tagged adult	Both kiwi survived for at least six months after the operation	C. Speedy, *personal communication* in Spurr and Powlesland 1997.
Little spotted kiwi, *Apteryx owenii*	Aerial 0.15% screened carrot, 15 kg/ha	Kapiti Island August 1984	Not monitored	Only known exposure of this species to 1080. In operations using cereal baits containing brodifacoum (eg, Talon), on Kapiti, at least one radio-tagged bird died from the poison, indicating potential vulnerability to cereal-based poisons	Spurr and Powlesland 1997.
Great spotted kiwi	Possum Aerial 0.15% RS5 cereal bait at 5 kg/ha	Gouland Downs, Nelson August 1994	**Birds** Nine radio-tagged adult	One radio-tag dropped off; other eight birds survived at least 6.5 weeks after the operation; five survived at least five months.	Walker 1997
	Possum Aerial 0.15% Wanganui No 7 at 5 kg/ha	Karamea, Westland December 1994	**Birds** Seven radio-tagged adult	All birds survived at least two months.	C Miller *personal communication* in Fraser et al 1995

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
North Island kokako	Possum Aerial 0.08% Wanganui No 7 cereal bait (8 g) dyed green + cinnamon lure at 5 kg/ha	Waipoua Forest spring 1990	**Birds** Territory mapping and roll calls before and after operation. Six pairs monitored before and after operation; one pair seen only once before and their territory only partially overlapped with treatment area	Five of six pairs re-located with both birds in each pair seen. An additional three single birds sighted. One pair not re-located, may have been using other part of its territory; been breeding, so less visible; died from poisoning or other causes; may have been a double-count of one of the other pairs.	Pierce and Montgomery 1992
	Possum/ship rat Aerial 0.08%cereal (assumed) at 8 kg/ha; dyed green; cinnamon lured Ground control 1080 or brodifacoum in bait stations	Mapara (1400 ha) annual treatment 1990–1993 (followed by ground control in subsequent years 1993–1997)	**Birds** Chick output based on % of monitored pairs which fledged young each season and % of nesting attempts which succeeded Number of pairs monitored per season 7–15 at Kaharoa 15–32 at Mapara 10–20 at Rotoehu Adult abundance measured as no. present at 1 November (start of breeding season) in census blocks Causes of nesting failures nests visited weekly **Possums** Pre-RTCI trap catch method **Rats** Tracking tunnels **Mustelids**	**Birds** Significantly more monitored pairs fledged chicks in managed blocks and years (mean 42% n=14) than unmanaged blocks and years (mean 13% n=8) Most pairs in unmanaged blocks failed to fledge young. At Rotoehu, proportion of successful pairs increased over time from 17% to 54% following pest control. At Kaharoa, proportion of successful pairs declined from 48% to 10% when pest control stopped (though not statistically significant) Overall, mean rat and possum indices were negatively correlated with chick output. At Mapara, the proportion of pairs which did not attempt to breed was estimated at 75% at the start of management in 1989/90, and decreased to 56% in 1991/91 and 8% in 1996/97, attributed to male-male pairs in early stages of monitoring, with banded males pairing off with newly fledged females. Similar observations were made at Rotoehu The number of young that fledged increased at all managed sites as did the number of adults at 1 November each year. Fledgling recruitment and survival were high. Predation was confirmed as the primary cause of most nest failures at the three sites.	Innes et al 1999
	Possum/ship rat Aerial 0.18% cereal (assumed) at 8 kg/ha; dyed green; cinnamon lured (toxic loading may be a typo in paper, should probably be 0.15% or 0.08% nominal loading) Ground control cyanide; brodifacoum in bait stations	Rotoehu (440–800 ha) 1994/95 followed by ground control annually 1995–1997			

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
	Possum/ship rat Aerial 0.15% cereal (assumed) at 8 kg/ha; dyed green; cinnamon lured Ground control Trapping and cyanide for possums; aerial 0.005% pindone at 10 kg/ha for rats	Kaharoa (380 ha) 1990/91 and 1992/93 (ground control in 1991/92)	Trapping **Feral cats** Incidental sightings	**Rats** Tracking indices during Oct-Feb significantly higher in unmanaged years and blocks mean 54%. In 10 of 14 operations (all treatments combined) first post-poison assessment was <4% tracking Repeated use of brodifacoum resulted in smaller, but not significantly different, tracking indices than 1080 applied once aerially. Rat populations generally recovered within 3–5 months of poisoning, independent of toxicant used. **Possums** Trap-catch mean 39/100 trap nights significantly higher in unmanaged blocks and years compared with 7/100 in managed blocks and years As for rats, repeated use of brodifacoum in bait stations resulted in smaller numbers of possums caught (mean 1 n=5) than in single aerial 1080 applications (mean 14 n=5). One 1080 operation at Rotoehu failed and killed virtually no possums; reasons unknown. Possum populations took 3–4 years to recover at Kaharoa	
Pukeko, *Porphyrio porphyrio*	Rabbits			Ancedotal reports of dead pukeko after rabbit control operations	Batcheler 1978
Whio, *Hymenolaimus malacorhychos*	Possum Aerial 0.15% RS5 cereal bait 6 kg/ha	Otira Valley	**Birds** Visual counts	No reduction in counts. Blue duck known to be vulnerable to prey switching by mustelids and cats after large reductions in rodent numbers after 1080 application. Considered unlikely to eat either cereal or carrot bait as they are invertebrate feeders.	C. Miller *personal communication* in Spurr and Powlesland 1997;

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
	Possum Aerial 0.08% carrot at 15 kg/ha	Waihaha, Pureora Forest August 1994	**Birds** 19 radio-tagged adults	All survived for at least four weeks after the operation	Greene 1995
Brown teal, *Anas aucklandica*				Not known to have been present during any 1080 operation but have been poisoned during an aerial application of brodifacoum (Talon 20P) cereal pellets on Tiritiri Matangi Island during a kiore eradication operation so would be vulnerable to poisoning by cereal baits. Unknown whether brown teal would eat carrot bait.	Spurr and Powlesland 1997
'Common' native forest birds fantail Grey warbler Kukupa/kereru Silvereye Tomtit Tui	Possum Aerial 0.08% Wanganui No 7 cereal bait (8 g) dyed green + cinnamon lure at 5 kg/ha	Waipoua Forest September 1990	**Birds** Five-minute call counts over 10 days, before (June 1990) and after the operation (Oct/Nov 1990) Call counts taken on two transects in operational block and one control; results are percent change in conspicuousness.	Fantail: significant decrease on all transects, but less so in the operational area compared with the control. Grey warbler: significant increase Kukupa: no significant differences Silvereye: significant decrease on all transects, but less so in the operational area compared with the control. Tomtit: significant decrease in the operational area compared with control for one transect but not the other; Tui: significant increase on all transects; greater in the operational area than control Before/after differences in call counts may reflect changes in food availability with time, and potentially shifts in preferred habitat with season No mention of dead birds in the report.	Pierce and Montgomery 1992

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
'Common' introduced forest birds Eastern rosella Myna Blackbird	Possum Aerial 0.08% Wanganui No 7 cereal bait (8g) dyed green + cinnamon lure; at 5 kg/ha	Waipoua Forest September 1990	**Birds** Five-minute call counts over 10 days, before (June 1990) and after the operation (Oct/Nov 1990) Call counts taken on two transects in operational block and one control; results are percent change in conspicuousness.	Eastern rosella: increased in all areas Myna: increased in all areas Blackbird: conspicuousness increased in the control block, but not the operational area. Trial prior to operation indicated birds had eaten non-toxic baits and also pecked at toxic baits. Before/after differences in call counts may reflect changes in food availability with time, and potentially shifts in preferred habitat with season. No mention of dead birds in the report.	Pierce and Montgomery 1992;
Introduced and native birds	Possum Carrot (assumed to be unscreened and undyed, although not clearly stated)	'Indigenous forest near Turangi' 1976	Search for dead birds	Number of dead birds found: no analyses for residues blackbird 26; song thrush 1; dunnock 2; chaffinch 3	Harrison 1978
	Possum Unscreened carrot	Exotic plantation, Karioi State Forest 1976	827 ha searched for dead birds	Number of dead birds found: no analyses for residues blackbird 36; chaffinch 66; robin 14; tomtit 7; whitehead 18; song thrush 5; rifleman 5; dunnock 5; goldfinch 1; yellowhammer 1	
	Possum Unscreened carrot, undyed, raspberry lure	Exotic plantation, Karioi State Forest 1977	723 ha searched for dead birds	Number of dead birds found: no analyses for residues blackbird 50; chaffinch 126; song thrush 8; dunnock 6; redpoll 2; rifleman 2; grey warbler 1; silvereye 11; tomtit 10; robin 6	

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
	Three trial blocks sown at 40 kg/ha 0.08%1080 dyed green One block unscreened carrot One block 16 mm screened carrot One block carrot which didn't fit through screen	*Pinus radiata* plantation Kaingaroa State Forest 1977	87 ha of each block searched for dead birds.	Numbers of dead birds reported for whole trial: no analyses for residues rifleman 8; grey warbler 1; silvereye 12; whitehead 80; tomtit 43; robin 10 blackbird 11; chaffinch 12 12 days after the operation total numbers of dead birds recovered from each block (read from graph) ~35 with carrot >16 mm ~55 with unscreened carrot ~85 with carrot <16 mm	
New Zealand falcon, *Falco novaeseelandiae*	Possum Aerial 0.15% Mapua cereal bait at 7 kg/ha	Motere, Pureora Forest Park June 1984	Visual observation; no studies with radio-tagged birds	A single territory was monitored during and after the operation and remained occupied	Spurr and Powlesland 1997
	Possum Aerial 0.08% Wanganui No 7 cereal bait at 8 kg/ha	Mapara Wildlife Management Reserve Three operations Sept 1990; Oct 1991; Oct1992		Two of three territories were occupied throughout the period of the three operations; none was unoccupied after completion of all operations	I Flux *personal coomunication* Spurr and Powlesland 1997
	Possum Aerial 0.08% screened carrot at 15 kg/ha	Waihaha, Pureora Froest Park August 1994		At least three territories remained occupied.	T Greene *personal coomunication.* Spurr and Powlesland 1997

