Appendix 1

Bait Improvement Initiatives – meeting discussion

Meeting: 10th Focus Group Meeting on Bait Quality
Date: 15 Oct 2014

Attendees: Matthew Hall, [redacted], Derek Kirk (Chairperson, ACP), [redacted]
Apologies: [redacted]

Chair: [redacted]

Review minutes from last meeting

Action points:

- [redacted] to finalise initial specification and distribute to manufacturers for consultation In progress
- [redacted] to check what type of bait is being used in the trials RS5 or No7 Complete (RS5)
- [redacted] to distribute bait sampling results to group. [redacted] to add to chart if deer repellent is used in each bait sample Complete
- [redacted] to advise if bait sample size can be increased [redacted] advised that ACP would prefer to take more samples of 10 baits rather than larger sample sizes. Have introduced online testing in the last 3 months
- [redacted] to invite [redacted] to next meeting Complete – unable to attend but will attend future meetings

Other notes:

- [redacted] questioned the sensitivity of the information distributed to the group regarding the ACP toxic bait size. Matthew advised that the information is received from the aerial contractors and part of our SOP procedure for all toxic bait.
- Page 2 of the minutes from the 9th bait meeting in the fragmentation section, paragraph 2 described the 'Kohl' tester in error, this should read 'Holmen' tester.
- [redacted] commented on the roadmap presented at the last meeting being a useful tool to show the work-streams related to the whole bait improvement initiatives project.
- Clarification that on the bait size analysis data for aerial operation that was distributed with the previous meeting minutes, the percentage of baits greater than 8g is calculated by *weight*. The sum of the weight of all baits >8g is divided by total weight of the sample.

Bait specification

[redacted] and Matthew have been working on a joint bait specification between DOC and TBfree. Data for 6-8g bait has been received from DOC. This has just been received from DOC so bait manufacturers will now be consulted. The objective is to have an agreed specification agreed between DOC, TBfree and bait manufacturers.
6-8g bait is mainly used in DOC operation and for TBfree's pre-feed.

Action: [redacted] to review 6-8g data and determine a spec for the size of the bait required. Once this is agreed consultation with manufacturers is to commence.

Optimum bait size
ACP has advised that they have implemented online testing every 30 minutes to ensure that there is a tight range in bait size produced.

[redacted] asked if there is related post operation RTC data that can be compared with the bait size sampling carried out before TBfree aerial operations. Matthew advised that only a few operations are monitored post operation for RTC data due to the cost involved and also because directly after the operations the RTC usually comes out much lower than what is actually the case. [redacted] suggested that this may be because a) survivors have eaten a sub-lethal dose making them more cautious, b) survivors may live in the trees more than forage on the ground, hence not eating the bait or picked up during monitoring or c) they may be more cautious due to the population taking a dramatic decline.

Trigger monitors are carried out 3 years after operations unless there is a particular issue with the operation that we may think will have a negative effect (e.g. bad weather), in which case the monitor will usually be done 6 months after the application date.

Discussion around the TBfree sampling procedure and if in certain cases, more than 1 sample per batch should be taken (e.g. samples taken from different parts of the storage facility for bait in the same batch).

Report for the 2nd phase of the study in Wanganui is due on the 15th Dec.

Action: [redacted] to discuss the TBfree sampling requirements with [redacted]

Discussed at previous meetings. Not discussed in detail in this meeting. Added for info:
Key findings from the first phase of optimum bait size field study (R-10756) – June 2013:

- There was no indication that eating small amounts of bait (<2g) resulted in possums not eating bait on subsequent encounters. Some possums ate whole baits on subsequent encounters even after consuming up to 7g of bait.
- The results suggest that, for a large-bodied possum population, a bait size of more than 9g is required to achieve near total mortality from a single bait encounter. However, for smaller-sized populations, 8-9g baits may be sufficient.
- The preliminary recommendation is that TB managers continue to use 20mm baits as the default bait choice, but attempt to somehow minimise the tail of <7g baits within the bait-size distribution.
- One alternative to using large 20mm diameter baits might be to increase the toxic loading of 1080 from 0.15% to 0.2%. A 9g bait with a toxic loading of 0.2% would become as lethal as current 12 g baits with 0.15% toxic loading. Furthermore, a change to 9g baits with the higher toxic loading would decrease the amount of bait required per ha by 25%.

Bait shyness findings

- Not all pre-fed possums consumed bait on first encounter. However, only a minor part of this seemed to reflect some form of bait aversion, as most readily ate whole baits on later encounters.
- There was no indication that eating small amounts of bait (<2g) resulted in possums not eating bait on subsequent encounters. In fact, some possums ate whole baits on subsequent encounters even after consuming up to 7g of bait. That suggests that learned bait aversion

may not develop unless the dose ingested is very close to the lethal dose for that particular possum.

Bait hardness and palatability

Assessing the hardness and palatability of baits produced with and without deer repellent milestone report complete. Key findings:

- EDR- treated baits were significantly harder (mean breakage value = 20.5kg, SE 0.5kg) than non-treated RS5 baits (16.1kg, 0.4kg respectively) ($t = 6.97$, d.f.= 38, 2-tail $p < 0.001$). This indicates that some part of the EDR treatment process (mostly likely the outdoors drying process) results in baits being slightly harder than the maximum breakage value of 18 kg (using the kahl motorised tester) recommended in previous research.
- There was no difference in palatability of the EDR- treated bait (39.9%) and the non-treated bait (39.5%). The hardening that occurred during treatment with deer repellent was not sufficient to reduce palatability. It is possible however that a reduction in palatability due to increased hardness was counterbalanced by improved palatability due to the taste of the deer repellent. Such an effect has been reported anecdotally (it is believed that in some operations rats and possums have removed the EDR coating and left the bait behind).

Discussed that it would be useful for all bait manufacturers and contractors doing the bait size analysis should also have either a manual or motorised test (manual in the field). This means that the results can be compared throughout the process. 9(2)(a), 9(2)(g)(ii) advised that a penetrometer less useful for comparing data due to the variation of the tips.

It would also be useful for EPRO to monitor bait hardness using the kohl tester during drying to ensure that it remains under the 18kg maximum hardness specification

9(2)(a), 9(2)(g)(ii) advised that a minimum sample of 10 baits (per unit of interest) is required to get reliable results. 9(2)(a), 9(2)(g)(ii) bought a manual tester recently for approx. $1250 including freight and duty etc.

Action: ACP & TBfree & EPRO to look into purchasing a kahl tester.

Bait durability

9(2)(a), 9(2)(g)(ii) reported that in recent research 95% of 88 radio collared possums died within 36 hours of bait being put on the ground, indicating that long lasting baits are not always necessary, though the time of year, other food sources available to possums and low sowing rates need to be considered also. No 7 is known to be more durable than RS5 in adverse weather.

Fragmentation

Discussed current plan to design test to measure fragmentation from manufacture through to application. The original design to fly over a piece of land and collect samples from the strip has become unfeasible after speaking to a statistician about bait collection. 100% of bait from the sample area would need to be collected. Also the amount of bait that would need to be applied for sampling would be very concentrated. New design is not to fly the bait over land but instead to lift the buckets over a robust container which would mean that all of the sample would be contained. Concern that hitting the container will influence the results, however if low fragmentation occurs then the test will show that fragmentation due to the bucket spinner is not a major concern. Further work on the design to be carried out.

9(2)(a), 9(2)(g)(ii) advised that if hardness of the bait is measured before each test, the fragmentation testing may also indicate what the minimum specification for hardness should be.

Bird repellent

[redacted] unable to attend this meeting as she is on a training course but will attend future meeting to update the group.

A kea repellent project de-brief was held on the 23rd of July to determine the next steps in the project as funds become available.
The following 5 research areas were identified as the next steps towards developing a bird repellent to protect kea:

1. Continued investigation of anthraquinone as a secondary repellent, for situations where:
    - Possums are the only target or
    - Rats are absent from the site or not the priority target
2. Seek advice from food technologists and chemists on likelihood and pathway for developing a stabilisation method for d-pulegone in cereal matrix.
3. Carry out a kea behavioural trial using d-pulegone RS5 cereal pellets, to confirm whether d-pulegone acts as a primary repellent in its own right (if advice in step 2 is favourable)
4. Carry out preliminary field screening of other potential repellents (e.g. tannic acid, caffeine (LCR), cinnamamide, garlic oil)
5. Test whether the Willowbank aviary kea would readily consume 0.14% anthraquinone baits if re-presented with the baits in several months' time.

Kea exclusions are a concern for TBfree for aerial operations and the importance of developing a bird repellent was re-iterated (DOC code of practice for aerial 1080 in kea habitat attached with minutes). With no major projects currently in place funding for the proposed next steps need to be discussed.

Action: [redacted] and [redacted] to meet to discuss possible funding options with [redacted] from DOC and report back to the group at the next meeting.

Deer repellent
See bait hardness & palatability section for further information regarding deer repellent.

A new study by Landcare Research is to be carried out to determine if deer repellent also repels horses (a non-target species). The literature found to date says that horses are not usually good with smell repellents and prefer sound repellents.

Other
Battle for our Birds: Alastair updated the group that DOC were roughly about 1/3 of the way through the battle for the birds operations which will run through until November.

Pigs – non target species: Update on claims that aerial operations were killing a large number of pigs in the north island. 9 pigs were found in a cluster in an area over 16,000ha in size. This could potentially be near an area where bait was trickle fed but not confirmed. [redacted] advised that for a 50kg pig it would need almost 5 baits to ingest a lethal dose.

Research: Update from [redacted] that the Hokonui proof of concept area is looking positive for TB eradication in the wildlife.

1080 Communication: Matthew advised that all of the groups involved in the communication of the positive 1080 story (DOC, Forest and bird, regional councils, federated farmers, 1080 facts website) are meeting on the 16th Oct to ramp up the interaction with the public and co-ordinate a collaborative response to negative media.

Sodium fluoroacetate: Noted that the EPA has said that it is OK to use Sodium fluoroacetate on warning signs without referencing to '1080'.

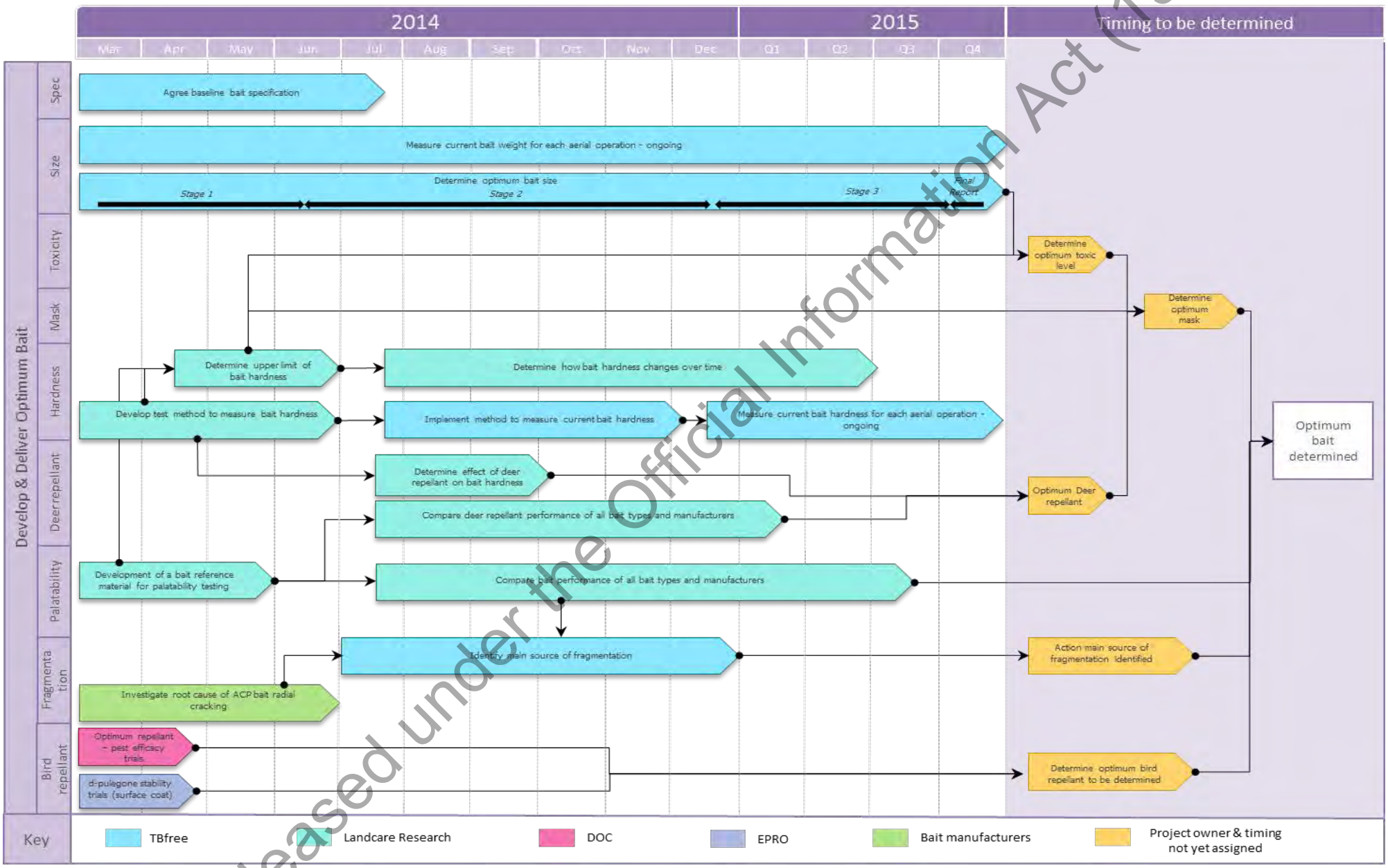
Summary of action points from this meeting:

- [redacted] to review 6-8g data and determine a spec for the size of the bait required. Once this is agreed consultation with manufacturers is to commence.
- [redacted] to discuss the TBfree sampling requirements with [redacted]
- ACP & TBfree & EPRO to look into purchasing a kahl tester.
- [redacted] and [redacted] to meet to discuss possible funding options with [redacted] from DOC and report back to the group at the next meeting.

Date for next meeting

Wednesday 28th January

Bait Improvement Initiatives Roadmap



Appendix 2

DOC code of practice for aerial 1080 in kea habitat

Version 1.0 approved for use effective from 1 June 2014.

The code will be reviewed by 1 February 2016. The code is a working draft and will be finalised when the supporting research is published.

Approved by

Suzanne Edwards
Acting Deputy Director-General Science and Capability
Date: 5 May 2014

Supported by

Kevin O'Connor
Deputy Director-General Conservation Services
Date: 23 April 2014

Date	Amendment details	Version Number
7 May 2014	Working draft of the Code released	1.0

1. Purpose

This code of practice sets out the compulsory performance standards that must be followed for aerial 1080 operations in areas where kea may be present on land managed by the Department of Conservation (DOC). These compulsory performance standards apply throughout the distribution of kea (Appendix 1). This includes new standards to achieve effective control of stoats with all aerial 1080 operations, so that any potential kea deaths are offset by improved productivity and survival. By designing operations to control stoats, we can reverse the decline of kea at managed sites.

This code is based on our current understanding of the risks and benefits of aerial 1080 to kea. Relevant research is summarised in four areas: predators of kea; non-target risk to kea at aerial 1080 cereal operations; benefits to kea from predator control via aerial 1080 cereal operations; and repellents to protect kea at aerial 1080 cereal operations.

2. Summary of kea research

2.1 Predators of kea

The kea is a large parrot endemic to the Southern Alps of New Zealand and is the world's only mountain parrot (Higgins 1999). Kea were re-classed from 'Not threatened' to 'Nationally Endangered' by Robertson et al. (2012); the criteria for this classification are a population estimate of 1000–5000 and an ongoing or predicted decline of 50–70% in the total population over the next 10 years due to recruitment failure. In order to prevent this decline, effective predator control is critical.

The kea is vulnerable to a range of introduced mammalian predators due to its ground-nesting habit and extended nesting cycle (i.e., it takes four months to fledge young, Jackson 1963). Kemp et al. (2014) identified the key predators of kea using a combination of nest cameras, corpse necropsy and inference from predator density fluctuations during nest survival monitoring. Nest cameras recorded visits by stoats, possums, ship rats, house mice and weka. Stoats were identified as the predator in 3 of the 16 nest failures recorded while no positive identification was possible for the other cases. Statistical modelling of the effect of predator visitation on nest survival suggests that visits by stoats, possums and rats were predictors of nest failure, with the strongest support for stoat visits. Two predation events were confirmed by corpse necropsy; one death by stoat predation was confirmed by DNA analysis and the other kea was predated by either a falcon or stoat. Kemp et al. (2014) also analysed the survival odds of kea nests at a rimu forest before, during, and after a mast event with no predator control. Survival odds were related to changes in stoat abundance but not to changes in rat abundance, implicating stoats as the important predator.

We have photographs of a possum appearing to kill kea chicks (DOC no date). However stoats are the far more important predator, particularly following mast events when kea nest failure and predation of juveniles and adults are at their greatest.

2.2 Non target risk to kea from aerial 1080 cereal operations

DOC is concerned about the potential population impact of kea deaths observed at some aerial 1080 cereal operations. Kea survival has been monitored through 10 aerial 1080 cereal operations in 9 locations (Appendix 2). Kea were captured and tagged with VHF radio transmitters prior to the operation; the transmitters were fitted with motion sensors that record the time (hour) when motion ceased. A total of 150 kea were monitored and 20 kea deaths resulted from consuming 1080 (Kemp and van Klink 2014). All 20 kea deaths occurred in the 3 operations where we monitored the largest samples of birds (Appendix 2). It may be that kea in these locations are at higher risk for some site specific reason. It is also possible that kea deaths were not detected at the other sites due to small sample size.

It appears that most kea ignore 1080 pellets but a small number are poisoned by them. Half (10) of 20 of the detected kea deaths occurred the day after 1080 baits were sown; 6 occurred within 2–5 days and 3 occurred within 10–14 days. One bird died 35 days after the operation but 1080 poisoning could not be confirmed by the time the corpse was recovered. Bright green contents (1080 cereal remains) were found in the gizzard or crop of the 18 corpses recovered in time for autopsy (Kemp and van Klink 2014; van Klink and Crowell 2014). This indicates direct poisoning of kea from eating 1080 cereal (as opposed to secondary poisoning from possum carcasses) and that probably more than one pellet was consumed. 1080 was detected in muscle tissue for all of the 11 birds tested.

2.3 Benefits to kea populations from predator control via aerial 1080

Predator control needs to take place on a landscape scale to protect kea nests from predation by stoats for two reasons:

- Kea breeding pairs and nests are found at a low density (Jackson 1960) so broad scale control is needed to cover even a small number of nests. For example, Bond and Diamond (1992) estimated that there were between 0.14 and 0.40 nests per hectare.
- Stoats have a large home range and dispersing young are capable of long distance travel (King and Murphy 2005). Stoats are short lived with high productivity (up to 13 young per year when food supply allows) so localised small scale control measures are quickly undone by immigration. Methods must target female stoats

are essential to achieving effective control. For example, an extensive area must be controlled to when stoats are targeted to protect other threatened bird species, such as Okarito kiwi (Miller et al. 2001).

Aerial application of 1080 baits is one of the main methods of rat and possum control on a landscape scale in New Zealand and can be effective for reducing stoat numbers through secondary poisoning. Murphy et al. (1998) first recorded a reduction in a stoat population following aerial 1080 by secondary poisoning; they observed prey remains in 12 of 13 radio-tracked stoat corpses after the operation including rat remains in 8 corpses and possum remains in a single corpse. Rats are reliable vectors for poison, based on consistent rat kills at aerial 1080 cereal pellet operations which are pre-fed (Fairweather et al. 2013) and on their common occurrence in the stoat diet (King and Murphy 2005). The significance of possums and mice as poison vectors for stoat control is less certain and has not been directly measured (i.e., in the absence of rats). Data on mouse kill from aerial 1080 cereal pellet operations appears to be variable, although we do not know if this will affect stoat kill (Fairweather et al 2013). If rats aren't present in a forest, such as at high altitudes or in pure beech forests, we are unsure of the extent of the stoat by-kill that would be achieved.

The potential benefit to kea populations from aerial 1080 cereal operations has been investigated by Kemp et al. (2014), through long term monitoring of kea productivity and survival at sites before and for 2 kea breeding seasons after aerial 1080 operations. This included a controlled (before-after-controlled-impact or BACI) study with a non-treatment area for a lowland rimu forest in Westland and a correlative modelling approach for 5 upland beech forests.

The BACI study monitored predator dynamics and kea nests before and after an aerial 1080 operation in the spring of a mast year (2011) at Okarito forest in Westland, as compared to the same measures at nearby Fox-Paringa forest where predators were not controlled. Aerial 1080 reduced the stoat tracking index to near zero for 2 kea nesting seasons whereas the stoat tracking index increased to about 80% in the year after the mast (the 'post seedfall year') at Fox-Paringa (Appendix 3). Kea nest survival was estimated in the treated area as 100% in the mast (seedfall) year and 69% in the post seedfall year, whereas nest survival in the untreated area was estimated as 38% and 1% respectively. During the 2 breeding seasons after the rimu mast, kea productivity was estimated at 4 times higher at the treated area (1.4 fledglings per adult female) than at the untreated area (0.32 fledglings per adult female).

Kemp et al. (2014) also monitored predator dynamics and kea productivity and survival at 5 upland beech forests, 3 of which were treated with aerial 1080 (including stoat trapping at one site). Beech mast (seedfall) occurred in all five upland beech forests in 2009, followed by a stoat irruption in early 2010. They concluded that kea productivity is near zero during uncontrolled stoat irruptions in beech forest, as it was in rimu forest. In the years between mast events, kea

productivity is 0.44 fledglings per adult female on average, but this increases to 0.95 fledglings per female with effective stoat and possum control. Again, this was similar to what was observed in rimu forest.

Operations need to occur when rodents are widespread in order to achieve effective stoat control. At Mt Arthur, the operation took place in May 2009, when rodent numbers were still climbing following beech mast seeding (Appendix 3). Monitoring showed that the stoat irruption was not prevented (Appendix 3), several adult kea disappeared and no kea nests were found despite extensive searches.

In summary, effective stoat control improves kea productivity and survival whereas unchecked stoat irruptions following mast years are strongly negative to kea populations. In order to make up for the few adult kea sometimes killed in aerial 1080 cereal operations, all operations should be designed to achieve stoat control. This can be achieved easily during and soon after a mast year, provided operations are timed for when rats are widespread. However it is less clear cut between mast years. For example:

- Effective stoat control appears more likely where rats are widespread in the operational area, but we do not know for sure if this is true when rats are scarce but mice and/or possums are widespread. Mice can be very patchy in their distribution in non-mast years.
- We know lowland mixed forests usually have rats but in upland pure beech forests they can be scarce between mast events. The transition from prevalent to low rat densities is likely to happen somewhere between 500 and 700m in mixed forests depending on the site and the season.

2.4 Repellents to protect kea at aerial 1080 cereal operations

The Department of Conservation is working with others to develop, register and implement an effective bird repellent to prevent kea deaths at aerial 1080 cereal operations (Crowell 2014). A number of trials have taken place in aviaries (Orr-Walker et al. 2012), pens (Cowan et al. 2013), and in the field (Kemp 2010, Crowell et al. 2014b, van Klink and Crowell 2014) since 2008, focussing on d-pulegone (which has a strong minty odour disliked by birds) and anthraquinone (which birds learn to avoid after post-ingestional discomfort). The research program is working to overcome limitations for each of these repellents. For d-pulegone, the focus is on stabilising the compound in cereal baits because monitoring has shown that it dissipates in manufacture and storage (Crowell et al. 2014a, van Klink and Crowell 2014). The addition of anthraquinone at the level used in the trials (0.1% wt/wt) seems to be detected and avoided by rats (Cowan et al. 2013). The proportional reduction in rat tracking was less in plots where both repellents were used, as compared to plots where d-pulegone or no repellents were used (Crowell et al.

2014b). The rat and kea responses to lower concentrations will be investigated; this may include using anthraquinone in experimental plots within an aerial 1080 cereal operation. Other repellents have been identified for preliminary screening with wild kea in 2014.

We are preparing for an aviary trial to test whether kea can be repelled from eating cereal pellets that contain anthraquinone (without d-pulegone). If successful, we will look at the feasibility of feeding kea non-toxic repellent cereal pellets prior to some operations, such as at car parks and huts, as part of the risk management.

None of the repellents are ready for operational use in 2014, other than a possible trial of anthraquinone in plots to monitor rat kills and a possible kea bait aversion programme at some operations should aviary trials provide strong evidence of efficacy. Whilst an effective repellent would prevent deaths of kea at aerial 1080 operations, we still need to reduce stoat predation in order to reverse the decline of this species.

3. Compulsory performance standards in kea habitat

This code of practice states and explains the compulsory performance standards that will apply to all pest operations aerially applying 1080 within the distribution of kea (Appendix 1) on land managed by DOC, using one of the following registered methods:

- Aerially applied 0.15% 1080 Pellets (pesticide use #1 on the DOC Status List)
- Aerially applied 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets (pesticide uses #7 and #10)
- Aerially applied 0.2% 1080 Pellets (targeting wallabies, pesticide use #22) or 0.04% 1080 Pellets (targeting rabbits, pesticide use #14) and aerially applied 1080 carrot (pesticide uses #25, 30, 33)

3.1 Aerially applied 0.15% 1080 Pellets

There are two sets of compulsory performance standards for all operations using aerially applied 0.15% 1080 Pellets within the distribution of kea (Appendix 1). The first set aims to reduce kea deaths and the second aims to ensure benefit to kea from stoat control.

3.1.1 Compulsory performance standards to reduce kea deaths:

Standard 1: Only use cinnamon-lured RS5 pellets.

Standard 2: Use a maximum of 2kg/ha of prefeed bait for 12g baits (or 1kg/ha for 6g baits).

Standard 3: Use a maximum of 2kg/ha of toxic bait for 12g baits (or 1kg/ha for 6g baits).

RS5 pellets are required because both Luey (2009) and Blyth (2011) observed a preference for Wanganui #7 baits amongst captive kea. The lure must be cinnamon because all kea monitoring has followed aerial operations using this lure. We do not know how other lures would affect bait attractiveness to kea.

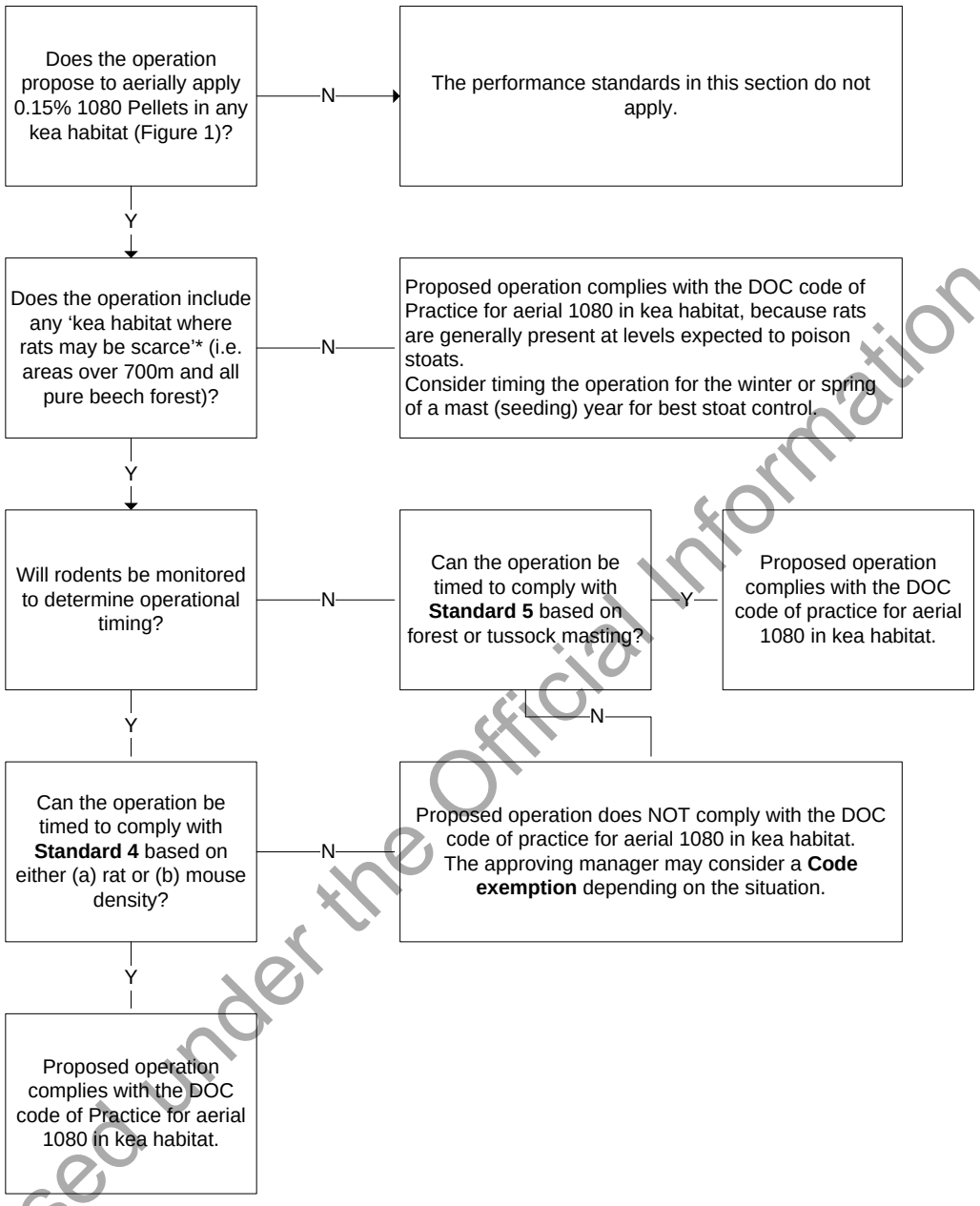
We restrict the prefeed sowing rate in order to limit kea encounters with prefeed pellets. Kea consumption of prefeed pellets could increase the likelihood that kea eat toxic bait.

We restrict the toxic sowing rate in order to limit kea encounters with toxic pellets.

A previous standard has been removed, which prevented baits being sown in areas of low structural vegetation cover (e.g. alpine herb fields and tussock) above the tree line. This was intended to protect kea by keeping baits out of open areas that could be easily avoided. Subsequent kea deaths at Okarito and Otira suggest that most kea ignore 1080 pellets but a small number will find and eat them whether they are highly visible or not. This draws into question the effectiveness of the alpine exclusion standard. At the same time, a need for predator control in alpine environments is emerging (O'Donnell 2013). Stoats and mice are prevalent predators in the alpine zone and possums are significant predators of snails.

3.1.2 Compulsory performance standards to ensure that kea benefit from stoat control:

This flow chart is designed to determine whether Standard 4, Standard 5 or neither standard applies to a proposed 0.15% 1080 cereal operation in kea habitat.



*A shape file of 'kea habitat where rats may be scarce' is available to DOC staff on the NATIS system: \\natissvr\NEGIS_connections\NATIS_1.sde\natis1.NATISADM.FAUNA_DOC_KeaHabitatScarceRats

It will be also be published on the DOC geoportal:
http://geoportal.doc.govt.nz/geoportal/catalog/main/home.page

Standard 4: Toxic bait application can occur when either (a) or (b) are met:

(a) Within 6 months prior to the operation, the tracking index for **rats** is 20% or higher on 8 out of 10 transects monitored in the operational area (following Gillies and Williams 2013).

Or

(b) Within 6 months prior to the operation, the tracking index for **mice** is 20% or higher on 8 out of 10 transects monitored in the operational area (following Gillies and Williams 2013). In this case, rats and mice must be monitored (ideally 2 weeks) before and after the operation; this monitoring should also include stoats where suitable transects are in place. Monitoring results must be reported and raw data made available, including any pre- and post-operational monitoring of possums (where completed, to allow the role of possums in secondary poisoning of stoats to be evaluated).

In both (a) and (b) where operations occur in the year following a forest or tussock mast, toxic bait application must occur prior to 31st August in the post-seedfall year (i.e. prior to kea nesting, see Appendix 3, Figure 3).

The above rodent-based thresholds are based on our current understanding of stoat poisoning via aerial 1080 operations. Stoats do not eat 1080 baits but can be poisoned when they prey on rats (and possibly mice and possums) that have taken bait. These thresholds will be revised over time as we learn from future operations.

Because stoats are the main predators of kea, we expect that nest survival and kea productivity to improve in the two years following an effective stoat knockdown (Kemp et al. 2014). Timing operations to benefit kea should offset any kea deaths that might occur at some operations.

Standard 5: Where rodent monitoring has not been done, toxic bait application can occur when the operation includes forest or tussock in a mast (seedfall) year or in the year following (post-seedfall), as determined either by seed monitoring or by expert judgement. In this case toxic bait must be applied in the 14 month period between 1st July of the mast (seeding) year and 31st August of the following year.

This standard allows mast seeding to be used as a proxy for rodent density where rodent monitoring data is not available, such as for some possum operations. The timeframe is based on the trend of rodent and stoat abundance observed in previous beech and rimu masts (Appendix 3, Figures 1-3).

Code exemption: Where standard 4 or 5 have not been met, aerial operations using 0.15% 1080 Pellets can only proceed in kea habitat where rats can be scarce at the discretion of the manager approving the permission. The approving manager will take the following factors into consideration:

- Potential number of kea put at risk
- Existing data on pest numbers (possum, stoat, rat, mouse)
- Other measures in place to control stoats
- Any early indications of upcoming mast seeding events

Handlaid 0.15% 1080 Pellets

In most cases, handlaying is used in conjunction with aerial application and all the same standards will be compulsory. For operations that are entirely handlaid, the above performance standards are recommended. Some or all of these standards may be compulsory for a specific operation, at the discretion of the DOC manager who approves the DOC permission for the operation.

3.2 Aerially applied 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets

These pesticide uses are subject to a **compulsory restriction:** Aerial application of 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets is **PROHIBITED** in areas of kea habitat (Appendix 1) on land managed by the Department of Conservation (DOC).

This product is only available in the Wanganui #7 formulation, which was preferred over RS5 pellets by captive kea in 2 aviary trials (Luey 2009; Blythe 2011).

Handlaid 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets

It is recommended that 0.08% 1080 Pellets and 0.08% Rodent Pellets are not handlaid where kea are present, given that it is only available in the Wanganui #7 cereal formulation. The decision to prohibit or allow handlaying of 0.08% 1080 Pellets or 0.08% Rodent Pellets lies with DOC manager who approves the DOC permission for the operation.

3.3 Aerially applied 0.2% 1080 Pellets or 0.04% 1080 Pellets and aerially applied 1080 carrot

These pesticide uses are subject to a **compulsory information need**: Any aerial 1080 operation in kea habitat (Appendix 1) using 0.2% 1080 Pellets, 0.04% 1080 Pellets or 1080 carrot must be monitored for kea survival (with support from DOC Science & Capability and following Kemp and van Klink 2014 or van Klink and Crowell 2014).

Kea monitoring requires specialist skills, involving capture of kea and tagging them with VHF radio transmitters weeks or months before poison baiting. Telemetry surveys are carried out during the risk period following the operation, on foot and from aircraft.

No aerial 1080 operations using these cereal baits have been monitored for kea survival so the risk is unknown. The cereal baits used to target wallabies (0.2%) and rabbits (0.04%) are different from either RS5s or Wanganui #7s and neither is lured with cinnamon.

Two kea were monitored and survived in one aerial 0.08% 1080 carrot operation in 2007 (Kemp and van Klink 2008). This method is seldom used in kea habitat, but any future operations need to be monitored to help quantify the risk to kea. Carrot is eaten by captive kea and may be attractive to wild kea.

Handlaid 0.2% 1080 Pellets, 0.04% 1080 Pellets or 1080 carrot

It is recommended that any handlaid 1080 operation in kea habitat (Appendix 1) using 0.2% 1080 Pellets, 0.04% 1080 Pellets or 1080 carrot is monitored for kea survival.

4. Frequently asked questions

1) When using 0.15% 1080 Pellets, the 'performance standards to reduce kea deaths' refer to a maximum sowing rate of 2kg/ha for 12g baits. Our target sowing rate is 2 kg/ha but we allow for 3–4 kg/ha to allow for overlapping swathes. Does this comply?

   Yes. The maximum sowing rate in the standard is an average or nominal sowing rate.

2) The 'performance standards to reduce kea deaths' no longer include a standard to avoid sowing open areas above the tree line. Is sowing above the tree line encouraged to protect kea?

   No. The standard was removed for two reasons. First, kea have found and consumed toxic bait in two operations where this standard was applied. We now question the importance of vegetation cover in preventing kea from consuming toxic baits. Second, the previous standard prevents application of bait in alpine and tussock areas for predator control to protect threatened alpine species like rock wren. The benefit of predator control in alpine environments could outweigh the potential non-target risk of visible toxic baits in some places. This balance will be evaluated on a case by case basis in the DOC permission process for each aerial 1080 operation where sowing is proposed to occur above the tree line.

3) We are planning to sow 0.15% 1080 Pellets in some open alpine areas to protect rock wren. What is the best timing to achieve this, considering that there could be snow for some of the year? Should rocky areas above the tussock be excluded?

   Avoid sowing toxic baits on snow. With regard to rocky outcrops, these should be evaluated along with other timing and boundary decisions in operational planning. Seek advice from technical and science advisors for your situation.

4) Our aerial 1080 operation using 0.15% 1080 Pellets targets possums not rats. Do the 'performance standards to ensure kea benefit from stoat control' apply to this operation?

   Yes, the performance standards apply throughout kea habitat irrespective of the target pest. Follow the flow chart to see how your operation is affected.

5) I have checked the 'Kea habitat where rats can be scarce' shape file and only 10% of our operational area overlaps with the shape file. Do we need to comply with the 'performance standards to ensure kea benefit from stoat control'?

This should be discussed with the assessor at the time of application for DOC permission. Any decision to exempt a DOC permission from the Code is at the discretion of the approving manager for the DOC permission.

6) For standard 4, do we need to establish monitoring transects in all high altitude (>700m) or pure beech forest areas included in the operation? Does the operational area need to be stratified when designing the monitoring?

   Gillies and Williams (2013) state that "it is very important to ensure that representative environments are sampled within the areas you are interested in (e.g. a rodent control block). The easiest way to do this is to consider the gross environment types that make up your study site or management block and what proportion of the area they make up. So, for example, if 50% of your study area is red beech forest, then 50% of your sampling effort should include that environment." Apply this protocol to your monitoring design. This would provide coverage of all major habitat types in your operation including any at higher altitudes. Formal stratification is not usually necessary.

7) For standards 4 and 5, the 'deadline' for operations in the year following the mast (i.e., the post-seedfall year) is 31st August. What if we plan our operation for June or July, but sustained poor weather means that we miss this deadline?

   The intention is to time the operation to achieve stoat control prior to kea nesting (see Appendix 3, Figure 3). If all practical steps have been taken to achieve this but this deadline is still not met, the operation should proceed as early as possible thereafter.