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
Australasian harrier, *Circus approximans*	Possums, brushtailed rock wallaby (*Petrogale penicillata*) Aerial 0.08% Wanganui No 7 cereal bait at 12 kg/ha	Rangitoto Island October 1990	**Birds** Visual observation Call counts in 1998 and 1999	Harriers observed feeding on poisoned possums and wallabies but none found dead. Five-minute counts in 1998 and 1999 indicated similar results to those pre-operation in 1990. Eighteen other species monitored: Silvereye and tui: counts significantly higher in 1998/99; all other species similar to the pre-poisoning observations in 1990. Increases attributed to a heavy pohutukawa flowering in 1999. Continued presence of predators (rats, mice, cats, stoats) likely to be a factor in ongoing predation and less than expected bird population recoveries along with changes in vegetation from removal of possums and wallabies.	Spurr and Anderson 2004
	Rabbits			Anecdotal reports of dead hawks from rabbit poisoning operations	Batcheler 1978
Ruru/morepork, *Ninox novaeseelandiae*	Possum Aerial 0.08% Wanganui No 7 cereal bait (8 g) dyed green + cinnamon lure at 5 kg/ha	Waipoua Forest Spring 1990	**Birds** Ten-minute call counts	Number of birds detected doubled after the operation, and declined in the control block. The latter was potentially attributed to a less experienced person counting. No longer term assessment of reduction in prey (rodents) on feeding behaviour Rodents numbers reported as 'low' after poisoning	Pierce and Montgomery 1992
	Aerial 0.08% carrot 15 kg/ha, partially screened	Pureora Forest September 1996	**Birds** Six radio-tagged	One found dead and tested positive for 1080	Powlesland et al 1998
	0.08% screened carrot at 15 kg/ha	Rangitoto Range, May/June 1996		One dead bird found; 1080 residues	M.Frank *pers comm.*. in Spurr and Powlesland 1997

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
	Aerial 0.15% RS5 cereal bait (6 g) at 5 kg/ha	Nelson and Marlborough 1994 two operations	**Birds** Seven radio-tagged,	All re-located five days after the operation; one transmitter fell off, the other six birds were re-located again one month after the operation	Walker 1997
	Aerial 0.08% Wanganui No 7 at 5 kg/ha	Mangamingi Ecological Area, Tongariro-Taupo Conservancy, September 1995		Two dead birds handed in, a further six reported dead. One bird carcass tested positive for 1080 residues.	C. Speedy *personal communication* in Spurr and Powlesland 1997
Weka, *Gallirallus australis*	Aerial 0.2% screened carrot at 20 kg/ha	Copland Valley, Westland National Park 1986	**Birds** Five-minute call counts	No measurable effects on call counts; insufficient number of weka present in the counts to assess potential impact of 1080	Spurr 1988
	Aerial 0.15% RS5 cereal bait at 5 kg/ha	Two locations Gouland Downs, North-West Nelson and Tennyson Inlet, Marlborough Sounds August 1994	**Birds** 24 radio-tagged adults	One radio-tagged bird found dead and 1080 poisoning confirmed. Remaining birds all survived for at least 4 weeks. One non-radio-tagged bird found sick, droppings contained 1080 but bird recovered.	Walker 1997
	Aerial 0.15% Wanganui No 7 cereal bait at 5 kg/ha	Rotomanu, West Coast 1994	**Birds** Eight radio-tagged adults	All eight birds survived	C Miller *personal communication* In Spurr and Powlesland 1997

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated) date of application	Monitoring method	Monitoring results	Reference
	Aerial 0.15% cereal bait at 3 kg/ha	Copland and Karangarua valleys, South Westland June 2000	**Birds** Fifteen radio-tagged adults	No baits distributed above sub-alpine scrub line; within 50 m of waterways or within 20 m of Copland track; within 100m of Welcome Flat and Douglas Rock Huts: traps used. Fifteen weka captured in December 1999, banded and radio-tagged; checked monthly until two months after the operation. Checked daily during the operation and immediately after. Five birds found dead prior to the operation: four known or probable stoat predation; one unknown Of the 10 survivors, two birds had a lower likelihood of exposure (mostly observed in the buffer zones immediately after the operation). In July and August 2000, all 10 birds were alive and five were recaptured for removal of bands and transmitters. In Sept 2000 three of the remaining five birds were recaptured; one located but not caught; one found dead (predation) and one not re-located. Note: Western weka listed as being in serious decline	van Klink and Tansell 2003

F2.1.3 Effects of 1080 operations on predation: benefits of control

The Agency notes that there are indications that rat tracking indices and possum RTCIs need to be below 5% to enable successful breeding of kereru and intensive possum and other predator management is needed to protect breeding kaka, preferably over large areas to minimise rapid immigration of pest species from adjacent blocks (Powlesland et al 2003). A target 1% RTCI for possums and 1% tracking frequency for ship rats at 1 November (peak breeding period for kokako is October onwards) have been established for kokako recovery; 5% for either is acceptable, but more than 5% represents a failure in terms of achieving the protection goal (Flux and Innes 2001).

Summary information on the vulnerability of key bird species to predation is in Table F2.

The robin is considered a useful indicator of predation impacts in relation to other birds that may be more difficult to observe, as robins can readily be trained to approach observers and are easily captured, marked and re-sighted (Powlesland 1997). Robin nests are as prone to predation as those of other forest passerines (Moors 1983, cited in Powlesland 1997).

In homogenous beech forest at Rotoiti, most fledgling kaka dispersed out of the managed area of 825 ha and juvenile dispersal from the Eglinton Valley suggests that 13,000 ha may not be a big enough management area in heterogenous beech forest where birds have to travel long distances to find food (Moorhouse et al 2003). The suggested minimum area for management in homogeneous beech has been simulated at 1,600 ha (Elliott et al *in prep*, cited in Moorhouse et al 2003).

To protect kereru from predation, large management areas are likely to be required; with Powlesland et al (2003) suggesting that the 2,250 ha treated with 1080 at Whirinaki Forest may have been too small to provide adequate protection.

The Agency notes that multiple species pest control over large areas, timed to coincide with the most vulnerable life-stages of threatened native species, may be required to provide protection from predation. Controlling any one pest species is likely to be inadequate. As noted elsewhere (section 7.6), there is significant ongoing research into multi-species pest management.

Table F2: Vulnerability of key New Zealand birds to predation

Species	Key predators	Vulnerable life stages	Monitoring outcomes
Kaka	Stoats and ferrets (possums and rats secondary)	Females incubate eggs and broods nestlings (Moorhouse et al 2003)	Monitoring of three sites with predator control (ground-based 1080, brodifacoum, trapping) and three without demonstrated significant impacts of predation on nesting success and adult female mortality. Pulsed control may be effective where predator numbers can be forecast (Moorhouse et al 2003) Highly skewed sex ratio adult male : female (3 : 1 at Waihaha; in 1994) attributed to predation (Greene and Fraser 1998)
Mohua	Stoats, (linked with mast seeding years and mouse irruptions)	Eggs/nestlings/incubating females (late breeding period coincides with nursing stoats with high food requirements and young stoats leaving dens) (Elliott 1996a)	*Eglinton Valley* 1990/91 high stoat numbers resulted in predation of 67% of nests and 50% of nesting adult females. When stoat numbers high the productivity and mortality of even the double-brooded birds were significantly reduced. (Elliott 1996b) *Catlins Forest* Declines in numbers noted in relation to stoat irruption in beech mast year (Ross 2006)*
Kereru	Ship rats, stoats, possums	Eggs/nestlings/(adults to a lesser extent)	*Pelorus Bridge* Thirty of 45 nests failed at egg stage and five at chick stage; six adult birds killed by stoats *Mohi Bush* Seven of 9 nests failed at egg stage and two at chick stage *Wenderholm* Twenty of 20 nests failed at egg stage (Clout et al 1995) *Whirinaki Forest* Ongoing predation noted after 1080 operation which achieved RTCI of 4.4% and rodent tracking index of 5% immediately after the operation; treatment area of 2250 ha may have been too small to be effective in reducing predation (Powlesland et al 2003)* *Motatua Forest, Northland* Monitoring of nests before and after four years' sustained ground control improved nesting for at least one season, including intensive trapping around nest trees (Innes et al 2004)*
Orange-fronted kakariki	Stoats, rats	Species only known to occur in three valleys in Canterbury. Breeding biology not well known but assumed to be similar to yellow-fronted kakariki, high productivity in beech mast years (Kearvell et al 2002) Yellow-fronted females are sole incubators; breeding late in season as for mohua (Elliott et al 1996) Assume all life stages vulnerable to predation;	*Eglinton Valley* (yellow-fronted kakariki) Stoat trapping was not effective in improving breeding success when stoat numbers were very high following beech mast; trapping in years between mast years may be effective in reducing later immigration from surrounding areas, large areas required due to high mobility of birds (Elliott et al 1996)

Species	Key predators	Vulnerable life stages	Monitoring outcomes
Brown kiwi	Dogs, ferrets (adult birds) rats, stoats, cats, feral pigs (juveniles) mustelids, possums (eggs) (McLennan and Potter 1992; McLennan et al 1996))	Eggs/juveniles/adults Adults too large (2–3 kg) to be attacked by rats/stoats; juveniles highly vulnerable to stoats until >800 g bodyweight. Juveniles can take up to 880 days to reach adult bodyweight (McLennan et al 2004)	49 northern brown kiwi monitored for up to 14 weeks: 22 (45%) died in first three weeks of life (nine natural causes, nine disappeared; four by predation), 27 (55%) fledged and left nest, 13 confirmed dead due to predation (mustelid 10; harrier 1; feral cat 2), five disappeared,(potential predation) Overall estimates 82–95% young northern brown kiwi do not reach adulthood. May be underestimated given duration of monitoring compared with time to reach adult size (McLennan et al 1996)
North Island kokako	Ship rats/ possums Harrier hawks (native) (mustelids to a lesser extent)	Females incubate eggs and broods young Eggs/nestlings/fledglings/ nesting adults (Innes and Flux 1999)	1979–84 research identified one nest in 10 producing a chick each season: attributed to predation (Innes and Flux 1999) Sustained pest control at three sites clearly improved chick output and adult abundance (including improved numbers of females (Innes et al 1999)* Pulsed pest control (3 years in 10) may be adequate to ensure ongoing population recovery after increases to 20 breeding females per population have been achieved. (Basse et al 2003)
Southern New Zealand dotterel	Cats and possibly rats (Stewart Island/Rakiura currently considered mustelid free)	Adult life expectancy in absence of predator control ~ five years Males undertake night-time incubation and are at greater risk than females (Dowding and Davis 2007)	Population at ~62 individuals in 1992 Current numbers ~250 individuals following intensive management since 1995 and not yet considered secure (Dowding and Davis 2007)
Robins	Ship rats, possums, possibly stoats	Up to 50% of nests affected on mainland Pairs may re-nest up to 10 times in a season if nests lost to predation Adult females sole incubator of eggs; sex ratio can become skewed in favour of males Fledglings vulnerable to predation in 1st week out of nest (Powlesland 1997) Eggs/nestlings/fledglings/ nesting adults	Large block treated (~37,000 ha) reducing immigration of pests; resulted in measurable improvements in nesting success in Pureora Forest after 1080 treatment in 1996–98; with benefits lasting two breeding seasons. Improvements in sex ratios female : male (pre-op 1 : 2; post op ~1 : 1 in treated areas) (Powlesland et al 1999)*
Tomtits	Ship rats, possums, possibly stoats	Adult females incubate eggs and broods young (Knegtmans and Powlesland 1999) (Assume similar vulnerability as for robins though little detail available: eggs/nestlings/fledglings/ nesting adults)	*Pureora* Differences in nesting success not significantly different between control and treatment blocks; mean number of chicks fledged greater in following season in treatment block; pairs raised more than one brood (mean 4/brood) (Powlesland et al 2000)* *Hampden, Otago* Increased population density one year after operation with subsequent decline (Hamilton 2004)* *Kaharoa, Central North Island* Two of 24 nests successfully fledged chicks; at least 92% of nests failed due to predation (Brown 1997 cited in Knegtmans and Powlesland 1999)

Species	Key predators	Vulnerable life stages	Monitoring outcomes
			Banks Peninsula Five of 16 nesting attempts successful (Kearton 1979 cited in Knegtmans and Powlesland 1999)

Note
* See Table F1 for further details of the pest control operations.