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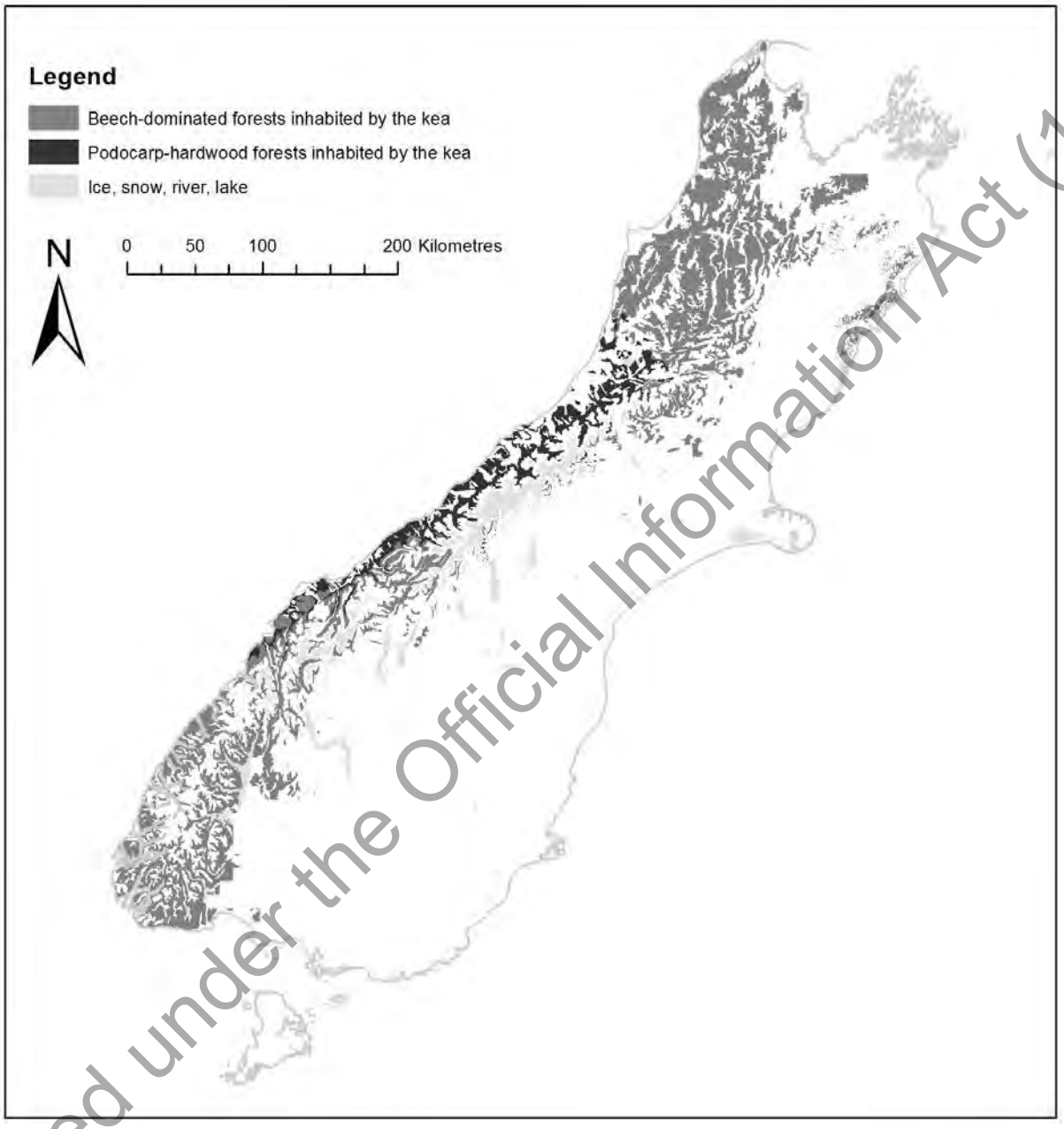
Appendix 1: Map of kea distribution

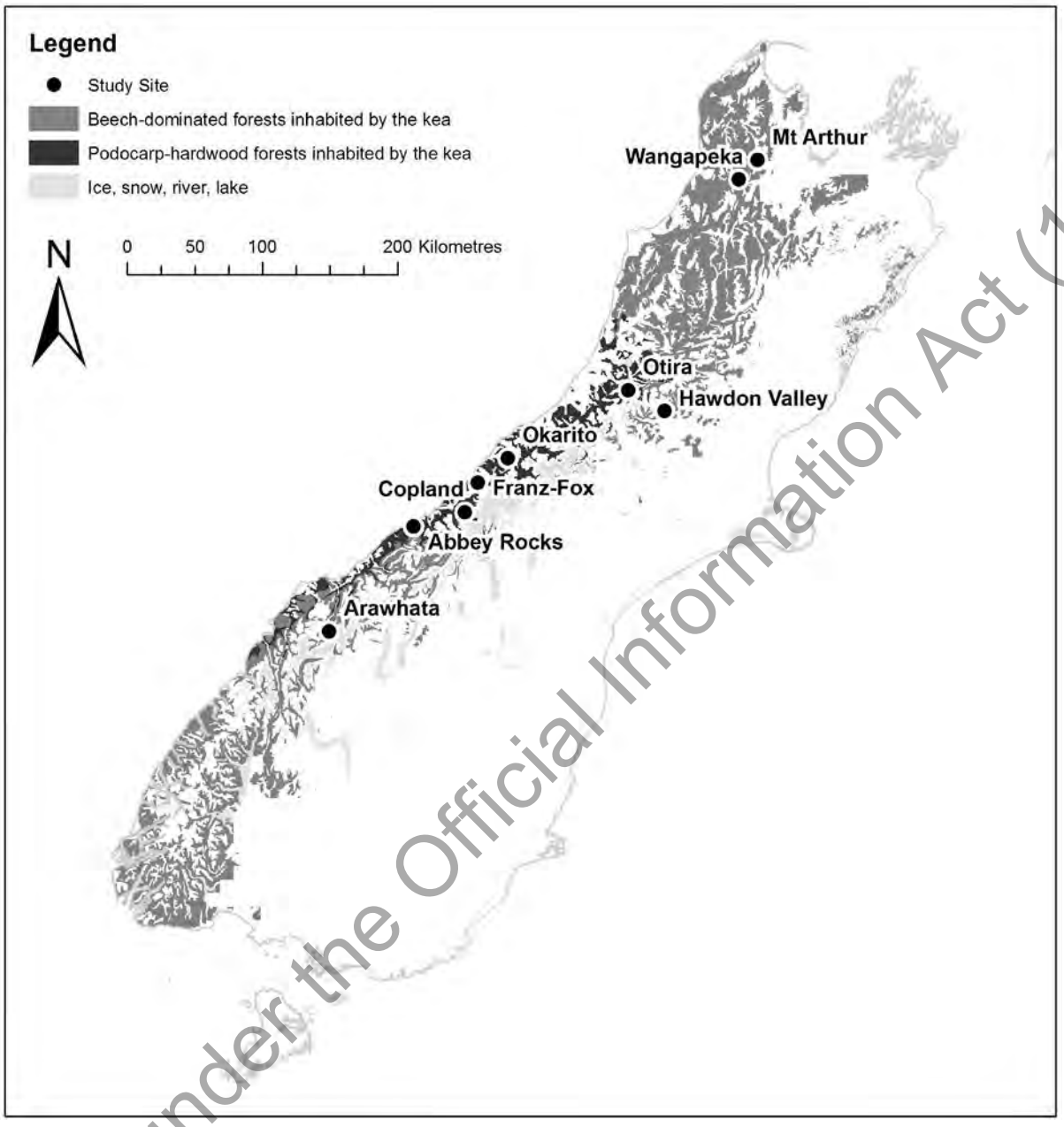


The distribution of kea in the South Island of New Zealand.

Appendix 2: Kea monitoring

Operation	Number of birds followed	Deaths recorded	Probability of survival	Lower 95% confidence bound	Upper 95% confidence bound
Arawhata 2008	10	0	100%	74.1%	100%
Fox-Franz 2008	17	7	58.8%	32.9%	81.6%
Mt Arthur 2009	13	0	100%	79.4%	100%
Hawdon 2009	10	0	100%	74.1%	100%
Okarito 2011	37	8	78.4%	61.8%	90.2%
Wangapeka 2011	13	0	100%	79.4%	100%
Abbey Rocks 2011	8	0	100%	68.8%	100%
Copland 2012	2	0	100%	22.4%	100%
Hawdon 2012	6	0	100%	60.7%	100%
Otira 2013	34	5	85.3%	68.9%	95%
Total	150	20	86.7%		

Sample size and outcomes for kea with known fates monitored before and after aerial 1080 cereal operations (from Kemp and van Klink 2014).



Location of the 9 aerial 1080 cereal operations where kea survival was monitored between 2008 and 2013.

Appendix 3: Pest abundance graphs

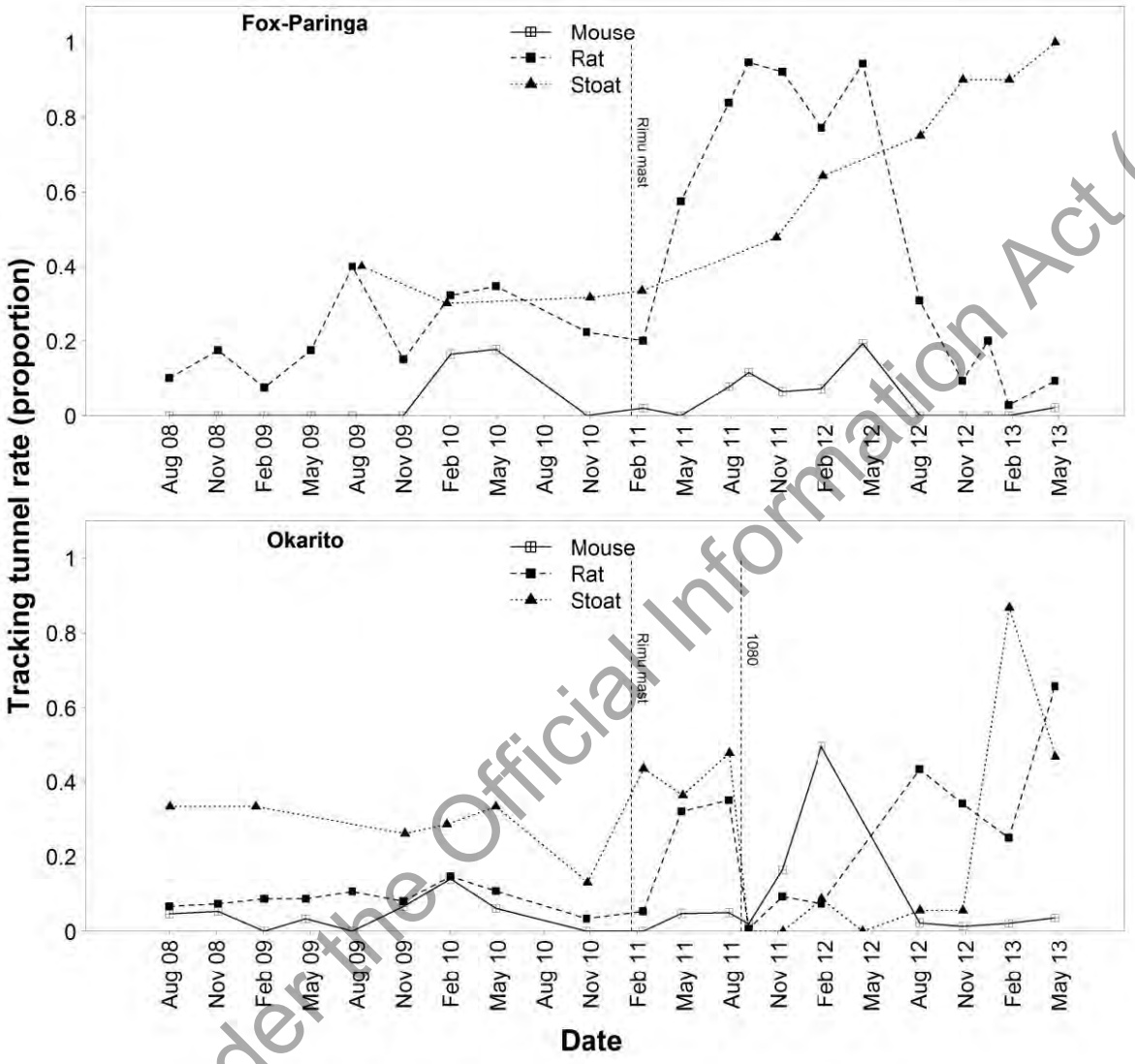


Figure 1 Relative abundance of stoats, rats and mice in a rimu mast year and in the following ('post-seedfall') year. An aerial 1080 cereal operation occurred at Okarito whereas Fox-Paringa received no predator control.

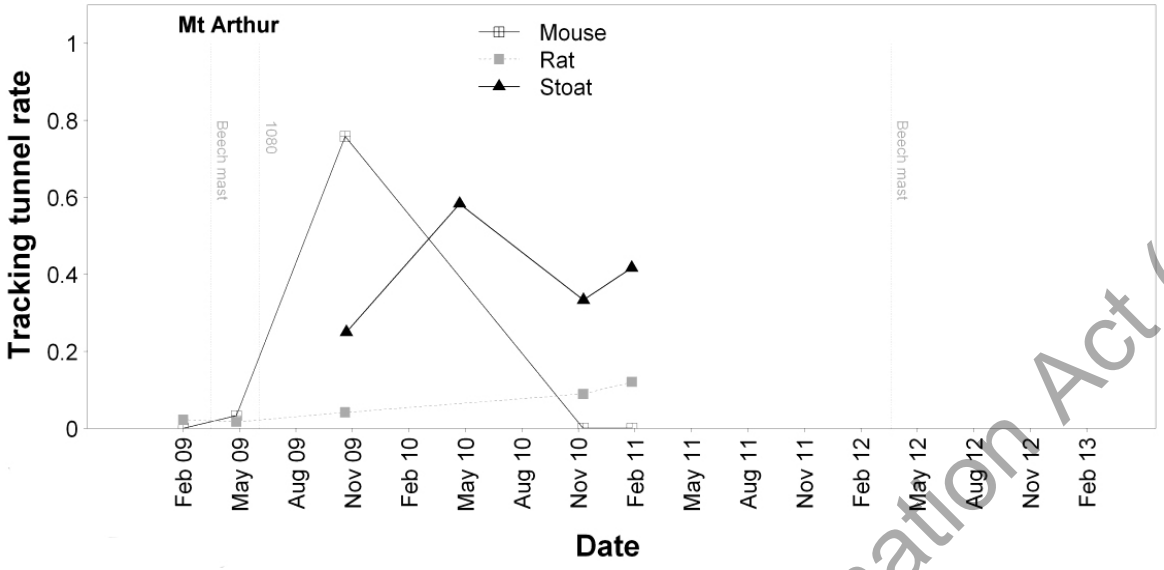


Figure 2 Relative abundance of stoats, rats and mice in a beech forest. An aerial 1080 cereal operation occurred at Mt Arthur in a beech mast year before rodents were abundant.

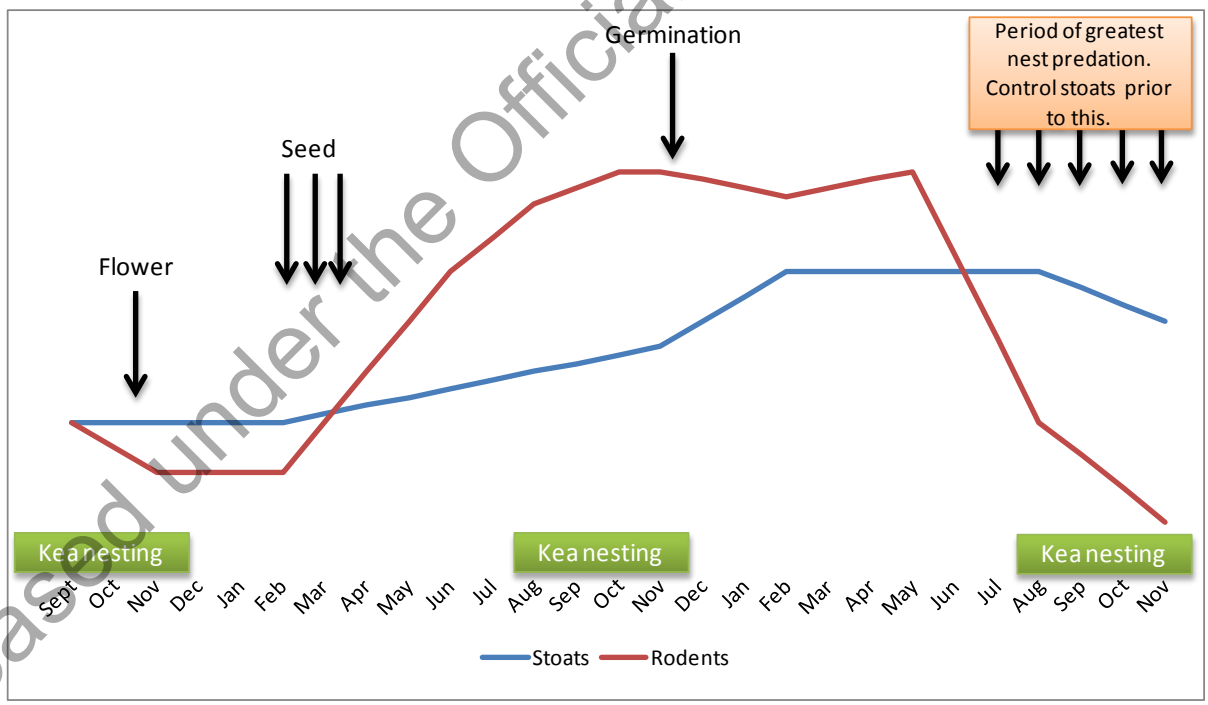


Figure 3 Illustration of how rodent and stoat tracking indices fluctuate during and after a beech or rimu mast. See also King and Murphy (2005) for a 4-year generalised model of the beech mast cycle with respect to mice and stoats.

Appendix 3

NATIONAL PEST CONTROL AGENCIES
Minutes of Management Committee meeting
held at OSPRI, Level 9 CallActive House
15 Willeston Street, Wellington
on 24 June 2014 at 9.12 am

PRESENT: [redacted] (OSPRI) – Chair
[redacted] (DOC)
[redacted] (LGNZ)
[redacted] (Landcare)
[redacted] (Contractor/PestNet)
[redacted] (MPI)
[redacted] (NPCA)

VISITORS: [redacted] (Pest Sign Team Leader)
[redacted] (12.30-1.57 pm)
[redacted] (Finance) (10.30-11.15 am)

IN ATTENDANCE: [redacted] (NPCA)
[redacted] - minutes)

1. **INTRODUCTION**

2. **PREVIOUS MINUTES – 18 March 2014**

Page 3: [redacted]

Page 5: [redacted] said that regional councils … "vertebrate" should be "invertebrate"

POST AGM MINUTES - ?? November 2013

Move/seconded: [redacted]

3. **MATTERS ARISING/ACTION SCHEDULE**

There were no matters arising that were not already on the agenda to be dealt with.

Out of Scope
[redacted]

- Joint research during the Hokonui aerial drop on non target species between DOC and OSPRI re morepork, 25 birds were radio collared/tagged, and were monitored for 3 weeks after the drop (during the acute high risk phase when they were potentially predating on easy prey i.e. dying rats and mice). Two lost their collars and we ended up with 23 with tracking devices and all survived through the aerial operation. Good result and positive news for 1080. Put this in the next NPCA newsletter.

(b) **DOC**: [redacted] reported as follows:

- Planning for beech mast: Pest irruption response (Battle for our Birds) is under way. Comprises 21 aerial 1080 operations collectively covering up to 650,000 ha of the South Island. A project team has been established to coordinate and provide support to on-the-ground delivery staff. Beech seed fall measures and rodent indices are being collected and a final decision on which sites to treat will be made in June, with operations that do go ahead to take place between June and November. This will be a big test for the department's new structure.

- 1080 programme ramp up.

- Department is committed to increasing area of 1080 control by 50,000 ha per year for the next 4 years to around 400,000 ha per year.

- DOC monitoring toolbox: Vertebrate pest control module to be completed by July. Will include specifications for trap catch, wax tag, and chew card monitoring for possums and methods for rodents, mustelids, cats. Existing specifications from NPCA protocols will be used where appropriate.

- Beech seed counts are higher in the northern South Island than in the south and western South Island. There is also a trend for higher rat numbers below 500 m than at higher altitudes.

- New code of practice for aerial 1080 operations in kea habitat.

- Goodnature A24 traps: Results of large scale trials controlling rats achieved consecutive 0% rat tracking rates in treatment sites vs 20% or more in non-treatment sites. Goodnature stoat paste (lure) is still unproven. The trials for the A12 possum trap were completed some time ago and they are considered to be fit for purpose. Significant improvements have been made to the traps' reliability and the lure efficacy.

(c) Out of Scope

[redacted]

Out of Scope

Out of Scope

Out of Scope

9(2)(g)(ii)

Out of Scope

[redacted]

NEXT MEETING: Tuesday 23 September 2014

There being no further general business, the meeting closed at 2.13 pm.

Appendix 4

Bait Improvement Initiatives – meeting discussion

Meeting: 9th Focus Group Meeting on Bait Quality
Date: 16 July 2014

Attendees: Matthew Hall, [redacted]

Apologies: [redacted]

Chair: [redacted]

Review minutes from last meeting

Action points

- [redacted] and [redacted] to send latest bait sample data to [redacted] Complete
- [redacted] to update bait specification In progress
- [redacted] to send EDR figures to [redacted] Complete
- [redacted] to advise suitability of pellet hardness tester Complete

Deer repellent schedule: 123 Tonne for the 2014 calendar year and 220 Tonne for the 2015 calendar year

Roadmap of bait improvement initiatives

[redacted] distributed a roadmap of all the projects involved in the overall bait improvement initiatives project (see attached). The roadmap demonstrates what projects are currently in progress and when they are due for completion. It also indicates which projects are dependent on the completion of other projects and what projects have not yet been assigned an owner.

Bait specification

[redacted] and Matthew have been working on a joint bait specification between DOC and TBfree. The specifications are still being drafted and some clarifications on particular points need to be made. The intention is that once DOC and TBfree have agreed an initial draft, the bait manufacturers will be consulted and adjustments made accordingly. The objective is to have an agreed specification agreed between DOC, TBfree and bait manufacturers.

Action: [redacted] to finalise initial specification and distribute to manufacturers for consultation.

Optimum bait size

[redacted] presented the group with the recent bait sampling results for 2014 operations (see attached). It was noted that in the recent Waipunga operation, approximately 85% of the bait sample of each batch was >12g. The bait used was No7. Bill Simmons advised that this could be due to the die not being changed from the RS5 settings to No7 settings.
Matthew requested that ACP should increase the sample size for their bait sampling process and [redacted] advised that this may be possible but he would need to discuss it with those doing the testing and report back.

9(2)(a), 9(2)(g)(ii) updated the group on the results from optimum bait size study co-ordinated by 9(2)(a), 9(2)(g)(ii) (Landcare Research) which is happening in Whanganui: They have just about finalised field preparations for the second year of the optimal bait size project. They are due to head out into the field (Whanganui area) in mid-July. This first trip is expected to last for 3 weeks, but will be weather dependent. They hope to head into the field for a second trip starting ~18th August (again, for a max. of 3 weeks). An extended milestone report for second year trials is due to TBfree NZ on the 15th December.

Matthew said that the trials must be done in areas where there is a large possum population. It is being carried out 2 different areas that are close by. One area had had a lot of toxins used in the area but the kill rate has been poor, the second area has had no 1080 control. 6,9 & 12g baits are being trialled.

Action: 9(2)(a), 9(2)(g)(ii) to check what type of bait is being used in the trials RS5 or No7
Action: 9(2)(a), 9(2)(g)(ii) to distribute bait sampling results to group. 9(2)(a), 9(2)(g)(ii) to add to chart if deer repellent is used in each bait sample
Action: 9(2)(a), 9(2)(g)(ii) to advise if bait sample size can be increased

Bait hardness and palatability
Landcare research have completed their assessment of Pam's liquorice as a reference material and are happy with the results, going forward this will the bait reference material.

Landcare have completed the hardness trials using a new tester. This can be a manual or electronic tester with the electronic tester being more accurate. It was discussed that we should use manual testers in the field which would give a good indication of whether the bait meets expectations and if not the bait should be tested by the manufacturer using the electronic tester for greater accuracy.

Landcare is currently working on developing hardness specifications and to determine the relationship between hardness and palatability.

9(2)(a), 9(2)(g)(ii) informed the group of a project currently being agreed between TBfree and Landcare Research to carry out a palatability comparison of all bait types including both RS5 and No7.

9(2)(a), 9(2)(g)(ii) raised the issue of bait shyness and that some baits will never be eaten by certain possums. Matthew agreed that we still need to have a number of tools for aerial possum control (e.g. carrot bait, different lures, masks, flavours). Matthew said that this is more important for aerials that are flown on a 3-year cycle and is not as big an issue for aerials done on an 8-9 year cycle as the possum population will be different to the previous aerial and may not have bait shyness.

Fragmentation
9(2)(a), reported that the occasional radial cracks in toxic bait have been resolved largely by changing existing machine settings, not by using a larger pellet die. It was found that the 20mm die produced similar results to the 22mm die and for a difference to be made by changing the pellet diameter; a 25mm die would be required. Instead of changing to the 25mm die the existing machine settings were altered giving good results. A 20mm die is currently being used. 9(2)(a), 9(2)(g)(ii) advised that there doesn't seem to be an issue with radial cracking in PCR baits but he has not looked into the issue previously.

Landcare have identified a new piece of equipment called a 'Kohl tester' which could potentially be used as a method of determining bait fragmentation. Initial trials are being carried out.

Bird repellent

9(2)(a), 9(2)(g)(ii) summarised that in trials of a primary repellent of D-pulegone in prefeed and toxic gave good rat kills and possum kills but not stable to meet the desired timeframe for effectiveness of 4-12 weeks after manufacture. Trials of a combined repellent with 0.1% anthraquinone in prefeed had high possum kills but low rat kills with the anthraquinone stable but d-pulegone not for the 4-12 week timeframe. A project de-brief on the 23rd of July will determine the next steps in the project.

Matthew advised that stoat control may have to be done as part of a new code of practice for aerial 1080 in kea habitat, depending on the operation timing (relative to a mast) and rat population levels. This is a trade-off for no longer having to have a number of holes in the operation block due to kea exclusion areas being present.

Matthew noted that for TBfree operations the main criteria for bait with repellent added to be effective in killing possums and not necessarily on rats.

Agreed by group that 9(2)(a), 9(2)(g)(ii) should be invited to attend the next meeting to give an update on the bird repellent work.

Action: 9(2)(a), 9(2)(g)(ii) to invite 9(2)(a), 9(2)(g)(ii) to next meeting

Deer repellent

The palatability trials for different bait types is also going to include bait with deer repellent applied. Landcare Research is carrying out other trials to determine the effect of deer repellent on bait hardness.

9(2)(a), 9(2)(g) advised that the trial using methylated spirits without pyridine to apply EDR is not going ahead as the cost is too high.

Other

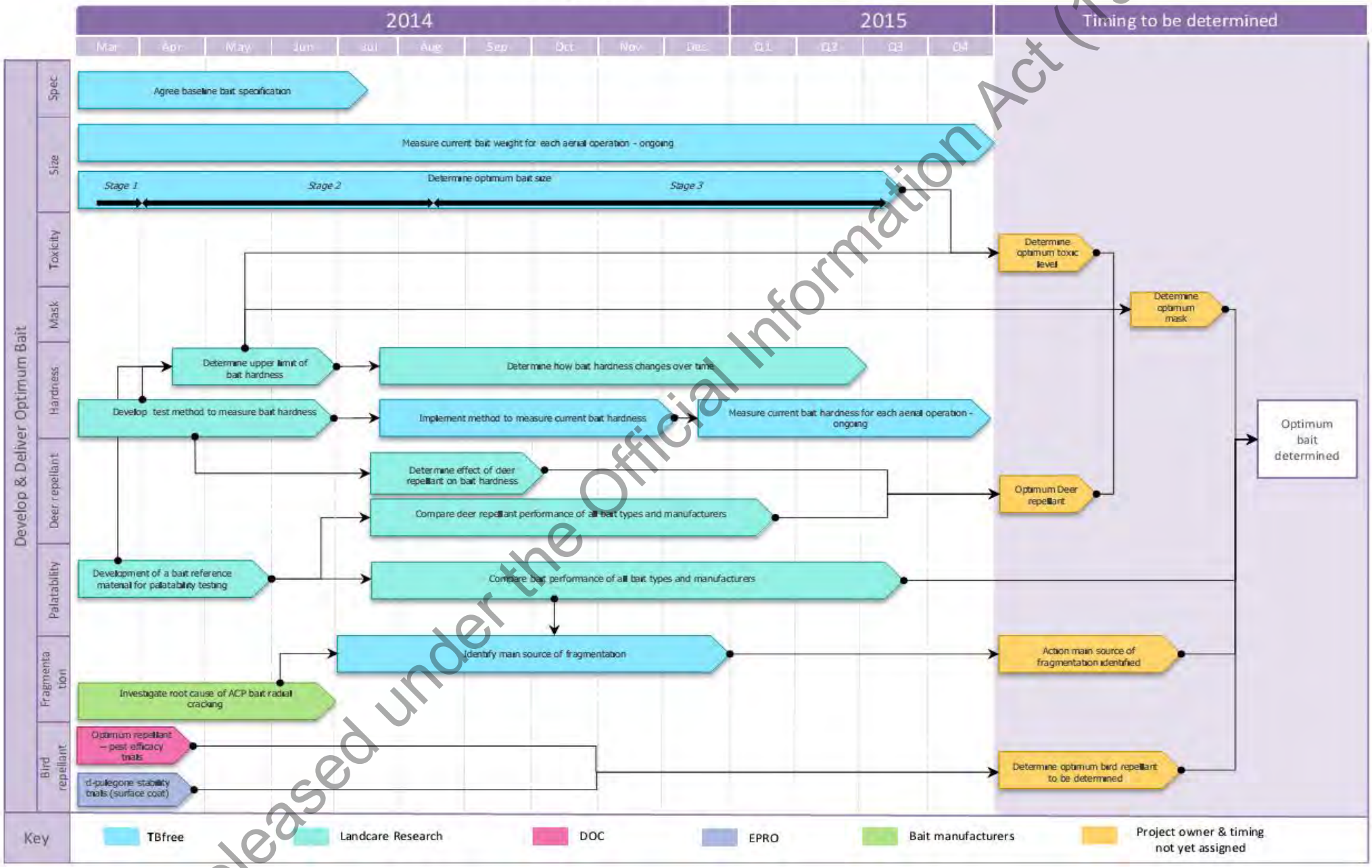
Battle for our Birds: TBfree are doing two aerial operations which are tied in with DOC's battle for the birds programme. 9(2)(a), 9(2)(g)(ii) informed the group that ACP's bait supply was on schedule with a busy August and September ahead. 9(2)(a), 9(2)(g)(ii) said that most of the battle for our birds operations were scheduled for mid-August to November and maybe later. All operations are pre-feed.

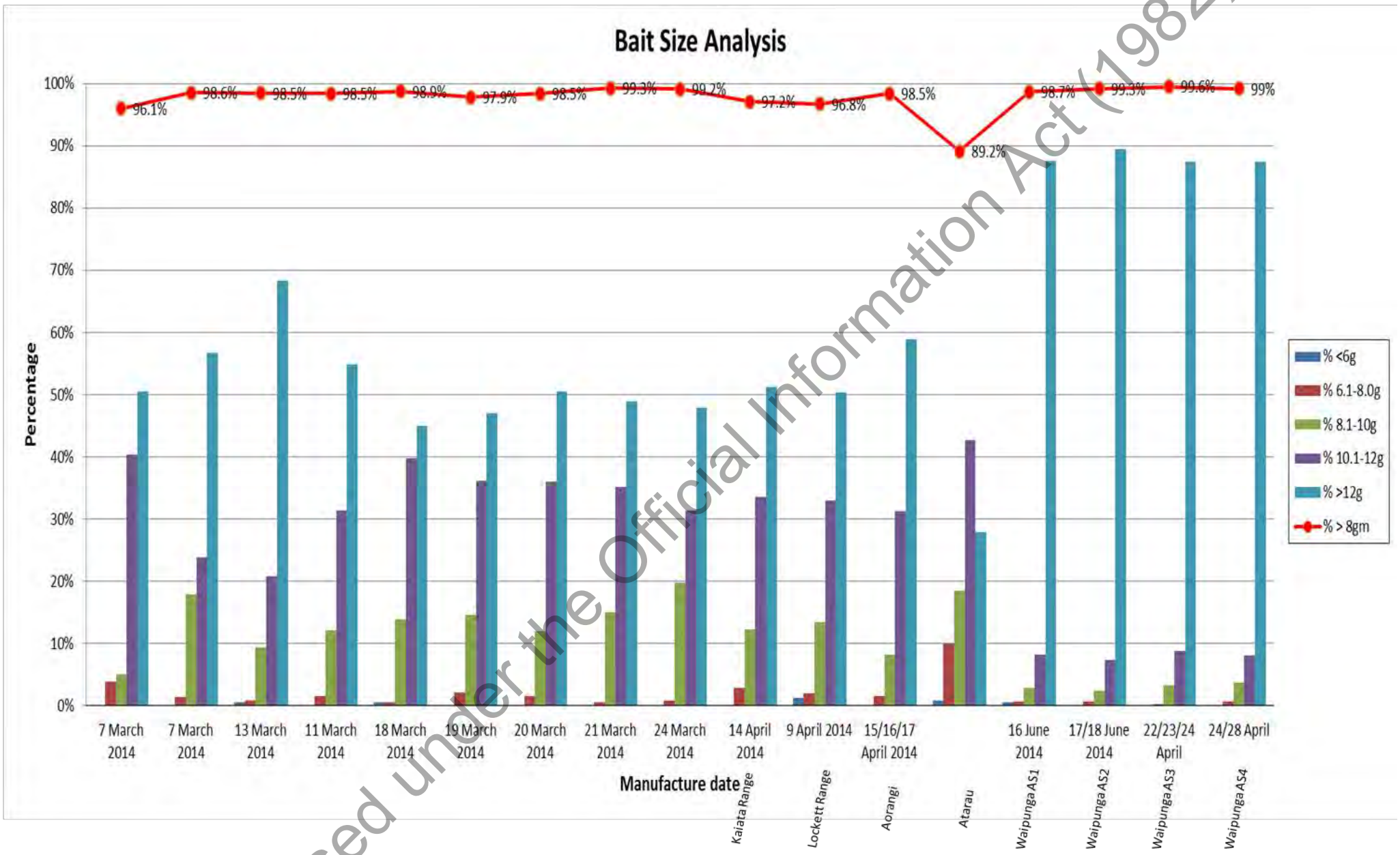
Pig kills: 9(2)(a), 9(2)(g) advised that a lot of wild pigs being killed by 1080 has occurred on operations recently. It is believed that RS5 is more attractive to pigs than No7 due to ingredients (higher sugar levels). Pigs of all size types are being killed. Potentially the issue may be down to the environment and time of year but the cause is unknown. Matthew commented that in Tasman pig hunters were constantly being advised to stay out of areas due to 1080 operations and so began to stay out of the bush so pig numbers increased due to low levels of hunting and this led to a large number of pig deaths. 9(2)(a), 9(2)(g) commented that in their area it is still heavily hunted and the increased number of pig deaths is raising issues for obtaining ground control access and having a negative impact in the local communities. 9(2)(a), 9(suggested that a trial could be carried out to see what bait is more palatable to pigs.

Date for next meeting

3 months time (~ 15th October)

Bait Improvement Initiatives Roadmap





Appendix 5

Department of Conservation
Te Papa Atawhai

Media release

15 December 2014

Largest ever control campaign knocks back predators

The Department of Conservation's largest ever aerial 1080 campaign to combat this year's rat and stoat plague has successfully knocked down predator populations in key target areas.

Over the last four months, DOC has completed an unprecedented 25 aerial 1080 operations over about 550,000 hectares to combat the biggest beech seed-fuelled rodent plague seen in 15 years.

Rat numbers reached extreme levels at some sites but early results from the Battle for Our Birds 1080 programme show rat populations crashing giving much needed protection to breeding populations of vulnerable native birds and bats. (see attached graph).

Project director Mike Slater says protecting native species is an on-going battle and DOC will be analysing the results closely to refine plague response techniques.

"We know that rats and stoats will inevitably re-invade many areas over time so the war is far from won."

But these operations will give some of our most vulnerable birds a precious window to raise their young this summer—we've already seen record numbers of whio ducklings in parts of the Tongariro Forest where 1080 was used in August."

Mike Slater says DOC acknowledges that some native birds have also been lost to 1080 through these pest control operations.

He says DOC tracked 43 radio tagged kea through Kahurangi and South Westland operations and three died from 1080 poisoning.

"It's unfortunate to lose any kea but without protection most kea chicks are killed by stoats so the population gains from one good breeding season more than offset the losses of individual birds."

Mike Slater says monitoring teams have also been unable to locate about 25 rock wren under study in Kahurangi National Park.

He says the small insect eating birds are very difficult to track in their alpine habitat and no dead rock wren have been found so it is too early to say what has happened to the wrens.

'It's not clear whether we have lost birds to heavy snow that fell in the area after the operation,1080 or predator attack and more work is required to try to pinpoint this."

Mike Slater says staff will continue to monitor bird and predator numbers over coming months and refine techniques where required.

He says DOC will also be stepping up other existing trapping and ground based control programmes.

"This year's aerial 1080 phase may be over but the Battle for Our Birds continues and we are moving to strengthen our predator control networks around the country to reinforce the gains made in recent months."

Mike Slater says DOC staff will be taking more than a thousand new traps into the Fiordland mountains over coming weeks to protect takahē from stoats.

Trap networks in Canterbury alpine valleys are also being extended to protect whio, kiwi and the critically endangered orange-fronted parakeet.

"Protecting native species from these imported killers is a constant battle and we are continually looking at where we need to target resources."

–Ends–

Contacts: 9(2)(a), 9(2)(g)(ii)

Background information

The 2014 beech-mast campaign is New Zealand's largest-ever coordinated pest control programme aimed at protecting the most at-risk populations of mōhua/yellowhead, kākāriki/parakeet, kiwi, whio/blue duck, kea, kākā, rock wren, giant land snails and native bats at sites across the South Island.

For more information on DOC's Battle for our Birds pest control response see: www.doc.govt.nz/battleforourbirds

Appendix 6

Pest efficacy of bird repellent at an aerial 1080 cereal operation

[redacted] 9(2)(a), 9(2)(g)(ii) [redacted]

1 Department of Conservation Science & Capability Group, Private Bag 4715 Christchurch 8041, 9(2)(a), 9(2)(g)(ii) @doc.govt.nz
2 Department of Conservation, Northern West Coast District Office, Hokitika
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Abstract

One of the criteria for an effective bird repellent in a pest management context in New Zealand is that possum (*Trichosurus vulpecula*) and the ship rat (*Rattus rattus*) kills remain high where repellents are used. Otherwise, compromised pest efficacy could counteract the longer term conservation benefits of using aerial 1080. We wanted to know whether there would be a significant difference in the proportional reduction in possum or rat population indices between standard aerial 1080 treatment, primary repellent treatment (d-pulegone in prefeed and 1080 baits), and combined repellent treatment (d-pulegone and anthraquinone in prefeed and d-pulegone in 1080 baits). Repellents were used in treatments blocks incorporated in a large aerial 1080 operation in November 2013 at a beech podocarp forest at Moeraki, Whakapohai and Mataketake near Haast on the West Coast of the South Island of New Zealand. Both repellents were near the target operational concentration, although the concentration of d-pulegone dropped below this soon after the operation. When the post-operational tracking rate of relative abundance for rats was compared to the pre-operational rate, the standard treatment was more effective than either repellent treatment and the combined repellent treatment was the least effective. Possums were monitored using WaxTags and there was no statistically significant difference between treatments. The repellent

strategies are not yet ready for operational use, given the instability of d-pulegone and the effect of anthraquinone on the effectiveness of rat control.

Keywords

1080, anthraquinone, d-pulegone, kea, possum, rat, repellent, New Zealand

Introduction

This report is part of a project led by the Department of Conservation (DOC) to develop, register and implement an effective bird repellent to prevent kea (*Nestor notabilis*) deaths in aerial 1080 cereal operations (DOC Innovation and Development project 12-13, DOC Investigations 4459 and 4466). This trial was funded by DOC and TBfree New Zealand (Project R-80719-03).

One of the criteria for an effective bird repellent in this context is that possum (*Trichosurus vulpecula*) and the ship rat (*Rattus rattus*) kills remain high where repellents are used. Otherwise, compromised pest efficacy could counteract the longer term conservation benefits of using aerial 1080.

Repellents were used in treatments blocks incorporated in a large aerial 1080 operation (29327 ha) in November 2013 at Moeraki, Whakapohai and Mataketake near Haast on the West Coast of the South Island of New Zealand (Figure 1). Possums and rats were monitored in treatment blocks and control (standard 1080) blocks at Mataketake before and after the operation, in order to detect any significant difference in the proportional reduction in pests between blocks. If there were no difference, this would indicate that the use of repellents was unlikely to adversely affect possum and rat kills.

Background

The first report in this publication reviews previous research on d-pulegone and 9,10-anthraquinone ('anthraquinone') as bird repellents (refer to Chapter 1). At the time

when this combination was recommended to the Kea Conservation Trust by Spurr (2008), there was limited information on palatability and efficacy for possums and rats. Day et al. (2000) monitored bait acceptance of repellent carrot baits (surface sprayed with 0.17% d-pulegone and/or 0.1% anthraquinone, nominal levels) and standard carrot baits to wild possums and rats at possum-specific and rat-specific bait stations. They found no difference in the overall amount of bait consumed by an unknown number of rats and possums, as compared to standard bait (Day et al. 2000 as interpreted by Spurr 2008).