F2.1.4 Reduced competition for food: benefits of herbivore control

Improvements in vegetation condition after reduction of browsing pressure can be expected over time where sustained possum and ungulate control is undertaken (see also vegetation monitoring results, section F2.5). Animals that include large proportions of flowers, fruit and seed in their diets may benefit of such control efforts.

Kaka breeding is influenced by availability of seed from certain trees (Moorhouse et al 2002), and those kaka which live in beech forest may only attempt to breed in mast years (Wilson et al 1998, cited in Moorhouse et al 2002). Kereru breeding is influenced by availability of fruit, in some cases no breeding attempts will occur in poor fruiting years, and death by starvation has also been reported (Clout et al 1995). Possums and rats may both significantly affect food availability in average or less than average fruiting years.

Long-term impacts to forests by introduced browsers and increased competition for food have been identified as secondary causes of kokako decline, with predation the primary cause (Innes and Flux 1999).

The increased abundance of tui and silvereyes on Rangitoto Island 8–9 years after the successful eradication of possums and brush-tailed wallabies was attributed to the increased flowering of pohutukawa (*Meterosideros excelsa*) and rewarewa (*Knightia excelsa*) after pest control (Spurr and Anderson 2004). The abundance of insectivorous and seed-eating birds did not increase following the eradication, with reasons potentially being attributed to the ongoing presence of ship rats, stoats and cats. Additional seed produced in response to the removal of browsing pressure may have lead to increased seed consumption by rodents. Rodents also consume large quantities of invertebrates, also reducing the resources available to birds. Commercial honey production on the island increased from 7.5 kg/hive in the four years before eradication and rose to 40 kg/hive four years after the eradication, rising to 57.5 kg/ha, potentially reducing the amount of nectar available to native species on the island (Spurr and Anderson 2004).

Sites in South Westland which had been colonised by possums for 10, 20 and 30 years were used to assess the relative trends in possum diet, abundance of forest birds and tree canopy condition (Sweetapple et al 2004). At more recently colonised sites, possum diet comprised 72% highly preferred foods, compared with 36% of total diet at sites which had been colonised for more than 20 years. Tree canopy condition declined with increasing periods of possum presence, as did overall forest bird abundance, though as a result of increased competition or predation is not clear. Numbers of kaka, kereru and brown creeper increased despite reliance of kaka and kereru on possum-preferred species. The authors concluded that the observed mixed trends in bird abundance indicate the influence of additional factors than solely time from initial possum colonisation. Numbers of both kaka and kereru increased on Kapiti Island after possum eradication (H Robertson unpublished, cited in Sweetapple et al 2004).

F2.2 Terrestrial invertebrates

Investigations of the potential adverse effects of 1080 on terrestrial invertebrates have been conducted over about the past 15 years. The more recent are summarised below and in Table F3.

F2.2.1 Meads report

Several submitters have raised concerns regarding the impacts of aerial 1080 applications on terrestrial invertebrates and ecosystems and cite “the Meads report” as supporting evidence for their concerns. DoC provided the Agency with a copy of the unpublished report: M Meads, 1994. *Effect of sodium monofluoroacetate (1080) on non target invertebrates at Whitecliffs Conservation Area, Taranaki, June.* A copy of the peer review report undertaken by an independent Crown research institute and several articles from newspapers and letters to the editor discussing the content and handling of the report in the media were also provided (additional information from the applicants, 22 December 2006). The report was not approved by DoC for release or publication on the basis of fundamental flaws in the methodology used, and the quality and interpretation of data. In the report, Meads concluded that 1080 caused a significant adverse impact on invertebrates associated with leaf litter.

The reviewer noted that pitfall traps were used and invertebrates trapped do not adequately reflect the full species assemblages present, but should be used to study species known to respond predictably to this method. Only a single control and single treatment transect were used, and sited only 50 m apart. Dust drift from the application of the baits was observed to contaminate the control site, with subsequent heavy rainfall further confounding the interpretation of results (181 mm in the ‘second fortnight’ after bait application coincided with the decline in the counts of individual species). Both control and treatment data showed declines after the heavy rain. No attempt was made to measure 1080 concentrations in ‘washout’ from dust and fragments in the canopy or to analyse the data at the community level. Baits were also moved to be closer to the traps, artificially increasing the bait density.

A paper by Notman (1989) is also cited by several submitters as evidence of ongoing adverse effects of 1080 on invertebrates. The paper was a short review of the literature on invertebrates reported to be affected by 1080 from 1949 to 1986, including studies investigating the use of 1080 as a systemic insecticide. The author indicated that further research was needed in this area. The Agency has summarised several of these in the following sections and in Table F3.

Acknowledging the concerns raised above, the Agency is satisfied that the more recent research summarised below addresses the potential effects of 1080 on terrestrial invertebrates (ie, direct assessment of vertebrates observed feeding on toxic baits and analyses of residues in invertebrates). The potential effects on birds feeding on invertebrates containing 1080 residues are addressed in Appendix N.

F2.2.2 Presence of invertebrates on baits

Studies have investigated the relative abundance and identity of invertebrate species that will feed on different types of non-toxic baits in different forest types, so give an indication of which species may be at risk from exposure to toxic baits.

Rata/kamahi forest

In two rata/kamahi forests (Bell Hill Scenic Reserve and Kopara Forest) on the West Coast, South Island, in July 1996, the ant *Huberia brouni* was the most common species found on four bait types (carrot, Wanganui No 7 cereal, RS5 cereal and Agtech cereal, the latter of which is used as a base for brodifacoum baits) (Spurr and Drew 1999). Other common species found were various weta species, beetles, earwigs, harvestmen and mites. Ants and weta were found mostly on cereal baits, and beetles, earwigs, harvestmen and mites mostly on carrot bait. Significantly greater numbers were found on baits at night than during the day. The presence of cinnamon oil in baits at 0.1% reduced the numbers of invertebrates by more than 50% compared with 'plain' baits. The authors concluded that the number of invertebrates on baits was small compared to the total number of invertebrates present in the forest litter. Whole invertebrate groups were absent from the observations (eg, native earthworms), which may be an accurate reflection that they do not feed on baits, or an artefact of the difficulties in observing invertebrates feeding under baits.

Podocarp/hardwood forest

A series of three systematic and quantitative investigations was undertaken on the use of toxic and non-toxic baits by invertebrates at 12 sites in podocarp/hardwood forest near Ohakune over two winters, 1995 and 1996 (Sherley et al 1999). Baits used were either 0.15% 1080 Wanganui No 7 cereal, dyed green and cinnamon lured or the non-toxic equivalent (which still contained 0.0009–0.006% 1080 due to preparation on same equipment as the toxic baits), or chopped carrot, dyed green and cinnamon lured.

In the first of the three studies, two permanent grids were established at each site, one for non-toxic cereal bait, and one for non-toxic carrot bait. Baits were laid to simulate aerial sowing at 18 kg bait/ha. Observations were made over 7–10 days in each month June to October 1995 and April to October 1996, on the basis that these are the periods when 1080 pest control operations are most commonly undertaken. Most observations were undertaken at night as preliminary studies indicated that invertebrates are most active at this time. Observations continued until most baits had disappeared, at which time the baits were replenished. Pitfall traps were also established adjacent to the trial plots to assess capture rates of species found on baits. In total invertebrates were observed on 11.6% of carrot baits (n=1346) and 22.7% of cereal baits (n=1587). The proportion of cereal bait with invertebrates present was consistently higher than for carrot in all months except October 1996. Of the 113 taxa caught and identified, three made up more than 66% of the total from both baits. The numbers of three of four of the most common taxa found on bait did not correlate with those caught in pitfall traps.

In the second study, after three nights deployment of non-toxic cereal baits, toxic cereal baits were substituted on grids at a rate equivalent to 5.8 kg bait/ha, with a three-night observation period (based on 90% disappearance/consumption of baits in study 1), any remaining toxic baits were then removed and replaced with non-toxic bait, with a further three-night observation period (nine days in total). Sequential repeat trials were undertaken in August and October 1997, with an additional three-day placement of toxic bait at days 13–15.

The number of taxa observed on baits during the first three days was similar to that seen in study 1 (at least 133), with 43% of baits observed with invertebrates present (n=9,352). Following placement of the toxic baits, the proportion of baits with invertebrates declined to 32–34%, with some recovery observed in the three days after removal of the toxic baits. A similar pattern was observed in the numbers of invertebrates per bait. Where toxic baits were replaced at days 13–15, a reduction in visits to baits occurred and was greater than that observed during the initial toxic bait placement at days 4–6. No attempt was made to determine whether reductions were due to avoidance of toxic baits, or poisoning of invertebrates.

In the third study, to assess the effect of toxic baits on invertebrates over distance, non-toxic baits were placed at distances of 20, 40, 60, 80, 100, 120 or 140 cm to their toxic equivalents (bait as in study 2). The observations followed the same pattern as for study 2, except that toxic baits were replenished with more toxic baits at day 4, that is, effectively simulating a second application of bait three days after the first. The results of study indicated that the reduction in invertebrate numbers extended to 20 cm from the toxic bait at most. The replacement of toxic baits within a week of the first application resulted in a greater reduction in invertebrate numbers, which was significant at day 18.

Beech/podocarp/hardwood forest

The presence of invertebrates on 0.15% Wanganui No 7 baits (4–6 g, dyed green; cinnamon lured) and in pitfall traps was assessed during an aerial operation at Karioi Rahui, on the southern slopes of Mt Ruapehu in August 1997 (Lloyd and McQueen 2000). Residues of 1080 in the invertebrates were also measured. Sampling was undertaken in part of the operational area treated with 5 kg/ha bait. The forest at this location is predominantly mature red beech (*Nothofagus fusca*), silver beech (*N. menziesii*) and rimu (*Dacrydium cupressinum*).

Two hundred baits were present along the transects in the study area, with invertebrates collected from baits two hours after dark on the first four nights and then on the sixth and eighth nights after the operation. Pitfall traps were cleared daily for 10 days after the operation.

At total of 70 individual invertebrates from 20 taxa (insects 60%, spiders and harvestmen 21%, millipedes and centipedes 11%, slaters and amphipods 7%) were collected from baits and 28 individuals representing nine taxa (insects 7%, spiders and harvestmen 14%, millipedes and centipedes 18%, slaters and amphipods 61%) from the pitfall traps.

Residues in invertebrates collected from baits one night after the operation were 66 mg/kg in one Auckland tree weta (*Hemideina thoracica*). Nine cave weta (*Gymnoplectron tuarti*) were collected during the study and pooled for analysis where appropriate. Residues in each sample were 32 mg/kg (n=1) on the first night, 53 mg/kg (n=3) nights two and three, 130 mg/kg (n=2) night four, 60 mg/kg (n=3) on night six. Three pooled samples of other invertebrates were analysed from nights one, two and three, and nights six and eight with concentrations of 22 mg/kg (n=15), 46 mg/kg (n=24), and 14 mg/kg (n=19) respectively for each. The weighted mean for all eight samples was 57 mg/kg.

The pooled sample of invertebrates collected from pitfall traps during the 10-day collection period contained 0.8 mg 1080/kg. A pooled sample of spiders collected from baits (n=2) and pitfall traps (n=2) contained 14 mg 1080/kg.

Cave weta may have a better escape response compared with tree weta (Bremner et al 1989), so the effects of reductions in predation of cave weta may be less readily observed.

Invertebrates on baits in canopies

Using non-toxic Wanganui No 7 cereal baits, dyed green and cinnamon lured, Shrubshall (1999) investigated the type of invertebrates which may be feed or come into contact with bait fragments lodged in the forest canopy at Lenz Reserve in the Catlins. Invertebrates from 21 orders (n=12,518 individuals) were caught in sticky traps in the canopy, of which 44 individuals were confirmed as having ingested bait.

Table F3: Monitoring effects of 1080 on terrestrial invertebrates under field conditions

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated), date of application	Monitoring method	Environmental conditions after bait laid	Monitoring results	Reference
Auckland tree weta, *Hemideina thoracica* Cave weta, *Isoplectron* sp., *Pharmacus* sp. Cockroaches, spiders, leaf-veined slugs	Possum/rodents Aerial 0.08% carrot (6–9 g) green-dyed, cinnamon lured; screened to remove chaff (<0.5g) prior 10 kg/ha Analysis of bait confirmed concentration 0.07–0.09%	Whirinaki Forest (podocarp/podocarp-hardwood), North Island, New Zealand (1800 ha treated; untreated 3,000 ha) May 2000	Abundance in artificial refuges one year before and during two years after treatment Possums: RTCI; rodents: tracking tunnel indices	Not reported	Variable occupancy of refuges in both areas in the pre-operational period limited comparisons which could be made between the two sites after treatment. Auckland tree weta: Numbers increased in treatment area after operation and remained higher after two years, possibly linked to declines in mouse abundance, and started declining with increases in rat and mouse indices Cave weta: Unaffected by treatment Cockroaches: No changes attributed to 1080 Spiders and harvestmen: Unaffected by treatment Leaf-veined slugs: Increased in treatment area but attributed to environmental conditions at that site being more favourable for slugs than the control site **Possums** Treatment area RTCI <10% for at least 12 months; untreated RTCI 30% **Rodents** Treatment area <10% for at least 12 months; untreated area 19–75% over 12 months	Powlesland et al 2005

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated), date of application	Monitoring method	Environmental conditions after bait laid	Monitoring results	Reference
Wellington tree weta *Hemideina crassidens* Cave weta, *Isoplectron* spp. Other invertebrates	0.15% Wanganui No 7 cereal bait (6 g), green-dyed, cinnamon lured; hand-broadcast at 5 kg/ha over 0.25 ha plots to simulate aerial deposition Bait also laid along a transect outside treatment and control plots to facilitate collection of invertebrates for analysis without disturbing refuges	Tararua Forest Park, North Island, New Zealand 22 August 2000	Abundance in artificial refuges and mark-recapture of individual weta: monitoring for 12 months before and 4 months after bait application Instantaneous counts of weta and other invertebrates found on baits on 'extra' transects were counted for three hours, one hour after sunset for first three nights after baits were laid and collected for 1080 residue analysis	First rainfall (15 mm) five weeks after treatment; 1000 mm in week 6	Concentration of 1080 in bait 1 week 0.075%; 2 weeks 0.027% 5 weeks <LOD No visible sign of bait after 6 weeks 5% of baits laid (n=3086) inspected at night had weta (0.5%) or other invertebrates (4.5%) on them at any one 'instant' over three nights; total of 16 weta and 158 invertebrates (mostly springtails (Collembola), harvestmen (Opiliones) and amphipods (Amphipoda). Concentration of 1080 in invertebrates 4 mg/kg: one live cave weta from a bait two nights after application (LOD 0.02 mg/kg) 8.6 mg/kg: one live but lethargic tree weta from ground outside artificial refuge seven days after application 10 mg/kg: one live weevil from bait two nights after application Dead possums and ship rats found in plots but no dead invertebrates. Weta in artificial refuges Two species occupied refuges: Wellington tree weta and a cave weta *Isoplectron* sp. The number of refuges occupied increased over time. Numbers of weta per plot increased over the 16-month observation period, twice as many tree weta in treatment plots compared with controls in May 2000 and half as many cave weta in treatment v control plots May and June 2000 (ie, pre-treatment). No significant differences for either species one week to four months after treatment. Individually marked weta No significant difference in the proportion of marked tree weta resighted in treatment and control plots up to four months after bait application. Other invertebrates No significant differences in numbers of invertebrates occupying artificial refuges before or after treatment. Authors noted the post-application monitoring period was too short to allow assessment of the benefits of possum/rat control on invertebrate numbers.	Spurr and Berben 2004

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated), date of application	Monitoring method	Environmental conditions after bait laid	Monitoring results	Reference
General invertebrate populations	0.15% Wanganui No 7 cereal bait green-dyed, cinnamon lured: hand-broadcast at 5 kg/ha over 0.04 ha plots to simulate aerial deposition Three size classes of bait used 'standard' sized large baits >1 g fragments <1 g	Tararua Forest Park, North Island, New Zealand 14 July 1998	Comparison of number of ground-dwelling invertebrates in pitfall traps before and up to four months after application of toxic bait. One trap in centre of each plot. Additional plots treated to allow for collection and analysis of invertebrates found on baits Number and identity of invertebrates eating baits assessed on first three nights during first four hours of darkness	'Showers' day after application; dry for the following week	Concentration of 1080 in leaf litter 0.01 mg/kg in one of four samples collected on day of application <LOD in 3 samples of beetles collected from leaf litter Invertebrates on baits 22.2% of baits (n=974) had invertebrates on them – most common (in order of abundance) amphipods, the ant *Huberia brouni*, millipedes, harvestmen, weevils, and weta Invertebrates in pitfall traps Most common species caught in control and treatment plots (by abundance) springtails, amphipods, mites and flies. Apart from one species of amphipod, too few of the others were present to allow for individual analysis of changes in abundance. No significant effects on numbers of invertebrates caught when assessed at the family, order or class level.	Spurr et al 2002
	Nominal 0.15% carrot (measured as 0.08% in standard size baits; 0.08% in large baits; 0.15% in chaff) green-dyed, cinnamon lured Hand broadcast as above Non-toxic baits also laid in additional plots	Tararua Forest Park, North Island, New Zealand 25 May 1999	May 1999 bad weather resulted in only two nights of counting invertebrates on baits; repeated in July 1999 in fine conditions	Heavy rain and gale force winds on first few nights in May	Reason for low concentration in bait unclear: correct strength of stock solution was used at correct rate; concentration in small bait pieces insufficient to account for low concentration in larger pieces. Samples of leaf litter, and invertebrates collected before, day of and seven days after carrot laid and invertebrates collected from baits were lost due to freezer malfunction. Invertebrates on carrot May: 3.5% of toxic baits (n=372) and 6.7% of non-toxic baits (n=329) had invertebrates present on them. July: 6.8% of toxic baits (n=1348) and 7.1% of non-toxic baits (n=1297) Difference between toxic and non-toxic baits was not significant for either sampling period	

Primary non-target species being monitored	Target species and 1080 application method, bait type, sowing rate	Location (area treated), date of application	Monitoring method	Environmental conditions after bait laid	Monitoring results	Reference
					Compared with cereal bait in July 1999 (above), invertebrates occurred on significantly lower percentage of carrot baits. Most common by abundance; millipedes (24%), harvestmen (23%), amphipods (21%), springtails (14%). No ants observed. Invertebrates in pitfall traps most commonly caught by abundance: springtails (82%), mites (7%). Apart from one species of amphipod, and the ant *Huberia brouni,* too few of the others were present to allow for individual analysis of changes in abundance. No significant effects on numbers of invertebrates caught when assessed at the family, order or class level.	
	Nominal 0.15% carrot (measured as 0.085% in standard size baits; 0.105% in large baits; 0.17% in chaff) green-dyed, cinnamon lured Hand broadcast as above Non-toxic baits also laid in additional plots	Tararua Forest Park, North Island, New Zealand 2 July 2000			Reason for low concentration in bait unclear: correct strength of stock solution was used at correct rate; concentration in small bait pieces insufficient to account for low concentration in larger pieces. Concentration of 1080 in leaf litter None detected in 10 samples before treatment; traces (mean up to 1.6 mg/kg) in samples on day of treatment and seven days after, including from control plots. Plots too far apart to be contaminated accidentally. Reason potentially redistribution by animal movement between plots. Invertebrates on carrot 6.9% of toxic bait (n=2839) 14.6% of non-toxic bait (n=1105); most common species by abundance millipedes (37%), amphipods (27%), harvestmen (8%), springtails (6%). Apart from one species of amphipod, too few of the others were present to allow for individual analysis of changes in abundance. No significant effects on numbers of invertebrates caught when assessed at the family, order or class level.	