Kemp (2010) carried out small scale field trial at Kahurangi National Park to compare the reduction of possum and rat indices between aerially applied standard 1080 RS5 cereal baits and three different repellent treatments. The repellent treatments were standard prefeed followed by 0.17% d-pulegone in toxic baits, 0.17% d-pulegone in both prefeed and toxic baits, and 0.17% d-pulegone and 0.1% anthraquinone in prefeed and 0.17% d-pulegone in toxic (nominal concentrations). The last of these treatments was the same as the scenario tested with non-toxic baits and captive kea by Orr-Walker et al. (2012). There was no significant difference in the estimated reduction in possum and rat indices between the four treatments in the Kemp (2010) field trial, however the number of transects may not have been enough to detect difference. Kemp (2010) notes that the last treatment (modelled on Orr-Walker et al. 2012) had a relatively low percentage reduction of rats.

In the United States of America, trials have been done to develop anthraquinone as a bird repellent in a rodenticide paste, at a higher concentration (1%) than being investigated in the present study (0.1%) (Werner et al 2011). There were zero mortalities and no observable signs of toxicosis when three species of non-target birds (Canada geese *Branta canadensis*, horned larks *Eremophila alpestris*, ring-necked pheasants *Phasianus colchicus*) were offered 2% zinc phosphide paste also containing

1 or 2% anthraquinone wt/wt (nominal levels, slight variation in actual concentrations). Unfortunately, significant repellence of the target rodent species (black-tailed prairie dogs, *Cynomys ludovicianus*) was observed in other trials in this study and the authors recommended further investigation at lower concentrations (0.25–0.5%) of anthraquinone in rodenticide baits.

As part of the project to develop a bird repellent to protect kea, five different repellent strategies using d-pulegone and/or anthraquinone were identified and tested in two-choice feeding trials with wild-caught possums and ship rats (Cowan et al. 2013). The feeding trials simulated an aerial 1080 cereal operation by presenting individually caged animals with a choice of the normal pellet diet and prefeed RS5 cereal pellets (standard or one of four different repellent combinations) for 3 days, returning them to the normal pellet diet for 5 days, and then presenting them with a choice of the normal pellet diet and toxic RS5 cereal pellets (standard or one of four different repellent combinations). For both possums and ship rats, the only repellent treatment that had similar palatability, consumption and mortality to the non-repellent RS5 pellets was the group offered prefeed and toxic pellets with 0.17% wt/wt nominal d-pulegone (actual d-pulegone concentration at the start of the trial was approximately 0.12% wt/wt). For possums, the groups that were fed 0.25% anthraquinone and no d-pulegone in prefeed pellets had lowest mortality of any treatments. All four treatment groups of ship rats who were exposed to anthraquinone in prefeed baits (0.1% or 0.25%, with or without 0.17% d-pulegone) ate progressively less prefeed over three days and ate few toxic pellets. Mortality was significantly lower for these four treatment groups of ship rats than in the group offered non-repellent baits or 0.17% d-pulegone in prefeed and toxic baits.

Cowan et al. (2013) recommended that further development with kea should focus on 0.17% d-pulegone in prefeed and toxic baits (as was done by van Klink and Crowell;

refer to Chapter 2). They noted that the strategy tested by Orr-Walker et al. (2012) and Kemp (2010) was not tested in the feeding trial (i.e., 0.17% d-pulegone and 0.1% anthraquinone in prefeed baits and 0.17% d-pulegone in toxic baits). They recommended that both of these strategies be tested in the field for possum and rat efficacy.

Methods

Trial design

Trial question

The trial was designed to address the following question:

In an aerial 0.15% 1080 RS5 cereal operation, is there any significant difference between primary repellent treatment, combined repellent treatment, and standard (no repellent) treatment with respect to a proportional reduction in possum and rat population indices?

All treatments were RS5 baits with 0.15% wt/wt cinnamon lure in prefeed baits (16mm diameter) and 0.3% wt/wt cinnamon lure in toxic 0.15% 1080 baits (20 mm diameter). In all treatments, the rate of application was 1 kg/ha for prefeed and 2 kg/ha for toxic baits, in line with DOC current agreed best practice. The three treatments were:

Primary repellent: 0.17% (wt/wt) d-pulegone in green RS5 prefeed baits and 0.17% (wt/wt) d-pulegone in green 0.15% 1080 baits

Combined repellent: 0.17% (wt/wt) d-pulegone and 0.10% anthraquinone in green RS5 prefeed baits and 0.17% (wt/wt) d-pulegone in green 0.15% 1080 baits

Standard: Undyed prefeed baits and green 0.15% 1080 baits

The stated repellent concentrations were the target concentrations. D-pulegone was known to be volatile (refer to Chapter 4) so a higher nominal concentration was used, as explained in 'Bait manufacture and analysis'.

Trial location

The trial was incorporated into an aerial 1080 cereal operation at a beech podocarp forest at Moeraki, Whakapohai and Mataketake, situated on the true left of the Haast Valley of South Westland (see Figure 1). The operation targeted possums to protect scarlet mistletoe (*Peraxilla colensoi*) and tree fuschia (*Fuchsia excorticata*) from browsing pressure. In the Whakapohai Valley, kaka (*Nestor meridionalis*) and ship rats are monitored as part of a research program to develop cost effective rat control strategies to protect kaka and other birds (G. Elliot, pers. comm.). Previous aerial 1080 cereal operations took place at Moeraki, Whakapohai and Mataketake in 2010 and 2007; earlier separate operations took place at Whakapohai (2003) and Moeraki (2004, 2000, and 1998).

As part of trend monitoring for these three areas, possums were monitored using residual trap catch index (RTCI) in November to December 2012. The mean RTCI (with 95% confidence interval) for Mataketake was 8.2% ± 3.4 (M. Martini, unpublished data). Rats were not monitored in Mataketake prior to the trial; however tracking tunnels were monitored at Whakapohai in May 2013 and the tracking index of relative abundance for rodents was approximately 42% (G. Elliot, pers. comm.).

Treatments

There were 2 replicates of each treatment, located as 2 sets of 3 blocks. Each block consisted of a **treatment block** (average size 840 ha) to be flown with a particular bait treatment and an inner **monitoring block** (average size 610 ha) where we would estimate population indices. We located the treatment blocks systematically. Starting with an operational map, we excluded areas that could not be monitored (too wet or too steep), areas above 500 m elevation (where rat population was expected to be too low), and the Whakapohai Valley (where the kaka research was located). The remaining

area was divided in half and then each half divided into three treatment blocks. Treatments were assigned randomly using an online die application. An internal buffer of 200m was applied to each treatment block using geospatial tools, to define the monitoring block. The 200m buffer was set to provide independence of treatments; with this buffer we expected negligible migration of possums and rats into the monitoring block from adjacent treatments (or the surrounding operation) between pre-operational and post-operational monitoring. Flight lines were parallel, with an additional perimeter swath to avoid any unsown areas at the edge of treatment areas.

Bait manufacture and analysis

D-pulegone 90% (CAS 89-82-7, 90% active ingredient) was imported by Connell Brothers Ltd. from Penta Manufacturing Company (Livingston New Jersey, USA). Anthraquinone (Avipel Dry® CAS-84-64-1, 95% active ingredient) was imported by Etec Crop Solutions Ltd. from Arkion Life Sciences LLC (New Castle Delaware, USA).

All repellent prefeed and toxic baits were manufactured by Animal Control Products (ACP) Ltd. (408 Heads Road, Whanganui). Repellents were added after the base ingredients for RS5 baits had been combined in the ACP factory mixer. This took place at the same stage when the cinnamon lure, green dye, and 1080 (where applicable) were added. After a period of further mixing, pellets were extruded and treated with steam to improve bait cohesion.

Chapter 4 describes work to monitor the stability of repellents and 1080 in RS5 cereal baits. We learned that some d-pulegone (about 30% on average) is lost in the manufacture process and more is dissipated over time in storage. For this reason, a higher nominal concentration of d-pulegone was used in order to achieve the target operational repellent concentration (~0.17% ± 0.05) 4 to 12 weeks after manufacture (refer to Chapter 4). The upper and lower bounds on this target were arbitrarily chosen to allow some variation. Based on previous batches of bait and allowing for prefeed

baits to be used sooner than toxic baits, we used nominal concentrations of 0.25% and 0.29% d-pulegone in prefeed and toxic baits respectively.

Three bags of combined repellent prefeed baits and three bags of repellent 1080 baits were stored at the Landcare Research Toxicology Laboratory (Gerald Street, Lincoln). The d-pulegone and anthraquinone concentrations in the combined repellent prefeed were assayed for both repellents on receipt at the laboratory and on the day after the prefeed baits were applied. Likewise, the repellent 1080 baits were assayed for d-pulegone and 1080 on receipt and for d-pulegone on the day that toxic baits were applied. Analysis of repellent concentrations allowed us to determine whether the actual d-pulegone concentration in the baits met the target operational concentration (~0.17% ± 0.05).

Monitoring design

Rats

We used the tracking index of relative abundance as the population index for rats and followed the DOC tracking tunnel guide (Gillies and Williams 2013). The design of the tracking tunnels varied from the design in the protocol, in that our corflute tunnel was triangular in profile rather than square. Using the tracking tunnel as the sampling unit, we determined that if we monitored 8 transects in each block we would be able to detect a 6% difference in the post-operational tracking index between standard and repellent blocks, at a statistical power level of 80% and p=0.05.

To locate transects, twenty random start points were generated for each monitoring block using geospatial tools. Starting with the first numbered start point, a 450 m transect was fitted in an eastern direction (90°, or in the western direction 270° where east was not possible). A transect was deleted if it was too close to a previously accepted transect or could not be monitored safely. This process was iterated until

eleven transects had been selected. Three of the eleven transects were then selected randomly and assigned as shorter (200 m) transects for possum monitoring only (see 'Possums' below).

Tunnels were established and baited with peanut butter on the planned transects 17th to 22nd September, about six weeks before the pre-operational monitoring. One change to the planned transects was made to make up for an error; one planned shorter transect of WaxTags was accidentally set up with tracking tunnels so another planned tracking tunnel transect was changed to WaxTags.

Possums

We used the three-night Bite Mark Index (BMI) as the population index for possums and followed the National Possum Control Agencies (NPCA) protocol (NPCA 2010). This protocol requires a minimum of 11 transects of Wax Tag devices for blocks 500–800 ha in size. Using the WaxTag as the sampling unit, this level would allow us to detect a 4% difference in the post-operational BMI between standard and repellent blocks, at a statistical power level of 80% and p=0.05.

In each block, eight of the eleven transects were located on the first 200m of the rat monitoring transects and other three transects were located as separate transects.

Data analysis

A mixed-effects logistic regression was applied to the data within the Bayesian framework. The fixed variables were treatment and status (i.e., pre-operational index versus post-operational index) and the response variable was the number of devices on each transect with rat tracks or possum bites. A vague normal prior distribution $N(0,10^2)$ was assigned to the fixed effects. Additive independent, identically distributed random effects were assumed for block, transect line, and tunnel location (rats only). All of the models were fitted using the WinBUGS software (Lunn et al. 2000). A chain of

100000 iterations was run after a burn-in of 5000, and every 10th iteration was recorded, producing a sample size of 10000 from the posterior distribution. The convergence was assessed visually.

Posterior means and credible intervals (a Bayesian version of confidence intervals) were estimated for the probabilities of observing rats or possums before and after each of the three treatments, as well as the respective odds ratios (ORs). Given the two probabilities p_0 and p_1 of observing a possum track or a bite mark before and after the treatment respectively, the odds ratio is evaluated as:

$$OR = \frac{\frac{p_1}{1-p_1}}{\frac{p_0}{1-p_0}}$$

An odds ratio below 1 indicates that the treatment was effective in reducing the number of rat tracks or possum bites. When comparing any two treatments, the one with the lower OR is the more efficient one.

In Bayesian framework, the weight of evidence in favour of a certain statement is assessed in terms of posterior probability rather than statistical significance and p-values. Thus, the posterior probability of the odds ratio being below 1 (P(OR)<1|data) corresponds to the weight of evidence (i.e., the observed data) in favour of the treatment being effective. The closer (P(OR)<1|data) is to 1, the more evidence for effectiveness there is.

In order to test whether the effectiveness varied between the treatments, we fitted 3 alternative models: (i) M1 where all the treatments were forced to have the same effectiveness; (ii) M2 where the effectiveness was allowed to vary between treatments; and (iii) M3 where the effectiveness was allowed to vary between treatments as well as between blocks (random effects). The 3 models were then compared using the Deviance Information Criterion (Spiegelhalter et al. 2002). DIC is a Bayesian measure of

model fit and complexity, similar to the classical AIC. The smaller it is, the better is the model. Commonly, a difference of 5–10 is considered suggestive and a difference of 10 definitive (http://www.mrc-bsu.cam.ac.uk/bugs/winbugs/dicpage.shtml#q9). Where applicable, odds ratios were compared between treatments to evaluate their relative efficiency at reducing the tracking index or BMI.

The possible presence of spatial autocorrelation in the tunnel- and line-specific random effects was investigated by estimating the Moran's I. Moran's I is a common measure of spatial autocorrelation (Moran 1950), taking values from -1 (perfect negative autocorrelation) to 1 (perfect positive autocorrelation). The value of 0 corresponds to spatial independence.

Results

Trial execution

The location of treatment blocks and the associated monitoring blocks and transect lines are shown in Figure 1.

Prefeed baits were applied on 11th November 2013 and the toxic bait was applied in block 6 and most of block 4 on 22nd November (11 days after prefeed) and in all remaining blocks on 23rd November (12 days after prefeed). Flight lines were checked on site for even coverage and perimeter sowing. Fine weather conditions prevailed on all days that baits were sown and for the nights of the 22nd through the 28th. There were light showers during the day on the 25th (25mm between 0600 and 1700) followed by fine weather through to the afternoon of the 29th November.

Bait manufacture and analysis

Standard prefeed and 1080 baits were manufactured on 30th October. Both batches of repellent prefeed were manufactured on the 1st November and repellent 1080 baits were manufactured on the 5th November.

The d-pulegone concentration in the combined repellent prefeed baits was 0.14% on receipt (6 days after manufacture) and 0.14% on the day after prefeed was applied (11 days after manufacture). The anthraquinone concentration was 0.089% on receipt; because this was less than expected, we re-sampled on the day after prefeed was applied and obtained a similar result (0.084%). This means that repellent baits contained the target operational concentration (~0.17% ± 0.05) of d-pulegone when prefeed was applied and the anthraquinone was very close to the target operational concentration (0.1%).

The d-pulegone concentration in the repellent 1080 baits was 0.21% and the 1080 concentration was 0.13% on receipt (2 days after manufacture). Baits contained the target operational concentration when aerially applied, as the d-pulegone concentration in stored baits was 0.15% on the first day toxic baits were sown (17 days after manufacture).

Monitoring execution

Pre-operational monitoring took place about 7–10 days prior to the aerial application of prefeed baits. Tracking cards were placed in tunnels on either the 31st October or 2nd November; weather was fine or overcast overnight and tracking cards were collected the following day. WaxTags were placed at the same time as tracking cards were collected; these devices were collected after 3 nights. Weather was fine or overcast for the 3 nights, other than a short period of rain in the early evening of 31st October.

Post-operational monitoring commenced on 5th December, 13–14 days after toxic baits were applied. Tracking cards were placed in tunnels on either 5th or 10th December and collected the following day. WaxTags were placed on the 6th December in blocks 1–3 and on the 9th December in blocks 4–6; these devices were collected after 3 nights. In terms of overnight weather, there were showers for periods on the nights of the 5th, 7th 9th and 10th December but weather was clear before dawn in all cases.

Data analysis

A summary of mean pre- and post-operational monitoring indices and proportional reductions observed for each trial block is presented in Table 1.

Rats

The DIC was calculated for the three models reflecting different assumptions as following: (M1) there was no difference in efficacy between treatments, DIC=621.077, (M2) there were differences in efficacy between treatments, DIC=616.209, and (M3) random block effect contributed to the differences in efficacy between treatments, D=616.652. The difference of 4.868 between the DICs for M1 and M2 suggests that M2 is a statistically better model than M1. The corresponding difference of 0.443 between M2 and M3 indicates that the treatment efficacy did not vary between blocks. For the best model, M2, the posterior mean estimated proportion of tunnels that were tracked before and after treatment and the corresponding odds ratio for each treatment are shown in Table 2.

The posterior mean OR was much less than one for every treatment, indicating that all treatments were effective at reducing the tracking index. Pairwise comparisons of the ORs (Table 3, Figure 2) indicated that the standard treatment was more effective at reducing the tracking rate than either repellent treatment and the primary repellent treatment was more effective than the combined repellent treatment.

We found no evidence of spatial auto-correlation among the estimated tunnel-specific random effects. The mean Moran's I was -0.0005, with a 95% credible interval of -0.0200 to 0.0209.

This analysis was also completed for WaxTags bitten by rats in the possum monitoring, with similar results.

Possums

The results were modelled to estimate the posterior mean estimated proportion of tunnels that were tracked before and after treatment and the odds ratio for each treatment was estimated (Table 4). The DIC was calculated for the model under the first two hypotheses: (M1) where there was no difference in efficacy between treatments, DIC=384.957; and (2) where there were differences in efficacy between treatments, DIC=385.548. The difference of 0.591 between the DICs suggests that there is no statistical evidence of difference in the efficacy of the three treatments; on this basis we did not look for random variation between blocks (M3).

The posterior mean OR was much less than one for every treatment, indicating that all treatments were effective at reducing the tracking index. No pairwise differences were found (Figure 3).

The random effect of transect location was investigated and we found no evidence of spatial auto-correlation. The mean Moran's I was -0.0266, with a 95% credible interval of -0.0711 to 0.0543.

Discussion

We were fortunate that the operation occurred soon after bait manufacture, which meant that prefeed and toxic baits met the target operational d-pulegone concentration of ~0.17% ± 0.05. The prefeed baits contained about 0.14% d-pulegone when sown 10 days after manufacture and the toxic baits contained about 0.15% d-pulegone when sown 17–18 days after manufacture. Stored bags of prefeed and toxic baits continued to be sampled and analysed as part of the bait stability study reported in Chapter 4 of this publication. This showed that the both the prefeed baits and toxic dropped below the target operational concentration shortly after the operation, despite being manufactured at nominal concentrations of 0.25% and 0.29% d-pulegone respectively.

Stored prefeed baits contained 0.087% d-pulegone 3 weeks after manufacture and toxic baits contained 0.11% d-pulegone 4 weeks after manufacture. This is not compatible with operational use, as South Island 1080 aerial cereal operations typically occur 4 to 12 weeks after manufacture ([redacted] DOC and [redacted] TBfree New Zealand, pers. comm.). This is discussed in more detail in Chapter 4; of all the batches monitored, only one batch of prefeed met the target operational concentration for up to 5 weeks and one batch of toxic baits met the target for 8 weeks after manufacture. With current production methods, we would struggle to achieve the target operational concentration of d-pulegone at operations given that few occur as quickly after manufacture as this trial and that the dissipation of d-pulegone has been highly variable across monitored batches.

The anthraquinone concentration was about 0.084% in the prefeed baits, which was slightly lower than the nominal concentration of 0.1%. We believe that this level was close enough to the nominal concentration to provide meaningful trial results.

There was a significant difference in the proportional rat reduction achieved between treatments. The standard treatment reduced the rat tracking index more effectively than either repellent treatment. The difference between the standard and primary repellent treatment is somewhat surprising. In the pen trial, palatability, consumption and mortality did not differ significantly between rats in the standard treatment and the primary repellent treatment (Cowan et al. 2013). The field trial results need to be considered within the limitations of the tracking index as a relatively coarse relative abundance index (Gillies 2013). [redacted] (pers. comm.) cautions that results should be interpreted broadly, in classes such as not detected (0%), low abundance (e.g., <5%), normal abundance (situation dependent) and high abundance. All of the standard and primary repellent blocks had mean post-operational tracking indices of either 0% ± 0%

or 1% ± 1%, so the difference in indices is unlikely to reflect a real difference in rat abundance.

The combined repellent treatment reduced the rat tracking index less effectively than either the standard or primary repellent treatment, with post-operational tracking indices of 3% ± 2% or 8% ± 6%. This is consistent with the observations of Cowan et al. (2013), where mortality was significantly lower in all treatments where anthraquinone was included in baits as compared with the standard or primary repellent treatment. Such a difference was not detected in the Kemp (2010) field trial, although a relatively low percentage reduction of rodent abundance was noted in his combined repellent treatment.

Effective rat control is critical for aerial 1080 operations aiming to protect a range of biodiversity values. The level of rat suppression achieved in the combined repellent treatment is not enough to protect native animals predated by rats, where operational targets are typically <5% tracking index. The level of rat suppression may be compatible with achieving stoat control, whereby poisoned rats are vectors for secondary poisoning of stoats (Murphy et al. 1999). Nonetheless, this trial indicates that the combined repellent treatment falls short of the project criterion that ship rat kills remain high.

There was no evidence of any significant difference in the proportional reduction in WaxTags bitten by possums between the three treatments. This suggests that the repellents do not reduce possum kills relative to standard aerial 1080 cereal. This result is similar to the pen trial observations of Cowan et al. (2013); measures of palatability and mortality did not differ between treatments other than two treatments not represented in this field trial (where prefeed contained 0.25% anthraquinone and 0% d-pulegone and toxic contained one or both repellents). This trial result indicates that

either repellent treatment from this trial could be used in operations without adversely affecting the reduction of possums.

Recommendations

A draft version of this report and the others in this publication were reviewed by DOC, TBfree NZ Ltd., Landcare Research NZ Ltd. and Kea Conservation Trust in March 2014. This group identified four research questions to be answered with respect to the broadcast use of bird repellents. These are stated in full in Chapter 1 of this publication. Two of these questions were directly informed by the outcomes of this trial.

1. Can d-pulegone be stabilised in cereal baits, to maintain the target operational concentration for 4 to 12 weeks after manufacture? The d-pulegone concentration was less than the target operational concentration within 4 weeks of manufacture for the prefeed baits and toxic baits used in this trial. This indicates that some means of stabilising d-pulegone is needed for operational use of this repellent.
3. Is there an anthraquinone concentration that will deliver high rat kills and still repels kea? The proportional reduction in rat tracking index of relative abundance was less in the combined repellent treatment where 0.1% wt/wt anthraquinone was used. We wonder whether a lower concentration of anthraquinone could be identified where there would be no significant difference between standard 1080 and a repellent treatment involving anthraquinone.

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We thank [redacted] for managing the operation and making it happen as soon as possible after bait manufacture. He made sure that the right bait was applied at the right sowing rate to the right blocks, both for this trial and other research at Whakapohai. [redacted] is also thanked for his work on the operation and for supplying weather data.

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[redacted] established the geospatial database for the trial and located the treatment blocks and monitoring transects. [redacted] updated the database with the monitoring results and provided geospatial support for the data analysis and mapping.

We were fortunate to have constructive feedback on the field trial design from [redacted]

[redacted] led the team at Animal Control Products to manufacture all baits for the trial. [redacted] managed the analysis of baits for repellent and 1080 concentrations at Landcare Research Ltd.

9(2)(a), 9(2)(g)(ii) and 9(2)(a), 9(2)(g)(ii) at TbFree New Zealand and 9(2)(a), 9(2)(g)(ii) at Landcare Research Ltd. are thanked for their support and advice on the trial.

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Tables

Block	Mean pre-operational tracking index for rats	Mean post-operational tracking index for rats	Proportional reduction of tracking index for rats	Mean pre-operational bite mark index for possums	Mean post-operational bite mark index for possums	Proportional reduction of bite mark index for possums
1 Primary repellent	14% ± 5%	0% ± 0%	100%	6.1% ± 1.8%	3.8% ± 2.3%	38%
2 Standard	35% ± 6%	0% ± 0%	100%	8.6% ± 4%	1.8% ± 1.8%	79%
3 Combined repellent	28% ± 9%	3% ± 2%	89%	2.2% ± 1.2%	0.5% ± 0.5%	77%
4 Combined repellent	36% ± 7%	8% ± 6%	78%	34.5% ± 10%	4.1% ± 2%	88%
5 Standard	24% ± 6%	0% ± 0%	100%	30.5% ± 8.6%	5.5% ± 2.8%	82%
6 Primary repellent	28% ± 6%	1% ± 1%	96%	23.6% ± 5.8%	1.4% ± 0.7%	94%

Table 1: Mean tracking index and standard errors and 3-night BMI summarised by trial block. Proportional reduction was also calculated for each block, using the mean indices pre- and post-operation. Eight transects of tracking tunnels and eleven transects of WaxTags were monitored in each block.

Treatment	Observed proportion before treatment	Observed proportion after treatment	Posterior mean estimated proportion before treatment	Posterior mean estimated proportion after treatment	Posterior mean estimated odds ratio	Lower bound of 95% credible interval for odds ratio	Upper bound of 95% credible interval for odds ratio	P (odds ratio < 1 |data)
Primary repellent	0.2063	0.0063	0.2274	0.0053	0.0176	0.0004	0.0694	>0.9999
Standard	0.2938	0.0000	0.2274	0.0004	0.0013	0.0000	0.0114	>0. 9999
Combined repellent	0.3188	0.0500	0.2274	0.0255	0.0866	0.0257	0.1868	>0. 9999

Table 2: Results from the mixed effects logistic regression applied to the proportion of tunnels tracked by rats before and after treatment. The posterior means and estimates of the odds ratios were estimated by the model within a Bayesian framework. The last column reports the probability of the odds ratio being greater or equal to 1 (i.e. treatment did not lower the rat tracking index) given the data we observed.

Comparison	Posterior Probability	Interpretation
odds ratio (P) > odds ratio (S)	0.9431	The standard treatment is on average more efficient than the primary treatment.
odds ratio (P) > odds ratio (C)	0.0296	The primary treatment is on average more efficient than the combined treatment.
odds ratio (S) > odds ratio (C)	<0.0001	The standard treatment is on average more efficient that the combined treatment.

Table 3: Pairwise comparisons of the odds ratios observed for rat tracking in the primary repellent treatment (P), standard treatment (S) and combined repellent treatment (C). When comparing any two treatments the one with the lower OR is the more efficient at reducing the proportion of tunnels tracked by rats than the other treatment. The closer is the posterior probability to 1, the higher is the weight of statistical evidence in favour of the hypothesis.

Treatment	Observed proportion before treatment	Observed proportion after treatment	Posterior mean estimated proportion before treatment	Posterior mean estimated proportion after treatment	Posterior mean estimated odds ratio	Lower bound of 95% credible interval for odds ratio	Upper bound of 95% credible interval for odds ratio	P (odds ratio < 1 |data)
Primary repellent	0.1500	0.0227	0.1032	0.0148	0.1145	0.0501	0.2108	>0.9999
Standard	0.1955	0.0364	0.1032	0.0130	0.1002	0.0489	0.1764	>0.9999
Combined repellent	0.1840	0.0227	0.1032	0.0073	0.0538	0.0217	0.1035	>0.9999

Table 4: Results from the mixed effects logistic regression applied to the proportion of WaxTags bitten by possums before and after treatment. The posterior means and estimates of the odds ratios were estimated by the model within a Bayesian framework. The last

column reports the probability of the odds ratio being greater or equal to 1 (i.e. treatment did not lower the BMI) given the data we observed.

Figures

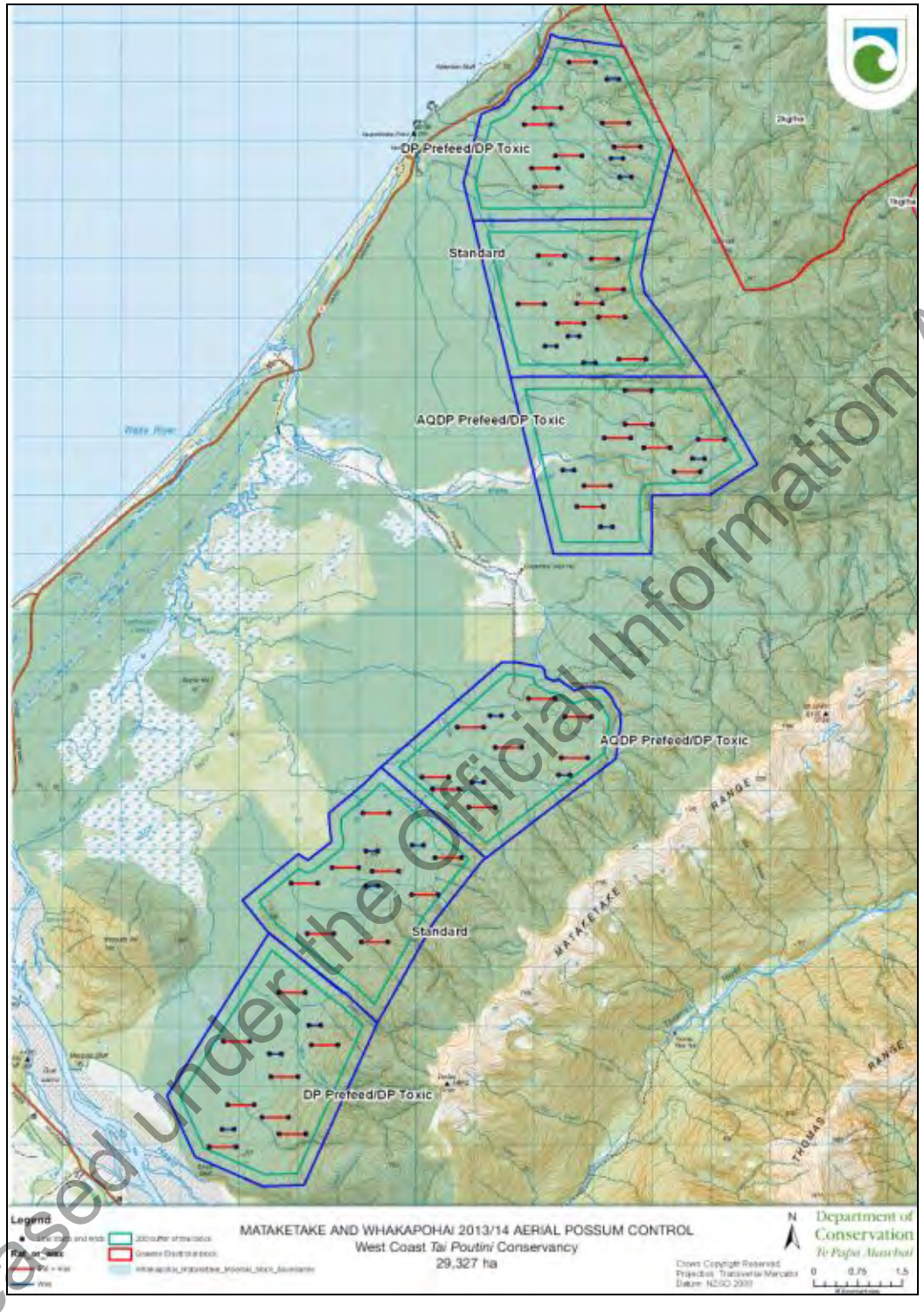

Figure 1: Location of treatment blocks and the associated monitoring blocks and transect lines. To be added: Location of the trial at Moeraki, Whakapohai and Mataketake on the West Coast of the South Island.

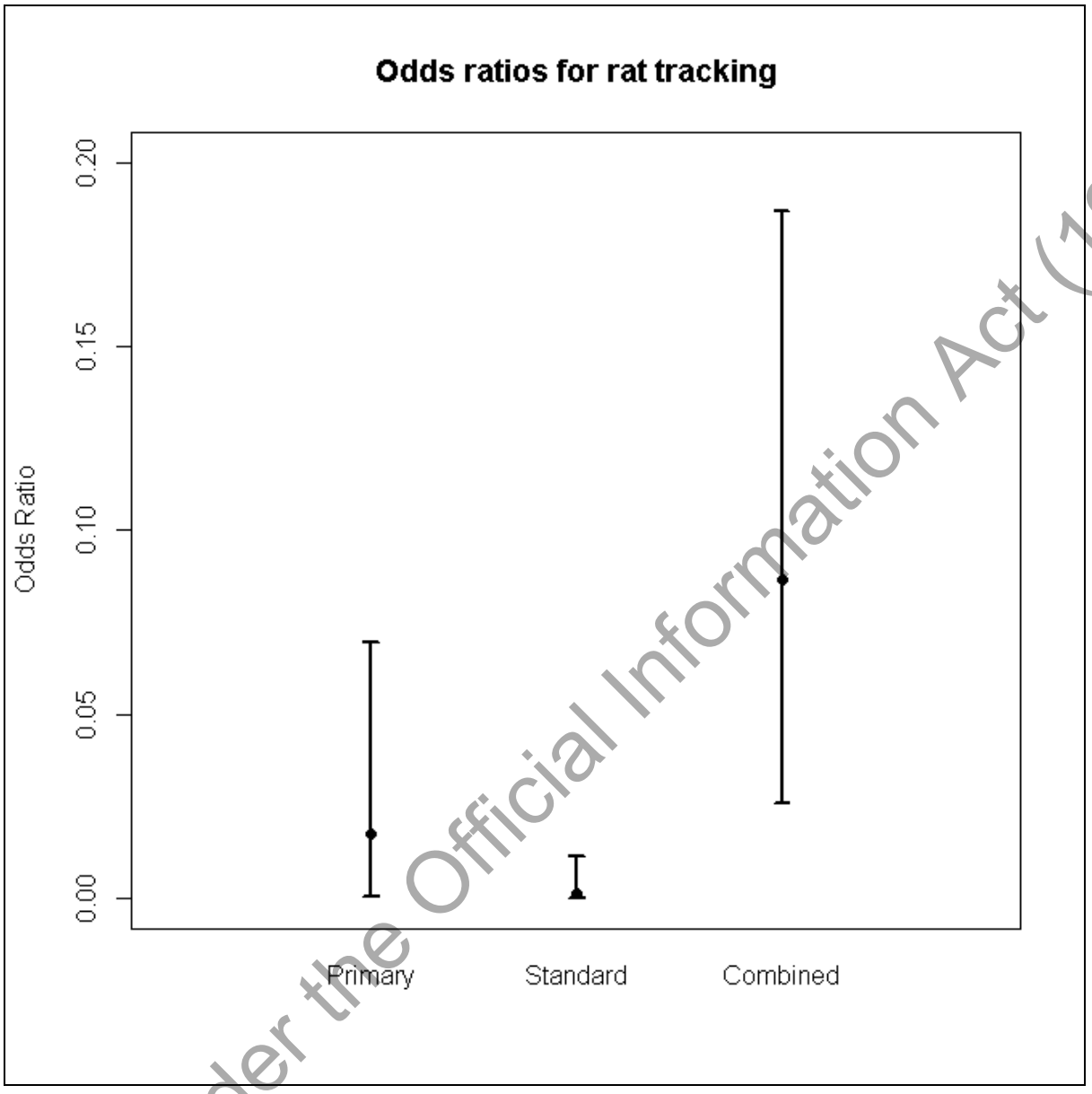

Figure 2: Mean odds ratio and 95% credible interval for the proportion of tunnels tracked by rats in the three treatments of aerially applied 1080 cereal pellets: primary repellent, standard and combined repellent.

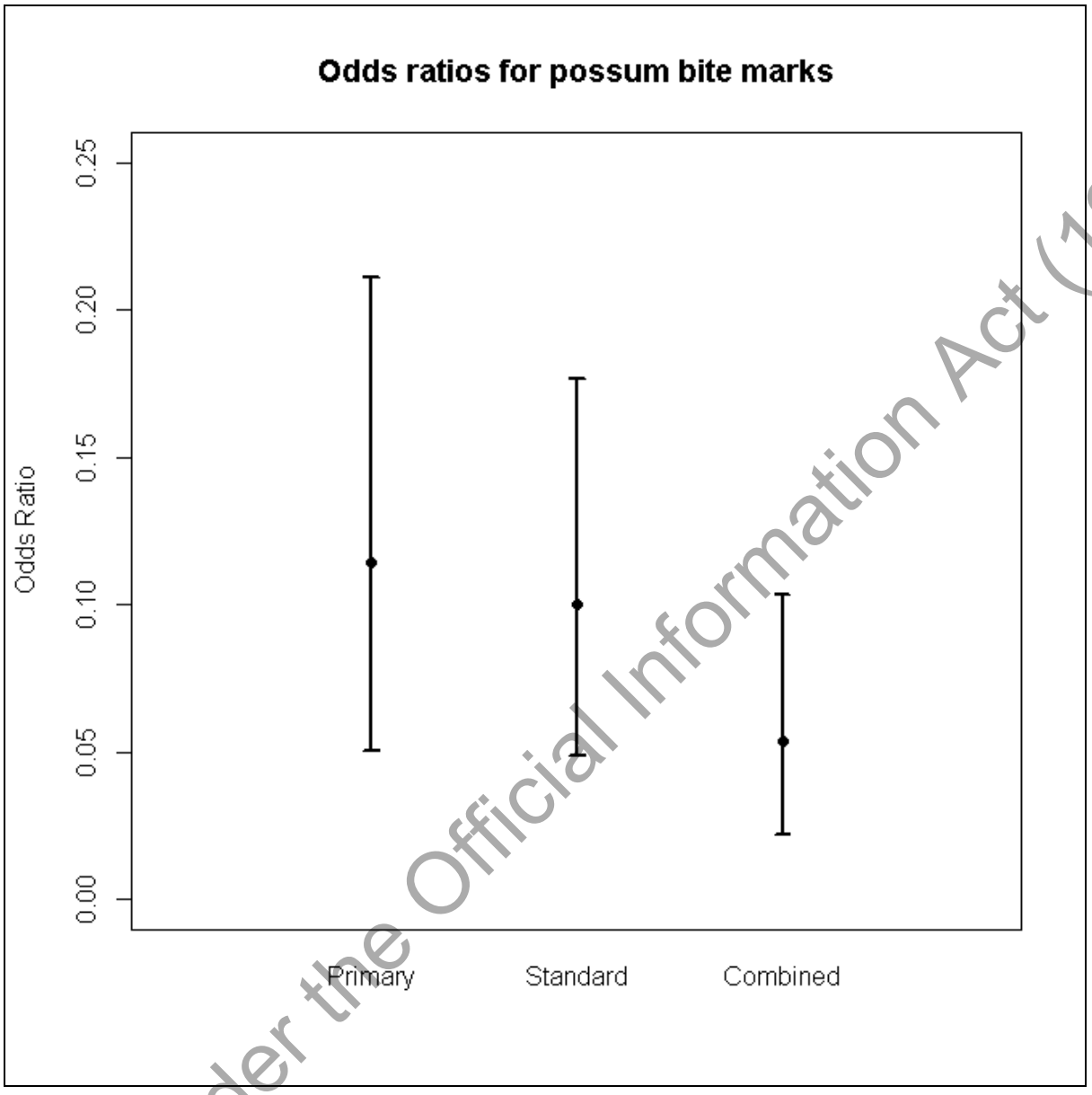

Figure 3: Mean odds ratio and 95% credible interval for the proportion of WaxTags bitten by possums in the three treatments of aerially applied 1080 cereal pellets: primary repellent, standard and combined repellent.

Appendix 7

Bird (Kea) Repellent Research

By [redacted] Landcare Research (for the Kea Conservation Trust)

1. Choice of active ingredients

Anthraquinone is used overseas as a seed treatment to prevent birds eating sown seed. It is an effective bird repellent by itself, and doesn't need to be combined with d-pulegone or blue dye (see Avery 2003). However, it may not be as effective as d-pulegone (Avery et al. 1997). Anthraquinone is a secondary repellent, which acts after birds have eaten baits containing it. d-Pulegone is a primary repellent and part of the reason for adding it to baits is to prevent birds eating baits in the first place. However, birds tend to habituate to primary repellents, which is why the combination of a primary repellent and secondary repellent, with colour as a visual deterrent, is theoretically more effective than either alone. However, further research on this topic is needed (Avery 2003).

Methiocarb is also used overseas as a seed treatment to prevent birds eating sown seed (Avery 2003). Like anthraquinone, it is a secondary repellent. Methiocarb is registered (as Mesurol) as a seed treatment in New Zealand .

Tannic acid is not used commercially as a bird repellent (although I note that Goose Chase, a bird repellent containing MA, says it is "laced with tannic acid"). Tannic acid by itself has been used only in experimental trials. Somehow, I get the feeling that if it was really effective it would be used commercially. However, the fact that it does not appear to repel laboratory rats makes it appealing to test further. Tannins are difficult for birds to digest (Avery 2003), and so are probably secondary repellents, but tannic acid may have an odour or taste that gives it some primary repellency. I'm not sure about this, but tannic acid may be like cinnamamide, and have both primary and secondary effects.

There are a number of other potential bird repellents, some of which are sold commercially overseas (e.g. thiram and aluminium ammonium sulphate, both taste repellents), which we could test if we had the resources (Spurr 2002; Avery 2003).

2. Concentration of active ingredients

Anthraquinone has been tested overseas at concentrations of 0.1–1% (wt/wt) on seed such as rice and millet (Avery et al. 1997, 1998a, 1998b; Dolbeer et al. 1998; Cummings et al. 2002). All concentrations reduced seed consumption by birds, with 1% concentration reducing seed consumption the most. For example, in a test where cowbirds had a choice of treated and untreated millet seeds, 0.1% anthraquinone reduced bird consumption of seed by about 90% over 4 days, whereas 0.5% and 1% anthraquinone reduced it by nearly 100% (Dolbeer et al. 1998). Bird consumption of treated seed decreased over time. Dolbeer et al. (1998) concluded that a minimum of 0.5% anthraquinone on millet was needed to maintain repellency to cowbirds for 4 days. Avery et al. (1998a, 1998b) and Cummings et al. (2002) tested only 1% concentration in field trials with rice seed.

In New Zealand , Day et al. (2003) found that 0.1% anthraquinone repelled robins by about 50% on day 1 and 80% on day 3. This concentration is lower than the 0.5–1% that seems to be favoured by overseas researchers.

Methiocarb has been tested at concentrations of 0.05–3% on seed such as corn, peas, and rice (Guarino 1972; Cummings et al. 1992, 1998; Avery et al. 1998a; Porter 1977; Porter et al. 1994). Red-winged blackbird and boat-tailed grackle consumption of seed was reduced by about 90–93% by 0.05% methiocarb and 92–97% by 0.1% methiocarb (Avery et al. 1998a). A concentration of 0.5% methiocarb is registered as a coating for pea seed in New Zealand .

3. Secondary repellent effects on birds

Anthraquinone affects birds by causing post-ingestional distress. It sometimes causes vomiting, but often the bird just sits quietly until the discomfort passes (Avery 2003). Unlike methiocarb, anthraquinone does not affect the bird's nervous system and does not immobilise affected birds (Avery 2003). Presumably the emetic response is produced through irritation of the gut lining, but the actual mechanism is unclear (Avery 2003). Dolbeer et al. (1998) found that cowbirds offered millet coated with 1% anthraquinone lost weight, whereas birds offered millet coated with 0.5% and 0.1% anthraquinone did not.

Methiocarb also causes post-ingestional distress. It inhibits acetylcholinesterase at nerve synapses (Avery 2003). Affected birds exhibit a range of symptoms including retching, vomiting, and temporary paralysis (Avery 2003). The severity of symptoms is dependent on the dose received. Typically, vomiting begins within 10 minutes of ingestion of treated food. An affected bird can become immobilised within 30 minutes of ingesting an appropriate dose, and it will recover fully in another 30 minutes (Avery 2003). That is, the effects are rapidly reversible.

4. Toxicity to birds

Methiocarb is more toxic to various species of birds than anthraquinone (LD50 generally <10 mg/kg for methiocarb vs. >100 mg/kg for anthraquinone) (Dolbeer et al. 1994, 1998). However, normally birds acquire a repellent dose and stop feeding long before a lethal dose is ingested (Avery 2003). There are few reports of dead birds following use of methiocarb (Dolbeer et al. 1994). However, some house sparrows and greenfinches were found dead after use of 0.34% methiocarb on pea seed in a trial in New Zealand (Porter 1977).

5. Field trial vs. lab trial

For either a field trial or a lab trial, I would suggest the following treatments:
Anthraquinone 0.1–0.5% (plus green dye and/or perhaps up to 2% d-pulegone)
Methiocarb 0.1–0.5% (plus green dye and/or perhaps up to 2% d-pulegone)
Tannic acid 2% (plus green dye)

Ideally, there should be a concentration screening trial of each compound.

6. Table of information on potential bird repellents for kea

I have updated the table. My initial summary was a bit misleading because I mis-interpreted Day et al. (2003). Day et al. (2003) stated they used 2% Avex in water and applied this to bait at a rate of 10% wt/wt, which equates to 0.2% Avex applied to bait, not 2% as I initially thought (see notes 1 and 2).

Table 1. Potential bird repellents for kea

Compound	Concentration (%)	Rats repelled	Possums Repelled	Kea repelled	Other bird spp repelled
Cinnamamide	0.1% 0.25% 0.5%	- Yes x 2 -	- - No	- - Yes	No No Yes
Anthraquinone alone	0.75–2%	Yes	No	-	Yes
Anthraquinone + blue dye	0.08%	? (see note 1)	No	-	Yes (tomtits)? (see note 1)
Anthraquinone + d-pulegone	0.1% + 0.17%	? (see note 2)	No	-	Yes (robins)
d-pulegone alone	2%	-	-	-	Yes
Methylanthranilate (MA)	2.5%	Yes	-	-	Yes
Dimethylanthranilate (DMA)	2.5%	Yes	-	-	Yes
Tannic acid	2%	No	-	-	Yes
OAP	0.01%	No	-	-	Yes
Methiocarb	0.5%	-	-	-	Yes

Note 1. Clapperton et al. (2005) claimed that fewer tomtits disappeared after 1080 poisoning using bait coated with 0.2% Avex (containing 43% anthraquinone, which equates to 0.08% anthraquinone) than after 1080 poisoning using bait without a bird repellent, although the difference was not statistically significant. They did not measure rat bait consumption in this field trial, but reported no reduction in rat bait consumption in a lab trial (but did not give any details of concentrations used or any results).

Note 2. Day et al (2000, 2003) claimed that rats were not repelled by baits containing a mixture of 0.2% Avex (containing 50% anthraquinone, equivalent to 0.1% anthraquinone) plus 0.2% d-pulegone (85% pure, equivalent to 0.17% d-pulegone), but their trial design was faulty. They should have said that there was no reduction in the overall amount of bait eaten by an unknown number of rats. Individual rats may have been repelled by the bait after first encounter, but new rats may have kept discovering and eating the bait. That is, they measured overall bait consumption rather than bait consumption per rat. Their trial needs repeating, either as [redacted] proposes with toxic bait in the field, measuring rat mortality, or with toxic or non-toxic bait in cage trials, measuring individual rat bait consumption (and/or mortality).

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Appendix 8

KEA 1080 BAIT REPELLENT TRIAL LITERATURE REVIEW

9(2)(a), 9(2)(g)(ii) **, November 2012.**

Introduction

This literature review is being conducted from a very naïve standpoint as I have no prior experience or skills in either aversion biology in birds or mammals and its associated action and physiology or the common scientific practices and operational processes of evaluating bait/repellent efficacy for target pests.

In reviewing the avian bait repellent literature and ancillary papers several key issues are driving my interpretation of the available data:

- As kea are the primary focus of this body of work and that we know that the LD50 of 1080 for kea is much less than a single 0.15% 1080 bait pellet at 1.8-4.7g dry mass (Orr-Walker et al 2012) I have given greater focus for seeking examples where repellent additives have achieved a large and immediate reduction in bait consumption by the non-target species whilst also identifying those primary and secondary repellents that consistently fail to meet such a standard.
- We are aiming to achieve an extremely high level of conditioned taste aversion in the non-target species population which requires a subtle yet significantly different perspective on primary repellent agents compared to common scenarios in the literature where minimising crop damage goal.
- As conditioned taste aversion is dependent on the non-target species being able to recognise and predict a negative consequence of bait consumption, signal recognition from the bait and association of the bait with the consequences of the secondary repellent action are the critical outcomes being sought.
- The avian repellents we seek to test must also have the potential to not act as a repellent for target rodents and possum.

Against these key issues a number of questions have been posed ([redacted] pers comm.) which pointedly advance our position to make experimental design and material decisions:

1. What studies have been done (with birds, rats or possums) using Aq as a secondary repellent without any primary repellent, and what were the findings?
2. What is the likely timeframe between consumption of Aq and parrots feeling gastrointestinal discomfort?
3. What primary cues (including primary repellents) would be candidates to add to the repellent strategy for kea?
4. What other investigations of conditioned taste aversion that could provide ideas for experimental designs?
5. Has research investigated whether target pests would be repelled by the preferred avian repellent materials?

General bird repellent perspectives

The toxin sodium monofluoroacetate (1080) has historically been used as an avicide (Spurr 2007) and directly implicated in mortality of non-target avian species following pest control operations (Veltman and Westbrooke 2011). Therefore it is both reasonable and urgent that the DOC place a priority on developing effective repellent strategies for the continued use of 1080 for pest control whilst minimising risk to species such as kea (Weser and Ross 2012; Orr-Walker et al 2012;Veltman and Westbrooke 2011)..

Primary repellents create a reflexive aversion in the target animal whereas secondary repellents require some consumption of the agent to which a learned aversion response is developed (Avery and Nelms 1990). Primary repellents are clearly the preferred method of achieving aversion as contact with the element for which repellence is being sought has the potential to neither require ingestion nor lengthy exposure. However, the

literature appears devoid of examples where a primary repellent has achieved complete or even near complete (>80%) aversion except under laboratory conditions and with lithium chloride repellent (Werner and Provenza 2011) which is also documented as an effective mammalian repellent (Brown et al 2000). As such, known primary repellents are not adequate on their own to achieve the desired outcome for kea and other non-target avian species. Given that any addition of materials to a pre-feed or toxic bait will require consideration of non-intended effects on target and non-target species and as such will need to be factored into experimental trial design it is desirable to evaluate whether any secondary repellents currently documented have the potential to provide an adequate level of bait aversion without additional primary repellents.

Literature review

As has been recommended ([redacted] unpublished report to KCT) the weight of evidence from the literature suggests that anthraquinone (AQ) is likely to be the most effective secondary repellent for kea and preliminary research suggests it has some utility (Kemp pers comm.; [redacted] pers comm.).

However, before discussing the published merits and limitations of AQ it is worth considering what other secondary repellents are reported in the literature as effective avian repellents and determine if any manuscripts provide examples of these alternatives being used as a sole repellent. The majority of secondary repellents the author read about have been withdrawn from use due to environmental and toxicological concerns. Notable among those are lindane (Walker et al 1999). This organochloride was licensed by the EPA in the USA as an insecticide and was also recognised as a secondary bird repellent but the licence for its use was withdrawn in 2006 due to the familiar concerns of organochloride use (EPA unreferenced website report).

Thymol the fungicide, together with the bittering agent denatonium saccharide, also appears in the literature as a secondary repellent (Clark 1998). Efficacy and current

status as a bird repellent was not verified but contemporary research continues into its use as an effective insecticide (Panday et al 2009).

Thiram (tetramethylthiuram disulfide) was the last remaining secondary avian repellent recorded as still in use (Kennedy and Connery 2008; Clark 1998). Crow damage to winter wheat was reduced by up to 70% with the use of thiram (Kennedy and Connery 2008). Thiram was also identified in the literature as an effective repellent to rodents including *Mus musculus* in the treatment of aerially sown pine seeds and so is most probably of no utility to our purpose (Nolte and Barnett 2000).

1. **What studies have been done (with birds, rats or possums) using Aq as a secondary repellent without any primary repellent, and what were the findings?**

Of ten published reports detailing Aq use as a secondary repellent only five cases were found that did not also include a primary repellent in the treatment (Werner et al 2011; Werner et al 2009; Cummings et al 2002; Avery et al 2001; Dolbeer et al 1998).

In a study where 1 and 2% Aq (wt/wt) was added to a 2% zinc phosphide acute rodenticide targeting black-tailed prairie dogs, laboratory trials suggested non-target birds demonstrated 100% survival following exposure to zinc phosphide (2%) baits with AQ following prior exposure to non-toxic bait containing only 2% Aq (Werner et al 2011). However the LD50 of zinc phosphide is brought into question by the authors following moderate toxic bait consumption by certain non-target birds. The most intriguing result from this study is that black tailed prairie dogs appear to be sensitive to Aq in a manner that is not directly related to the Aq concentration (r^2=0.2, P=0.4). This finding raises concerns regarding the parameters by which we might evaluate Aq repellence to rodents in the current study. I find it difficult to extrapolate the findings of this study to the likely outcomes of a field treatment of 1080 baits with Aq, other than to confirm that a period of

exposure is necessary to enable aversion to be learned, and that this study should undermine our confidence that Aq does not hold repellent qualities for rodents.

Another study where Aq is applied without a primary repellent details the treatment of rice production with 1% active Aq to minimise damage by blackbirds (Icterinae) (Cummings et al 2002). Damage was significantly reduced by the treatment (effective Aq ~0.5% w/w) but the results do not explain whether this was the result of reduced seed predation by all blackbirds or the consequence of a proportion of blackbirds not being averse to AQ. It is also my interpretation of the paper that the treated rice fields were a small proportion of the available foraging habitat available to this highly mobile species and so apparent repellent effects may be over-stated.

In a trial of Aq, methiocarb and MA, Aq was found to be effective at creating aversion in Dickcissel above 0.05% although at this concentration emesis was observed at the one-cup trial but apparently did not lead to greatly reduced consumption (Avery et al 2001).

The oldest paper identified evaluating Aq as an avian repellent is Dolbeer et al (1998) where 0.1%, 0.5% and 1.0% (w/w) formulations of Aq achieved repellence in geese and cowbirds. Interestingly, at the 1.0% formulation even birds in a two-choice laboratory experiment exhibited weight loss and 3 of 12 cowbirds died in the 0.5 and 1.0% Aq two-choice trials suggesting that in such concentrations for some species (cowbirds, Icteridea) Aq is more than just a emetic irritant.

There appear to be no examples of studies of Aq palatability to possum in the absence of other repellents although no apparent aversion to Aq (0.2%) and d-pulegone treated carrot baits was described by Day et al (2000). I am unable to find any test of d-pulegone repellence for possum in the literature.

A cursory literature search suggests that there are no studies detailing rodent responses to Aq treatment of bait in isolation of other repellents. Day et al (2000) describe that both rats and possum take avex (Aq) and d-pulegone treated carrot bait as readily as bait

treated only with cinnamon oil in field trials suggesting that at concentrations below 2% (w/w) that there are no significant repellent effects of Aq on rats.

2. **What is the likely timeframe between consumption of Aq and parrots feeling gastrointestinal discomfort?**

No specific reports were found detailing the time period of exposure to Aq (or any other repellent) in parrots (Psittaciformes) and the following physiological response. Malhe et al (2003) expose rose ringed parakeets to Methyl Anthranilate but give no details of the timing of any behavioural response outside of the 3-4 day period between treatments. A curious study testing attractiveness and palatability of repellent treated baits to orange fronted parakeets, which revealed neither the bait medium nor the repellent agents, failed to detect any meaningful aversion or notable behavioural response to the repellent (Clapperton et al 2005).

No comment is made in Orr-Walker et al (2012) regarding gastrointestinal discomfort or emesis in the kea exposed to Aq and d-pulegone in the trials described but reference is made to the significantly different rates of consumption of bait between individual kea. This might suggest that some individuals require more exposure to repellents (Aq and d-pulegone in this case) than others before an aversive response is generated. Indeed such an aversive response is suggested to be governed by physiological state in the conclusions drawn by Werner et al (2009) due to inter and intraspecific differences in the doses necessary to achieve 80% repellence.

3. **What primary cues (including primary repellents) would be candidates to add to the repellent strategy for kea?**

Primary repellents and signalling cues offer far greater choice than when considering secondary repellents. It would seem that they are also very likely to enhance the efficacy

of secondary repellents such as Aq and facilitate the learned aversion response (Clapperton et al 2011; Baker et al 2007).

Amongst the literature, **methyl anthranilate (MA)** is a common primary avian repellent with studies examining it's effectiveness in isolation (Kentish et al 2003; Moran 2001; Umeda and Sullivan 2001). Despite it's apparent widespread use, at worst, these three studies call into question the efficacy of MA as a repellent as Moran (2001) fails to detect any repellence in a no choice food trial for sparrows and pigeons at 2ml MA per kg of bait and at best suggest broad interspecific variability in sensitivity to MA. Kentish et al (2003) also struggle to demonstrate any significant repellence of MA with a somewhat confounded study design. Neither was the efficacy of MA enhanced (it was reduced) by the addition of an adjuvant (Umeda and Sullivan 2001). Most notable is that Avery et al (2001) found that whilst repellence was achieved in Dickcissels with AQ (0.5%) and methiocarb (0.05% g/g), the same study found MA ineffective. In the New Zealand context Spurr et al. (2001) found the repellent effect of MA consistently reduced palatability of bait to rats across the spectrum that is of use for the repellence of birds.

Methiocarb, whilst apparently being a very effective primary repellent, is probably best excluded from the primary repellent option to consider in our study as it is known to cause malaise, temporary paralysis and repeated emesis in affected birds (Avery et al 2001). Such consequences would themselves put species such as kea at risk from predation, exposure and general miss-adventure.

Cinnamon oil is currently added to toxic cereal baits yet clearly hasn't worked in the 1080 operations that have killed kea (Veltman and Westbrooke 2011). The additional repellent effects of cinnamon oil is directly tested by Clapperton et al (2011) and resulted in no change in the repellence of Aq but I remain a little confused by their experimental design.

Cinnamamide is also recorded in the literature as being effective as a primary repellent for birds (Crocker et al 1993). Despite being effective it was documented that up 94% of

the cinnamamide had washed off the treated plants within three days. Persistence was enhanced through subsequent research into 'sticker' agents (Cotterill et al 2004). However, cinnamamide has also been recognised as an effective rodent repellent at moderate concentrations (0.8% w/w) (Gurney et al 1996). Interestingly in this study house mice maintained a strong learned aversion to the treated bait yet the wood mouse, (*Apodemus sylvaticus*) returned to pre-trial levels of bait consumption within three days of the treatment. This is a clear indication of the degree to which repellent responses may vary between conspecifers. Cinnamamide fairs very poorly for the demands of bird repellence and rodent palatability in the New Zealand context in Spurr et al (2001).

Caffeine has also been tested as a primary repellent for birds (Werner et al 2007; Avery et al 2005). Being moderately cheap, caffeine looks like a promising and effective primary repellent with repellence at >85% in blackbirds when treatments contain 2500-20000ppm caffeine with sodium benzoate solubility enhancer. However I can find no literature that describes the effect of caffeine on rodents.

Garlic oil has also been recorded as an effective avian repellent (Hile et al 2004). At moderate concentrations moderate repellence is achieved (50% reduction in starling bait consumption with 10% garlic in bait, 17% reduction with 1% treatment). Whilst no formal literature exists that evaluates the repellent qualities of garlic for rodents the (very) grey literature abounds with reportedly rodent repellent potions and sprays containing garlic.

Tannic acid has been recognised as a potential bird repellent for some time although levels of repellence and physiological action have remained unclear (Crocker and Perry 1990; Crocker et al 1993). A better evaluation of the potential value of tannic acid as a primary repellent is offered by Spurr et al (2001). In this study tannic acid (20g/kg) and ***ortho*-aminoacetophenone** (1g/kg) both demonstrated potential as a suitable primary repellent yet both suffered poor persistence for the period necessary to provide aversive cues over the likely field life of toxic baits. Spurr et al (2001) suggest condensed tannins may be a solution to this issue.

d-pulegone has been recognised as an avian repellent for some time (Wager-Page and Mason 1996). A peppermint compound, d-pulegone offers a primary and secondary repellent function to birds due to its volatile nature and strong flavour. It has been shown to achieve aversion in a small range of avian species at a relatively low concentration of 1% w/w (Mason 1990; Mastrota and Mench 1995; Day et al 2003). Most significant is that d-pulegone at the tested 1% w/w has proven not to be a detectable repellent to rodents or possum in New Zealand based trials(Day et al 2000). This identifies d-pulegone as a strong candidate for our consideration. No details are provided in any of the literature regarding the persistence of d-puligone but issues have been reported and require further exploration ([redacted] pers comm.). Day et al (2000) go on to suggest that the coupling of proven secondary repellents with other signal components of bait such as bait colour as a potentially more cost effective solution to the need to enable recognition of the treated baits for learned aversion.

Human perceived bait colour has been identified as a factor in non-target consumption rates for quite some time (Caithness and Williams 1971). Captive weka displayed an aversion to green dyed baits in feeding trials yet a number of examples exist where the evidence is compelling that weka populations were directly impacted by the broadcasting of green dyed 1080 baits (Udy and Pracy 1981; Empson and Miskelly 1999). Further work suggested that blue is also a repellent colour to weka (Hartley, L.J., J.R. Waas, C.E. O'Connor and L.R. Matthews 2000). With this result in mind we should be cautious about placing too much aversion relance on the finding of Weser and Ross (2012) that kea are least attracted to green and dark-blue dyed baits. Indeed, as kea are known to be both highly intelligent and inquisitive of their environment in the search for food we should not be surprised if such colour preferences evaporate in the field if not reinforced with a secondary repellent.

Ultraviolet (UV) light absorption or reflectance is a well documented visual signal component amongst many of the avies and is supported by a complex physiological, structural and ethological literature neatly summaried in Blackwell (2002). Whilst we

have no data to investigate the spectral vision in kea, Werner et al (2012) used a spectrometer to confirm UV absorption by Aq (Du et al 1998) in baits that held repellent qualities for kea. The study then demonstrated that birds conditioned with Aq subsequently avoided baits that contained either Aq or another UV-absorbing compound. This provides a very strong indication that UV absorption may act as a cue for kea. This cue may be extremely helpful in achieving efficient learned aversion in kea.

4. **What other investigations of conditioned taste aversion that could provide ideas for experimental designs?**

   - In reading through this broad and novel (to me anyway) field of literature a large number of issues have been raised with regard to testing conditioned taste aversion. The deadline for this review has not permitted sufficient time for me to properly synthesise my notes but a number of issues stand out:

   - Gentle et al. 2006 suggest repellence may be over-estimated in lab conditions where subjects are maintained on a monotonous diet, although it is arguable as to whether captive kea held in appropriate conditions have a more or less diverse diet in the broadest sense when compared to wild birds. Irrespective, the captive and *in situ* conditioned taste aversion trials intended are equally important components of the investigation.

   - Persistence of aversive stimulus in the materials tested must match the likely maximum timeframe of bait availability in the environment as Spurr et al (2001) and other studies detail examples of rapidly increasing bait consumption in some species following the removal of repellents from bait provisioned. Thus if the aversive effect is weathered from the bait quicker than the toxic agent we may be placing non-target species at unacceptable risk.

- In social species such as kea it is important to account for the influence of conspecifers may have on ethological responses to bait and repellent stimuli. As detailed in Orr-Walker et al (2012), it is essential that multiple trial stations be available with visual barriers to control for food monopolisation and the resulting skewed preferences exhibited.

- Avoid free feeding trials (where baits may be easily carried away from the feeding station) in captivity or field situations as bait removal totally obscures actual ingestion data. This issue essentially renders the findings of Clapperton et al (2005) un-interpretable.

- Individual bird identification is likely to be critical to a competent trial design to evaluate conditioned taste aversion especially as a number of studies have described the individual variability in bait preference (Day et al 2003).

- Subtle cues created by bait materials such as the specific UV reflectance of Aq should encourage us to ensure that our experimental design involved as much consistency of ingredients as possible across pre-feed and toxic baits.

- Ensure a capable statistician familiar with behavioural type studies and innumerate herpetologists is engaged at the earliest opportunity to assist in the development of an analytically robust trial design.

5. **Has research investigated whether target pests would be repelled by the preferred avian repellent materials?**

We can take some confidence from the work of Day et al (2000) who describes that both rats and possum take avex (Aq) and d-pulegone treated carrot bait as readily as bait treated only with cinnamon oil. Rodent aversion to Aq has been documented but in prairie dogs (*Cynomys* spp.) which are taxonomically distant from *Rattus* spp. (Werner et al 2011). This study treated zinc phosphide baits with 2% Aq.

Cinamamide is evaluated by Crocker et al (1993) as a rodent repellent for crop treatment and offers a reduction in grain consumption in a no-choice test of 62% at 0.5% (w/w) suggesting that this primary repellent is likely to not be of much assistance in our study.

Methyl anthranilate is repellent to rodents at concentrations of 25g/kg (Spurr et al 2001) and as detailed earlier in the document is not appropriate for use with sensitive avian subjects.

Conclusions

Considering my reading of the literature I find it very difficult to refute or meaningfully advance the assessment of primary and secondary repellent options for kea beyond those already offered by [redacted] to the Kea Conservation Trust ([redacted] unpublished data). This will largely be due to [redacted] long history in the field of pest control and his thorough assessment of the issue but probably also reflects my absence of any background knowledge, training or skills in this field to date.

Primary repellents

The recommended primary repellent option is **d-pulegone**. This is based on the weight of evidence in the literature for its inclusion in successful trials. The volatility issue remains and a priority is to investigate the options for achieving greater persistence in d-pulegone. The **0.17-0.2% concentration** would seem quite appropriate.

Caffeine and tannic acid offer additional options but I lack the pharmacological perspective to know whether such elements could or should be considered for addition to

the baits. The rodent caffeine literature seems a bit thin so if recommending an additional primary repellent for consideration I lean towards tannic acid if a persistent form can be found.

The literature would seem to support the use of **Aq** as the preferred secondary repellent. Concentrations that would seem prudent to test include **0.1%, 0.2% and 0.5%**.

Visual cues

UV absorptive qualities of Aq appear to factor in the learned aversion response in kea and therefore it would seem prudent for this reason to ensure this property is retained in the toxic baits as well as the pre-feed. I find the literature on bait colour preference and aversion unconvincing but see no reason not to follow the findings of Weser and Ross (2012) if it causes no compromise to the inclusion of primary and secondary repellents.

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Appendix 9

Animal Health Board Final Report:

The effects of aerial 1080 on kea populations

Draft: 16 August 2013

9(2)(g)(ii)

Department of Conservation

186 Bridge Street

Nelson

Contents

OVERVIEW OF THE KEA-1080 RESEARCH PROJECT, STUDY AREAS AND METHODS

9(2)(a), 9(2)(g)(ii)

INTRODUCTION

The kea (*Nestor notabilis*), a large parrot endemic to the South Island of New Zealand, is distributed over approximately three million hectares of native forests and alpine areas (Robertson et al. 2007)(Figure 1). Kea density appears to be very low across most of its range. The species is classified as 'At risk' by Miskelly et al. (2008), having previously been 'Nationally endangered' (Hitchmough et al. 2007). The classification may be viewed as precautionary, as population measures on which to base it are scant. Nonetheless, numerous threats to the kea population have arisen with the arrival of humans in New Zealand. Grounds for concern about the population trajectory of the kea exist in the literature on a sympatric congener, the kaka (*Nestor meridionalis*). Robertson et al. (2007) report a definite reduction in kaka species range over the last three decades, and other authors report very low recruitment rates and high mortality of adult females due to impacts of invasive predator species (Wilson et al. 1998; Moorhouse et al. 2003). The kea population is unlikely to be free from similar invasive species impacts. In addition, the kea's scarcity may be partly due to a history of persecution by humans. Bounty hunters are thought to have killed at least 150,000 kea between 1860 and 1970 when the species was considered a pest on high country sheep runs (Cunningham 1948; Anderson 1986).

The kea is now an absolutely protected species, but invasive species with the potential for very strong impacts remain ubiquitous throughout the range of the kea. The ground-nesting habit of the kea makes it potentially vulnerable to invasive predator species such

as the stoat (*Mustela erminea*), the ship rat (*Rattus rattus*) and the possum (*Trichosurus vulpecula*). Attempts to measure the impact of invasive predators have been few and are mostly unpublished (Kemp 1999; Elliott and Kemp 2004).

The forests inhabited by the kea are dominated by the Southern beeches (*Nothofagus spp.*) and rimu (*Dacrydium cuppresinum*). These are all masting species, within which reproductive effort is episodic (Wardle 1974; Wardle 1984; Norton and Kelly 1988). Mast years punctuate longer periods of very low reproductive effort A mast year is a major ecological event in both *Nothofagus* (King 1982; King and Moller 1997; Fitzgerald et al. 2004) and rimu forests (Harper 2005). As well as providing food for parrots such as the kea, kaka and käkäriki (*Cyanoramphus spp.*), beech and rimu mast leads to increases in the abundance of rodents. Invasive rodent species ubiquitous in kea habitat are the house mouse (*Mus musculcus*) and the ship rat (*Rattus rattus*). These rodents tend to become scarce in kea habitat years without mast. After mast, however, their numbers increase dramatically.

The increase in availability of rodents drives the production of a peak-year cohort of stoats, a phenomenon known as a stoat plague(King 1983). Stoat plagues are manifest in the summer following the ripening of beech mast, when extra-large litters of stoats, raised on a diet of rodents, become independent. The cohort of young stoats produced after non mast years is markedly smaller (King 1983). Every year only one cohort of young stoats is produced. This cohort becomes independent during December-January (King 2005), which is toward the end of the kea nesting season (Jackson 1963; Kemp 1999).

Studies of other New Zealand birds, especially the kaka, highlight the potential importance of stoats and stoat plagues in contemporary kea demography and management. Linking predator control effort to the beech mast cycle has increased the

efficiency and success of conservation management programmes for other forest birds, and bats (O'Donnell et al. 1996; Dilks et al. 2003).

The possum is a predator of kaka nests (Moorhouse et al. 2003; Powlesland et al. 2003) and is therefore another potential predator of kea nests. Possum numbers are quite stable compared to rodents and stoats, depending primarily on local factors such as forest composition and forest condition rather than on episodic events such as mast.

Options for controlling predators to enhance kea numbers are limited by the scale required to encompass enough kea. Jackson (1960) reported breeding pairs of kea at a density of one per six hundred hectares in the upland beech forests of Arthurs Pass National Park. At this density, predator control covering six thousand hectares would be required to encompass as few as ten breeding pairs. Design of predator control regimes for kea also needs to account for juvenile dispersal, as the kea is a strong flier and juveniles could easily disperse out of a six thousand hectare area.

Currently available tools for predator control on such a scale in mountainous landscapes include 1) a network of stoat traps, and/or 2) aerial 1080.

Stoat trap networks currently exist over approximately 150,000 hectares of kea habitat, but trap line spacing exceeds the best practise 1km over most of this. About two-thirds of the trapped area (c.100,000 ha) also receives periodic aerial 1080 treatment (O'Donnell and Hoare 2012, for example).

Aerial 1080 baiting without stoat trapping is much more common, with about one million hectares currently treated in this way by either the DOC or the AHB. This represents about one-third of the species range of the kea. This makes it by far the most commonly deployed pest control tool deployed in kea habitat. The period between repeated baiting varies from two-yearly to seven-yearly. Managers hope that the abundance of kea might be positively influenced, but measurement has never been

attempted. In fact, the effect of any type of predator control on any kea population has not been measured before.

A review of non-target 1080 risk by Spurr & Powlesland (1997) identified the kea as a high priority for non-target 1080 research. Spurr (1979) highlighted the fact that, for a long-lived, slowly reproducing species like the kea, even a small reduction in the otherwise-high survival rates of juveniles and adults could result in significant population decline. Veltman and Westbrooke (2009) published some non target risk data gathered during the early stages of this study, in which some mortality of radio tagged keas was detected. This data is presented again here, alongside additional data from other study sites and an analysis of effects of environmental and individual covariates.

The primary aim of this study was to measure the effects of aerial 1080 baiting on kea populations, considering both non target risk and potential predator control benefits. The mathematical framework we use to balance costs and benefits of aerial 1080 is matrix population modelling (Leslie 1945; Caswell 2001). Matrix population models are, fundamentally, calculations of the net effects of survivorship and recruitment. This study, therefore, is one of quantifying survivorship and recruitment in order to parameterise a Leslie matrix. The speed and power of modern computers allows extension of the basic Leslie matrix modelling approach, so that different Leslie matrices reflecting environmental process variation may be used in a single simulation. This study, therefore, not only parameterises Leslie matrices, but uses evidence to decide which covariates can be justifiably input to the models.

This reporting of this project is structured as follows.

1. Details of study sites, field methods and data analysis methods common to parts 2-4 (below).

2. Quantification of non target risk (cost of aerial 1080).

3. Quantification of productivity with respect to covariates including aerial 1080 (benefit of aerial 1080).

4. Quantification of annual survivorship with respect to covariates including aerial 1080 (benefit of aerial 1080).

5. Population modelling to assess net outcome of aerial 1080

Here, we describe in detail our study areas, and present common elements of field methods and data analysis. Factors (covariates) hypothesised to effect kea vital rates are described here, rather than repeated throughout the reports.

STUDY AREAS

The primary aim of this study was to measure the effects of aerial 1080 baiting on kea populations, considering both non target cost and predator control benefit. Our main study areas, therefore, were chosen due to aerial 1080 being the sole predator control tool. These study areas are called 'Westland' and 'Kahurangi' (Figure 1). At both of these we measured kea vital rates with and without aerial 1080 treatment. At Westland we maintained a BACI (Before-After-Control-Impact) design throughout the study period. Two important supplementary study areas 'Rotoiti' and 'Hawdon Valley' were also maintained in collaboration with the Kea Conservation Trust (www.keaconservation.co.nz). These sites included areas in which ground based control was ongoing (a stoat 'press'), complementary to possum control by trapping (Rotoiti) or aerial 1080 (Hawdon). These supplementary sites provided vital-rate data from keas living under more-intensive predator control than aerial 1080 alone (i.e. stoat traps as well as possum control). At Rotoiti a sub-area of no predator control existed (Raglan Range) in which some vital rate data was also gathered.

141 At Westland, Kahurangi, Rotoiti and Hawdon Valley we maintained intensive field
142 operations for more than three years, gathering data on kea vital rates under various
143 environmental conditions. Concurrently, the relative abundance of rodents and stoats
144 was measured.

145 Additional vital rate data was gathered at a site in eastern Fiordland ('Borland'), in
146 collaboration with the KCT. This site lacks predator control of any form. Field work
147 was attempted here to boost the amount of data available from the untreated situation.
148 However, the Borland study area has been difficult to maintain due to logistical and
149 financial challenges and yielded little useful data for this analysis.

150 Three further study areas were initiated primarily for measurement of survival through
151 the risk period after aerial 1080 (Figure 1). These are 'Arawhata', 'Franz-Fox' and 'Abbey
152 Rocks'. Small amounts of supplementary survival data were collected at these sites and
153 this is included in our age-specific survival analysis.

154 **Westland**

155 The Westland study area comprises lowland podocarp forests on weathered glacial
156 moraines between the Tasman Sea and the Southern Alps. The soil is infertile and
157 drainage is often poor, resulting in rimu trees dominating the landscape. Southern rata is
158 present on ridges and occasional stands of kahikatea exist on wetland edges.

159 The Westland study area is divided into three parts: an untreated area and two treated
160 areas. We call these 'Fox-Paringa', 'Lower Copland' and 'Okarito', respectively. The
161 Fox-Paringa area has no history of predator control and remained without control for the
162 duration of this study. The Lower Copland area was originally within the Fox-Paringa
163 area, but was split off when the home areas of two radio tagged adult female study birds
164 were included in an aerial 1080 operation in 2012. The Okarito area was subject to aerial
165 1080 (Figure 2) in the third year of the study, at the start of the 2011 kea nesting season.

Field work in Westland took place over five years, 2008-2012. At Westland we attempted a BACI style (Before-After, Control-Impact) study.

Kahurangi

The Kahurangi study site is beech dominated, with silver beech (*N. menzeisii*) above 1000m a.s.l., hard beech (*N. truncata*) dominant at <700m and a band of red beech (*N. fusca*) at about 700-1000m. The area is steep and mountainous, with a timberline at about 1300m a.s.l. and sub-alpine tussock lands above. Areas of karst landscape are found within the study area.

The Kahurangi study area is divided into two parts, which we call Mt Arthur and Wangapeka. The boundaries of these study areas are defined by the aerial 1080 operations that took place in 2009 and 2011, respectively (Figure 3). However, field work was concentrated into areas defined by ease of access and the home ranges of the keas we radio tagged.

The Mt Arthur area had not received any prior predator control (including aerial 1080) when we commenced field work in spring 2008. The Mt Arthur area was treated with aerial 1080 in June 2009. The Taylor Stream part of the Wangapeka area had not received any prior predator control when we commenced field work in 2009, but the rest of the area had received aerial 1080 in 2006. A low level of stoat trapping in valley floors, for whio protection, was maintained along the Wangapeka River by the Department of Conservation, but this was too remote from our kea to be considered. For the 2009 and 2010 seasons, we focussed our field work within the Taylor Stream untreated area. After the aerial 1080 operation in September 2011, we expanded our field effort to the south. Data collection in the Mt Arthur area was downscaled after 2010 due to insufficient kea numbers and difficulty of access. Data collection in the Wangapeka area has continued until now and the Kea Conservation Trust intends to continue.

Mast driven mouse irruptions occurred in Kahurangi in 2009 and 2012 (**Error! Reference source not found.**). The years of 2010 and 2013, therefore, are classed as stoat plague years. Rodent abundance was low during both the Mt Arthur 2009 and Wangapeka 2011 aerial 1080 operations.

Rotoiti

This study area is in Nelson Lakes National Park in the northern South Island. The valley floors, at 600-700 m above sea level, support a mixture of beech forest and grassy flats. River terraces, alluvial fans and steep valley sides support red beech (*Nothofagus fusca*) forest up to about 1000 m a.s.l., within which occasional silver beech (*N. menziesii*) are scattered. Above this grows a monoculture of mountain beech (*N. solandri* var. *cliffortioides*) up to the tree line at about 1400 m a.s.l.. Above the tree line, snow-tussock grasslands (*Chionochloa* spp.) include a variety of alpine and subalpine shrubs and herbs such as *Celmisia* spp., *Podocarpus nivalis* and *Hebe* spp. Above that, there are bare rocks and fellfields with mountain peaks reaching 1600 – 2011 m a.s.l.

The study area was chosen for the presence of convenient roads, tracks, and a navigable lake to allow rapid travel around the study area and the traversable nature of forest and the mountain ranges and because of a history of kea monitoring in the area during the 1990s.

An untreated sub area at Rotoiti, which we call 'Wairau Valley' comprises the Raglan Range, on the eastern side of the Wairau River, the Wairau Valley south of Six Mile Stream and St Ronans Stream. A treated area, in which ground based possum and stoat control has been undertaken, comprises the Six Mile stream and the St Arnaud range north of Six mile stream.

Rotoiti predator indexing

Hawdon Valley

The Hawdon Valley is similar to Rotoiti in landscape and vegeation, but ground-based stoat control is continuous. Aerial 1080 occurred in 2006, 2009 and 2012. Kea monitoring commenced in 2009.

Hawdon predator indexing

Arawhata

The landscape in the Arawhata valley is mountainous, with the valley floor at about 300m above sea level and tree line about 1000m. Vegetation comprises mixed beech-podocarp-hardwood forest at lower altitudes, pure beech forest at mid-altitudes and sub-alpine scrub at high altitude.

Abbey Rocks

Borland

Franz-Fox

FIELD METHODS

Kea

Keas were lured for capture using recorded kea calls and stuffed kea decoys. Keas were captured using purpose built snares and small net guns. In the beech forest sites, most keas were captured on the open tops (i.e. above treeline). In Westland, keas were captured in the forest.

VHF radio tags weighing 24 grams were fitted using a backpack harness made of 2mm braided nylon (Karl and Clout 1987). Coloured metal leg bands (size V) were fitted to the birds to enable identification of individuals from a distance.

Radio transmitters were purchased from Sirtrack Ltd and Kiwitrack Ltd. All transmitter had a mortality-indicating function. This function switches the pulse rate from 20 pulses per minute (PPM) to 40 PPM after twelve hours of inactivity, indicating either mortality of the bird or the shedding of the transmitter. The transmitters had a battery life of between 38 and 46 months.

The transmitters were attached to the kea using flying-bird harnesses (Karl and Clout 1987). The harnesses have a biodegradable link, which allows the eventual shedding of the transmitter.

The gender of each bird was assessed by measuring head size, culmen length and body weight. Birds were classed as adult (> 3 years), Subadult (2-3 years), juvenile (1-2 years) and fledgling (0-1 years) based on morphology. The primary features used were the colouration of the ceres and eyelids, combined with plumage characteristics. New fledglings have particularly pale crowns and protruding retrices on the trail feathers. They also do not moult in the first year and are poor feather groomers, resulting in frayed, scruffy looking plumage until they moult at about 15 months of age. Juvenile keas, aged 13-24 months, retain yellow ceres and eyelids but the crown darkens with the first moult and the feathers are better groomed. The ceres and eyelids may begin to darken from 24 months onward, but the rate is inadequately quantified and appears to be highly variable, with some adult females retaining yellow tinting well beyond four years of age.

Predators

We collected relative abundance measures for rodents using the footprint tracking index (Gillies and Williams 2007). Maps and descriptions of infrastructure.

We conducted pre-control possum indices using the RTCI method (NPCA 2011) or the BMI method (NPCA 2008), both of which are industry standards in New Zealand.

COVARIATES

Individual covariates

Two basic individual covariates are included in our vital rate estimation procedures throughout this report. These are Age Class and Sex. Age Class is assigned as either Fledgling (0-1yrs), Juvenile (1-2yrs), Subadult (2-3yrs) or Adult (3yrs+).