F2.2.3 Benefits of mammalian pest control to invertebrate species

Few studies have attempted to assess the benefits of mammalian pest control on invertebrates, other than the giant native land snails *Powelliphanta* spp. in Nelson/Marlborough, though this an area of complex research identified by Sherley et al 1999 as warranting further investigation. The information available to the Agency is summarised in Table F4.

Browsing mammals may cause impacts on soil fauna through soil compaction, trampling and scuffling (Wardle et al 2001). While some people are of the view that the impacts of deer via compaction may be no different to those of the now extinct moa, a study of foot pressures and edge loadings of moa, emu, red deer and thar indicate significant differences between ratite birds and ungulates, with ungulates having the greater loading (Duncan and Holdaway 1989). The ungulate foot exerts a greater load and the front edge of the foot acts like a chisel with sudden weighting of the foot and shearing of the substrate. The emu foot transfers weight in a gradual, rolling manner without deep impressions. Comparisons were made between live emu foot prints and those of moa found in sub-fossil mud, indicating similarities in locomotion between the two species.

Table F4: Effects of pest control on giant snail abundance

Species	Application method, bait type, rate, area treated	Location	Mean RTCI	Monitoring method	Results (mean number per plot)	Reference
Native giant land snails, *Powelliphanta* spp.	Aerial, cereal pellets	Parapara Peak, Kahurangi National Park 1995 2000	2000 Pre-control 3.2% Post-control 0.0%	Snail abundance in same seven plots in 2000 and 2002	*P. gilliesi* stayed the same at ~1.5/100m^2 *P. hochstetteri* increased from 0.7 to 1.3 per/100m^2 Rats stated as not present at the altitude of the study site; pigs in low numbers during 1990s. Snails take about three years before young big enough to detect reliably, further monitoring needed to determine benefits of possum control	K Walker unpublished data cited in Green 2003a
	Aerial, 0.15% cereal pellets (6g) at 5 kg/ha, 13,790 ha	Gouland Downs, Kahurangi National Park 1996 2002	2002 Pre- control 3.8% Post-control 0.2%	Snail abundance in plots in 1991, 1994, 1996, 1999, 2003	*P. superba mouatae* and *P. gilliesi* <0.5 live snails/100m^2 in 1994 declined close to zero prior to aerial operation in 1996. Steady but small recovery to 2.8 live snails/100m^2 in 1999 and 4.5/100m^2 in 2003 Rats and pigs not present in the area	Napp 1999 and K Walker unpublished, in Green 2003a
	Aerial, cereal pellets	Burnett Range, Nelson/Marlborough 1994 2000	2000 Pre- control 7.3% Post-control 0.2%	Snail abundance in plots in 1994, 1996, 1998, 2000, 2003	*P gilliesi* 3.3/100m^2 at time of 1994 possum control 4.4/100m^2 by 1998 8.8/100m^2 in 2000 13.2/100m^2 in 2003 Pigs known to have returned to the area in late 1990s	DoC and K Walker unpublished, in Green 2003a

F2.3 Reptiles and amphibians

The Auckland Regional Council monitored Hochstetter's frogs (*Leiopelma hochstetteri*) at three sites in the Hunua Ranges before and after an aerial operation using 0.15% Wanganui No 7 cereal bait (dyed green and cinnamon-lured) at 5 kg/ha over a total of 21,894 (McNaughton and Greene 1994). The bait was applied over four days in June 1994 and frogs monitored weekly (three times) before the operation and weekly for four weeks after the operation, further observations were made 18 weeks after the operation. There was no control area within the catchment, limiting the conclusion that could be drawn from the observations. Changes in frog numbers at two sites were strongly correlated with minimum temperature, and at the third site (warmer with less variation) numbers remained similar before and after the operation. The small sample size limited the interpretation of results. One frog found was dead immediately after the operation and tested negative for 1080 residues.

Populations of Hochstetter's and Archey's frogs (*L. archeyi*) were monitored along transects at Tapu, Coromandel Forest Park during an aerial 1080 operation in June 1995 (Perfect and Bell 2005). Bait (0.15% cereal (4–6 g) was applied aerially over 11,279 ha at approximately 5.5 kg/ha.

No change was detected in the Hochstetter's frog population but statistical analysis of the data indicated that there was only a very small probability of detecting an impact as the numbers of frogs observed were too small. As such, no conclusions could be drawn from the observations.

Declines in numbers of Archey's frogs occurred in both treatment and control areas over June to September 1995, attributed to seasonal and/or disturbance factors, including flooding. Higher monthly counts on treated sites compared with controls may have been attributable to differences in habitat. 1995. Population declines of Archey's frogs have been reported from late 1996 and attributed to the chytrid fungus.

One Archey's frog was found foaming at the mouth, a symptom which has been reported from a related species on Maud Island while feeding (Bell personal observation, cited in Perfect and Bell 2005). The symptoms may also have indicated 1080 poisoning, as foaming at the mouth has been reported for some other species (eg, shingle-backed lizard, McIlroy et al 1985). However, other signs of 1080 poisoning seen in 1080-poisoned frogs were not observed for example, immobility, outstretched limbs, shallow breathing, either due to the short observation periods in the study, or because they did not occur (ie, 1080 was not the cause of the symptoms). Presumably, no analysis for 1080 was undertaken as the animal was still alive.

F2.4 Mammals

F2.4.1 Bats

Bat mortality was assessed for 11 days after an aerial application of 0.15% Wanganui No 7 cereal bait at 5kg/ha in lower altitude forest and 3 kg/ah for the remainder in Rangataua Conservation Area adjacent to Tongariro National Park (Lloyd and McQueen 2002). Groups of bats were captured when returning to their roost and held in captivity for 48 hours. No mortalities occurred and none showed signs of 1080 poisoning. Statistical analysis of the data indicated that there was at least a 95% likelihood of detecting mortality when the rate was above 11.1 mortalities per thousand flights. The authors noted that further information on bat population demography is needed in order to fully assess the potential impact of 1080 operations on population viability.

As noted by Lloyd (2001), bat populations continue to inhabit forests at Pureora and North Waitanga, areas with extensive ongoing pest control operations using a range of toxic baits, including 1080.

F2.4.2 Livestock and companion animals

There is little data available on confirmed poisonings of livestock and companion animals. A collation of cases from 1976 to 1985 was published by Bruere et al (1990) and from 1986 to 1992 by Orr and Bentley (1994). The data summarised by Orr and Bentley were from the Animal Health Laboratory network and were stated as occurring when animals entered areas that had been treated with 1080 or as a result of accidental application of bait to stocked paddocks or return of stock to treated areas before the bait had been determined as being no longer toxic (Table F5). Other cases documented in 1986–1992 included 150 sheep dying 10 weeks after toxic carrot had been laid in paddocks in central Otago to control rabbits; 78 sheep dying after grazing an airstrip used to load toxic carrot for rabbit control 20 weeks after the operation, piles of toxic carrots were observed on the site (Orr and Bentley 1994).

The Agency has also searched the Ministry of Agriculture and Forestry’s publication *Surveillance* (MAF 1993–2006) for reports of confirmed 1080 poisoning from 1993 to 2006; the results are included in the table below. No cases were reported from 2003 to 2006 but the Agency does not know whether poisonings occurred and were not formally diagnosed or not reported via this publication. Notes accompanying the reported cases indicate several instances where stock had access to toxic bait.

The operational report produced by DoC after the 2002 treatment of Egmont National Park (Ovenden and Merridale 2003) stated that seven feral cattle which were in the park were killed by 1080 and one fox terrier. The owner of the cattle had given written permission for his private block to be treated but did not know the whereabouts of these animals. He subsequently paid for the removal of the carcasses. The dog owner confirmed that she had received all the necessary information about the 1080 operation and chose not to use the free muzzles provided.

Table F5: Number of confirmed 1080 poisonings in livestock and companion animals

Year	Cattle	Sheep	Dogs	Deer	Pigs	Cats	Goats
1986	1	1	8	1	12		1
1987	4	2	9	2			
1988	4	6	10	2			
1989	3	9	8				
1990	2	9	4				
1991	3	5	16			1	
1992	12	3	17	5			
1993			1				
1994			1				
1995							
1996							
1997							
1998			'several' farm and pet dogs				
1999			2 farm dogs				
2000	'several' heifers						
2001	3 cows						
2002		Positive diagnosis – No. of sheep not reported	1* (suspected malicious poisoning) 2 farm dogs*				
2003	3+2+2+30 (+30 sub-lethal effects)*						

Notes: Data for 1986–92 Animal Health Laboratory Network data (Orr and Bentley 1994); remainder from various issues of *Surveillance* (MAF).

* Indicates deaths in separate cases of poisoning.

F2.4.3 Wild deer

The social, ethical and market economy issues associated with mortalities of deer and other game species are addressed in sections 7.3.5.2, 7.3.5.9, 7.3.6.10 and 7.3.6.11 of the Evaluation and Review Report.

Feral deer and other ungulates have been direct targets of 1080 operations in areas where densities are high and spread of Tb is possible, or in areas where they pose a threat to indigenous biodiversity. They may also be killed as incidental 'by-kill' from poisoning operations targeted at possums, and as such are considered to be non-target species by many people.

Table F6 summarises some of the available information on reported deer mortalities which have occurred during aerial 1080 operations to control possums and in some cases deer (see Appendix N for information on the effectiveness of deer repellent on carrot bait). The Agency was not able to locate additional information on substantiated non-target deer kills other than the report on the effects on fallow deer in the Blue Mountains (Nugent and Yockney 2004).