Environmental covariates

Study Area

The covariate 'Study Area' was included in all statistical analyses as a fundamental purpose of our project was to assess the relative importance of site effects as opposed to other covariates. The division of the Kahurangi, Westland and Rotoiti study areas into treated and untreated areas and repeated measurement over multiple years controlled for random site and time effects.

Unfortunately the Study Area covariate is confounded with forest type. The forest in which keas mostly live and breed can be classified into two main types: beech forest and podocarp-hardwood forest (Figure 1). Pure podocarp-hardwood forests (i.e. containing no beech) are found only at our Westland study area. The two forest types appear different in many ways and kea behaviour may vary accordingly.

The Study Area covariate is also confounded with the availability of unnatural food from humans at villages, rubbish dumps and tourist carparks. The Westland site contains several such sources whereas the other sites contain few or none.

Stoat plague

Predation and survival studies of the kea's sympatric congener, the kaka have shown the stoat to be a key predator of this large treehole-nesting species (Beggs and Wilson 1991;

Moorhouse et al. 2003). Similar evidence exists for stoats as a key predator of other large New Zealand birds sharing native forest habitat with the kea (McLennan et al. 1996). A high rodent abundance during the previous year elevates stoat abundance during the following year (King 1983), an event known as a stoat irruption (O'Donnell et al. 1996) or a stoat plague year. Impacts of stoats on some birds is known to vary between years, being worse during stoat plagues (O'Donnell et al. 1996).

We considered explicitly modelling the relative abundance of stoats as an environmental covariate. However, achieving consistent stoat indexing with adequate precision across our study areas was a major logistical challenge attracting considerable expense. We did not achieve it with adequate consistency to model the FTI *per se* as a covariate. Instead, we used the untreated rodent FTI data to classify each year at each study area as either a stoat plague year or a normal year. Stoat plagues are taken as affecting entire study areas regardless of internal treatment divisions.

Two stoat plagues occurred, one at Kahurangi 2010 and another at Westland 2012.

Predator control

We set up two dummy variables Aerial 1080 and Ground Control,to categorise the predator control under which the survival of each kea, or kea nest, was measured. A kea, or kea nest, either did or did not have an Aerial 1080 in the previous 18 months, or did or did not have Ground Control implemented around it. Ground control of stoats was ongoing at two sites, the RNRP and the Hawdon Valley. This comprised networks of stoat kill traps set and maintained according to Department of Conservation best practise. At the Hawdon, aerial 1080 (with rodents) was periodically used in conjunction with the stoat traps, while at RNRP ground control of possums using kill traps occurred along the stoat trap lines. Ground control was absent from all other sites.

*Study Area * Predator Control interaction*

Rodents are the primary vector of 1080 to stoats (Murphy et al. 1998). Rodent densities are highly variable in the forest types that dominate our study areas. The level of stoat control may, therefore, depend on the density of rodents at the time of baiting.

Potential covariates not modelled

We considered explicitly modelling the relative abundance of possums as an environmental covariate. However, our initial possum indices at Kahurangi and Westland indicated similar possum abundance across the board (Figure in prep) and we did not expect this to change over time, other than after aerial 1080.

We could not rule out the non-arboreal predators the European hedgehog, the ferret and the feral cat, all of which can potentially access kea nests. However, cats and ferrets are scarce across most of the kea species range (Clapperton and Byrom 2005; Gillies and Fitzgerald 2005). We, therefore, excluded these predators from our a priori list of covariates. We remained mindful of our assumptions, however, and used automatic trail cameras at kea nest sites as a check on it.

Temporal covariates

We did not explicitly test for random temporal effects such as Year. We assume that random year effects are controlled for by the use of multiple sites with independently varying mast events (and hence stoat plagues) and independently varying levels of predator control treatment, including paired treated-untreated sub-areas within study areas.

We did not model within year effects such as Season, as we were not interested in these and our data sets were unlikely to be sufficient.

DATA ANALYSIS METHODS

Our data analysis is essentially a series of logistic regression modelling exercises to estimate survival rates for input to matrix population models, followed by a matrix modelling exercise. We built our regression models either in Program R (R Core Development Team) or in Program MARK. We built our matrix models in R.

Logistic regressions were run on a logit scale. We formulated our covariates into sets of competing models, which we ranked against each other using Akaike's information criterion (AIC) (Akaike 1973; Burnham and Anderson 1998). AICc was calculated for each competing model using the number of parameters and deviance of the data from a generalised liner model of the form

$$\text{Logit(S)} = \beta 0 + \sum_{i} \beta i \times Factor i + \varepsilon$$

where S is the probability of survival, $\beta 0$ is the intercept, βi s are coefficients for each factor and ε is a random error term assumed to be normally distributed with an average of zero and unknown variance.

Sampling units were exposure-day for nest survival (Dinsmore et al. 2002) and exposure-month for age-specific survival estimated from radio telemetry data. The animal or brood either survives or dies during each unit. This approach avoids bias arising from partial monitoring histories, such as when a nest is located partway through its life cycle (Mayfield 1961). The analyses generate daily or monthly survival rates and associated standard errors. Overall percentage nest survival is then calculated as the product of 116 daily nest survival estimates (116 = the number of days in the kea nest life cycle). Annual survival rates are calculated as the product of twelve monthly survival rates.

We used Akaike's Information Criterion (Akaike 1973)(AIC) corrected for bias arising from small sample sizes (AICc) (Burnham and Anderson 1998) to seek the most

parsimonious explanations for the variation within our data, given our *a priori* covariates. We compiled a list of competing logistic regression models and then ranked the models using AICc.

We examined the beta coefficients for the covariates present in the best models to assess their importance. We used the beta coefficients from the best models containing the important covariates to estimate survival rates on the logit scale and then back transformed them to the real scale for result presentation.

The matrix population model sampled randomly from normal distributions on the logit scale, defined by the point estimates and standard errors generated by our favoured logistic regression models. A new Leslie Matrix was generated in this way for each year of each simulation, for multiplication with the population vector.

SURVIVORSHIP OF KEA THROUGH AERIAL 1080 BAITING

INTRODUCTION

Ten-eighty poison pellets, delivered aerially, have been used for possum control in kea habitat for about fifty years. Currently, aerial 1080 is the predator control tool most frequently deployed in kea habitat, with approximately one million hectares under some sort of aerial 1080 regime (Figure 4). The period between repeated baiting varies from two-yearly to seven-yearly, depending on the objectives of the pest control.

Aerial 1080 baiting potentially delivers both benefit and cost to the kea population, in terms of kea abundance. Here, we present an attempt to measure the non-target cost that may be incurred by the kea population when aerial 1080 is used.

Direct ingestion of poison pellets is the primary risk for kea, as the pellets are cereal based and parrots are seed eaters, and kea commonly forage on the forest floor where they are very likely to encounter 1080 baits. Being an opportunistic omnivore, keas, have a tendency to investigate novel objects and sample novel foods. This may be particularly so for young birds (Diamond and Bond 1991). The death of a kea could potentially result from ingestion of a single typical 1080 pellet, assuming a similar susceptibility to the sulphur crested cockatoo (*Cacatua galerita*) (McIlroy 1983). Secondary poisoning may also be an issue, as the kea is known to scavenge dead possums (*pers. Obs.*), deer (Jackson 1960) and other animals.

Previous studies of 1080 impacts on kea are few. Existing studies lack statistical power and are out of date with respect to current 1080 practises. In 1964, four dead kea were found after a 1080 operation in the Dobson Valley (Douglas 1967). Two carcasses were tested for 1080 residues and 1080 was found in both. However, the proportion of the

kea population that died is unknown and the operation was highly atypical compared with current best practise: carrot bait was sown at the extremely heavy rate of 30kg/ha, including large areas above the treeline. In 1983 and 1986, in Westland, kea call rates in five minute bird counts were similar before and after another atypical 1080 operation with carrot bait sown at 20 kg/ha (Spurr 1994). The statistical power of this study was very low. 1080 practises have changed since these studies, with the advent of cereal pellets and pre baiting and reductions in sowing rates. The current standard is to use cereal pellets broadcast at no more than 1kg/ha for prefeeding and no more than 2kg/ha for toxic baiting.

The lack of recent measurement of 1080 risk to kea is due, at least partly, to the logistical difficulty associated with counting and monitoring kea. It may also be due to the common misperceptions that keas reside permanently above the timberline and that aerial 1080 is not used there.

Here, we present and analyse radio tracking data gathered from free living wild kea during the risk periods associated with aerial 1080 baiting. We use these to estimate survival rates and model the effects of environmental and individual covariates on non target risk.

METHODS

Keas were captured and radio-tagged prior to nine aerial 1080 drops at eight sites (Figure 1). Telemetry surveys were conducted over time, from which a survival history was generated for each bird. Telemetry surveys were conducted either on foot or from aircraft (fixed-wing aircraft or helicopters). On foot, radio signals from all radio tagged keas were listened-for using either a TR4 (Telonics Ltd) or R1000 handheld receiver, whenever an observer deemed that their location gave sufficient coverage to warrant it. Observers planned their field work to maximise coverage, visiting points with extensive

fields of view. Each attempt to obtain a radio signal was recorded, and if a signal was obtained it was recorded as alive or dead and inside or outside the 1080 area. Birds were judged to be either inside or outside the 1080 area depending on the direction from the VHF signals were coming. Only kea that were consistently inside the 1080 risk area are included in this analysis. Monitoring histories prior to aerial 1080 baiting varied in length from several years to several days.

After delivery of aerial 1080, telemetry surveys were undertaken every 1-2 days.

After 7-10 days without mortality, survey frequency was decreased to once every 3-4 days, and eventually to once every 7-14 days.

The data we gathered is binomial: radio tagged keas either survived, or did not survive, the risk periods associated with aerial baiting.

Baiting specifications and prevailing environmental conditions varied among sites. Baiting specifications were standardised in 2009: bait type was restricted to the RS5 pellet and low sowing rates were mandatory.

Covariates of survival

We modelled the effects of environmental covariates Operation, Study Area and Bait Type. The distinction between Operation and Study Area reflects the repeated use of aerial 1080 at some sites and the fact that some operations were adjacent or nearly adjacent and therefore in similar habitats. Abbey Rocks and Arahwata are grouped as a South Westland study area. Fox-Franz, Okarito and Copland are grouped as Westland. The two Hawdon Operations are grouped as 'Hawdon' study area, and Wangapeka and Mt Arthur are grouped as Kahurangi. Bait type is either Wanganui Number 7or RS5.

Individual covariates modelled were Age Class and Sex. Age Class was modelled as two alternatives: four age classes (three pre adult year classes and one adult stage) or two age classes (pre adults and adults).

All covariates were modelled as categorical data types.

RESULTS

A total of 118 radio tagged keas were exposed to 1080 risk through the nine 1080 operations at eight sites (Table 1). In total, 103 out of 118 keas survived. At seven of the operations all monitored keas survived the risk period (n=62 keas). At the other two operations, 10/17 and 29/37 keas survived. Cause of death was confirmed as being due to direct ingestion of 1080 pellets in fourteen cases (Table 2). The fifteenth carcass could not be recovered from steep terrain near Franz Josef Glacier. Most non target deaths occurred within the first few days of baiting. A more delayed time to death was recorded in four cases at Fox-Franz 2008.

Models including the Operation term did not rank highly according to AICc (Table 3). Risk was better modelled as constant within study areas. This is not surprising as two operations in South Westland recorded no deaths, two in the Hawdon recorded no deaths, two in Kahurangi recorded no deaths, and two out of three in Westland recorded the deaths (Table 1). Risk among the other study areas was similar, with no kea deaths recorded at any of them.

Support was present in our data for the Bait Type covariate (Table 3), despite Study Area and Bait Type being somewhat confounded (only RS5 pellets were used at Hawdon and Kahurangi). The support for the bait type covariate reflects the improvement in survival within the Westland study area from the Fox-Franz 2008 operation with Wanganui Number 7 pellets to the Okarito 2011 and Copland 2012 operations with RS5 pellets.

462 Kea survival was 59%, 78% and 100% respectively, although only two kea were followed
463 through the Copland 2012 operation.

464 Among the individual covariates we modelled, Sex received little support (Table 3). The
465 Two Age Classes covariate, however, was supported, with adults surviving better than
466 pre-adults. Unfortunately the age class and Study Area covariates are somewhat
467 confounded, with larger samples of pre-adults monitored through the Westland 1080
468 operations (27 pre-adults to 29 adults, versus 14 pre-adults to 46 adults at the other sites
469 pooled). The apparent Westland effect may be partly an artefact of this better
470 representation. However, six adult kea were killed by the Westland operations and all of
471 14 pre-adults survived at the other study areas. Hence the overriding support for
472 Westland as an explanatory covariate.

473 Estimates of survival for Westland derived using Model 2 (Table 3) represent the worst
474 case scenario we can predict from our data set. Under this scenario, the survival estimate
475 (and 95% CI) is 73% (60-83%).

476 The best case scenario we can predict from our data would be using Model 4 (Table 3),
477 for non Westland-like sites using RS5 pellets. Under this scenario, the survival estimate
478 (and 95% CI) is 100% for both adults and pre-adults (93-100% for adults, 77-100% for
479 pre-adults). (The lower 95% confidence bounds are approximated by the formula 3/(n-
480 1) (Veltman and Westbrooke 2011). They cannot be estimated from our model as
481 standard errors cannot be calculated for 100% survival.)

482 Given that the mechanism behind the apparent 'Westland' effect is poorly understand
483 (see discussion), we also estimate survival using Model 11 (Table 3). Under this model,
484 with RS5 pellets, the survival estimates for adults and juveniles, respectively, are 94% (88-
485 99%) and 85% (73-97%).

We intend to use these three scenarios in population modelling of the effects of 1080 on kea.

DISCUSSION

Our analysis supports the notion that non target risk was higher in Westland than in any other study area. In fact, we detected no risk anywhere but Westland. However, the biology behind this association is not understood. Possibly it is due to the presence of several sources of unnatural foods in Westland, namely the Fox and Franz Josef villages, the Fox and Franz Josef glacier car parks and the Franz Josef rubbish dump. Experience of foraging at these sites potentially makes the local keas more inclined to investigate novel foods such as cereal pellets when they are delivered into a forest. If this were true, then we might expect to detect mortality at similar sites such as Arthurs Pass National Park where a large alpine village and numerous tourist car parks and ski areas exist.

Our analysis also supports the notion that risk is higher for pre-adults than it is for adults. Behavioural studies have shown that young kea spend more time investigating novel items than adults. This may explain our finding.

We also found support for the notion that RS5 pellets are safer for keas than Wanganui number sevens. Several causal mechanisms may be involved, including more rapid neutralisation of RS5 by water, and reduced attractiveness of RS5 due to the absence of fruity sugars and lower fat content.

Ideally we would have modelled 'prior exposure to aerial 1080' as an individual covariate to explore the notion that a kea which has survived one aerial 1080 drop might thereafter be bait shy. However, we could not robustly assign covariate scores to individuals due to a lack of history on each kea. Moreover, prior exposure is likely confounded with Age Class and Site, as pre-adults have a much lesser chance of prior exposure (aerial 1080 is

510 normally used four-six yearly at a given site) and all adult birds within a site will have a
511 similar history of exposure. For example, deaths of adult kea were recorded only in the
512 Fox-Franz site and the northern half of the Okarito site, neither of which had ever
513 previously received aerial 1080. Conversely, our samples at the Hawdon 2012 and Abbey
514 Rocks 2011 comprised almost entirely of adults and the sites had received aerial 1080
515 three and two years prior, respectively. Given that most aerial 1080 drops are not first
516 time operations, the worst case mortality estimates we generated for Westland by Model
517 2 (Table 3) may seldom occur. Prior 1080 should remain a factor of interest pending
518 further data collection.

519 Agencies regulating the use of aerial 1080 should treat our results with a degree of
520 caution when making policy for kea areas, due to small sample sizes, confounding of
521 factors, and lack of understanding of causal pathways. We recommend the undertaking
522 of further survival measurement at remote back-country sites (i.e. remote from unnatural
523 food sources), with a particular focus on tracking young birds through the risk period.
524 We also recommend further measurement of risk at another 'Junk food' site such as
525 Arthurs Pass. This further tracking will clarify the relative importance of Age Class and
526 Junk food. A junk food site that has had prior 1080 treatment would also be useful.

527 If junk food is found to be of primary importance, then actions can be implemented to
528 reduce risk at such sites. Such actions would include the removal of access to junk food,
529 and/or the use of bird repellents. If risk is detected at remote sites, then actions to
530 reduce risk may need to be implemented across the board, such as the use of bird
531 repellent.

532 To be sustainable, the non target mortality we have detected needs to be offset by
533 improved productivity and survival. Improved productivity and survival may result
534 directly from the aerial 1080 operation itself, as aerial 1080 is known to control potential

predators of kea. Alternatively, the non target risk could be offset by alternative means for predator control, such as stoat-specific trapping or poisoning. For a long-lived, slowly reproducing species like the kea, the worst case survival rates we present will require high-magnitude benefits to be offset. Conversely, the best case scenario will require little offsetting and it is likely that the benefit will outweigh the cost even if predator control benefit is short lived.

NEST SURVIVAL OF THE KEA WITH RESPECT TO AERIAL 1080 AND OTHER COVARIATES

INTRODUCTION

The kea is one of a small subset of parrot species for which nest cavities are located on the ground. The kea has an extended nesting period, in which incubation of eggs takes 3-4 weeks and the altricial nestlings remain in the nest cavity for three months. These two behavioural traits make nesting a potentially risky activity in the forests in which keas breed, given the invasive predator species that are naturalised in these forests. Nest survival studies of the kea's sympatric congener, the kaka (*Nestor meridionalis*) report a very high rate of nest predation by the invasive species the stoat (*Mustela erminea*) and the Australian brushtail possum (*Trichosurus vulpecula*) (Wilson et al. 1998; Moorhouse et al. 2003; Powlesland et al. 2003). These exotics are naturalised throughout the species range of the kea (Cowan 2005; King 2005) and are possibly having similar impacts on them. Predator impacts on kea nests might be worse than for kaka, as the kaka is a tree nesting species. Broods of the ground-nesting kea (i.e. eggs and nestlings) may be easier for stoats and possums to find, plus they may fall prey to the non-arboreal mammals the feral House cat *(Felis catus)* the European hedgehog (*Erinaceus eruopaeus occidentalis*) and the ferret (*Mustela furo*). The ship rat (*Rattus rattus*), another ubiquitous invasive in South Island forests, is not a significant predator for the kaka (Powlesland et al. 2003), but may be for the kea. Kaka appear to fortuitously avoid nest predation by rats due to their episodic breeding efforts naturally coinciding with periods of naturally low rat abundance at the onset of mast. The kea breeds in most years (Jackson 1963; Bond and Diamond 1992) and so kea broods may fall prey to rats in years of high rat numbers.

Kaka productivity increases when possums and stoats are simultaneously controlled (Moorhouse et al. 2003), and when stoats are controlled in isolation (Dilks et al. 2003), but possum control without stoat control is of questionable benefit (Greene et al. 2004). Kea productivity might similarly benefit from control of stoats and possums. Stoat numbers fluctuate between years over orders of magnitude within South Island forests (King 1983). The impact of stoats on kea nests may vary accordingly, and, therefore, so too the benefits (and difficulty) of controlling stoats.

Effective possum control consistently results from aerial 1080 when non toxic pre baiting is used (Coleman et al. 2007; Nugent et al. 2011). Stoat control by secondary poisoning, in contrast, has only ever been demonstrated in the presence of abundant rodent vectors (Murphy et al. 1998). Stoat control effectiveness has not been comprehensively measured in the absence of rodents and may be relatively poor.

Here, we aim to:

1. Identify the primary predators of kea nests in New Zealand forests
2. Model the effect of stoat irruptions on kea nest survival
3. Model the effect of aerial 1080 on kea nest survival
4. Estimate kea nest survival under different environmental conditions as supported by the data.

METHODS

Field methods

Kea broods were located by radio tracking adult keas and by visiting previously-known kea cavities.

Nest survival data was collected visually, by looking inside nest cavities and by placing automatic 'stills' cameras inside cavities. Once visually confirmed or photographed, the fate of the brood was followed over time. Cameras placed outside the nest cavity were used to assist monitoring the final stages of nesting, enabling us to distinguish between late-stage nest failure and successful fledging.

Scoutguard brand cameras were used in 2010 and 2011, but these were superseded in 2012 by the Ltl Acorn. When placed externally, the cameras were 2-4 metres from the cavity entrance, aiming toward it. Triggering was by infra-red movement sensor, three photographs were taken in quick succession. We programmed the cameras with no delay interval after triggering, so that photos could be taken in succession as fast the cameras were able, if there was ongoing activity.

Cameras placed inside the nest cavity assisted in the early detection of eggs, which we may not have detected for some weeks without them, or perhaps not at all. These internally placed cameras were set either on time lapse mode or on trigger mode with an extended delay (10-30 mins) to avoid rapid overflow of the memory card due to frequent movements of the female or the nestlings.

We also fitted VHF radio tags to fully grown nestlings and this further aided in determining the fate of the nests during their final stages.

Predator identification

We initially hoped that the automatic cameras would identify the predators responsible for any predation on broods that might occur. However, it rapidly became clear that this was overly optimistic and that effective predator diagnosis would require time lapse video recorders. Time lapse video was too expensive and labour intensive for routine use in our study areas to the rugged and remote terrain therein. Video surveillance was

610 restricted to a few broods whose front-country locations allowed reasonably efficacious
611 servicing of video gear.

612 We compiled a list of predators that visited kea nests based on the photos taken by the
613 automatic cameras.

614 **Covariates of nest survival**

615 Here, we assess the effect of the environmental covariates Study Area, Predator Control,
616 and Stoat Plagues, on kea nest survival. Some models included an interaction term which
617 explores the possibility that benefits to kea nest survival varied among aerial 1080
618 operations/Study Areas.

619 **Nest survival data analysis**

620 The nest survival dataset comprised a collection of 'exposure days' tabulated as an 'inp'
621 file following Dinsmore et al. (2002). The inp file is an abbreviated 'capture history',
622 comprised three key dates, *k* the day of first visual confirmation of the brood, *l* the last
623 day on which the brood was last confirmed as active and *m* the day on which the last
624 observation of the brood was made. For successful nests *l* and *m* are the same. For
625 failed nests, *l* and *m* differ by one day if the exact day of failure was captured on camera.
626 If the exact day of failure is not known then *l* and *m* differ by the interval between
627 observer visits.

628 **RESULTS**

629 **Kea nest/brood survival**

630 A grand total of seventy kea broods contributed survival data to this analysis (Table 4).
631 More broods were located at the Westland study area (49 broods) than at the other study
632 areas Kahurangi (11 broods), Hawdon Valley (6 broods) and Rotoiti (4 broods).

633 Model selection using AICc revealed a single outstanding model (Table 5). This model
634 included a term for Stoat Plague years, a term for each possible combination of Predator
635 Control regime and Study Area. The beta coefficients and standard errors for the terms
636 in this model show a strongly negative effect of stoat plagues (with 95% confidence
637 interval excluding zero) (Table 6), a strongly positive effect of aerial 1080 in Westland
638 (the Okarito 2011 operation), a strongly positive effect of combined aerial 1080 and stoat
639 trapping in the Hawdon Valley, and a strongly positive effect of the ground control of
640 stoats and possums in the RNRP. The effect of the Kahurangi 1080 drops was
641 approximately zero.

642 The survival estimate (and 95% CI) generated by our best model for broods in untreated
643 sites during non-plague ('normal') years is 40% (23-59%) (Table 7). The dataset for this
644 group is based on 29 broods dominated by Westland (n=27 broods). The remainder
645 were in the Wairau sub area of Rotoiti. No untreated nests were monitored in a non
646 plague year at Kahurangi.

647 The survival estimate for broods in untreated sites during stoat plague years is 2% (0-
648 11%)(Table 7). All ten broods in this group failed (7 at Fox-Paringa in 2012, 3 at
649 Wangapeka in 2010). The strong support for the Stoat Plague term is, therefore, not
650 surprising.

651 The survival estimate for broods at Okarito during the two nesting seasons after aerial
652 1080 is 94% (74-99%) (Table 7). The first year after 1080 (2011) appears to have been
653 better than the second (2012), with 8/8 and 5/7 broods reaching fledgling stage,
654 respectively.

655 Seven out of eight broods monitored in the intensively managed Hawdon Valley and
656 RNRP sites reached fledging stage. Nest survival in the Hawdon appears to be better in
657 years of both 1080 and trapping than it is in years of trapping only, although both are

reasonably high. Sample sizes, however, were small. The two broods at RNRP were from the same female in the same cavity, which is located within 20m of a trap line that targets both stoat and possum.

Nest survival at Kahurangi was measured for only one season after the Mt Arthur 2009 1080 drop and for two seasons after the Wangapeka 2011 drop. Eight broods were located, four of which survived to fledging stage. The resulting survival estimate is 26% (3%-61%) (Table 7). This rate is similar to the estimate for untreated broods in non-plague years, indicating that these 1080 drops did not provide substantial benefits, if any, to kea nest survival. Sample sizes were small, however, and we lack data from untreated normal years in the Kahurangi study area. We cannot firmly conclude that the Kahurangi operations did not boost nest survival, but we can conclude that the high magnitude effects of the Okarito 1080 operation and the intensive control Hawdon Valley and RNRP were not achieved.

Predator species at kea nests

The automatic cameras recorded visits to kea nests by possum, stoat and rat. Often two or more predator species were recorded visiting a nest cavity over several weeks. When a brood failed, the externally-mounted cameras seldom provided a clear indication of exactly when the brood failed (kea visitation tended to gradually tail off rather than suddenly stop) and which predator was responsible. Possum visits were very common, but usually were not associated with nest failure. In two cases possums appear to be the most likely cause of failure, but a fast moving stoat could have easily evaded detection by our cameras. Possum visitation was near zero after aerial 1080 and at the RNRP nest cavity. Stoat visits were common during the untreated stoat plague at Fox-Paringa. In one case, a stoat was photographed rolling the kea eggs away before the clutch had been fully laid. Stoat visits did not always immediately result in nest failure, but the association

683 between stoats and brood failure appeared to be stronger than for possums. Ship rats
684 were photographed at broods during high rat years in Westland 2011 and the Hawdon
685 2012. In only one case (Hawdon 2012) were rat visits associated with failure, but the
686 diagnosis was not conclusive.

687 No cats, ferrets or hedgehogs were photographed. No avian predators were
688 photographed visiting kea nests at Westland. One nest at Kahurangi was visited by a
689 weka.

690 **Predator indexing**

691 The limited predator indexing we achieved using footprint tracking tunnels revealed a
692 strong apparent association between nest survival and stoat abundance. At Westland,
693 stoat tracking rates were stable at about 40% prior to the Okarito 2011 aerial 1080
694 (Figure 5). Nest survival was also stable at about 30%. During the 2012 stoat plague at
695 Fox-Paringa, stoat tracking increased to c.70%, and kea nest survival declined to near
696 zero. Concurrently, within the Okarito 1080 area, stoat tracking declined to near zero,
697 and kea nest survival increased to high levels. At Kahurangi, stoat tracking rates did not
698 decline after the Mt Arthur aerial 1080 drop (Figure 6) and kea nest survival apparently
699 did not increase. Stoat tracking rates were already low in the Wangapeka aerial 1080 area
700 when baiting took place. Stoat tracking rates at Hawdon Valley and RNRP were near
701 zero throughout the study.

702 **DISCUSSION**

703 Predator control, especially stoat control, appears to have a strong positive effect on kea
704 nest survival. Stoats have a high magnitude impact on kea nest survival during stoat
705 plague years, and this can be completely averted by either intensive ground control,
706 combined ground and aerial control, or aerial control alone. However, aerial control did

not improve kea nest survival in all cases. In the best case, Okarito 2011, effective stoat control lasting two years was achieved, including mitigation of a stoat plague. At Mt Arthur 2009 and Wangapeka 2011, however, stoat control was apparently not delivered and nor were the high rates of kea nest survival achieved elsewhere. Key ecological factors that might explain this pattern are 1) the abundance of rodent vectors (for transmitting toxin to stoats) and 2) the size of the baited area and natural boundaries (for slowing repopulation rates). At Okarito, the presence of abundance rats appears to have delivered a high stoat kill. The large size of the baited area, plus natural boundaries, appears to have delivered a slow rate of repopulation by stoats. The Mt Arthur 2009 operation, by contrast, happened whilst rodents were scarce (although numbers were building due to the 2009 mast seeding) and the Wangapeka 2011 operation occurred in a non-mast year when rodents were confined only to the lower reaches of the site.

The native forests in which keas breed are dominated by beech and rimu which periodically produce large seed crops (mast). Mast invariably leads to rodent irruptions, which, in turn, cause stoat plagues. It is a fortunate thing that the optimal timing for achieving stoat kills (the spring of a mast year once rodent numbers have built up) is also the optimal timing for mitigating stoat plagues by removing the breeding adults that are about to produce peak-year litters of young. If the operation is sufficiently large, then the reinvasion occurring during the stoat plague year appears to be minimal enough, at least in the case of Okarito, to reverse the heavy impact of the stoat plague into a year of high nest survival.

Conservation managers wishing to conserve the kea population should target predator control to controlling stoat plagues. Pest control agencies or developers wishing to offset any population level costs to the kea populations from their actions should do the same.

BALANCING THE COSTS AND BENEFITS OF AERIAL 1080 TO KEA POPULATIONS

INTRODUCTION

Aerial 1080 for possum and rat control in South Island forests is known to both benefit and cost kea populations. Cost is incurred as non target deaths of kea individuals, resulting from direct ingestion of poison pellets. Benefit is accrued as improved productivity and survivorship, due to predator control resulting from the poison baiting. Weighing the cost against the benefit is best undertaken in a matrix population modelling framework (Leslie 1945). The vital rates required to build a matrix population model for the kea are annual age-specific survival, annual productivity and non target mortality rates. Ideally, a measure of dispersal rates would be incorporated into annual survival rates of pre-adults. All of these vital rates have already been estimated (see the other sections of this report) using the best models selected from *a priori* sets of competing models. Here, these estimates are brought together into a matrix model and used to assess the net outcome of aerial 1080 for kea populations.

METHODS

Leslie matrix

A four stage Leslie matrix of the form $\begin{bmatrix} 0 & 0 & 0 & f \\ s_1 & 0 & 0 & 0 \\ 0 & s_2 & 0 & 0 \\ 0 & 0 & s_3 & s_4 \end{bmatrix}$ is used to model the kea population, where f= productivity, s_1 = fledgling survival (0-12 months), s_2 = juvenile survival (12-24 months), s_3 = subadult survival and s_4 = adult survival. This matrix allows only individuals aged four years or older to reproduce.

753 We wrote computer code in Program R to simulate kea populations over time using this
754 matrix. Our previous analyses of covariates influencing vital rates showed strong
755 between-year effects of stoat plagues and predator control. Rather than using a single
756 matrix parameterised with vital rates averaged across different year types, we
757 parameterised separate matrices for different year types. For example, a matrix for an
758 untreated stoat plague year had lower rates of survival and productivity than those for the
759 years following a well-timed aerial 1080 operation.

760 Our approach to population simulation was to simulated a single population for 10,000
761 years. We incorporated the between-year variation in predator impacts resulting from
762 stoat plagues and predator control using a repeating cycle of 'year types'. For example, a
763 simulation could model an untreated population in which a stoat plague occurs every x
764 years. Alternatively, a simulation could model a treated population in which predator
765 control prevented stoat plagues and boosted productivity for y years. Non target
766 mortality is incorporated into the simulations in a similar fashion. A cycle of aerial 1080
767 operations is defined prior to simulation, along with the risk arising at each operation. In
768 a 1080 year, the population vector is reduced by the mortality rate.

769 Sampling error arising from our field studies due to limited sample sizes results in
770 significant parameter uncertainty that we wished to incorporate into our simulations.
771 This was achieved by generating a new Leslie matrix for each year of a simulation by
772 random sampling from normal distributions on the logit scale defined by the best logistic
773 regression models for the given vital rate for the type of year in question (see previous
774 chapters). The vital rate from each random draw is back-transformed to the real scale for
775 input to the Leslie Matrix.

776 The key output from a simulation is the average population growth rate over the last
777 9000 years of the simulation. The first 1,000 years were discarded to allow age
778 distributions to stabilise.

779 Demographic stochasticity is not incorporated into simulations due to the size of the
780 populations being usually more than thirty individuals for any given aerial 1080
781 operation.

782 We ran simulations to represent kea populations subjected to:

783 1. Worst-case non target risk coupled with best case predator control outcomes
784 (such as occurred at Okarito).

785 2. Best-case non target risk coupled with worst case (zero) predator control
786 outcomes (such as apparently occurred at Kahurangi).

787 3. Best-case non target risk coupled with best case predator control outcomes (a
788 potential scenario that probably occurs but did not occur during our study).

789 4. Worst-case non target non target risk coupled with worst case predator control
790 outcomes (another potential scenario that also possibly occurs but did not occur
791 during our study).

792 5. Medium-case non target risk coupled with medium case predator control
793 outcomes.

794 All simulations used a four yearly stoat plague and a four yearly aerial 1080 operation.

795 **RESULTS**

796 **Population trajectory**

797 For untreated kea populations during non stoat plague periods, our modelling predicts a
798 mean annual decline of 1.13%. The standard deviation of the growth rate is 4.3%, which

translates to a 95% confidence interval of (-9.8% to +7.6%). This reflects the relatively high level of parameter uncertainty in our estimates of the vital rates in the model. Accordingly, we place weight on comparisons between scenarios than on the growth rates *per se* produced by our simulations.

Introducing a stoat plague every four years depresses the mean rate of decline by 4.07% to an estimated -5.2%, at which rate the kea population goes extinct over the course of a few hundred years (Figure 7). This scenario equates to the best-case non target risk scenario coupled with worst-case predator control benefits – the aerial 1080 has had no effect on the kea population.

Introducing aerial 1080 operations with worst-case non target risk and best-case predator control benefit produces a mean annual growth rate to -0.09% (cf. -1.13% without 1080). The increased growth rate indicates that the non target cost has been offset by the predator control benefit (Figure 7). The growth rate under this scenario is highly variable due to the high parameter uncertainty around the estimate of non target risk. A scenario of medium case non-target risk coupled with best case predator control benefit is obviously an improvement over worst case non target risk and best case predator control benefit.

The scenario of best-case non target risk and best case predator control produces a much improved growth rate of 1.89% (Figure 7).

Sensitivity analysis

DISCUSSION

Our population modelling clearly shows that the worst case non target risk detected during our field studies can be offset by predator control benefits. However, predator

control benefits varies among 1080 operations, depending (we think) on the timing of baiting with respect to mast and the ensuring predator plagues, and on the size of the baited area. We believe that the non target risk detected at Okarito in 2011 is really worst case, but also that the predator control is really best case. Therefore, we conclude that the Okarito kea population is better off now than it would have been had the aerial 1080 not occurred. However, the kea is an endangered species and the non target risk meant that the potential for very strongly positive benefit was not realised. Reduction of non target risk would improve the chances that the aerial 1080 programme will help to secure the future of the kea population.

Aerial 1080 operations that put kea at risk of non target poisoning but do not avert stoat plagues run a strong risk of hastening the decline of the kea population. If risk to kea cannot be reliably reduced, then agencies delivering 1080 need to ensure that stoat plagues are mitigated in order to offset the risk. This could be achieved either by optimising the timing and scale of the aerial 1080, or by deploying alternative stoat control tools.

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TABLES

Table 1. Summary of sample size and outcomes for keas with known fates monitored through risk periods resulting from aerial 1080 baiting.

Operation	N Birds fate followed	Deaths recorded
Araw hata 2008	10	0
Fox-Franz 2008	17	7
Mt Arthur 2009	13	0
Haw don 2009	10	0
Okarito 2011	37	8
Wangapeka 2011	13	0
Abbey Rocks 2011	8	0
Copland Valley 2012	2	0
Haw don Valley 2012	6	0
Total	118	15

1038 Table 2. Summary of necropsies for keas that did not survive aerial 1080 baiting. N/A = not aquired due to obvious cause of death. .

Operation	Band No	Sex	Age class	Time to death (days since baiting)	1080 assay (mg/kg)	Necropsy results		
Franz-Fox 2008								
	L-23934	Male	Adult	1	2.2	Proventriculus and gizzardright contained green, visible cereal matter and some brown & black seeds.		
	L-35852	Female	3rd yr	2	1.9	Green tinge but no obvious cereal matter, green seeds.		
	L-23949	Female	2nd yr	4	2.9	Bright green, visible cereal matter, some brown & black seeds.		
	L-41021	Male	Adult	10	0.63	No visible cereal matter. Rimu seeds & a small piece of plastic.		
	L-41026	Male	3rd yr	11	2.3	Green tinge, possibly cereal matter, brown seeds & several pieces of black rubber.		
	L-23948	Male	3rd yr	14	2.5	Bright green, visible cereal matter, some brown & black seeds.		
	L-35868	Male	2nd yr	35	N/A	Carcass too decomposed for necropsy (recovered after x months)		
Okarito 2011								
	V-0789	Female	Adult	1	N/A	7 grams of intensely green coloured solid granular cereal-like ingesta; none of this material was visible in the small or large intestine.		
	V-0761	Female	1st yr	1	N/A	There was intensely green-stained vomitus present around the upper and lower beaks and in the oral cavity. The crop contained 5 gms of green-colored semi solid granular cereal-like ingesta. Three grams of similar ingesta were present in thre proventriculus and gizzard.		
	27-103438	Female	3rd yr	5	N/A	Carcass too decomposed for necropsy (recovered after 5 months)		
	V-1267	Male	1st yr	1	N/A	The bird was in good body condition. The proventriculus and gizzard contained 10 grams of intensely green coloured solid granular cereral-like ingesta; multiple segments of similar looking material was present in the small and large intestine.The liver and spleen were congested.No other gross abnormalities were observed.		
	V-0798	Female	2nd yr	1	N/A	Good subcutaneous fat reserves were present. Five grams of liquid green coloured ingesta was found in the crop. The provenmtriculus and gizzard contained 23 gms of solid granular cereral-like ingesta mixed with some leafy material. The liver and spleen were moderately congested.		
	L-35856	Male	Adult	1	N/A	Good subcutaneous fat reserves were present. Small amounts of bright green semisolid vomitus was present in the oral cavity. Approx 4 gms of liquid green coloured ingesta was found in the crop. The provenmtriculus and gizzard contained 16 gms of solid granular cereral-like ingesta. The liver and heart were slightly congested.		
	V-1265	Male	Adult	1	N/A	The bird had moderate subcutaneous fat reserves. The crop contained approx 10 gms of intensely green coloured solid granular cereral-like ingesta. The proventriculus and gizzard contained mixed leafy material and several 5mm diam circular white vegetable structures mixed with green coloured cereal. The liver and spleen were congested and the heart was slightly dilated. No other gross abnormalitis were observed.		
	V-0788	Female	Adult	1	N/A	The bird weighed 822 grams and was in moderate to good body condition; moderate subcutaneous fat reserves were present. The proventriculus and gizzard contained 6 grams of intensely green coloured solid granular cereral-like ingesta; none of this material was visible within the small or large intestine. The liver and spleen were congested. No other gross abnormalities were observed.		

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Table 3. A ranking of the top ten competing models of kea survival through aerial 1080 baiting.

	Covariates in model						Model selection statistics				
Model ID	Operation	Study area	Bait type	Four age classes	Two age classes	Sex	df	logLik	AICc	delta	weight
1		+	+				5	-31.307	73.160	0.000	0.313
2		+					4	-32.542	73.445	0.286	0.272
3		+			+		5	-31.971	74.487	1.327	0.161
4		+	+		+		6	-31.172	75.114	1.954	0.118
5		+				+	5	-32.542	75.630	2.470	0.091
6		+	+	+			8	-30.725	78.796	5.636	0.019
7		+		+			7	-31.902	78.842	5.682	0.018
8	+						9	-30.834	81.367	8.207	0.005
9	+				+		10	-30.748	83.591	10.431	0.002
10			+				2	-42.354	88.815	15.655	0.000
11					+		2	-42.486	89.077	15.918	0.000
12			+		+	+	4	-40.681	89.723	16.563	0.000
13							1	-44.669	91.372	18.212	0.000
14				+			4	-42.343	93.047	19.887	0.000
15						+	2	-44.624	93.355	20.195	0.000

Table 4. Numbers of kea nests/broods located and monitored for the purposes of modelling determinants of nest survival and estimating nest survival rates.

	No predator control						Predator control									Total	
	Normal year			Uncontrolled stoat plague			1080 year			Year after 1080*			Ground Control only				
	Found	Survived	Failed	Found	Survived	Failed	Found	Survived	Failed	Found	Survived	Failed	Found	Survived	Failed	Found	Survived
Fox-Paringa	13	6	7	7	0	7										20	6
Wairau	2	0	2													2	0
Wangapeka				3	0	3										3	0
Okarito	14	8	6				8	8	0	7	5	2				29	21
Kahurangi							8	4	4							8	4
Hawdon							3	3	0				3	2	0	6	5
RNRP													2	2	0	2	2
Total																70	38

Table 5. Competing models of factors affecting kea nest survival, ranked according to Akaike's Information Criterion.

Model ID	Parameters in model	AICc	Delta AICc	AICc Weights	Model Likelihood	Number of parameters	Deviance
1	Stoat Plague + Predator Control * Study Area	232.163	0	0.82318	1	5	222.1489
2	Study Area + Stoat Plague + Predator Control * Study Area	235.4532	3.2902	0.15887	0.193	7	221.427
3	Predator Control + Stoat Plague	242.4245	10.2615	0.00487	0.0059	4	234.4151
4	Predator Control * Study Area	242.4811	10.3181	0.00473	0.0057	4	234.4717
5	Predator Control + Stoat Plague + Study Area	242.8826	10.7196	0.00387	0.0047	6	230.8629
6	Stoat Plague + Sub Area	243.2478	11.0848	0.00322	0.0039	7	229.2215
7	Sub Area	245.8597	13.6967	0.00087	0.0011	6	233.84
8	Predator Control	247.6211	15.4581	0.00036	0.0004	3	241.6155
9	Year	253.7299	21.5669	0.00002	0	4	245.7206
10	Stoat Plague	255.8676	23.7046	0.00001	0	2	251.8648
11	Constant	257.042	24.879	0	0	1	255.0411

Table 6 Beta coefficients, standard errors, and 95% confidence intervals for the terms in Model 1 (Table 5), the best model.

Term	Beta estimate	Standard error	Lower 95%CI	Upper 95%CI
Intercept (No predator control, no stoat plague)	4.835	0.260	4.325	5.345
Stoat Plague	-1.501	0.402	-2.290	-0.712
Okarito 1080	2.622	0.753	1.146	4.099
Kahurangi 1080	-0.383	0.569	-1.499	0.733
RNRP	16.738	NA	NA	NA
Hawdon do both	16.669	NA	NA	NA
Hawdon traps only	0.700	1.036	-1.329	2.730

1059 Table 7. Estimates of nest survival generated by the best model in Table 5, for the Study Area * Predator Control combinations under which kea nest

1060 survival was measured.

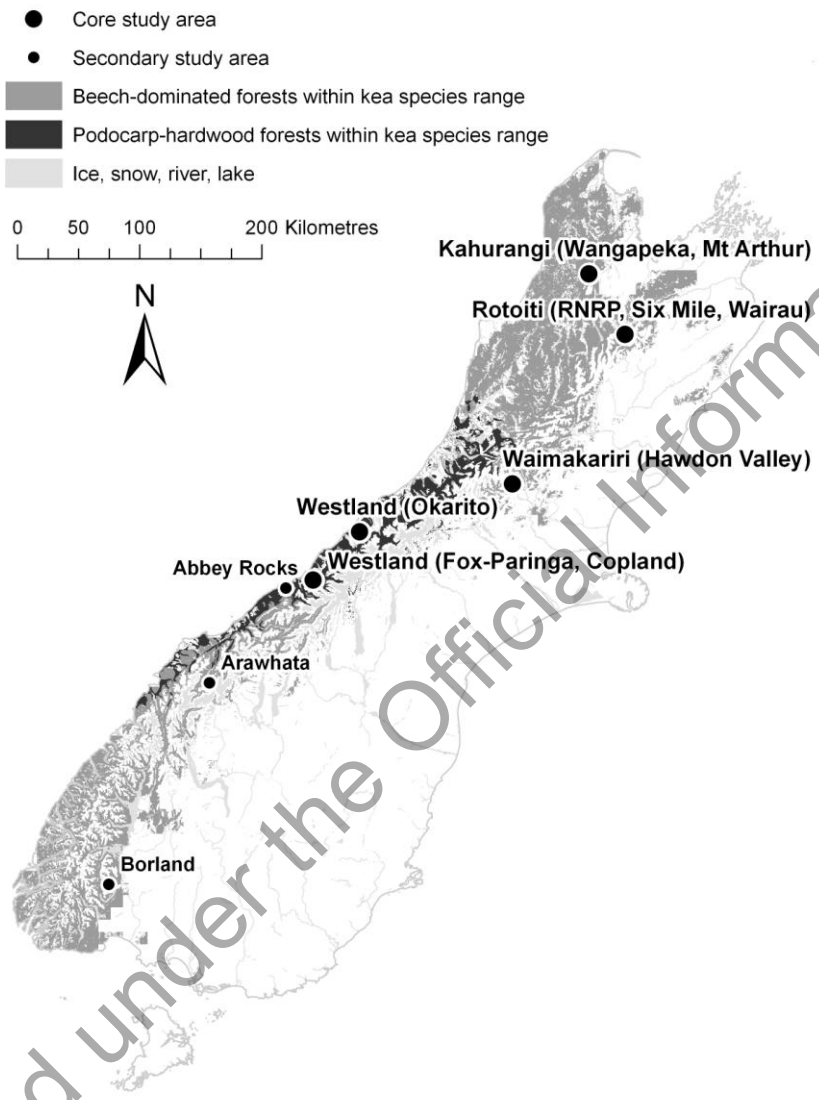
1061

	No predator control						Predator control								
	Normal year			Stoat plague year			1080			Ground Control			1080 + Ground Control		
	Point	LCI	UCI	Point	LCI	UCI	Point	LCI	UCI	Point	LCI	UCI	Point	LCI	UCI
Do nothing	40%	23%	59%	2%	0%	11%									
Okarito							94%	74%	99%						
Kahurangi							26%	3%	61%						
Hawdon										63%	4%	94%	100%	23%	100%
RNRP										100%	23%	100%			

1062

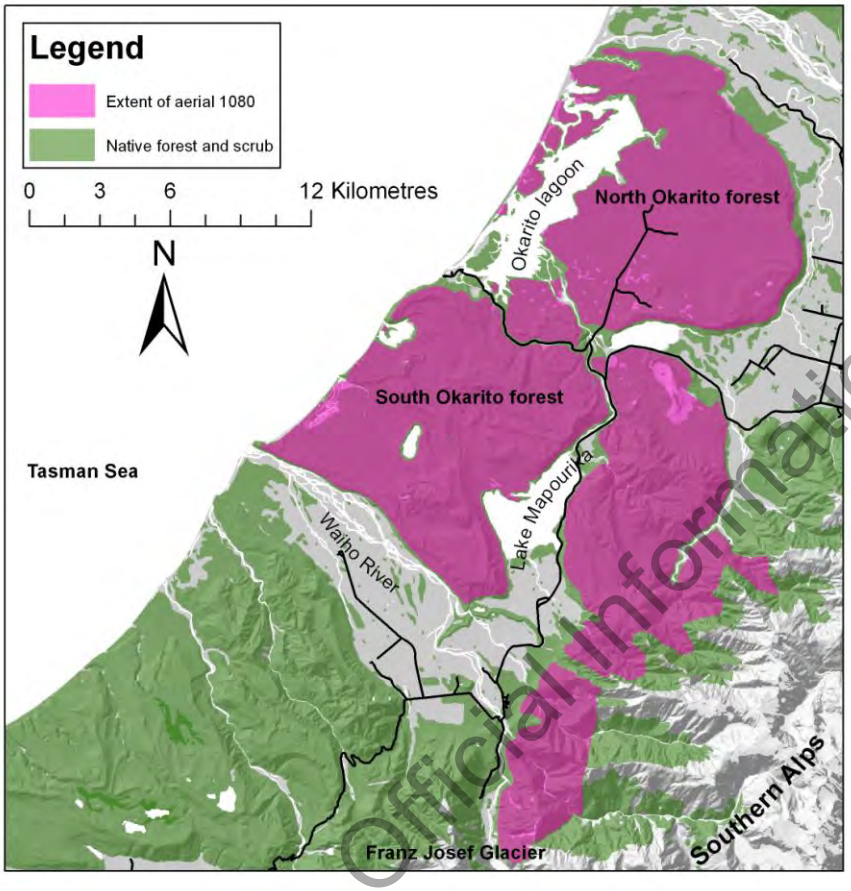
FIGURES

Figure 1. Map of South Island showing study areas and forest types within the species range of the kea.



1068 **Figure 2. Map showing 30,000 hectare area treated with aerial 1080 in spring 2011, at the start of**

1069 **the kea nesting season.**



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1072 **Figure 3. Map showing extent of Mt Arthur 2009 and Wangapeka 2011 aerial 1080 areas.**

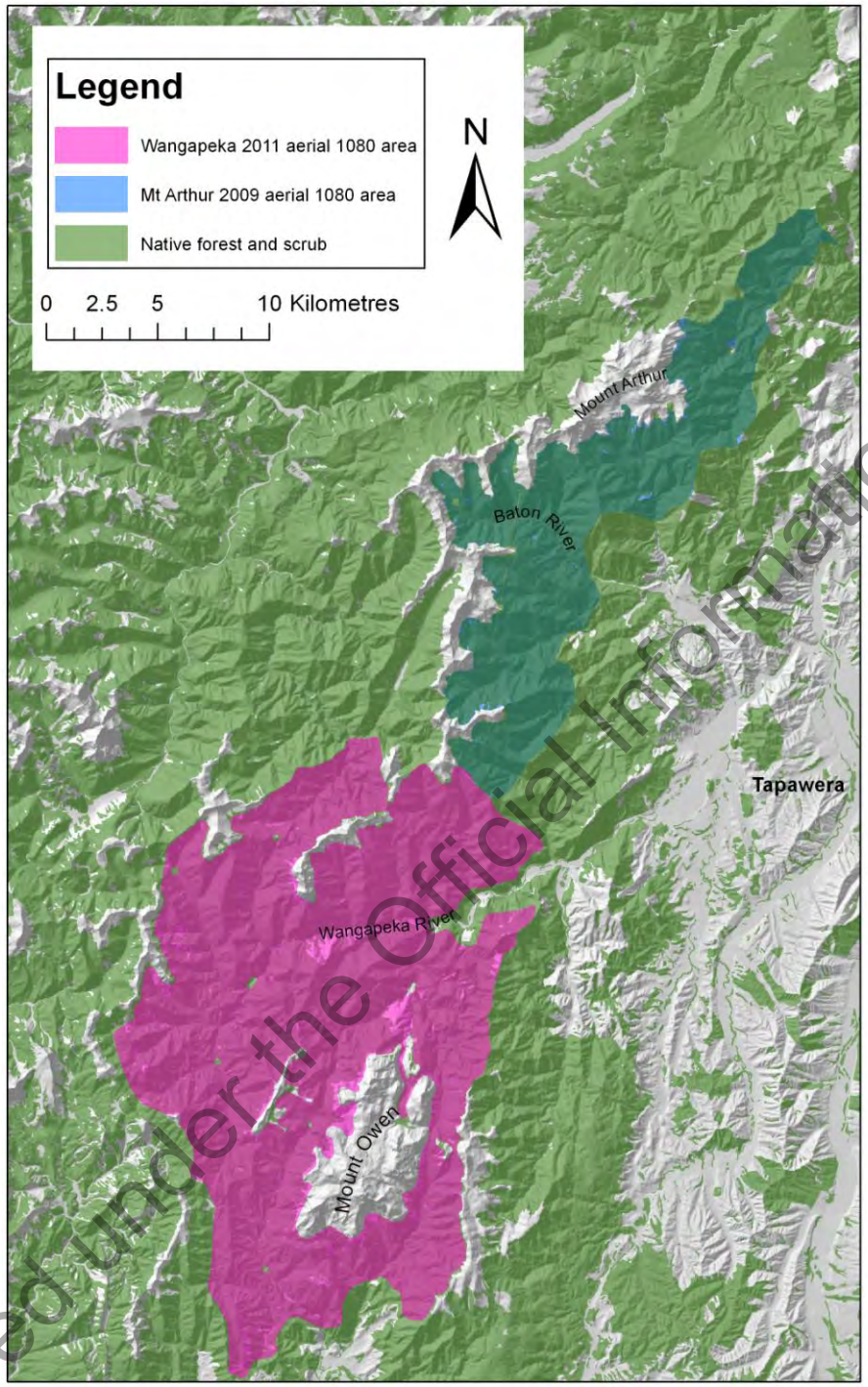

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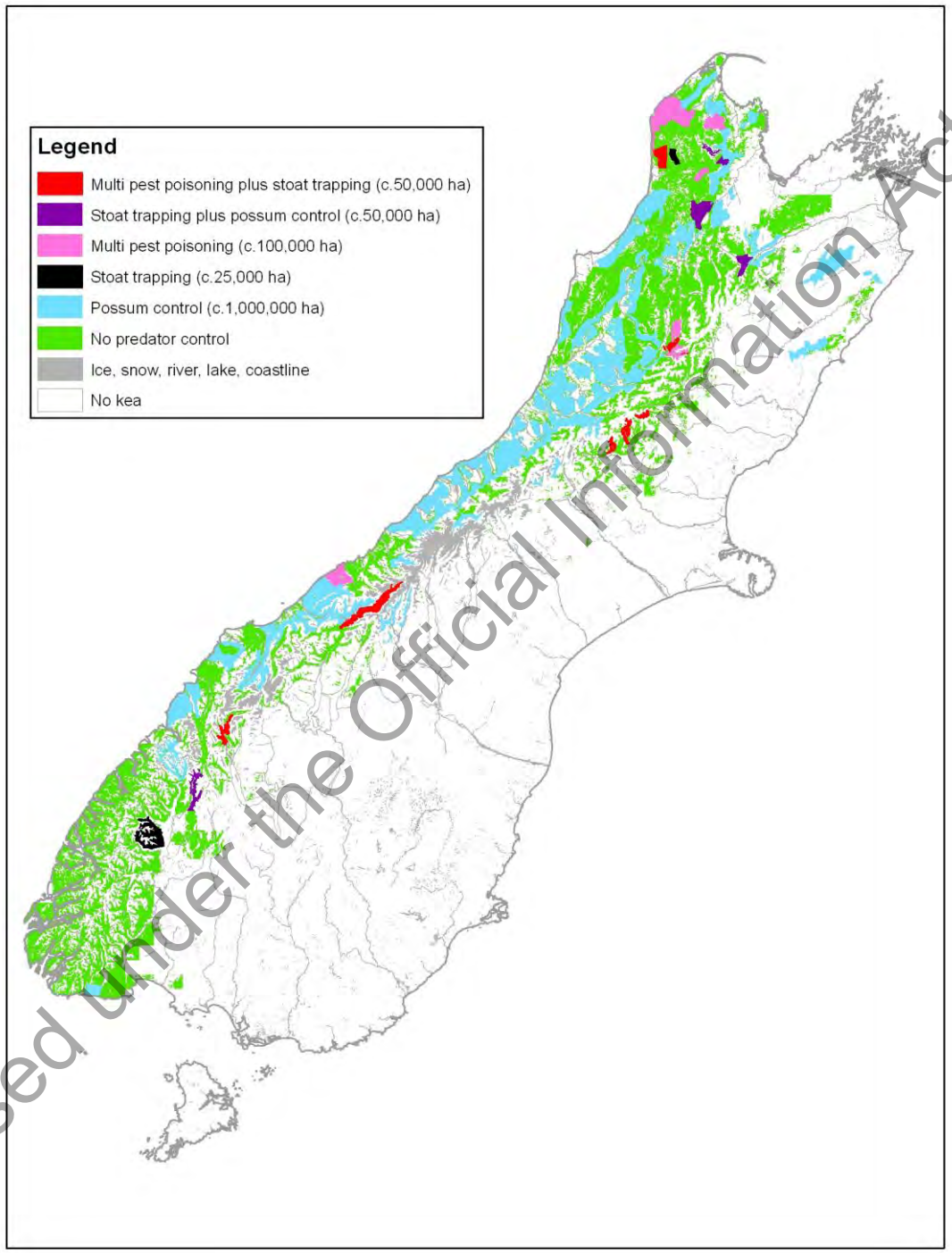
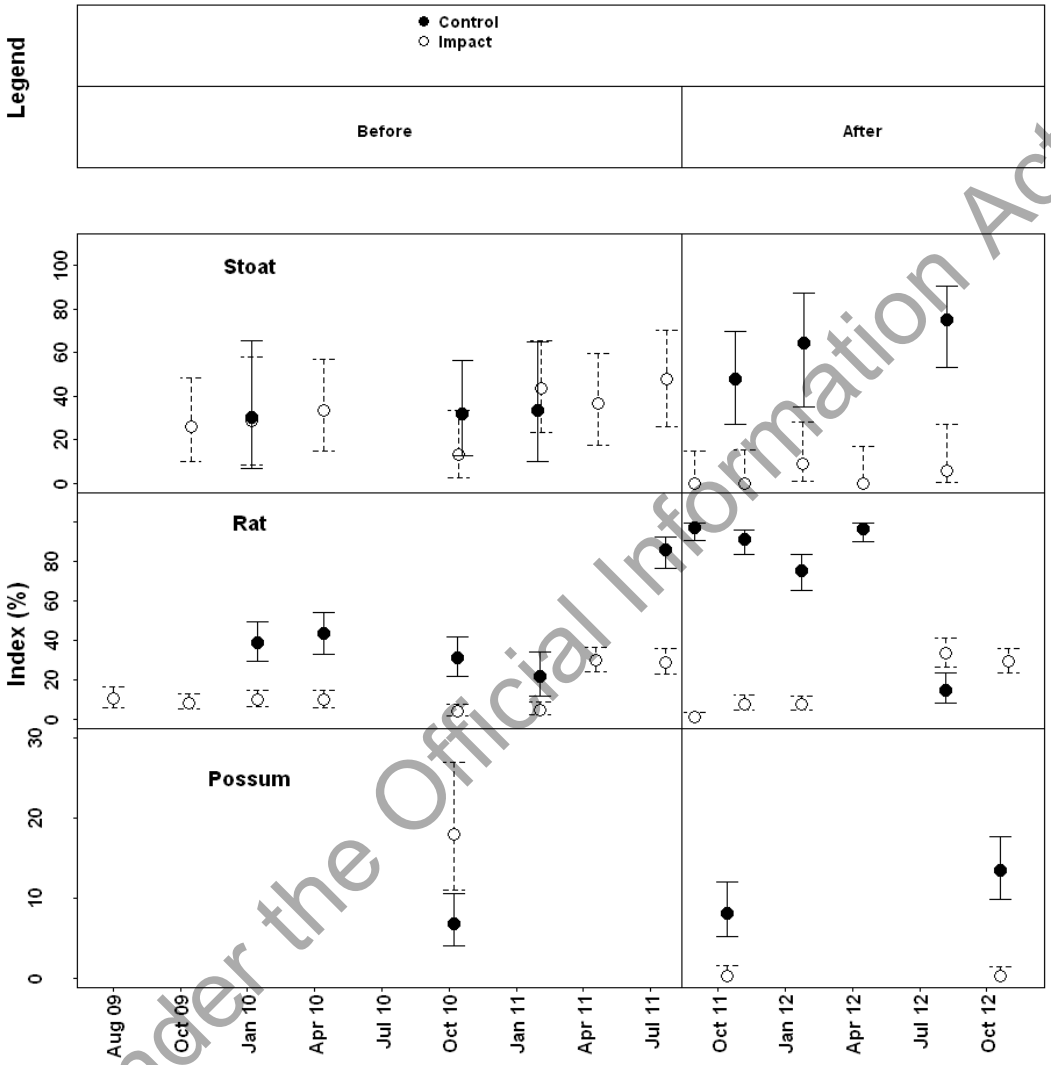
Figure 4. Map showing the extent and location of large scale predator control regimes in kea habitat.



1078 Figure 5: Predator indexing at Westland during the period of kea nest survival

1079 measurement. Control = Fox-Paringa, Impact = Okarito.



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1083 Figure 6: Predator indexing at Kahurangi.

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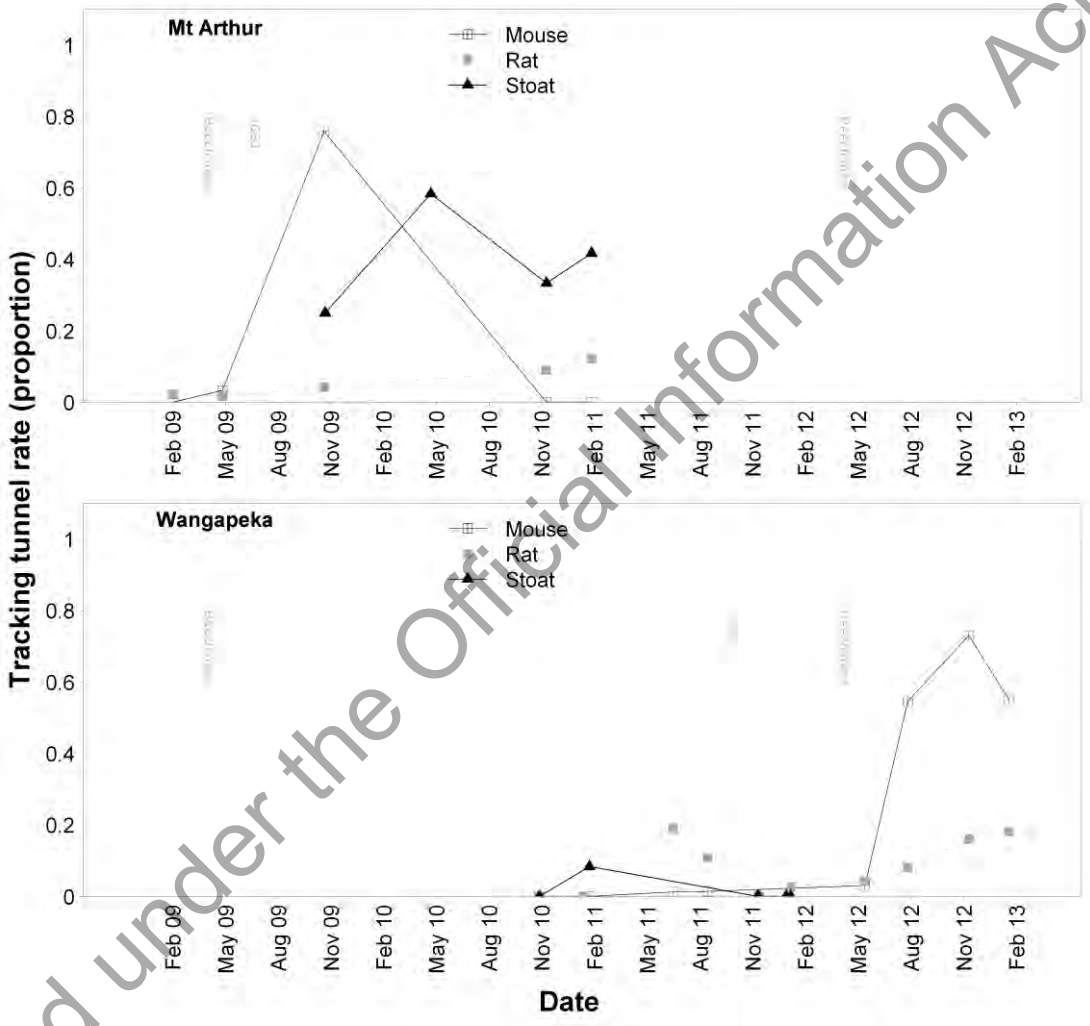

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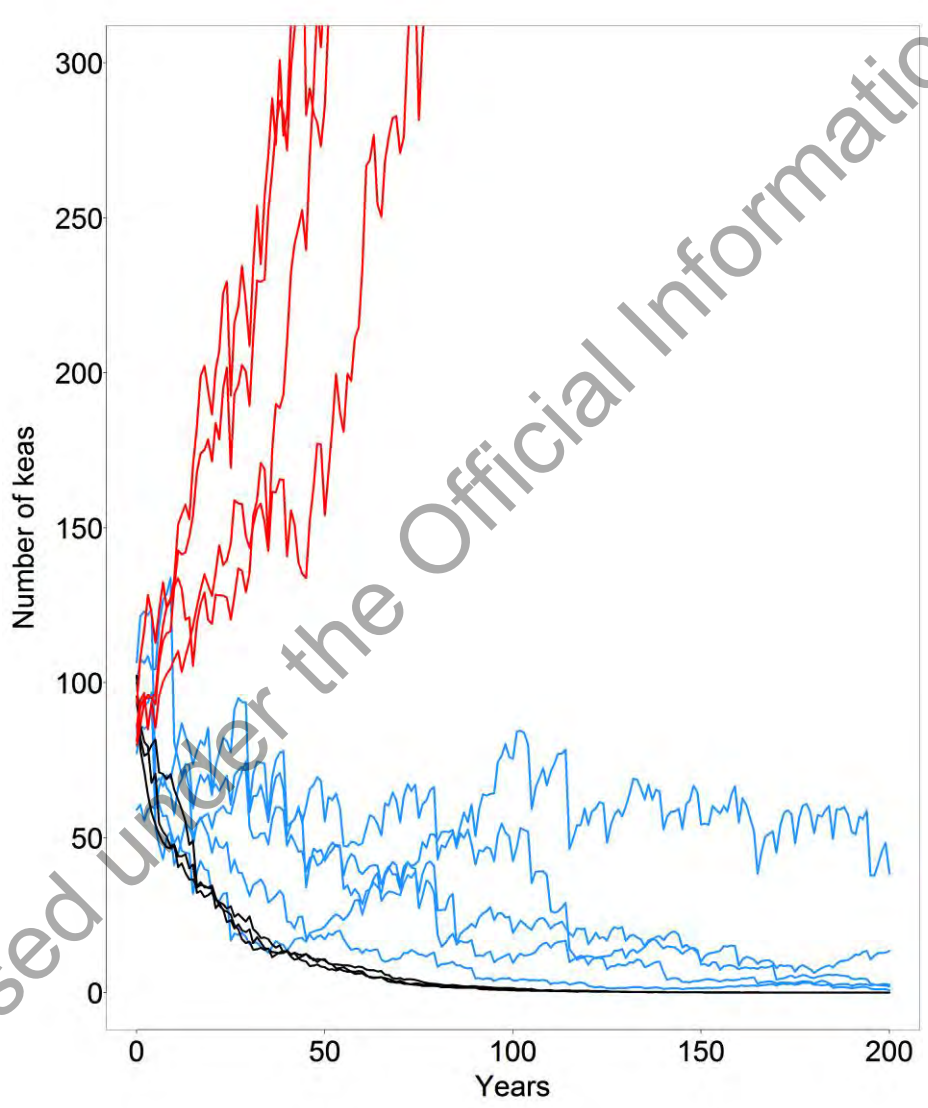
1088 Figure 7. Simulations of kea populations under different scenarios of non-target risk and
1089 predator impacts. Black = untreated population (zero non-target risk) with four yearly
1090 stoat plagues. Blue = worst case non target risk with best case predator control benefit.
1091 Red = nest case non target risk with best case predator control benefit. Worst case non
1092 target risk with no benefit would decline even faster than the Black line.

1093



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Appendix 10

Proposal and field plan for exploratory aversion training study on kea with Anthraquinone and cinnamon

9(2)(a), 9(2)(g)(ii) **, 14 March 2014.**

Objective

Determine whether the inclusion of Anthraquinone in a readily-accepted novel food can result in subsequent aversion to that food and, if so, decide on the best concentration of Aq for use in aversion training of keas to RS5 cereal pellets at junk food sites at which aerial 1080 baiting is scheduled.

Note

This trial is designed primarily for targeted aversion training of wild keas habituated to human foods at junk food sites. It is envisaged that training will occur at the sites of human activity, and therefore only effects on kea are taken into account. A parallel project is considering effects of Anthraquinone on efficacy of aerial 1080 for controlling target pests. While this study may have implications for a strategy to deliver aversion training via aerially broadcast cereal pellets, it is not the primary objective of the study.

Methods

1) Milford Road contains five tourist car parks at which kea are commonly present. Thirty-five kea have been colour-banded at these car parks over the past four years. The first stage of this study is to visit each car park three times for two hours each over three days to identify keas that are frequenting the car parks. Whilst doing so, any un-banded kea should be captured and banded in increase the number of birds available for the study.

2) Once five target birds have been identified, a bait presentation phase can begin. RS5 pellets containing 0.1% Aq bait are to be made available to each bird. The aim is to provide bait to one kea at a time in such a way as to observe the complete consumption of each pellet. If successful, a second pellet should be provided. More pellets should not be provided.

3) The observer will need to assess the response of the first few kea to the bait to see if the amount consumed can be reliably assessed. If the kea are not interesting in eating the bait, or if there is difficulty assessing how much has been eaten, then steps can be taken to increase acceptance. Such steps include 1) Softening of the bait in a damp environment, 2) fixing the baits to a tray so they cannot be moved out of site, or 3) abandoning the use of cereal pellets and attempting to use an alternative, fatty, novel food.

4) Kea are known to covet animal fat. We propose that, if working with cereal pellets proves problematic, an animal fat product be used to tempt kea to consume a measured dose of

Aq. We propose to use cooking fat because it is cheaply and widely available and largely tasteless. We propose that the duck fat available from supermarkets be used due to its lack of smell and taste and its mixing properties. At room temperature, duck fat is a smooth paste, to which additives such as Aq, cinnamon oil, and food colouring can be added and very evenly mixed in a cake mixer. The resulting mix can then be carefully measured into small bottles for delivery to kea. Kea may be more likely to quickly consume at entire pottle of such a mixture than they are to consume an RS5 pellet. The duck fat + Aq mixture can be easily made at various concentrations. Initially we would try a concentration that gives a similar quantity of Aq as two 12g 0.1% Aq RS5 pellets. We would also dye them green and scent them with 0.15% cinnamon oil to make them novel and provide a strong olfactory cue. If keas are not trained off the pottles of fat using this concentration of Aq, then we would increase the dose with the aim of establishing a point at which aversion training occurs.

5) We anticipate that some kea will eat the Aq RS5 pellets but others will not. Similarly, we anticipate that some keas will eat the duck fat pottles but others may not. Either way, phase three of the study is the aversion testing phase, in which keas that have eaten either Aq pellets or Aq duck fat will be offered the substance again. Their reaction and behaviour will be carefully recorded.

6) This study needs to occur in a progressive fashion with review points along the way to decide whether the design can be improved.

7) We envisage that aversion will be long-lasting once a kea is successfully trained. However, if initial results indicate successful training, this assumption will be tested in the medium term (months) and long term (years) by re-visiting the car parks in the hope of encountering the same keas and offering them whichever device (RS5 pellet or duck fat pottle) was used to deliver the initial training.

Outcomes

If it can be shown that around two pre-feed pellets laced with 0.1% Aq can condition an aversion in kea , or aversion results from an equivalent dose of Aq delivered in duck fat, then a program of aversion training using 0.1% Aq pellets will commence immediately at the Milford Track, the West Matukituki and at Arthurs Pass village and the surrounding ski areas, so that keas visiting these sites may be trained prior to the Battle for our Birds aerial 1080 operations proposed for these sites in September-December. Alternatively, if it takes more Aq to condition aversion, then higher dose cereal pellets will be used.

Appendix 11

KEA REPELLENT DEVELOPMENT REPORT

July 2014

Adult kea (*Nestor notabilis*) grazing *Coprosma* sp. Bushes in Lawrenny Ranges 2011

SUMMARY

D-pulegone (Dp) and Anthraquinone (Aq) were tested as a kea repellent agent in RS5 cereal bait pellets. These studies first exposed free ranging wild kea to cereal pellets containing 1.7% (w/w) Dp that were afixed to feeding stations and then exposed 13 captive kea to non-repellent prefeeds initially to determine bait palatability. Following this the kea were exposed to two concentrations of anthraquinone, 0.45% and 1.75% (w/w) respectively before a final exposure to non-repellent baits. The intention of the trials was to test a methodology whereby kea habituated to anthropogenic food sources might be targeted for aversion training prior to non-repellent 1080 pest control operations. Whilst consumption rates diminished for 8 of the 13 kea, 12 of the 13 kea returned quickly to consuming large quantities of non-repellent bait during the final exposure session. Our threshold for success of our repellent strategy was no more than 10 seconds feeding behaviour in the final bait exposure, a threshold that was exceeded by 12 of the 13 kea. Thus our study failed to demonstrate conferred bait aversion in kea following repeated exposure to high-dosage Aq repellent pre-feed baits.

The free ranging kea trial with Dp impregnated baits suggested very low palatability during the trial but these results were invalidated by field trials of the repellent concentrations in 1080 pest operations that suffered kea mortality of monitored birds. Results of the captive study of Aq repellence do clearly show a diminishment of bait consumption rates by the study kea when exposed to baits containing Aq but this was not as strong an effect as was anticipated for the high concentrations of Aq used. This may be the result of a number of factors including the misinterpretation of previous results and the rate at which the bait was consumed. The results also raise concerns over the ability to mask signals that enable kea to differentiate between repellent and non-repellent baits.

BACKGROUND

Kea are subject to non-target deaths in aerial 1080 operations with the limited monitoring suggesting that in some instances mortality rates can reach 41% of exposed birds (Veltman and Westbrooke 2011). This issue has raised concerns amongst the public and conservation biologists, and the Department of Conservation has stated that it will respond through the investigation of repellent strategies to minimise kea bait consumption.

A review of the literature suggests that there are two repellent agents that offer the greatest likelihood of success, these being D-puligone and anthraquinone ([redacted] DOC internal report).

D-puligone

The primary repellent D-puligone (DP) has been recognised as an avian repellent for some time (Wager-Page and Mason 1996). A compound of penny royal which delivers a pepper-minty taste and smell, d-pulegone offers a primary and secondary repellent function to birds due to its volatile nature and strong flavour. It has been shown to achieve aversion in a small range of avian species at a relatively low concentration of 1% w/w (Mason 1990; Mastrota and Mench 1995; Day et al 2003). Most significant is that d-pulegone at the tested 1% w/w has proven not to be a detectable repellent to rodents or possum in New Zealand based trials (Day et al 2000). This identifies d-pulegone as a strong candidate for our consideration. No details are provided in any of the literature regarding the persistence of d-puligone but issues have been reported and require further exploration ([redacted] pers comm.). Day et al (2000) go on to suggest that the coupling of proven secondary repellents with other signal components of bait such as bait colour as a potentially more cost effective solution to the need to enable recognition of the treated baits for learned aversion.

Anthraquinone

Any repellent strategy is likely to be improved by the complimentary effects of both primary and secondary repellents. A secondary repellent does not need to create aversion on contact but rather relies on negative consequences of consumption associated to a strong signal (which may be a primary repellent) to work best. An excellent candidate for use as a secondary repellent is Anthraquinone. Anthraquinone (Aq) is an emetic substance causing nausea and vomiting when consumed in sufficient quantities. In a study where 1 and 2% Aq (wt/wt) was added to a 2% zinc phosphide acute rodenticide targeting black-tailed prairie dogs, laboratory trials suggested non-target birds demonstrated 100% survival following exposure to zinc phosphide (2%) baits with AQ following prior exposure to non-toxic bait containing only 2% Aq (Werner et al 2011). However the LD50 of zinc phosphide is brought into question by the authors following moderate toxic bait consumption by certain non-target birds. The most intriguing result from this study is that black tailed prairie dogs appear to be sensitive to Aq in a manner that is not directly related to the Aq concentration (r^2=0.2, P=0.4). This finding raises concerns regarding the parameters by which we might evaluate Aq repellence to rodents. I find it difficult to extrapolate the findings of this study to the likely outcomes of a field treatment of 1080 baits with Aq, other than to confirm that a period of exposure is necessary to enable aversion to be learned, and that this study should undermine our confidence that Aq does not hold repellent qualities for rodents.

Another study where Aq is applied without a primary repellent details the treatment of rice production with 1% active Aq to minimise damage by blackbirds (Icterinae) (Cummings et al 2002). Damage was significantly reduced by the treatment (effective Aq ~0.5% w/w). It is also my interpretation of the paper that the treated rice fields were a small proportion of the foraging habitat available to this highly mobile species and so apparent repellent effects may be over-stated.

In a trial of Aq, methiocarb and MA, Aq was found to be effective at creating aversion in Dickcissel above 0.05% although at this concentration emesis was observed at the one-cup trial but apparently did not lead to greatly reduced consumption (Avery et al 2001).

The oldest paper identified evaluating Aq as an avian repellent is Dolbeer et al (1998) where 0.1%, 0.5% and 1.0% (w/w) formulations of Aq achieved repellence in geese and cowbirds. Interestingly, at the 1.0% formulation even birds in a two-choice laboratory experiment exhibited weight loss and 3 of 12 cowbirds died in the 0.5 and 1.0% Aq two-choice trials suggesting that in such concentrations for some species (cowbirds, Icteridea) Aq is more than just a emetic irritant.

No specific reports were found detailing the time period of exposure to Aq (or any other repellent) in parrots and the following physiological response. Malhe et al (2003) exposed rose ringed parakeets to Methyl Anthranilate but give no details of the timing of any behavioural response outside of the 3-4 day period between treatments. A curious study testing attractiveness and palatability of repellent treated baits to orange fronted parakeets, which revealed neither the bait medium nor the repellent agents, failed to detect any meaningful aversion or notable behavioural response to the repellent (Clapperton et al 2005).

No comment is made in Orr-Walker et al (2012) regarding gastrointestinal discomfort or emesis in the kea exposed to Aq and d-pulegone in the trials described but reference is made to the significantly different rates of consumption of bait between individual kea. This might suggest that some individuals require more exposure to repellents (Aq and D-pulegone in this case) than others before an aversive response is generated. Indeed such an aversive response is suggested to be governed by physiological state in the conclusions drawn by Werner et al (2009) due to inter and intraspecific differences in the doses necessary to achieve 80% repellence.

Methodologies for D-puligone

Initial trials attempted to test the effectiveness of DP alone as an effective repellent. This was largely justified by our concern over sensitivity of target pests to Aq. A trial conducted at ski-field car parks was initiated in 2013 to evaluate the effect of 0.17% DP in RS5 cereal pellets. This involved birds being given access to 2 secured repellent RS5baits nailed to the feed tray on 2 occasions, 2 weeks apart.

Trays were available for up to 3 hours morning and afternoon on each occasion in the presence of kea for up to three days at the first exposure (prefeed) and 3 days at the second exposure (pseudo-toxic).

Results for D-puligone

Of a fluctuating test population at Treble Cone ski field of approximately 12 kea we achieved bait consumption that never exceeded 0.3g during the first exposure and 0.06g during the second exposure (Table 1.)

Table 1. Kea bait consumption totals for Treble Cone field trial

Kea leg band ID	1st exposure	2nd exposure
KCO	0.33	0.07
W6R	0.33	0.06
YJB	0.08	0.06
KJW	0.01	nil
KDG	nil	0.06
KBW	nil	0.05
WIO	nil	0.01

The results of the Treble Cone trial appeared promising however whilst gather these data a field trial of the same bait repellent treatment was conducted in the Otira catchment of the West Coast which resulted in significant mortality of kea undermining any value in these results. The most useful learning from the trials were to exemplify that controlled field trial conditions do not effectively reflect the natural behaviours and variations therein of kea. Our concerns include firstly that baits were secured to the feed

stations preventing kea from taking bait away for feeding and that bait were only available for defined periods of daylight and kea are well known crepuscular and nocturnal foragers.