Table F6: Mortality of deer during aerial 1080 operations

Primary species being monitored	Target species and 1080 application method/bait type/sowing rate	Location (area treated), date of application	Monitoring method	Monitoring results	Reference
Red deer *Cervus elaphus*/possum	Red deer/possum Aerial Carrot at 0.08% and 0.15% applied at 10 kg/ha (after pre-feed at 5 kg/ha) (toxic loadings confirmed by analysis as within acceptable tolerances)	Mt Titiraupaunga, northern Hauhangaroa ranges (3,500 ha and 5,100 ha) Winter 1997 Control (untreated): Mt Pureora	Faecal-pellet group density for both species immediately after and one year after treatment	**Red deer** 92.8% kill with 0.08%1080 91.6% kill with 0.15% 1080 Authors estimated ~10 years for deer population to recover to pre-control densities, in the absence of hunting and immigration from adjacent uncontrolled areas.	Fraser and Sweetapple 2000
	Red deer/possum Aerial Wainuiomata 0.15% Wanganui No 7 cereal (10g); cinnamon 0.3%, green dye applied in narrow high-density strips (mean 4m wide) at 21–30 kg/ha with 70 m gaps, overall average 3 kg/ha (intended to maximise by-kill) Pre-fed with non-toxic bait, also in strips Orongorongo catchment Bait type as for Wainui, but standard aerial application at 3 kg/ha, no pre-feed; block resown 13 days after 1st application	Orongoronga (3556 ha) and Wainuiomata (3,817 ha), catchments Wellington June 1997 Two control blocks: lower Orongorongo and Wairongomai	Faecal-pellet group density for both species both species before and one year after treatment RTCI for possum	**Deer** Orongorongo 54±43% kill Wainuiomata 5±79% kill one dead deer seen in each catchment, and several seen in both blocks post-operation Very large 95%CI attributed to low pre-control deer densities at ~2/km^2 **Possum** Orongorongo 2.7% RTCI Wainuiomata 1.1% RTCI Goats were also present in the treatment areas but not considered to be a significant by-kill species during possum control	Meenken and Sweetapple 2000

Primary species being monitored	Target species and 1080 application method/bait type/sowing rate	Location (area treated), date of application	Monitoring method	Monitoring results	Reference
	Red deer/possum Carrot at 0.08% and 0.15% applied at 15 kg/ha (after pre-feed at 5 kg/ha) Analysis of bait indicated mean of 0.095%1080 with high variability between samples	Rangitoto Range, in and around the North Block of Pureora Conservation Park (~40,000 ha) Winter 1996	Faecal-pellet group density for both species before and one year after treatment	**Red deer** Pre-op estimate 5 deer/km^2 Post op 57±15.4% kill (residual ~2 deer/km$^{2)}$ **Possums** 99.3% reduction Authors note that kill estimates conservative due to lag between operation and monitoring, with likelihood of immigration in the intervening period. Intrinsic rate of increase cited as ~35%/year	Sweetaple and Fraser 1997
	Red deer/possum Carrot (toxic loading not stated) applied at 15 kg/ha (after pre-feed at 5 kg/ha)	Hauhangaroa Ranges 1994 Deer specifically targeted as Tb vector	Not stated	**Red deer** 30–42±50% kill **Possums** 78–96% kill	(Landcare data cited in Sweetapple and Fraser 1997)
Fallow deer, *Dama dama*	Possum Aerial 0.15% RS5 cereal bait at 2 kg/ha	Blue Mountains, Otago (6,400 ha, encompassing 10 hunting blocks) August 2001 Deer (and possums) in area reported to be infected with Tb	Three radio-tagged (♀one adult; ♂ one fawn, one sub-adult) Eight 'search-cells': searched systemically for carcasses 4–6 weeks after treatment	Total carcasses found 1 pig; 53 deer (including all 3-radiotagged animals), 58 possum. 20 birds (16 blackbirds; 1 chaffinch; 1 grey warbler; 2 tomtits Fresh deer sign seen in all eight search cells; eight live deer seen while searching) Based on statistical analysis of search data and historical hunting data, the authors concluded that 'some hundreds of deer' were killed across the total treatment area	Nugent and Yockney 2004

F2.5 Vegetation

F2.5.1 Impacts of possums: benefits of possum control

Extensive possum-induced vegetation damage was observed in the 1980s, including canopy collapse in rata/kamahi forest (eg, Leutert 1988; Rose et al 1992) and significant dieback in fuchsia dominated forest in South Westland with relatively recent possum invasions (Rose and Pekelharing 1995).

In order to assess whether DoC is achieving its intended goals of protecting forest ecosystems through the aerial use of 1080, an extensive review of the effects of pest control on forest vegetation was commissioned (Green 2003a, 2003b). The author reviewed 70 monitoring reports from operations at 40 locations within nine conservancies, spanning 1990–02. Pre- and post-operational possum densities were included in the monitoring reports. The assessment of monitoring results were grouped to cover northern forests, central North Island forests, Nelson/Marlborough forests, West Coast forests and are summarised in Table F7.

Table F7: Overview of vegetation monitoring by DoC in relation to 1080 possum control operations using 1080

Location of study sites	Key monitoring results*
Northern forests: eight locations in Northland, small scenic reserves to Waipoua forest	**Mahoe** Showed significant improvement within a year of possum control even when possum indices relatively high **Kohekohe** (identified as a 'critical indicator' in Northland forests) Comparative study at Motatau and non-treatment block indicated significant improvements within one year of control (RTCI 2%)
Central North Island forests: 18 locations	**Mahoe** Significant benefits compared with control block (Wanganui, Urewera National Park) **Kohekohe** Significant benefits at three locations but not at two others. Poor possum kill (RTC 10%) after aerial operation at Moetatoa Forest, Waikato, but significant improvement in foliage cover 55–66% in two years, with decline in the next year to 62%. At three other locations where 5% RTC was almost achieved, 42% foliage cover (poo) showed little or only temporary improvement. At Mt Karioi, significant increase in foliage cover two years' post-control, decline to pre-control levels in third year **Kamahi** Mt Pirongia, aerial 1080 slowed but didn't halt decline despite RTC<5%; at Wharerino and Mt Karioi, improvement observed for first two years, then dropped to pre-control levels with possum densities low for five years post-control. Higher altitude kamahi at Mt Karioi already stressed by environmental factors may require greater reductions in possum numbers. Several locations in Bay of Plenty and East Coast/Hawkes Bay already in good condition showed no further improvement; at other locations poor condition improved significantly compared with non-treatment plots. **Northern rata** Waikato and Wanganui, no significant improvement but issues with adequacy of the Rata View monitoring method **Totara/cedar forest** Egmont National Park significant improvements (RTC 7.9%). Banding of individual cedar indicated if <25% foliage cover, decline will continue unless complete removal of browsing.

Location of study sites	Key monitoring results*
	Mistletoes Pureora Forest – RTC<2% dramatic improvement; when RTC recovered to 3% decline observed
Nelson/ Marlborough forests: six locations	**Hall's totara** Improvements in foliage cover, though still poor-moderate **Mahoe** Variable, significant improvement in foliage cover (19–39% after four years at one site (may have been assisted by concurrent goat control); at Tennyson's Inlet initial significant gain followed by decline and then improvement (environmental factors possible cause and/or observer differences); **Scarlet mistletoe, *Peraxilla tetrapetala*** Significant benefits when RTC<1%, with significant damage at 3%
West Coast forests: eight locations	**Tree fuchsia** main indicator species monitored Haast Valley and Arawhata and Waipara valleys – (areas relatively recently invaded by possums prior to 1st treatment in 1994) – possum control has slowed but not stopped forest decline **Otira and Copland valleys** Initial increases of foliage cover in wineberry/pate/fuchsia after 1996 treatment, then declined between 1997 and 2000, mortality also increased. **Landsborough Valley** (~40 years of possum presence) Fuchsia and wineberry in good condition. Possum control in 1994 and 1998 significantly increased foliage cover and decreased tree mortality. Two mistletoe species had increased foliage scores linked to decreased possum densities **Abbey Rocks** (ground-control with 1080) Post-control RTC <1% all species had low possum browse scores but canopy condition declined in all species monitored by 10% (wineberry/kamahi/pate/fuchsia/mahoe/horoeka-lancewood) except mahoe which showed an improvement. In the non-treatment area (Jacksons River) there was a significant decline in foliage cover scores for wineberry and fuchsia to <30% and increasing mortality; kamahi scores stayed the same over the period in 2001–02

Note

* Indicator species; mahoe, *Melicytus ramiflorus*; kohekohe, *Dysoxylum spectabile*; kamahi, *Weinmannia racemosa*; Hall's totara, *Podocarpus hallii*; pate, *Schefflera digitata*; tree fuchsia, *Fuchsia excorticata*; Northern rata, *Metrosideros robusta*; makomako/wineberry, *Aristotelia serrata*.

As a second step to reviewing the DoC monitoring reports, Green (2003b) provided a critique of the application of the monitoring methods and their use by DoC as a tool for assessing the outcomes of pest control and determining frequency of further 1080 control. He identified the need for further investigations with respect to setting specified targets for vegetation recovery in relation to possum densities and noted a 10-year study is under way (Nugent et al 1999; Nugent et al 2001). Other recommendations included: greater consistency in choice of indicator species (where possible due to differences in distribution nationally) and greater consideration of the timing of vegetation monitoring with respect to whether the species responds quickly or slowly to removal of browsing pressure; investigation of the accuracy of the RTCI at low possum densities.

In relation to the latter point, Green noted that if the RTCI is not reliable at low densities, incorrect assumptions may be made about the time to the next treatment of the same area for example, 5–7 years when post-control densities may rise to 50% within 3–4 years, which may mean some species are not adequately protected. As noted in section F1.1.1, while the RTCI does have some limitations, it is relatively linear at low possum densities and is still the best method currently available (Forsyth et al 2005).The use of non-treatment (control) sites for comparison against treated areas was fairly sparse in the reports examined, limiting conclusions which could drawn in many cases in terms of the effects of possum control versus other environmental variables which may adversely affect vegetation.

Fruiting and flowering data were generally not reported in the monitoring studies reviewed by Green (2003a), despite the significance of the flowers and fruit for both ongoing ecosystem maintenance and regeneration (ie, production of new seedlings) and as food for a variety of animals. Fruit can form a substantial part of the diet of many birds for example, kokako up to 50%, and therefore browsing of fruit by possums, and indirect effects on vegetation from other herbivorous mammals, may result in birds not obtaining sufficient nutrition to reach reproductive condition and/or not being able to adequately feed their young (Leathwick et al 1983). Similar conclusions have been reached for kaka which may have a seasonal reliance on fruit, seed and nectar of species known to be browsed by possums (Moorhouse 1997). Initiation of breeding may be linked with the flowering of some species.

Individual studies have been undertaken on the effects of possums on fruiting in various species; for example, hinau, *Elaeocarpus dentatus* (Cowan and Waddington 1990), nikau, *Rhopalostylus sapida* (Cowan 1991), indicating significant adverse impacts.

Mistletoes are preferentially browsed by possums and several studies have indicated that possum densities need to be maintained below 3% RTCI to ensure the ongoing survival of these preferred food species (Green 2003a; Sweetapple et al 2002).

The extent of vegetation monitoring undertaken by agencies other than DoC is unknown.

The Agency notes that overall, the relationship between possum density and vegetation response is complex and still not fully understood, with a number of variables, including whether a species responds quickly or slowly to release from possum browsing pressure, impacts on seedling regeneration by ungulates and the effects of environmental factors.