D-Pulegone volatility

Another issue that arose in the testing of these repellent agents was the volatility of Dp. As an expensive agent Dp concentrations make a significant difference to the cost of operations and so careful attention needed to be paid to its persistence in bait. Analysis of assay results (Fig.1. Westbrook and Crowell, unpublished data)

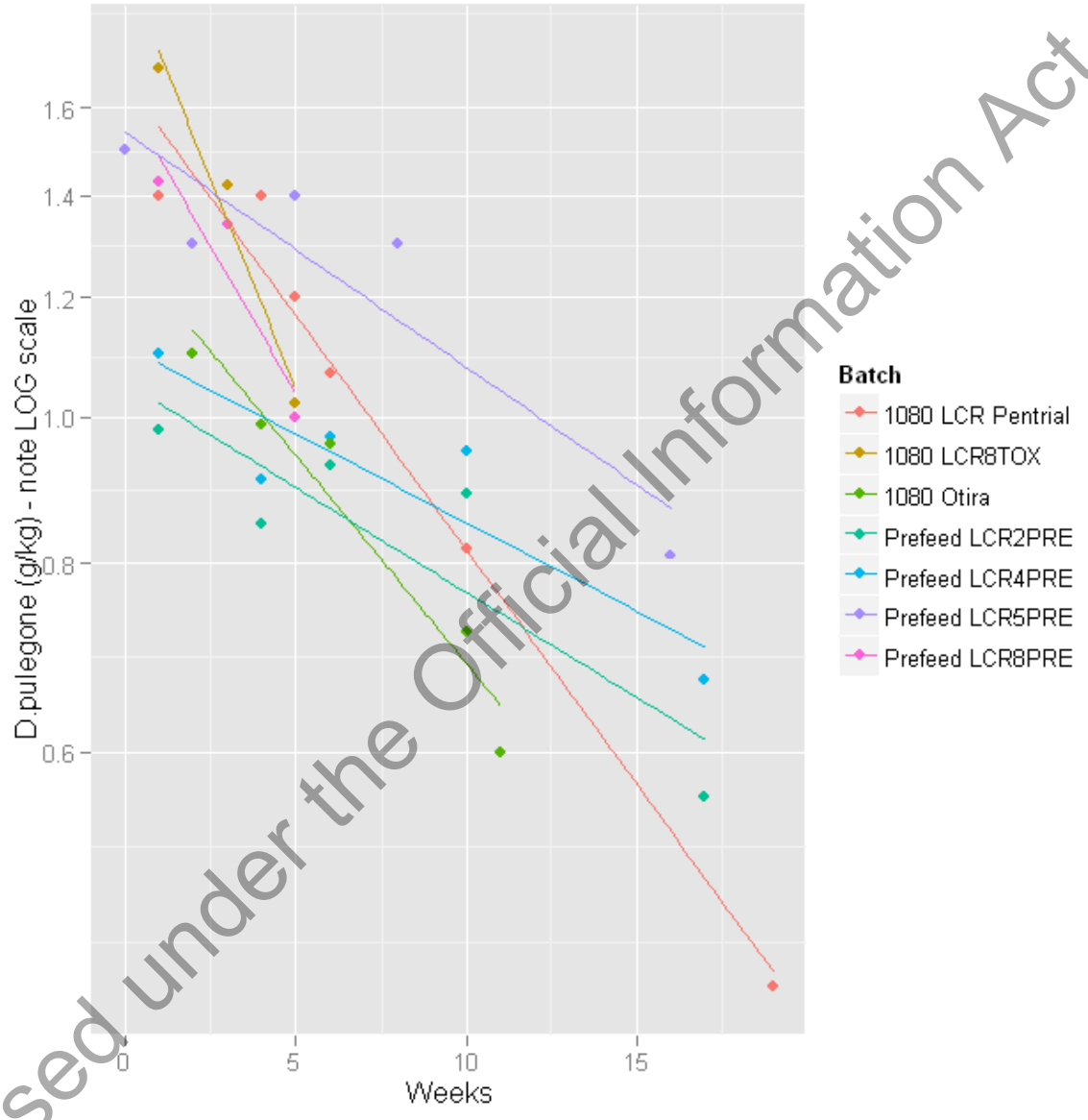

Fig.1. D-pulegone decay rates (Crowell and Westbrook unpublished data).

The level of volatility observed suggests that the combined issues of operational timing and batch manufacture accuracy place a large question mark over the reliability of Dp as a primary repellent.

Non-broadcast repellent strategy

Further field trials of the effect of repellent additives on the level of pest suppression achieved in the wild suggested that similar concentrations and combinations that had limited efficacy for repelling kea were causing some aversion in rodents (Crowell et al. in prep.). This result signalled a failure to achieve either pest suppression or non-target aversion with the existing strategy.

However, a theory exists that kea that are familiar with novel food items due to a history of frequenting car parks and huts means that additional options may exist to minimise non-target deaths. Evidence that Aq in concert with Dp had caused conditioned taste aversion suggests a risk management option may exist especially if higher concentrations were able to be used(Ord-Walker et al. 2012). We therefore felt it necessary to evaluate the conditioned taste aversion achieve by feeding kea baits including higher than previously tested Aq in RS5 cereal bait pellets in captivity.

Willowbank Reserve Feed Trial

Methodology

To investigate options for a targeted aversion training programme with kea that frequent human infrastructure we conducted a feeding trial where we offered captive kea access to cereal pellets over a number of sessions including pellets treated with 2% (w/w) Aq which according to the effect of 0.1% Aq and 0.17% Dp in the Orr-Walker et al. 2012 trials should elicit a strong repellent effect. Our intended methodology was to present pellets to kea to establish palatability via a 2-4 day exposure period depending on rates of consumption. Following this and a 2-3 day break we switched the pellets to those with the same characteristics but also treated with a 2% (w/w) component of Aq. This exposure will be for 14 days followed by a 5 day period when kea will not be offered any pellets. Following this non-repellent bait were once again offered to kea for a period of 14 days. This was intended to simulate the laying of non-repellent baits in a 1080 operation.

Kea exposed to the treated cereal pellets will have the opportunity to feed or not feed on the pellets at their own discretion. Throughout the trial the birds normal feed regime will be made available but with delayed timing to encourage consumption of cereal pellets.

Observers followed each bait provisioned to determine its fate. Trials were started daily at 8am and ran for 3hrs each. We will be using the 13 captive kea held at Willowbank Wildlife Reserve for this trial. All birds will be individually identifiable by all team members. Abbreviations for these band combinations are as follows:

Blue - Left	BL
Blue - Right	BR
Orange - Right	OR
Pink - Left	PL
Pink - Right	PR
Red - Left	RL
Silver-Right-Adult	SRA
Silver-Right-Juv	SRJ
White - Left	WL
White - Right	WR
Yellow - Left	YL
Yellow - Right	YR
Katie	K

Table 2. Trial sessions for provisioning Willowbank Reserve kea with bait treatments.

Session dates	Bait type
May 26th to May 27th	Non-repellent pre-feed (hard)
May 30th to June 2nd	Non-repellent pre-feed (soft)
June 6th to June 9th	0.14% anthraquinone treated prefeed
June 17th to 19th	1.75% anthraquinone treated prefeed
June 24th to June 27th	Non-repellent pre-feed (soft)

Birds given access to a minimum of two and maximum of three feeding stations within the aviary which are the feed stations at which they are regularly fed their normal diet (Fig. 2.). Pellets will be presented at the start of each exposure period timed to match their usual feeding regime. The baits will be monitored by the observers and once a bait is consumed/discarded additional baits will be provisioned by observers.

Fig. 2. Kea feeding on platforms in aviary, Willowbank Reserve (photo: M. van de Wetering)

All kea have free access to the whole aviary but territories do exist within the area making multiple feed stations necessary for their husbandry.

Data

Two key variables were recorded: Feeding time (classified as pellet or part of pellet in beak being crumbled) and Consumption levels (1=<1/2 a bait, 2= ½-1 bait, 3=1whole bait) during an interaction with any one pellet.

A census of all bird behavious (active/inactive, unfluffed/fluffed, asleep/awake, foraging, socialising/isolated) was also recorded for all trial birds every 15 minutes during and for 1hr post every trial exposure.

Critically some *a priori* thresholds were determined for consumption and interaction times that would signal a failure of the method to effectively repel kea to a degree that we would be prepared to go operational. That threshold was >10seconds feeding behaviour on the final exposure sessions to non-repellent pre-feed.

Behavioural state and interactions were also recorded by the observer teams enabling an assessment of bird behaviour post exposure to repellent baits and also an assessment of hierarchy amongst the aviary birds.

Results

Due to issue with bait supply, trail exposure periods varied to those intended as described in table 2. Consumption rates varied across the sample of kea as would be expected for such individualistic animals. Total bait consumption by day for each individual kea can be seen to follow a clear pattern of high consumption of in initial non-repellent prefeeds, a clear decline in consumption rates during the provisioning of bait containing 0.14 Aq and a further deline during the provisioning of bait containing 1.75% Aq. The consumption rates then return to non-repellent prefeed levels in the final sessions where non-repellent prefeed are provisioned (Fig. 3).

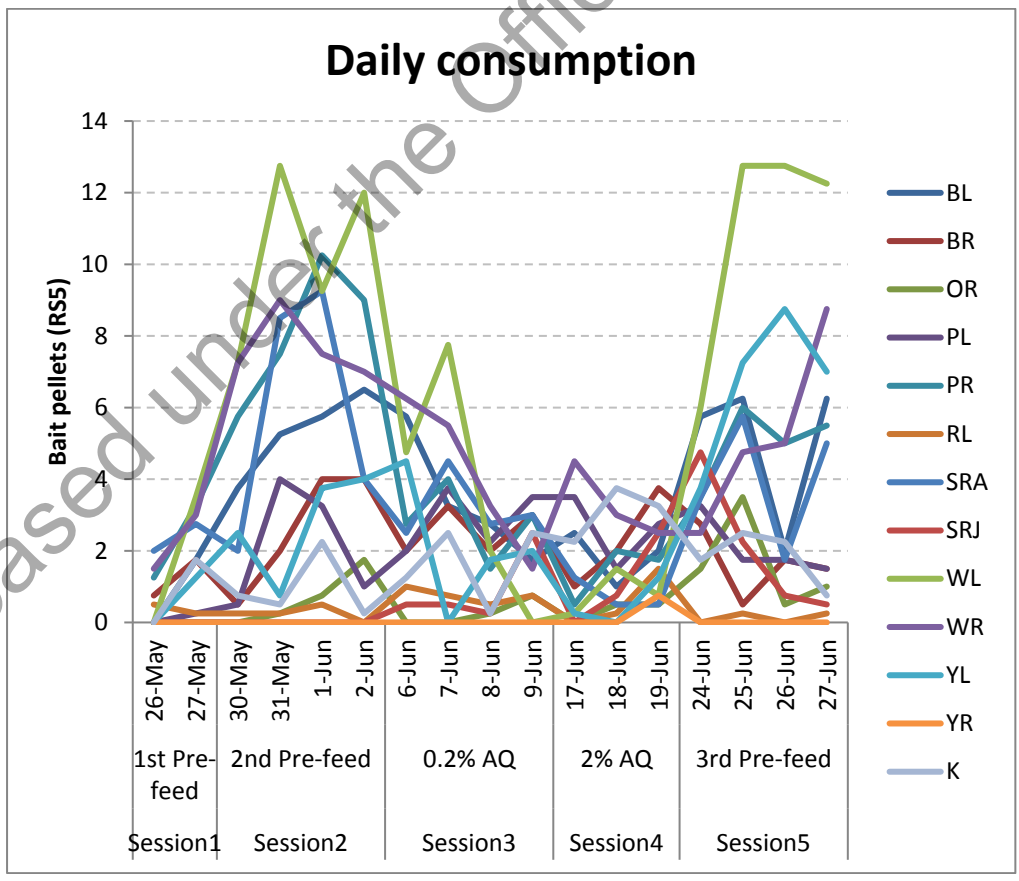

Fig.3. Daily pellet consumption by kea during Aq feed trials, Willowbank Reserve.

The threshold of 10 seconds feeding behaviour observed during session 5 was exceeded by all except one individual (Yellow Right).

Patterns of bait consumption in individuals varies considerably and whilst there is a relationship to social hierarchy, this does not adequately describe the data (table 3.).

Table 3. Kea social rank and bait consumption rank.

Kea ID	Displacement of other birds	Social rank	Bait consumption rank
White - Left	39	1	1
Pink - Left	37	2	8
Yellow - Left	27	3	6
Katie	23	4	9
Yellow - Right	19	5	13
White - Right	13	6	2
Blue - Right	11	7	7
Pink - Right	9	8	3
Blue - Left	7	9	5
Red - Left	7	9	12
Silver-Right-Juv	3	10	10
Silver-Right-Adult	0	11	4
Orange - Right	0	11	11

Individual bird consumption totals are provided in Appendix I.

Conclusion and Discussions

In the execution of these trials there were consistent issues with bait quality. An initial non-repellent prefeed was discovered to have been treated with D-pulegone, which whilst undetectable to the human nose necessitated the acquisition of a different source of non-repellent prefeed. The first exposure to Aq treated baits which were assumed to be 2% (w/w) were actually 0.2% preparations meaning that the Aq exposures were two stage with 2% Aq baits presented after the 0.2% Aq bait presentation session. On assay these baits proved to actually contain 0.14% and 1.75% Aq respectively. The recently manufactured 2% Aq baits were then discovered to contain traces of brodifacoum which halted their provisioning.

The results clearly show that the strategy of achieving conferred repellence in non-repellent baits following exposure to repellent baits has failed in this instance. Despite the variability in consumption rates and total amounts 12 of the 13 kea would have potentially received a lethal dose of 1080 where these trial results replicated in the field.

Despite this failure of the strategy, we do observe clearly reduced rates of consumption of the repellent baits confirming that there is indeed a repellent effect of Aq in the cereal pellets.

An unexpected variable that caused the field team to have serious concerns about the veracity of the data gathered was the consistency of the baits provisioned. The team noted a marked difference in bait crumbliness which appeared to translate into palatability to kea. The interpretation was that kea became bored more quickly with harder baits and therefore consumed less as once bored kea tend to discard food items. This finding is important and should be regarded as an important new variable to consider in the use of cereal bait pellets. Manufacturing standards will always involve some variability but perhaps an

important priority would be to establish a minimum acceptable bait hardness for operations where kea may be present. It is also noted that bait harness appeared to relate to bait age.

The level of repellent effect appears far less dramatic than anticipated with a concentration of 2% (w/w) given the previous impact of far lower concentrations (Orr Walker et al. 2012). This could be explained by a number of factors: first, that the synergistic effect of combining both primary and secondary repellents was absent in this trial; second, that the interpretation of repellent effect of previous exposure to Aq has been misinterpreted and third, that the rate of consumption in these trials was sufficiently slow to prevent the total quantities of Aq consumed to bare the expected physiological effects because of the dose-rates.

This final possible cause can be investigated by an assessment of the rate of Aq treated bait consumed during each exposure period. Anecdotal information suggests that the effects of Aq only persist for 30 minutes or so after a 10-20 minute period of delay (T. Orr-Walker pers. comm.., M. van de Wetering pers. com.). So if doses inadequate to elicit a response are consumed over an extended period, even though the total consumed may be high, the likelihood of repellent agents achieving a physiological response may be very limited. To further this study it would be advisable to determine the range of consumption rates in kea and consider the repellent dose rates that should achieve a strong repellent effect.

Irrespective of these issues, the results seem to make clear the ability of kea to differentiate quickly between bait types. This may be caused by two factors; first that kea continually test potential food items for palatability, which would mean that any hope of achieving conferred repellence will be limited at best and second, that they are able to differentiate between repellent and non-repellent baits using their senses.

The UV reflectance of Aq has been noted (ref) and during the trials the field team noted that the presence of Aq was accompanied by a reddish hue caused by the marker dye added to the commercially available Aq preparations. It would seen extremely likely that an intelligent and visual bird like kea could determine those not-so-subtle differences by sight, smell, taste, texture or a combination of those factors.

In light of this it would seem important that if such repellent strategies are pursued further that benign signal blocking agents are investigated. Green dyed baits were not used in this Aq trial because of the issues of adding the dye to short runs of repellent treated prefeeds. The addition of a agent or agents that masks any colour, reflectance, taste, differences between non-toxic repellent baits and non-repellent non-toxic and toxic baits is probably fundamental to the success of these repellent strategies for kea.

Acknowledgements

This trial would not have been possibly were it not for the superb efforts of [redacted] and [redacted] g, ably assisted by [redacted], [redacted] and [redacted]. I thank the Animal Ethics Committee, especially [redacted] for patience and support in reviewing the experimental design and I would like to acknowledge [redacted] for her support and advice on both design and interpretation of the study. Finally I must recognise the steady hand of [redacted] who has steered this shaky vessel through the choppy waters of our restructured business.

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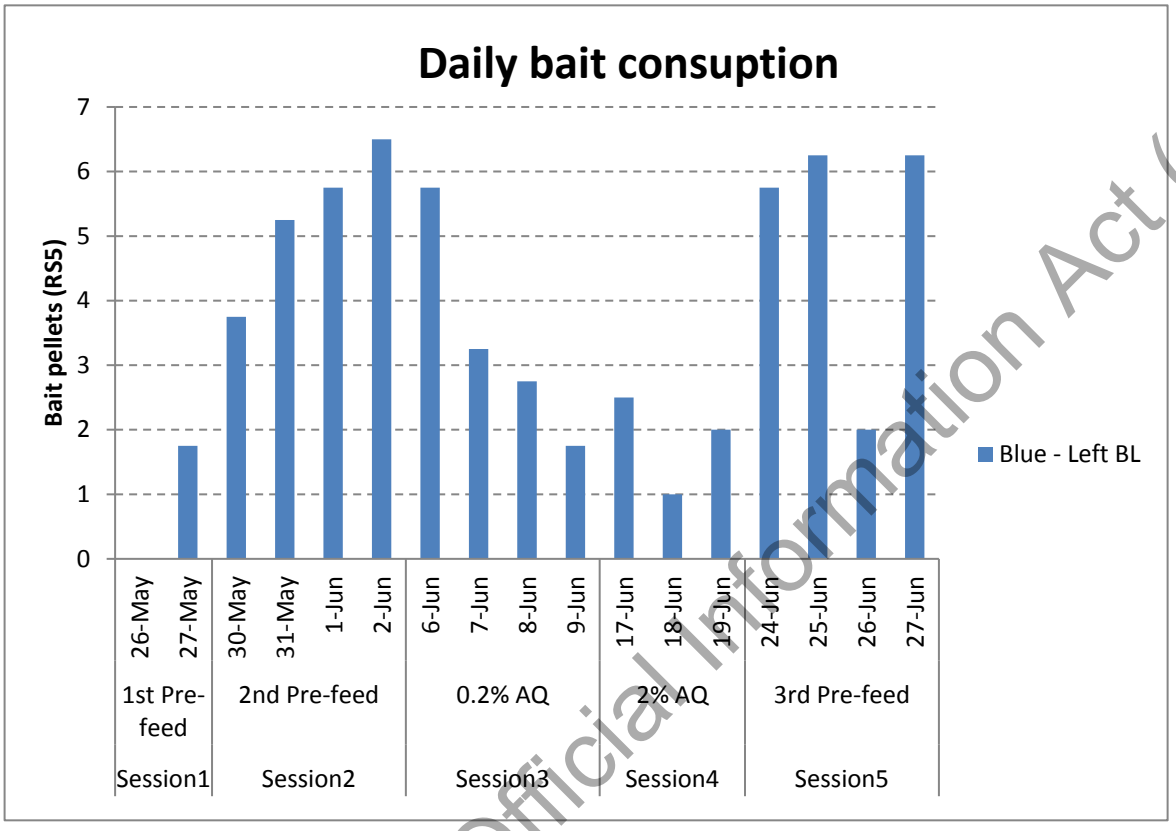
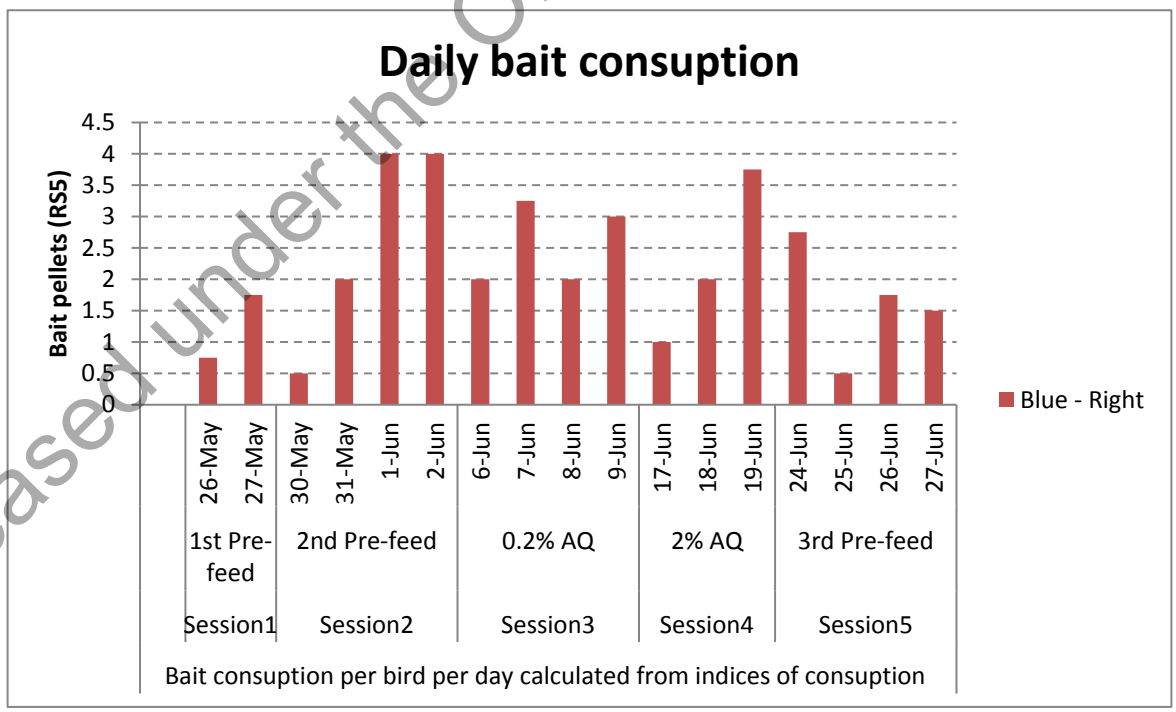
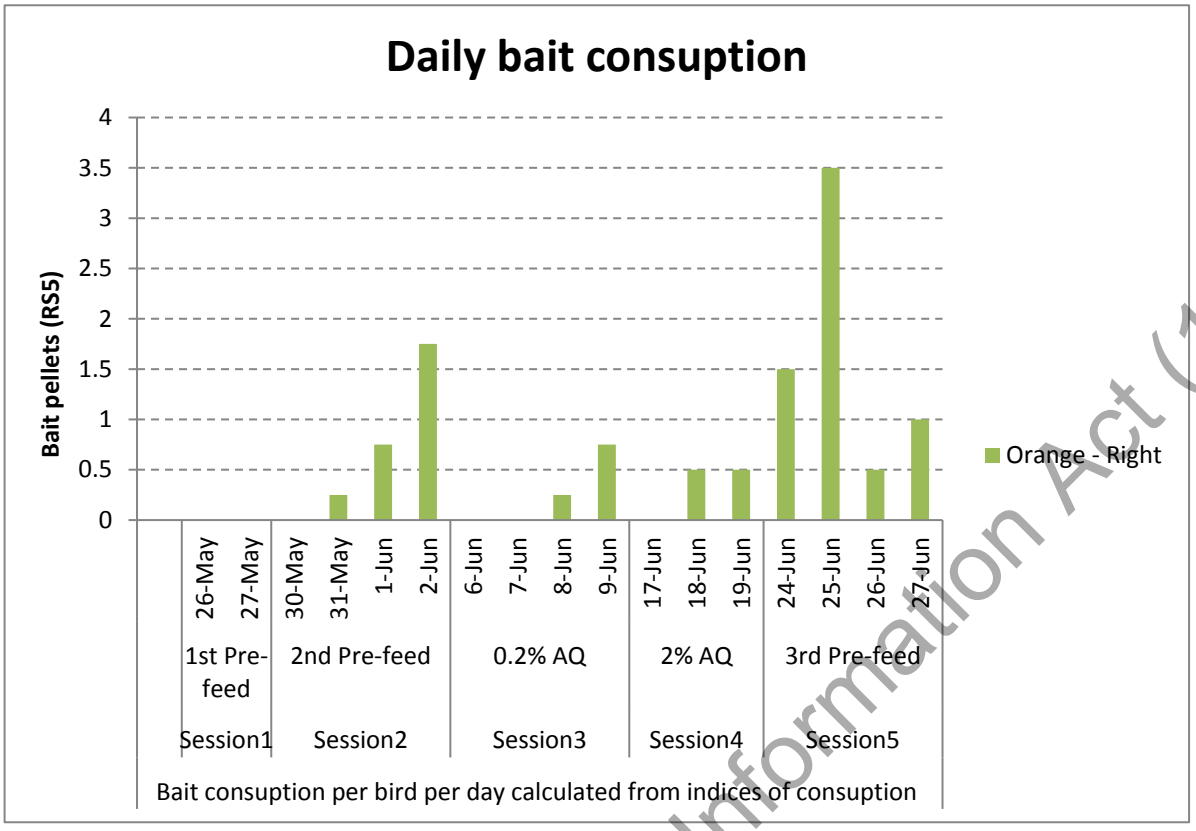
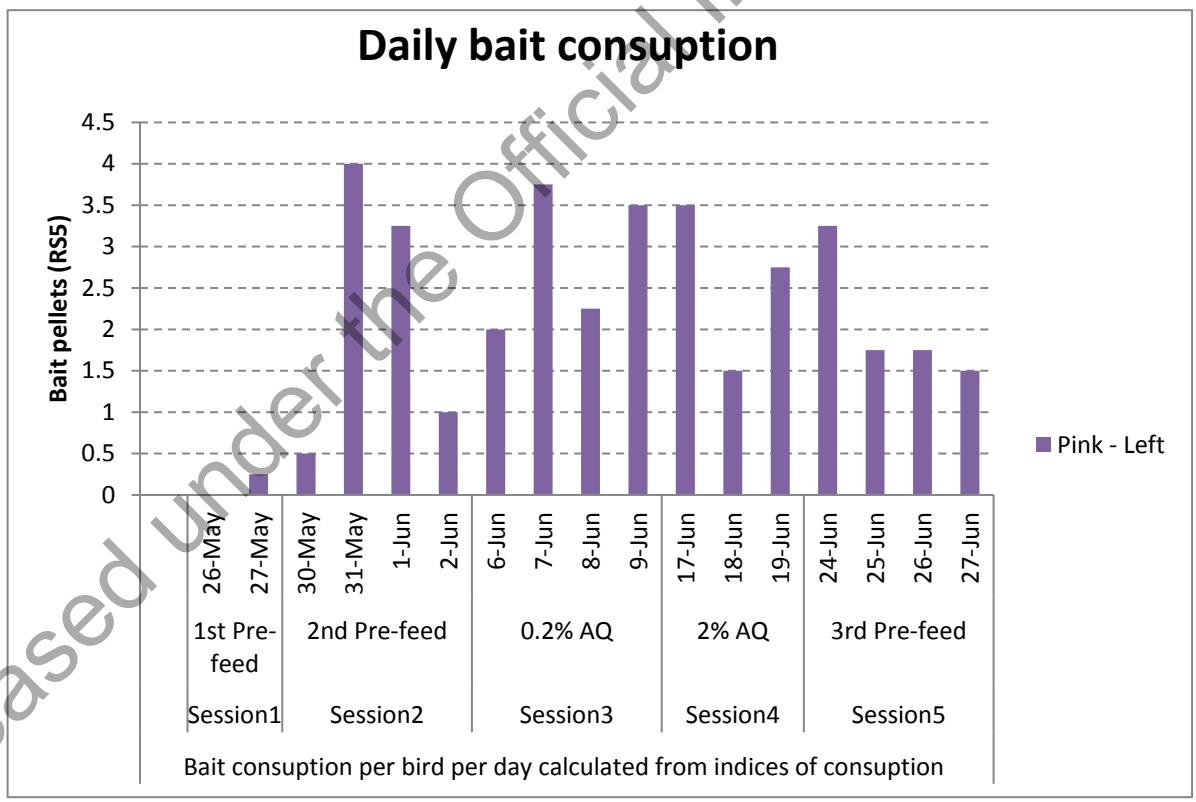
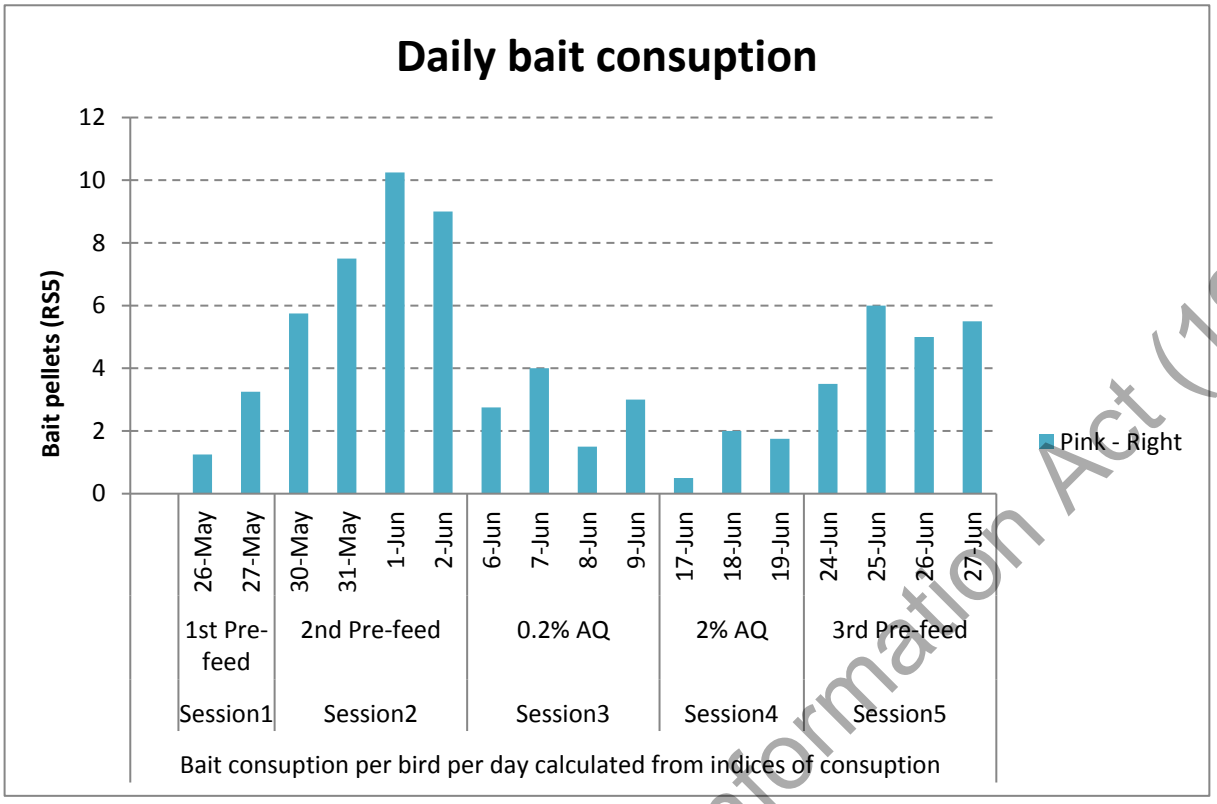
Appendix I.