F2.5.2 Impacts of deer: Benefits of deer control

Numerous studies have been undertaken on the impacts of deer on vegetation, although there is very little information in the application. Green (2003b) indicated that little systematic monitoring of understorey vegetation was noted in the reports he reviewed, with the focus being on possum impacts.

The Agency has reviewed some of the recent literature on the impacts of deer of vegetation.

Seven species/sub-species of deer are present in New Zealand: red (*Cervus elaphus scoticus*), wapiti (*C. e. nelsonii*), sika (*C. nippon*), sambar (*C. unicolour*), fallow (*Dama dama*), whitetail (*Odocoileus virginianus*), rusa (*C. timorensis*) (Nugent and Fraser 2005).

Red deer are the largest and most widespread of these species, occupying approximately 120,000 km^2 and including habitat from sea-level to high mountainous areas, including established exotic plantation forests (Nugent and Fraser 2005). They are both browsers and grazers and will preferentially feed on more palatable species where available. Preferred forest plants include large-leaved *Coprosma* species, pate (*Schefflera digitata*), broadleaf (*Griselinia littoralis*), hen and chicken ferns (*Asplenium bulbiferum*) and leaves and bark of *Pseudopanax colensoi* and *P. arboreus*. A significant proportion of the diet may include fallen leaves in grasslands, large-leaved herbs and grasses on fertile sites are preferred (Nugent and Fraser 2005).

A study using deer enclosure plots and experimental clearing of vegetation in Waitutu Forest has demonstrated that red deer significantly reduced the re-establishment of woody seedlings and the species composition was also affected (Wilson et al 2006). The changes which may result from such herbivory may have impacts on the ability of forests to recover from natural and human-induced disturbances (eg, landslide, fire, wind throw), with slower regeneration on these sites, and an altered species composition.

The impacts of red deer and feral pigs on tree regeneration and growth in Aorangi Forest, Wairarapa were examined following 70 years' colonisation by these species (Husheer et al 2005). Feral goats had also been present during part of this time but had been eradicated in the 1960s and not recolonised the area. Data from fenced and unfenced plots established between 1981 and 1987 and remeasured in 2004. Red deer prevented regeneration of kanono (*Coprosma grandifolia*) and reduced the growth of mahoe (*Melicytus ramiflorus*). Regeneration of less palatable species appeared to have been unaffected.

Sika deer may have a greater impact on species which are moderately palatable to red deer due to differences in their digestive abilities (Husheer et al 2006). Data were compared from mountain beech forest (*Nothofagus solandri* var. *cliffortioides*) with sika deer (one region, Kaimanawa) and without sika deer (four regions, Craigieburn, Rangitaua Forest, Hurunui Valley, Murchison Mountains). Red deer were present in all regions. In areas where sika deer had been present for more than 10 years, the regeneration of mountain beech was poor. In areas without sika deer, regeneration of mountain beech appeared to be strong in stands with low numbers of trees. Enclosure plots in the Kaimanawas established in the 1980s show increased mountain beech seedling and sapling abundance inside the plots compared with outside the plots. In regions with only red deer, there was little difference between fenced and unfenced plots for mountain beech. Husheer et al (2006) noted that sika deer may competitively exclude red deer in areas with low basal area due to their abilities to more effectively digest less palatable species.

In a review paper, Coomes et al (2003) noted that impacts of deer may not be reversible in a number of situations including: where palatable species remain highly browsed even at low deer densities; occupation of niches by unpalatable species; local extinction of seed sources; alteration of succession pathways; shifts in ecosystem processes.

F2.6 Aquatic species

F2.6.1 Macroinvertebrates

The potential effects on aquatic invertebrates of joint DoC/Taranaki Regional Council aerial 1080 operations on Mt Taranaki/Egmont in 1993/94 were monitored (TRC 1993, 1994) (see Appendix E for further operational details). Five streams were monitored before and after stage 1 in 1993, and four streams before and after stages 2 and 3 in 1994. Minor variations in species diversity and Macroinvertebrate Community Indices (MCI) were noted in both monitoring programmes but were attributed to natural variation in response to flow conditions on periphyton abundance in the streams.

The potential impacts of 1080 on aquatic invertebrate communities were assessed in four streams running through Haupiri Forest following an aerial 1080 drop in April 2002 (Suren and Lambert 2002). Cereal baits (6 g) containing 0.15% 1080 were applied at 3 kg/ha to Haupiri Forest near Kopara in the South Island. No major changes in invertebrate communities were reported. A small short-term reduction in the number of ‘sensitive’ taxa (ie, stoneflies, mayflies, caddisflies) was noted five days after the drop. A short-term drop in the total number of species collected also was observed in some streams. Such reductions were not observed in the control stream. Fourteen days after the operation, both species richness and abundance were generally higher than before the operation. The authors concluded that the changes were related to a flood event which occurred prior to the 1080 operation. All water and sediment samples taken one and 14 days after the operation were below the limit of detection (0.0001 mg/L).

F2.6.2 Fish

Controlled studies have been undertaken with caged fish (koaro, bullies, eels) and invertebrates (Suren and Lambert 2004), and eels (Lyver et al 2005; 2006). These reports are summarised in section C2.5.1, Appendix C.

F3 Monitoring effects on target pest populations

This section is related to the efficacy of 1080 as a tool to manage (largely) mammalian pests in the New Zealand environment. An assessment of efficacy under field conditions is directly relevant to the assessment of benefits of the use of substances containing 1080.

Some information on the kill rates achieved in DoC's operations was included on page 391 of the application (assessment of significant benefits) but was not as comprehensive as the Agency had anticipated. No information was included in this section of the application from the AHB. The Agency sought further information from both DoC and the AHB on kill rates for various species and operational conditions. Where such information was provided by DoC, it is indicated in the text below. The AHB was not able to provide any further information as its database is still under construction (further information from the applicants, 22 March 2007) and they referred to a report (Speedy 2003) requested previously by the Agency (1 March 2007). DoC indicated that it would take a considerable amount of time to revisit the information provided and determine whether there were additional operations meeting the criteria.

F3.1 Possums

DoC reviewed possum kill rates achieved in 1080 operations between 1990 and 2003. A summary of these was included on p 391 of the application and they are listed below. The Agency sought clarification as to why there appeared to be so few results included in the summary list given the time-frame indicated. Several criteria were applied to the selection of results (further information from the applicants 22 March 2007). Operations had to use 1080 only, either applied as ground only or aerial only, in order to ensure that the comparisons were like with like. Operations using multiple techniques were therefore excluded. To demonstrate efficacy in terms of percent kill, the timing of the pre-control and post-control RTCI monitoring had to have occurred within one year before, and within three months after, the operation.

Other operations excluded were those which are initiated based on a damage threshold (eg, to vegetation), whereby control occurs without any pre-operational RTCI monitoring and also those which are subject to ongoing trend monitoring every 2–3 years. In the latter situation, once the possum numbers reach a trigger level, a control operation is then planned to occur 1–2 years later.

> *Possums* (operations since 1990, following standard operational procedures)
>
> The mean kill following pre-fed aerial operations using:
>
> - 1.5 g/kg 1080 cereal pellets was 92.9% (n=23);
> - 1.5 g/kg 1080 carrots was 93.7% (n=4); and
> - 0.8 g/kg 1080 carrots was 90.5% (n=5).

The mean kill for non-pre-fed aerial operations using cereal pellets was 77.6% (n=16).

The mean kill for uncontained ground operations using:

- Handlaid 1.5 g/kg 1080 cereal pellets was 85.3% (n=4); and
- Handlaid 1.5 g/kg 1080 paste is 77.1% (n=5).

The mean kill for contained ground operations using:

- 1.5 g/kg 1080 cereal pellets in bait stations was 94.4% (n=4);
- 1.5 g/kg 1080 gel (No Possums® 1080 gel block) was 78.4% (n=2); and
- 1.5g/kg cereal pellets in bait bags was highly variable.

Reasons for lower than anticipated kill rates can include: bait shyness/aversion as a result of prior sub-lethal exposure to baits containing 1080; ingestion of a less then lethal dose due to loss of 1080 from the baits due to weathering/leaching/poor bait palatability; poor masking of the taste/smell of 1080; less than optimal toxic loading requiring possum to find and ingest more than one bait. Switching between different bait types (cereal, carrot) and/or different lures (eg, cinnamon, orange) when treating the same area in subsequent operations can assist in minimising bait shyness (O'Connor and Matthews 1999).

F3.2 Rodents

New Zealand is reported as the only country in the world where broad-scale control of ship rats (*Rattus rattus*) is undertaken to protect other species from predation, elsewhere crop-protection is the main focus of control efforts (Innes et al 1995).

Rat populations have been observed to decline rapidly (more than 90%) within 2–3 weeks of aerial 1080 operations (Innes et al 1995). The authors also noted that an acute poison such as 1080 is needed to respond to rapid increases in ship rat numbers where threatened bird (and other) species require immediate protection due to slower acting nature of other available poisons such as brodifacoum. The recovery of ship rat populations to pre-control levels within 2–5 months of a 1080 control operation has been noted by several authors (Warburton 1998 and Innes and Williams 1991, cited in Perfect and Bell 2005; Innes et al 1995). Operations targeting ship rats, or relying on a by-kill of rodents, therefore need to be timed to maximise benefits for biodiversity outcomes as noted by Flux and Innes (2001) where a 1% tracking frequency for ship rats is required at 1 November for kokako protection as the peak breeding period for kokako is October onwards; 5% is acceptable, but more than 5% represents failure.

Mouse populations (*Mus musculus*) are reported to increase rapidly 3–6 months after reductions in ship rat numbers, peaking after approximately 9 months before declining to pre-poisoning levels (Miller and Miller 1995; Innes et al 1995).

As noted in section F3.3, the indirect effects of possible changes in predator-prey relationships are a key area of ongoing research.

From p 391 of application, kill rates achieved in DoC rat control operations were:

> *Rats* (operations since 1990, following standard operational procedures)
>
> The mean percentage kill following pre-fed aerial operations using 1.5 g/kg 1080 cereal pellets was 92.7% (n=3).
>
> The kill rates for bait bag operations using 1.5 g/kg 1080 cereal pellets was 87.7% - 100%

Innes et al (1995) note the reduction in efficacy due to repeated use of 1080, resulting in learned aversion or bait shyness. Changes in bait flavour or the bait matrix can assist in reducing bait shyness, as can switching to alternative toxicants such as brodifacoum, although the latter is significantly more persistent and slower acting than 1080.

F3.3 Predators (excluding possums and rats)

Possums, stoats (*Mustela erminea*), weasels (*M. furo*), cats (*Felis catus*) and rats (*Rattus rattus*, *R. norvegicus*) are all known to prey on native birds and invertebrates (eg, Murphy et al 1999). Mice (*Mus musculus*) compete with native species for food such as fruits, seeds, and prey on invertebrates (Ruscoe and Murphy 2005).

Mammalian predators are frequently killed during 1080 operations targeting possums and/or rats as a result of secondary poisoning from feeding on poisoned carcasses. A reduction in predator numbers over large areas of land is seen as a significant benefit to agencies undertaking pest control for conservation/biodiversity management purposes and also for Tb vector control. The indirect effect of reductions in predator numbers in terms of prey switching and impacts on native species is an active area of research. Indications are that in some circumstances, the anticipated benefits of possum and rodent control may result in unforeseen impacts on highly valued species through prey switching, for example, decreased rodent numbers and leading to increased stoat predation on birds (Murphy et al 1998a; Tompkins and Veltman 2006).

No 1080 formulations are currently approved for use against mustelids as the target species. However, as noted below they can be affected by secondary poisoning from ingestion of rodents containing 1080 residues.

An aerial 1080 operation targeting possums and ship rats in Pureora Forest killed all 13 radio-tagged stoats within 2–18 days of the operation (Murphy et al 1999). The authors noted that, previously, achievement of high rates of secondary poisoning of stoats has been focused on the use of the anti-coagulant brodifacoum, rather than on 1080. Brodifacoum is known to cause significant persistent residues in game and other non-target species when sub-lethal doses are ingested (eg, Murphy et al 1998b).

In a similar study at Trounson Kauri Park, Northland, with 1080 baits in bait stations, all radio-tagged predators (six feral cats, one stoat and one ferret) died of secondary poisoning within 5, 10 and 21 days respectively (Gillies and Pierce 1999). All dead animals contained 1080 residues. Examination of gut contents indicated consumption of poisoned rodents or feeding on possum carcasses. Two non-tagged cats were also found dead two days after the operation commenced, one of which contained 1080 residues.

Secondary poisoning of ferrets and cats scavenging poisoned rabbit carcasses has also been observed (Heyward and Norbury 1999).

One formulation is currently approved for use specifically against feral cats though cats may also be affected by secondary poisoning from possum, rodent and rabbit control operations using 1080.

F3.4 Herbivores (excluding possums)

F3.4.1 Rabbits

There was very little information in the application regarding rabbit control, presumably as this species is not a key pest for either the AHB or DoC.

Two bait strengths are currently approved for rabbit control, 0.02% 1080 on carrot, oats and apple and 0.06% apple paste. The application rates for applying 1080 vary according to the density of rabbits, with sowing rates at >40 kg/ha (Otago Regional Council provided as additional information from the applicants, 22 December 2007).

In an assessment of rabbit density in the Mackenzie Basin, 0.02% carrot was laid over 1000 ha and numbers of dead rabbits counted in 26 1 ha quadrats 11–20 days later (Moller et al 1997). A kill rate of more than 90% was achieved in 20 of the 26 quadrats, and as low as 50% in the remainder. Greater kill rates occurred in the areas with highest rabbit density. Nine percent of carcasses showed signs of scavenging, with one feral cat found dead in one of the quadrats.

The National Possum Control Agency best practice guidelines indicate that treated oats are best suited to dry areas and are not widely used, and are particularly unreliable when aerially applied (NPCA 2006). The Otago Regional Council indicated that it used more than 500 tonnes of carrot and 4 tonnes of oats in 2006 (additional information from the applicants, 22 December 2007).

Prey switching by cats and ferrets from rabbits to other species may occur following rabbit control operations, with native skinks highly vulnerable to large swings in numbers of rabbits (Norbury 2001).

Resistance to 1080

Some rabbit populations in south-western Australia appear to be developing resistance to 1080 due to over-reliance on a single control method (Twigg et al 2002). The sensitivity of wild-collected rabbits from four populations was tested using a modified LD_{50} procedure, with the results indicating that three out of the four populations were less sensitive to 1080 compared with Australian rabbits 25 years previously. The LD_{50} values for the three groups ranged from 0.744 to 1.019 mg pure 1080/kg and were significantly greater than those previously reported (0.34–0.46 mg pure 1080/kg). The LD_{50} for the fourth group was 0.584 mg/kg, not significantly different from the historical values and those animals were from an area with the least prior exposure to 1080. In the field, efficacy of 1080 baiting was lower in populations which had the higher LD_{50}s, with mean reductions in numbers of 52% to 65% in the resistant populations and about 76.5% in the sensitive populations. The authors attribute the increased resistance to an over-reliance on the 'one-shot' oat baiting strategy (not used in New Zealand), where highly toxic oats are mixed with untreated oats before deployment. A single toxic oat contains sufficient 1080 to kill three average rabbits, with 80% of the 1080 absorbed by the husk. Factors which may contribute to ingestion of a sub-lethal dose include: leaching of 1080 from the oats, de-husking of the oat grain by the rabbit and consumption of less than a whole grain.

Resistance of rats and house flies to 1080 has also been reported (Howard et al 1973, cited in Twigg et al 2002).

F3.4.2 Wallabies

Both Bennett's (*Macropus rufogriseus)* and Dama/Tammar (*R. eugenii*) wallabies are considered agricultural and conservation pest species in New Zealand. The brush-tailed wallaby (*Petrogale penicillata penicillata*) was also considered a pest on Rangitoto and Motutapu Islands in the Hauraki Gulf (Mowbray 2002).

Cereal pellets at 0.2% 1080, treated carrot at 0.15%, and high strength gels (5% and 10% 1080) are approved for wallaby control. DoC has indicated that the cereal pellets are not very palatable to Dama wallabies, whereas treated carrot is highly palatable (further information from the applicants 22 December 2006). On p 391 of the application, it is stated that a wallaby kill of more than 90% was achieved after a pre-fed aerial operation using 0.15% 1080 carrot bait.

The brush-tailed wallaby was successfully eradicated from both Rangitoto and Mototapu Islands through a combination of methods which included aerial application of 0.08% 1080 pellets followed up with hunting (Mowbray 2002). Cyanide and trapping were also used as follow up control for possums.

Use of 1080 gels to control wallabies is not common at present. In the 1980s and 1990s most of the work was undertaken by Wallaby Control

Boards, which have been disbanded and their records are not readily accessible, if at all. Bennett's wallaby were not considered a problem during the late 1990s but have now increased to the point where the use of 1080 (carrot, pellets, gel) is being considered as a tool to reduce their numbers. Gel has been used to control Dama/Tammar wallabies in forest and scrub but a suitable and cheap monitoring technique is not available, so kill rates are difficult to estimate (further information from DoC, 22 March 2007).

Trials have been undertaken in Canterbury to control Bennett's wallaby in 1983 using 10% gel and in Rotorua in 1988 to control Tammar wallaby using the 5% gel. The results were compared with those from aerial 1080 operations (Warburton 1990). In both trials the gel was applied to leaves of preferred trees/shrubs.

The mean kill of Bennett's wallabies was 91.3% based on faecal pellet counts, and reported as relatively uniform, with 10 of 12 transects at >80% and the other two at 64% and 73%. Two aerial operations which had targeted the same species in nearby Waimate forests resulted in less than 10% to 70% kills (Warburton 1986 cited in Warburton 1990). The Rotorua gel trial resulted in a mean kill of 86.2% of Tammar wallabies, which was below that achieved in two aerial operations with kills of 95.9% and 93.7% (DoC 1987, 1989, cited in Warburton 1990).

F3.4.3 Ungulates

A high-strength 1080 gel (10%) is available to target deer and goats by applying the gel to leaves of preferred plant species.

DoC has advised that they have not yet undertaken any full scale operation using the gel for goat control (additional information from DoC, 22 March 2007). A trial with the gel was undertaken in 1982 (Parkes 1983) to assess the efficacy of a 10% 1080 gel (carbopol-based) in a 1200 ha block in a sub-catchment of the Motu River. Twenty leaves per branch were treated with 0.25 g of gel (one leaf effectively delivering a leaf dose for a goat. Fifty three carcasses were located after the poison was laid, 'with others being smelt' but not actually located, and possibly other carcasses not being found due to the nature of the terrain. A hunting trial was conducted in an adjacent 1,200 ha block resulting in 112 shot out of 127 seen. Assessments of faecal pellet densities and counts of animals seen were used to assess the effectiveness of hunting and poisoning relative to that of a control block. However, the author indicated that neither of the indices derived was capable of much precision, so it was not possible to draw a conclusion as to whether hunting or poisoning was more effective. The pellet count indicated poisoning was most effective, and animal counting indicated hunting was more effective. Similar man-hours were required to lay poison (56 hours) and to hunt (61 days), with far greater skill required for hunting. As this was a trial, several matters were noted for improvement in future eg laying bait only on goat-preferred tree/shrub species and in goat-preferred feral habitat.

Full operational use of the 10% gel has also not been undertaken in recent times to control deer (further information for the applicants 22 March 2007). There are reports of the gel having reduced populations of white-tailed deer on Stewart Island by over 90% in the 1980s (Challies and Burrows 1984, cited in Fraser et al 2003) and a moderate-density red deer population in the central North Island by 78% (Sweetapple 1997, cited in Fraser et al 2003). A form of the gel was also used on Secretary Island, Fiordland, in the 1970s to assist in controlling red deer, resulting "in 1976 to a significant reduction in the deer population" (Brown 2005). One non-target kill has been reported in association with the 10% gel, where one weka on Secretary Island was seen paralysed and subsequently died 15 minutes later (Main 1979, cited in Brown 2005). No analysis was undertaken for residues but proximity to area being baited indicated 1080 as the likely cause, with baits having slipped off treated leaf surfaces.

Treated carrot bait at 0.15% 1080 is also approved for use to target deer. As has been noted in section F2.4.3, variable deer kills have been achieved when targeted with carrot bait. Non-target kills have also occurred with cereal baits of varying toxic loading.

F3.5 Wasps

The introduced German and common wasps (*Vespula germanica* and *V. vulgaris*) are significant competitors with native birds for both invertebrates and honeydew in beech forests and invertebrates in scrubland-pasture (Harris and Oliver 1993). They also are known to prey on nestling birds (Moller 1990).

A fish-based paste containing 10 g/kg (1%) 1080 is approved for use to control the German and common wasps. However, the applicants only provided one study on the experimental use of the paste, which they reported indicated a high degree of efficacy (Spurr 1991), but no studies monitoring its more general use. Monitoring reports from Rotoiti (eg, Paton et al 2005), where wasps are a significant problem, indicate that alternative substances have been used instead.