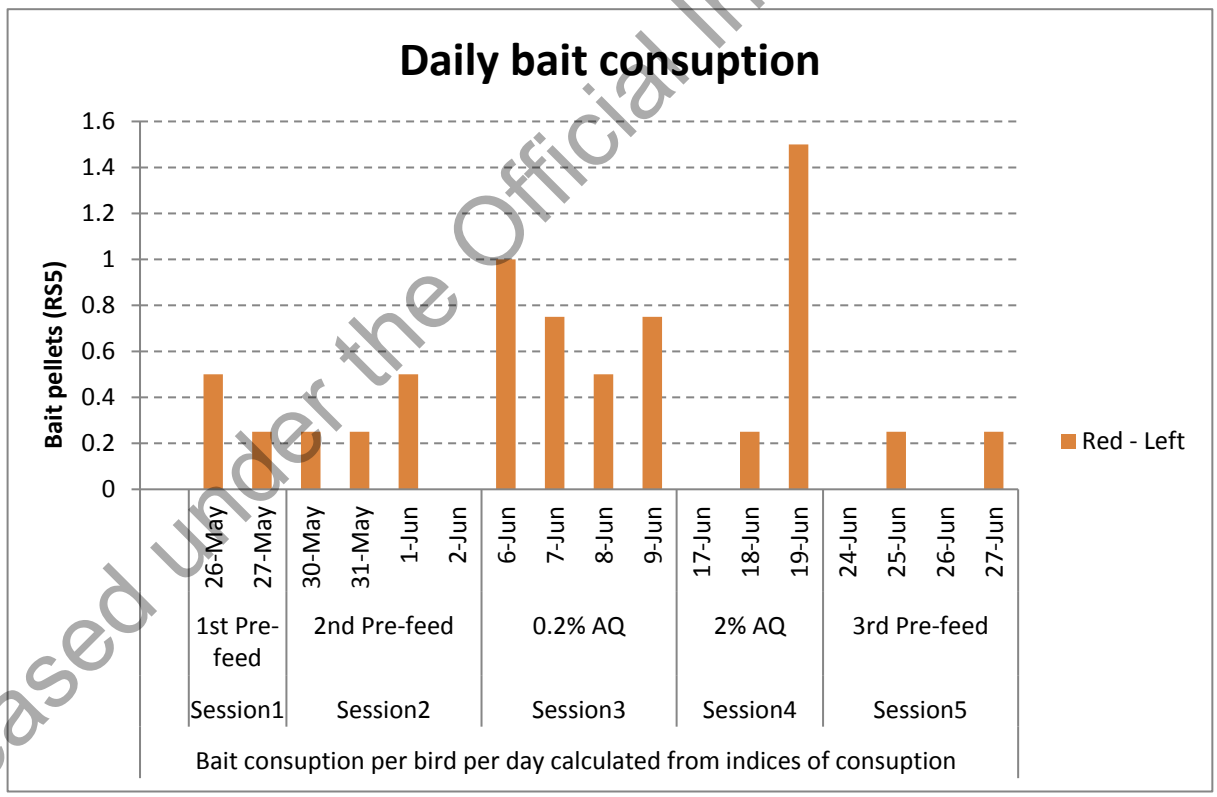


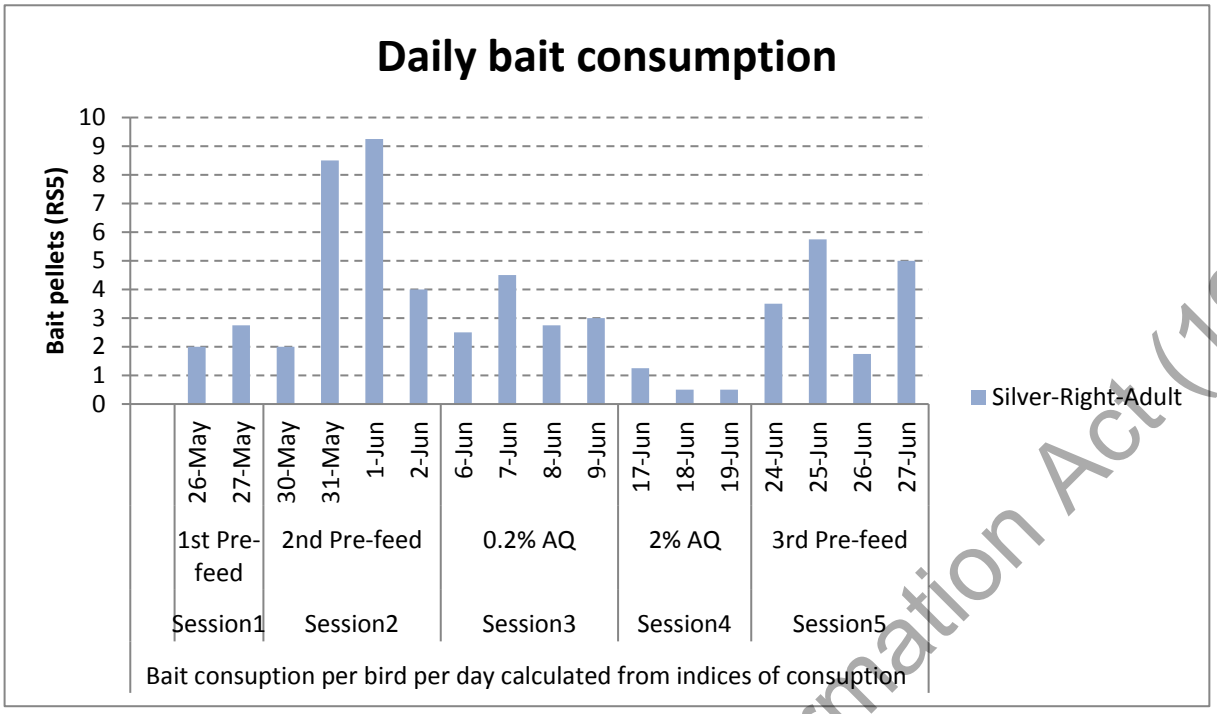


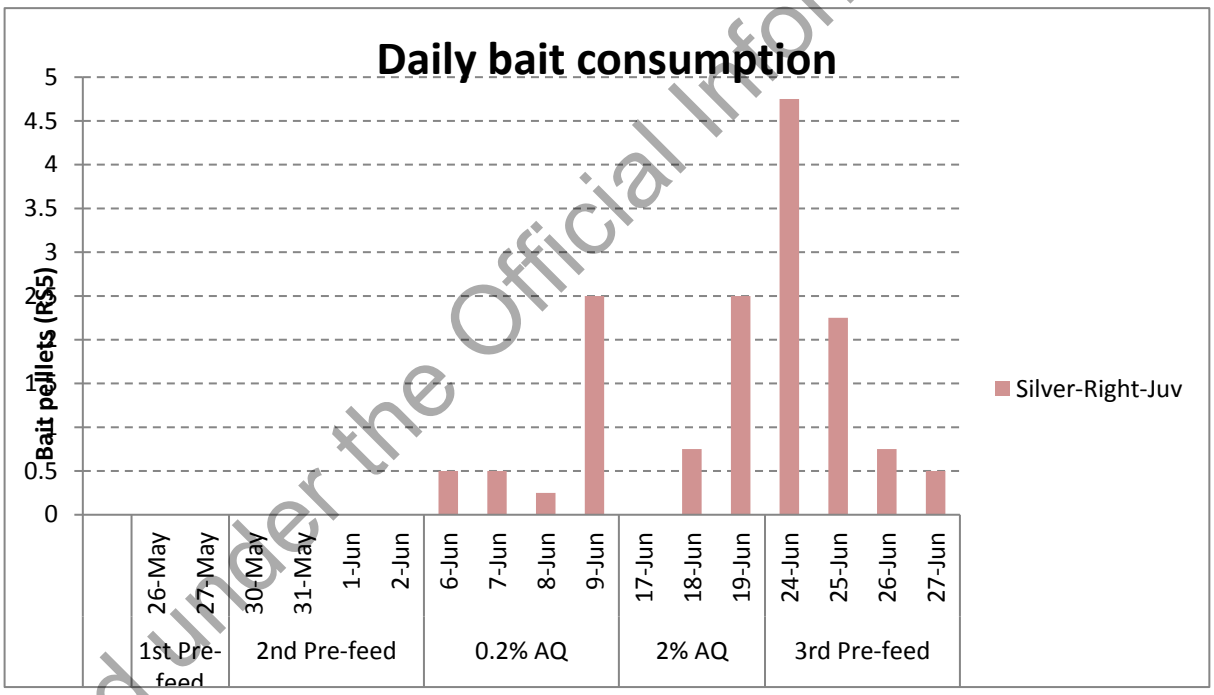


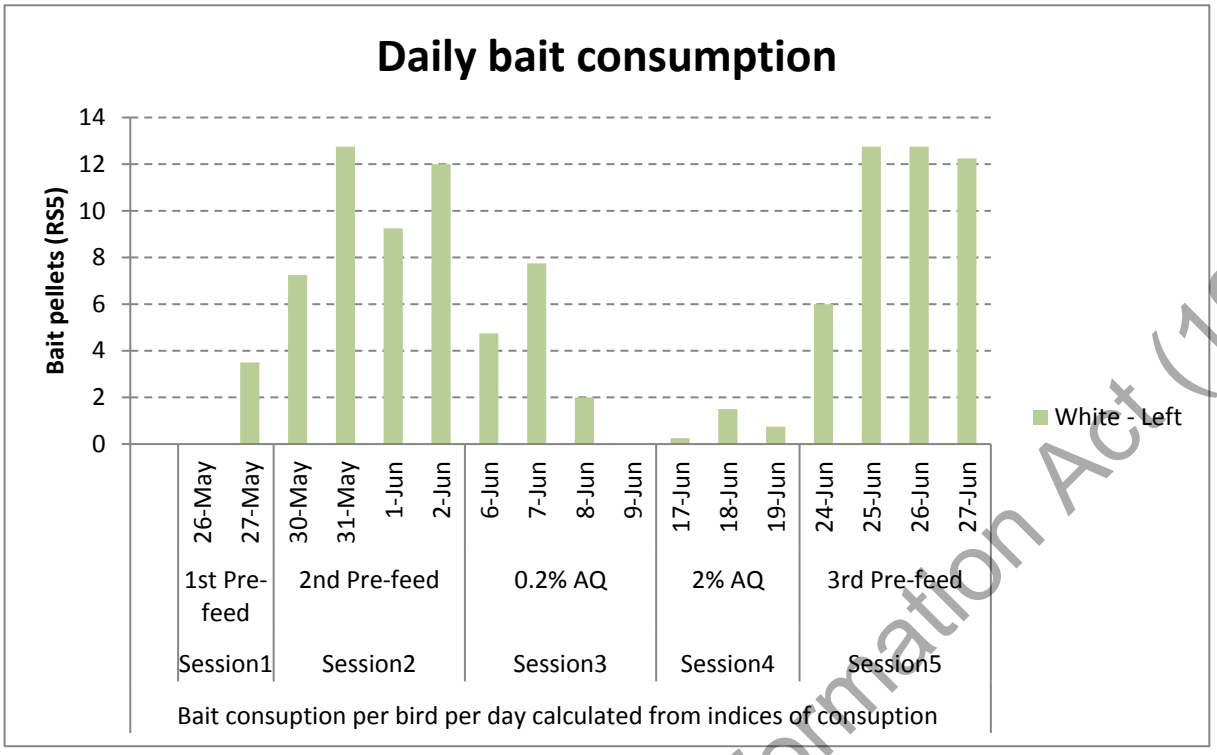


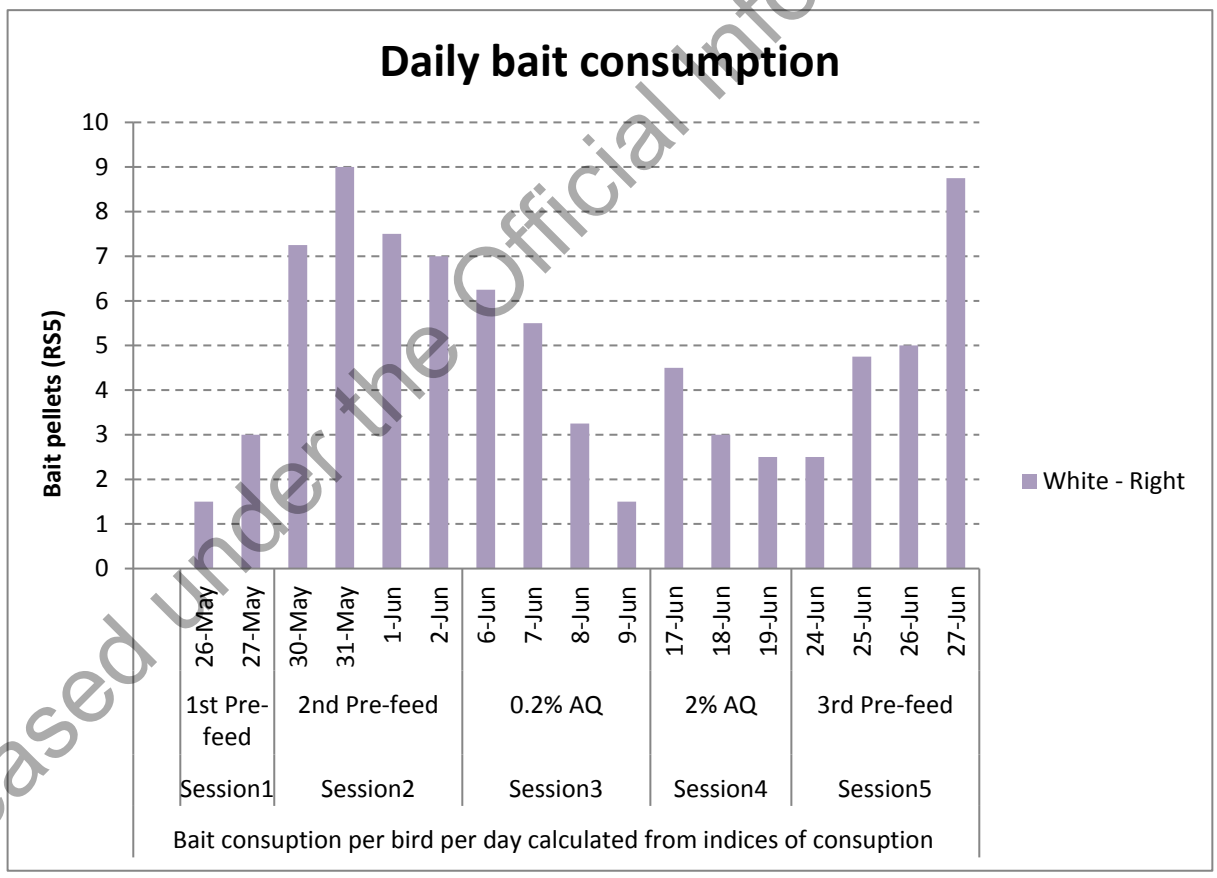


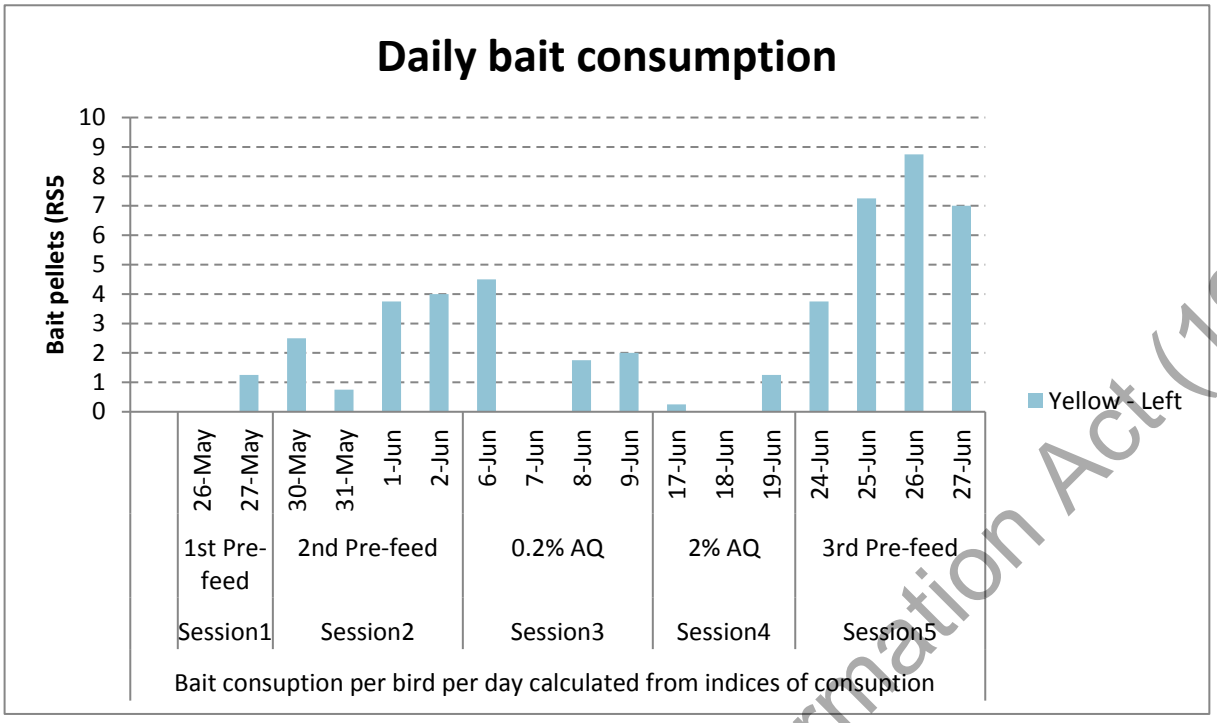


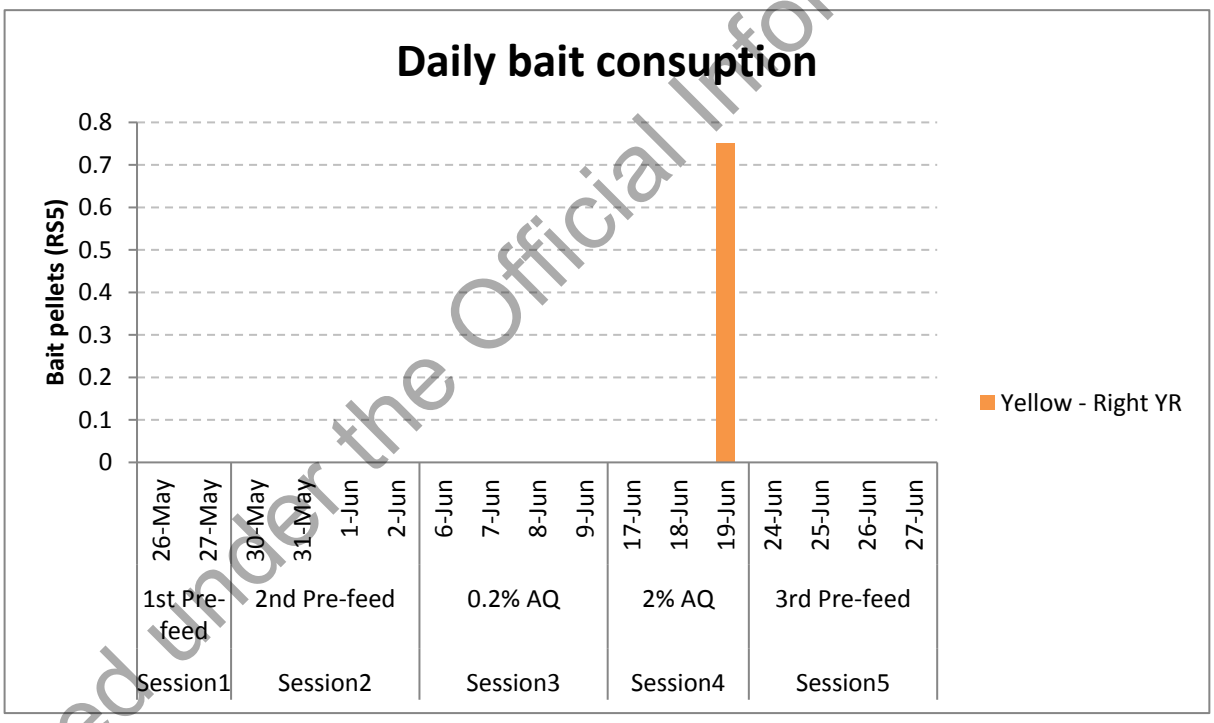


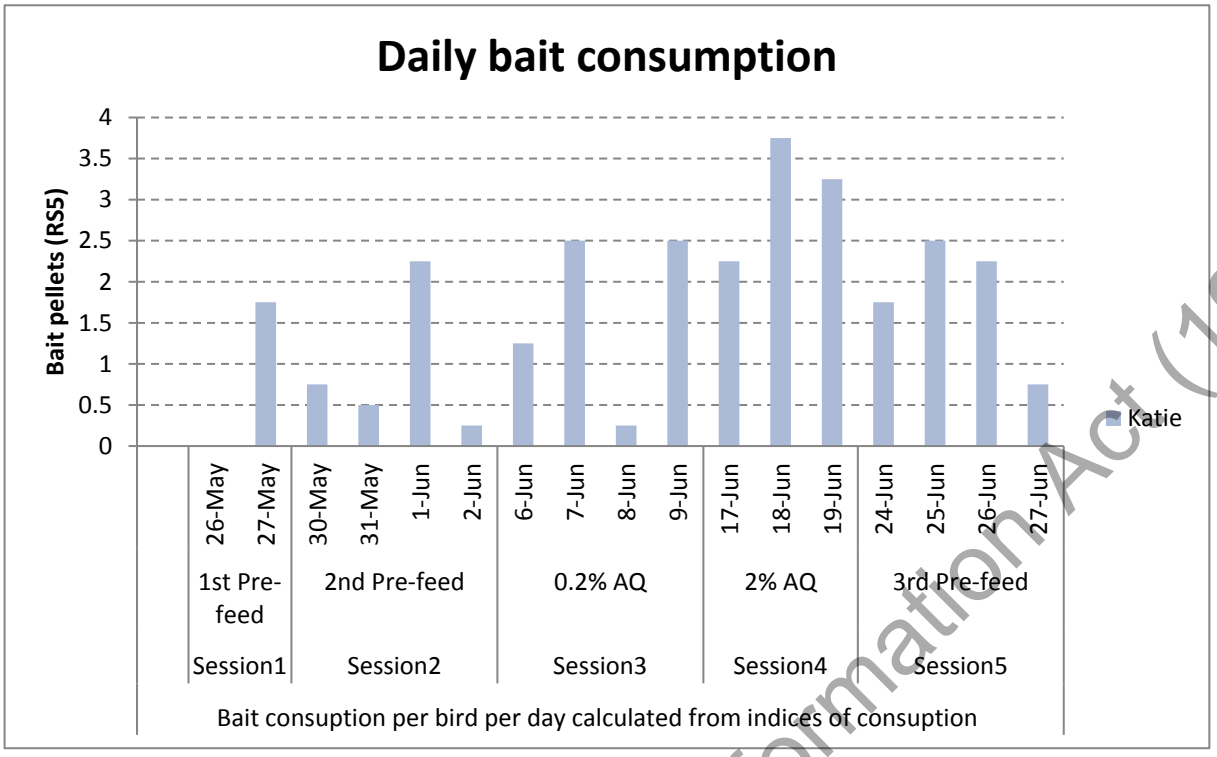












9(2)(a), 9(2)(g)(ii) She cut up and sorted the individual graphs into groups

- 3 birds who ate nearly nothing (23% of sample) = not interested
- 4 birds Moderate propensity to eat baits
- 6 birds (46% of sample) who contribute most to understanding = period when recruited into eating prefeed (i.e. all eating lots of baits by end of 2nd prefeed) but ALL STOPPED INTERACTING with baits by the end of the 0.14% AQ baits THEN went back to the final prefeed

9(2)(a), 9(2)(g)(ii) Definitely they knew the difference with the final presentation. The 6 bird group is made up of all dominant birds. Consumption dropped right off during AQ. Were able to dominate on the hard 0.2% baits and exclude the others.

9(2)(a), 9(2)(g)(ii) what sort of behaviours after consumption of AQ baits?

9(2)(a), 9(2)(g)(ii) Not a lot for most birds. The moderates ate only a bit at a time.

9(2)(a), 9(2)(g)(ii) Saw behavioural effects for birds that ate 2 baits in quick succession. It took 30 minutes before we saw them move away to the side, sit quietly and fluffed up and became uninterested. This was yellow blue left.

[redacted] Red blue left was given re-gurgitated food and looked quite unwell. See photo.

[redacted] repellent effects lasted 20-30minutes for those big eaters only.

[redacted] when we re-introduced the prefeed baits they were straight back into it.

[redacted] The interesting result is that when they feel unwell they stop eating baits. Pleasantly surprised to see the physiological effect coming through.

[redacted] clarified that 1.75% AQ baits were red and crumbly so final baits looked different, even to human eyes. So it may or may not be a case of the AQ signature coming through.

Discussion about Orr-Walker results. Threshold there was consumption less than an estimated LD50. We (DOC and KCT have lowered the threshold of acceptable consumption by kea to near zero, since the Otira operation.

[redacted] If AQ were to be used operationally it might need multiple prefeeds to achieve that and use in toxic. This hasn't been tested for pest efficacy in the field.

[redacted] what if the bait had been dyed green (least preferred colour for kea)?

Trial team: Doubted there would have been much of a difference. Would be interesting to know whether they can see the anthraquinone.

[redacted] For future repellents, the possibility of visual signature needs to be looked at. If present, need to either develop and test means for masking any visual signal from repellents or use them in the toxic too.

[redacted] Noted the variation in baits (soft, crumbly versus hard). Trial team agreed. [redacted] said that the 2nd prefeed and final prefeed were baits that were more than a year old. The 1.75% AQ baits were much higher concentration than ever before, the amount of powder made the baits crumbly. So variation is explained.

Congratulations to the trial team for achieving a high degree of experimental control in a difficult situation!

Appendix 12

Appendix 14 - DOCDM-1436810 - Kea repellent debrief wrap up .doc

Kea repellent trial debrief and project wrap up

Wednesday 23rd July 2014 945-245pm
DOC Otautahi Office, 70 Moorhouse Avenue Christchurch
Te Waipounamu Meeting Room

Chair: [redacted] (DOC)
Minutes: [redacted] (DOC)
Participants: **DOC**—Andy Cox, [redacted] attended afternoon only. (Apologies from [redacted] and [redacted])

TBfreeNZ Ltd—[redacted] (Apologies from [redacted])

Landcare Research Ltd—[redacted]

Kea Conservation Trust—[redacted] (arrived 1130am due to flight delay)

Purpose

Bait aversion trial (AM):

- To discuss and record what happened in this trial—e.g. inception, design and preparation, execution, analysis, communication
- To record lessons learned from the trial
- To record any tasks remaining from the trial

DOC-led kea repellent project wrap up (PM):

- To revise the 'next steps' identified at the Kea repellent stakeholder meeting on 10th March, in light of the bait aversion trial results.
- To document lessons from the research so far, to guide future repellent research

Overview of bait aversion trial results and opportunity for questions

[redacted] provided an overview of the report.

In the DP Car park trials, the key variable measured was bait consumption – highly affected by way bait presented (which was constrained). Otira result 'invalidated' the car park trial results

AQ Aviary trial was a worst case scenario in that birds were accustomed to novel food items (e.g. from 'farmyard feed' bags and other bits from by visitors) already. [redacted] thinks that consumption *rate* might be a key variable and has started some analysis of this.

[redacted] Most birds didn't get symptoms?

[redacted] None got symptoms from 1.75% AQ but there were a couple of birds that ate 2 baits in quick succession and one was fed regurgitated bait. These were the 3 that showed symptoms, for up to 30 minutes.

[redacted]: Haven't had a chance to look at whether there were birds that consumed a lot of bait but didn't show symptoms.

[redacted]: Clarified typo in summary – actual concentrations were 0.14% and 1.75% AQ.

[redacted] Are kea such that they will keep investigating a food source, because they are hard wired to do this? We'd need to find something that they actually stops them wanting to investigate.

[redacted] Wondered whether the 1.75% AQ was actually acting as a primary repellent?

[redacted] 0.14% we saw consumption with symptoms (consistent with acting as secondary) whereas 1.75% very little consumption. Possibly yes it may have been acting as a primary repellent. Whether this was taste, texture (crumbly as powder affected consistency) or colour.

[redacted] Relayed [redacted] feedback. Parrots have keen eyesight so the visual deterrent may be critical to repelling birds (rather than taste as kea have few taste buds which are at the back).

[redacted] Noted there is an immediate drop in bait consumption with the 0.14% AQ so was it secondary.

Discussion in response: [redacted] noted high degree of variability between birds. JR pointed out that it was confounded by fact that AQ baits were harder. [redacted] clarified that bait consumption declined over the first day.

[redacted] clarified that sessions 2, 4 , and 5 were comparable levels of softness and texture (session 2 and 5 were same, old plain baits whereas 4 was crumbly because AQ powder didn't mix in well). The fresh baits in session 1 and 3 were hard.

[redacted] Asked about cinnamon consistency across batches. [redacted] and [redacted] said there didn't seem to be a difference.

[redacted] White left seemed to have learned bait aversion on 0.14%. His consumption was low on the 1.75% but he resumed eating on the final session.

[redacted] Were there birds with no symptoms whose bait consumption declined?

[redacted]: No, though difficult to tell because went from secondary repellent effect almost no consumption of 1.75% AQ baits.

[redacted] Could also interpret the results as primary repellent effect throughout.

[redacted] We have some birds that have been taught to avoid anthraquinone. Will there be any follow up to see how long they remember this? Could they be re-exposed to anthraquinone to see how they respond to the baits.

[redacted] Would be something that could be considered if the project were picked up again. To be raised in the 'next steps' list.

[redacted] Would it be worth doing a similar trial but without the plain prefeed first? That way the birds aren't 'reassured' by their experience with the plain baits first. It seems that the kea keep trying the

baits even after experiencing AQ. This could be because their first experience with the baits was a good one.

9(2)(a) We need to consider masking the 'UV' signal of anthraquinone or the visual impact of any prefeed.

9(2)(a) It is all around making the prefeed and toxic as similar as possible.

Debrief of bait aversion trial

Trial Phase	Lessons
Start up (turning the concept of a bait aversion trial into a project) 9(2)(a), 9(2)(g)(ii)	**What went well (future focus: what made it successful? what should be shared?)** Had phone conference to air all views and get a proposal defined. **What could have gone better (what is the key lesson for the future?** Start up process a bit fraught and in a difficult environment. Background of time and financial pressure, public pressure. Context of Battle for our Birds. Limitations on technical/science availability—haste and stress on 9(2)(a), 9(2)(g)(ii) to pull it off. In hindsight it was under-resourced. Confusion over the concentration of the baits—microcosm of lack of communication in a fluid project
Design and early planning (including AEC, recruitment, trial resources) 9(2)(a), 9(2)(g)(ii)	**What went well (future focus: what made it successful? what should be shared?)** Finding a person to run it was good but... 9(2)(a), 9(2)(g)(ii) supportive when asked for advice. Identified 9(2)(a), 9(2)(g)(ii) early on and involved them in the experimental design **What could have gone better (what is the key lesson for the future?** 9(2)(a), 9(2)(g)(i felt he didn't have the background to design the behavioural experiment. External review of trial would have been ideal. "Design by consensus" didn't work (human nature/group think)– lesson is for 1-2 experts to design the trial with expert review. Possibly not as well coordinated as it could have been, with time pressure. The hypothesis to test was not clear. Just today realising there are differences in understanding of 'junk food hypothesis' and what we were trying to achieve. 9(2)(a), 9(2 had an original research objective in his proposal which differed from what was subsequently designed– no longer done with a highly palatable food source to find out whether

	AQ is a useful training chemical. (Discussion – we used pellets allowing time for birds to habituate to them first. This would need to have been done after a 'palatable food' trial.)
Trial execution (everything that happened at Willowbank) 9(2)(a), 9(2)(g)(ii) [redacted]	**What went well (future focus: what made it successful? what should be shared?)** Willowbank staff and vet fantastic and supportive, even with all the changes and bait problems. Left with a positive relationship. For a captive group they seemed to be a naturally functioning group with dominants and a mix of ages. ACP and PCR were both supportive and came to the party when we needed new bait. Having smart operators running the trial was essential. They didn't make any assumptions and (with the potential brodifacoum contamination) stopped work to evaluate what to do. Having one contact person ([redacted] between vet and the Willowbank. Being upfront with the Willowbank vet about every issue. Collective problem solving with them. Good team problem solving through which worked even though we were in different locations. **What could have gone better (what is the key lesson for the future?** 5 bait crises (no plain prefeed, then DP prefeed, old crumbly plain prefeed, confusion over 0.2/2% nominal levels, brodifacoum contamination). Lesson: Needed to have all bait purchased and checked (visual, AQ concentration assay) before the trial 1.75% AQ colour was patchy, raising questions over consistency of manufacture. Quality control issues around prefeed and potential contamination where toxin has been manufactured on the same machine. Wider discussion of bait issues wrt operations. Potential need to increase bait testing for hardness and moisture content—for operations, not just trials. **Are there any loose ends to be followed up?**

	Need for debrief after this season between DOC, manufacturers, and TBfreeNZ Ltd. The TBfree-led Bait Quality Initiative could be the best forum for this. Willowbank asked that DOC provide a report to AAZ Captive Coordinator to vouch for the good state of health and management of the kea. [redacted] has provided a brief note to [redacted] but will follow up with a more detailed report. [redacted] will follow up on [redacted] proposal to thank Willowbank to assist with weed removal and replacement with natives in the aviary. Potential for better kea information at the aviary. Make sure that any reports or communication about the repellent program go to Willowbank.
Decision making on the outcome of the trial (i.e. phone conference on 3rd July) 9(2)(a), 9(2)(g)(ii) [redacted]	**What went well (future focus: what made it successful? what should be shared?)** Phone conference worked well, at least with this clear cut result.
Communication of outcome 9(2)(a), 9(2)(g)(ii)	**What went well (future focus: what made it successful? what should be shared?)** Emailed out decision, no response. **What could have gone better (what is the key lesson for the future?** Had we had a positive result there are differing views of how it could have been implemented in time given all the other BfoB pressures. It could have been making a start in a longer term program. We hadn't thought out the spacing, frequency of provisioning, and how long the period was needed. It may have turned out to be simple or complicated once we got into it. **Are there any loose ends to be followed up?** Completion of the report, including analysis of bait consumption rates.

Recommended next steps in repellent research:

A list of five research areas were identified by the group as the recommended next steps toward developing a bird repellent to protect kea in aerial 1080 cereal operations. We used the earlier 'next steps' list from the March stakeholder meeting as a starting point, and amended this in light of the aviary trial results. This list of research areas should be used to guide the choice of research to complete as funds become available.

Before further trials are completed with kea, we need to define that an acceptable level of kea mortality in an aerial 1080 operation. This would give us a threshold of how effective the repellent needs to be in order to prevent the decline of the local kea population. This should be defined using [redacted] modelling. In general terms the current model suggests that mortality in the order of 10% of the local population would still have a positive benefit (assuming good nest survival post-operation for 2 years). This figure needs to be refined through some further analysis using [redacted] model.

An effective repellent would eliminate kea deaths from consuming 1080 baits, however this will not reverse the decline in kea without sustained stoat control. Research is required to increase the scale, frequency and effectiveness of stoat control. This includes:

- Refining our understanding of the conditions required for effective stoat control in aerial 1080 operations (e.g., are mice an effective vector for 1080 poisoning of stoats in the absence of rats?)

- Developing other broad scale stoat control tools that can be used between aerial 1080 operations (e.g. best practice for PAPP in bait stations, new methods for using PAPP such as the spit fire or aerial application, improvements to stoat trapping regimes)

The research list is not in priority order as it may be that the funding, personnel or time frames available dictate which project is tackled first.

1. Continued investigation of anthraquinone as a secondary repellent, for situations where:

- Possums are the only target (e.g., TBfree NZ) or

- Rats are absent from the site or not the priority target

For example, we need to define the maximum concentration of anthraquinone that could be used without affecting possum kills (noting that 0.25% AQ is the maximum we can use without affecting the current EPA approval for 1080 pellets or causing prefeed pellets to become hazardous). Further trials could be completed pairing anthraquinone with other cues. We recommend that green prefeed is used in further trials, as it is the least preferred colour for kea and provides consistency with the appearance of toxic baits. If anthraquinone is not used in both phases of an operation, further work would be needed to either mask the appearance of anthraquinone in prefeed or to add a compound to 1080 baits that looks the same to a parrot.

2. Seek advice from food technologists and chemists (e.g., Food Technology Massey, Plant & Food Ltd.) on likelihood and pathway for developing a stabilisation method for d-pulegone in cereal

matrix. This advice would be reviewed to decide whether to pursue the repellence trials outlined in 3 and whether to invest in stabilisation.

3. This research would be carried out if the stabilisation advice is favourable. Carry out a kea behavioural trial using d-pulegone RS5 cereal pellets, to confirm whether d-pulegone acts as a primary repellent in its own right. If it is a repellent, then we need to invest in stabilisation. If it is just a cue we could use something else with anthraquinone. The trial involves a second visit to look for evidence of habituation. We note that the trials to date would suggest it is a acting as a cue for secondary repellent at the concentrations we have been working with. For this reason, a higher nominal concentration of d-pulegone should be used for this trial.

4. Carry out preliminary field screening of other potential repellents. Put the repellent on known attractive bait (butter, cheese, live huhus) and see how wild kea react. Huhus have benefit that it would be recognised as a food. We can rule out any repellents where kea seem to feed on the food readily. Small quantities would need to be sourced of the candidate repellents:

- Tannic acid
- Caffeine (LCR)
- Cinnamamide
- Garlic oil

5. Test whether the Willowbank aviary kea would readily consume 0.14% anthraquinone baits if re-presented with the baits in several months time. Given that three of the kea learned to avoid these baits it would be interesting to see how they respond to the baits after a period of non-exposure.

Wrap up of DOC-led project

Project phase	Lessons
Sept-Oct 2012 DOC initiation of funded project (PAG recommendation through to DOC innovation & development fund, selection of project team) 9(2)(a), 9(2)(g)(ii)	Good team work opportunity Project management skills were strong DOC Innovation & Development funding process not strategic Project governance poor engagement with what the project would deliver KCT were happy to see their 2010 trial picked up and put into this collaborative project.
Oct-Nov 2012 Selection of repellent strategies to test (DOC move to investigate both d-pulegone and anthraquinone); selection of Otira case study 9(2)(a), 9(2)(g)(ii)	TBfree NZ feedback was good clear communication about the trials and why they were being done. TBfree NZ felt that part of the project, which is why they were keen to put funding in. DOC managed expectations that there wasn't a silver bullet. ("it's best we've got-we're giving it a go" which made it easier to respond when kea died in the Otira operation. LCR Ltd. was motivated to do what was most informative so changes requested by DOC were manageable.
Jan-March 2013 Lead up to expanded LCR pen trial and stability monitoring as a pre requisite for the Otira case study 9(2)(a), 9(2)(g)(ii)	DOC really helpful with rat shortage for the trial. DOC Hokitika goat team caught dozens of rats at short notice.
March-April 2013 Execution of pest efficacy pen trial and subsequent decision making of repellent choice for Otira 9(2)(a), 9(2)(g)(ii)	Pen trials were straightforward. In hindsight, KCT should have been involved in the decision making about repellent choice for Otira.
August 2013 Execution of Otira trial and subsequent decision making 9(2)(a), 9(2)(g)(ii)	Otira debrief (DOCDM-1265057) contains lessons learned from this trial. 9(2)(a), 9(feels more structure is needed for the broader kea monitoring program. There are only a few contractors with the

	right skills. There isn't continuity of work to keep the skilled, experienced people involved in this work. Forward planning and coordination of transmitter/monitoring work across DOC would provide continuity and manage conflicting projects. This was echoed by [redacted] who often find 'we need highly skilled people-this week!' [redacted] clarified that there was more structure within the original 3 year program, but this has dissipated. Working with KCT on strategic plan to collaborate on kea research and share resources.

Kea repellent project stakeholder meeting

Venue: DOC North Canterbury District Office, 70 Moorhouse Avenue Christchurch (Te Waipounamu meeting room)

Date: Monday 10 March, 1030 to 230, lunch supplied 1230-1pm

Participants:

DOC—Andy Cox, 9(2)(a), 9(2)(g)(ii) (Chair), 9(2)(a), 9(2)(g)(ii)

Kea Conservation Trust—9(2)(a), 9(2)(g)(ii)

Landcare Research Ltd—9(2)(a), 9(2)(g)(ii)

TBfree New Zealand Ltd—9(2)(a), 9(2)(g)(ii)

Purpose of meeting

We want to discuss the recent results from the pest efficacy and bait stability trials, in order to support DOC's Science & Capability Threats managers to make the best decision about the next steps in the project. We would like to look again at the reviews of repellents that have not been tested with kea, as these could be worth investigating as the next steps.

Objectives

1. Re-evaluation of the repellent strategies currently under investigation (i.e., primary repellent and combined repellent treatments) on the basis of:
    - Pest efficacy field trial results where these treatments were compared to standard 1080 (draft MS docdm-1314934),
    - A summary of advice from DOC pest scientists on the rat results in the combined repellent blocks (emailed 4 March)
    - Bait stability trial results (draft MS docdm-1290516) and any update on the surface spraying trial at EPRO Ltd.
    - As context, the Otira kea monitoring report (draft MS docdm-1281172) and an associated introduction to d-pulegone and anthraquinone (draft MS docdm-1334857). Preliminary results from a captive takahe feeding trial at the Burwood facility near Te Anau (emailed 4 March)
2. Shortlist of possible alternative repellents or strategies to consider testing with wild kea in non-toxic prefeed baits, from:
    - 9(2)(a), 9(2)(g)(ii) 2008 literature review for KCT (docdm-1094747)
    - 9(2)(a), 9(2)(g)(ii) 2012 literature review (docdm-1118511)

- Any advice from 9(2)(a), 9(2)(g)(ii) or his overseas network of contacts
- Any more recent papers found by any of us, ideally distributed or summarised beforehand
- Options for using these repellents differently—e.g. 9(2)(a), 9(2 has suggested feeding anthraquinone prefeed baits directly to kea at known congregation points prior to aerial 1080 operations

3. Record views on proceeding with one or more of:

	Views	Next steps would be...	Roles for stakeholders if pursued
Combined repellent treatment			
Primary repellent treatment			
Other options involving anthraquinone or d-pulegone			
Alternative repellents			

Stability of bird repellents and 1080 in RS5 cereal baits

[redacted] 9(2)(a), 9(2)(g)(ii) [redacted]
[1]Department of Conservation, Private Bag 4715 Christchurch 8041
9(2)(a), 9(2)(g)(ii) [redacted] @doc.govt.nz
[2]Landcare Research Ltd, PO Box 40 Lincoln 7640

Abstract

One of the criteria for an effective bird repellent is that it stays effective long enough for operational use. This project focuses on repellent use to protect kea (*Nestor notabilis*) at aerial 1080 cereal operations; most of these operations occur within 4 to 12 weeks after manufacture of prefeed and toxic baits. The concentration of d-pulegone was monitored in several batches of prefeed and toxic baits in order to estimate the loss of d-pulegone in manufacture and subsequent rate of decay over this period. There was a high degree of loss of d-pulegone in the manufacture process for most batches; the estimated proportion of d-pulegone retained in manufacture ranged from 50–97%. Increasing the nominal concentration of d-pulegone appeared to make very little difference to the estimated proportion of d-pulegone retained in baits at the time of manufacture. The estimated rate of decay ranged from 3.2–7% per week. None of the batches met our operational target concentration of d-pulegone (0.12–0.22%), however this target could likely be reduced to 0.08–0.15% if we apply the bait monitoring from this trial to an earlier aviary trial with kea. We recommend that some means of stabilising d-pulegone is found before any further testing is done of repellent strategies involving d-pulegone.

Stability monitoring of three batches of toxic baits was continued for up to 6 months after manufacture, in order to support a potential future application to amend the product registration of 0.15% 1080 Pellets to include d-pulegone.

1080 and anthraquinone was stable over the 6 month monitoring period for all three batches (2 batches not finished).

Keywords: 1080, anthraquinone, d-pulegone, kea, repellent, New Zealand

1. Introduction

This report is part of a project led by the Department of Conservation (DOC) to develop, register and implement an effective bird repellent to prevent kea (*Nestor notabilis*) deaths in aerial 1080 cereal operations (DOC Innovation and Development project 12-13, DOC Investigations 4459 and 4466).

One of the criteria for an effective bird repellent is that it stays effective long enough for operational use. The repellents under investigation are d-pulegone and 9,10-anthraquinone ('anthraquinone'). Most South Island pest managers expect to apply 1080 cereal baits aerially within 4 to 12 weeks after manufacture of prefeed and toxic baits 9(2)(a), 9(2)(g)(ii) DOC and 9(2)(a), 9(2)(g)(ii) TBfree New Zealand, pers. comm.). Previous studies with New Zealand native birds used a nominal concentration of 0.17% d-pulegone (wt/wt). On this basis, we defined the target operational concentration to be (~0.17% ± 0.05) from 4 to 12 weeks after manufacture. The upper and lower bounds on this target were arbitrarily chosen to allow some variation. We wanted to avoid concentrations being too high (i.e., >0.22%) after 4 weeks (as we don't know whether pests would be repelled) and to avoid concentrations being too low after 12 weeks (i.e., <0.12%, as we don't know whether kea would be repelled). The concentration of d-pulegone was monitored in several batches of prefeed and toxic baits in order to estimate the loss of d-pulegone in manufacture and subsequent rate of decay.

In addition, stability monitoring of three batches of toxic baits was continued for up to 6 months after manufacture, in order to support a potential future

application to amend the product registration of 0.15% 1080 Pellets to include d-pulegone.

2. Background

Chapter 1 of this publication outlines the motivation for developing a bird repellent and reviews previous studies undertaken with the two repellents under investigation.

In a study central to this project, Orr-Walker et al. (2012) carried out an aviary trial to find out whether captive kea could be repelled from consuming Wanganui #7 cereal baits treated with d-pulegone and anthraquinone. Kea were offered a sequence of four treatments, simulating a prefed 1080 cereal operation (3 days of untreated baits; 7 days of combined repellent baits containing 0.17% d-pulegone and 0.10% anthraquinone; 3 days of primary repellent baits containing 0.17% d-pulegone; 3 days of untreated baits). The results indicated that mean daily consumption rates decreased significantly between untreated cereal baits and both of the subsequent repellent treatments; consumption increased when kea were presented with the final treatment of untreated baits. Furthermore, mean daily consumption of repellent baits was similar to or lower than an estimated LD50 for kea (1.8–4.7 g (dry mass) of 0.15% 1080 RS5 cereal bait based on McIlroy 1984).

Baits were not analysed for repellent concentration at the time of the trial, however samples were analysed about 7.5 months after manufacture (Booth and Fisher 2010). Anthraquinone was present at the nominal concentration (0.10% wt/wt) however d-pulegone was present at a much lower than the nominal concentration in both batches of repellent baits (i.e.; 0.03% wt/wt instead of 0.17%). This suggested that the volatility of d-pulegone required further investigation, on a timeframe more relevant to an aerial 1080 cereal operation.

For this reason, repeated analysis of d-pulegone was planned and carried out in association with all subsequent development trials. This included:

- Three repellent prefeed treatments and one repellent toxic treatment in a pen trial to assess the palatability and efficacy of 5 repellent treatments for possums and ship rats (Cowan et al. 2013)
- Repellent toxic baits used for an aerial 1080 operation at Otira, Arthur's Pass where 5 kea died out of 34 monitored birds present in the operational area (see Chapter 2 in this publication)
- A batch of repellent prefeed and repellent toxic baits used for bait stability monitoring only
- Repellent prefeed and repellent toxic baits used for a field trial to assess efficacy of two repellent treatments for possums and rats (see Chapter 3 in this publication)

3. Objectives

3.1 To estimate loss of d-pulegone in manufacture and subsequent rate of decay, when prefeed and toxic RS5 cereal baits contain a low nominal concentration (0.17% wt/wt) of d-pulegone

A concentration of 0.17% d-pulegone was selected because this was the nominal concentration in primary repellent prefeed baits and combined repellent prefeed baits used with kea by Orr-Walker et al. (2012) and in dough baits by Day et al. (2003).

Booth and Fisher (2010) found that d-pulegone was significantly lower than the nominal level 7.5 months after manufacture (see Background). Using prefeed and toxic RS5 cereal baits manufactured with 0.17% d-pulegone, we wanted to estimate the expected loss in manufacture and subsequent rate of decay of d-

pulegone concentrations, focusing on the period 4 to 12 weeks after manufacture.

Anthraquinone was not monitored as the Booth and Fisher (2010) observations indicated it was stable.

3.2 To estimate loss of d-pulegone in manufacture and subsequent rate of decay, when prefeed and toxic RS5 cereal baits contain higher nominal concentrations of d-pulegone.

After monitoring three batches of prefeed and two batches of toxic bait prepared with 0.17% d-pulegone, it became clear that baits needed to be manufactured with a higher nomination concentration of d-pulegone in order to achieve the target operational repellent concentration (~0.17% ± 0.05) 4 to 12 weeks after manufacture. This was reinforced by the deaths of 5 monitored kea at the Otira 1080 operation (see Chapter 2), which took place 9 weeks after toxic baits were manufactured. The concentration of d-pulegone in stored baits was about 0.072% when sampled a few days after aerial application, far less than the target.

Guided by the results using the low nominal concentration, we manufactured two further batches of prefeed and toxic bait with higher nominal concentrations of d-pulegone and monitored d-pulegone decay.

3.3 To monitor stability of 1080 and repellents over six months in support of registration amendment for 0.15% 1080 Pellets

The concentration of 1080 in toxic baits needs to be stable for the entire recommended shelf life of 0.15% 1080 Pellets, even after d-pulegone has declined below the level where birds might be repelled. The current label for 0.15% 1080 Pellets recommends that the product is used within 3 months of manufacture to ensure best palatability (V2848, approved 9th April 2013).

Morgan and Arrow (2012) found that the 1080 concentration in this product was stable over a 13 month period for RS5 baits, suggesting that the label recommendation could be extended in future. To allow for future extension of the recommended use period, we monitored 1080 stability over 6 months rather than 3.

Repellent stability was also monitored over 6 months, as it required little additional effort to gain this extra information. If an application to amend the registration of 0.15% 1080 Pellets is made, we intend to state a much shorter timeframe for expected repellency (e.g., 4 to 12 weeks after manufacture) on the label. This would mean that the product could be used for pest control for 3 months after manufacture but repellency could only be expected in the shorter timeframe stated on the label.

4. Methods

All repellent prefeed and toxic baits were manufactured by Animal Control Products (ACP) Ltd. (408 Heads Road, Whanganui). All baits were made using the RS5 formulation of cereal baits, as this is the cereal type permitted by DOC for aerial 1080 cereal operations where kea may be present on land it manages. There is evidence that captive kea prefer the other available formulation (Wanganui #7) over RS5 baits (Blyth 2011; Luey 2009). All baits included cinnamon lure, with prefeed baits single-lured (0.15% wt/wt) and toxic baits double-lured (0.3% wt/wt) in line with DOC Current Agreed Best Practice. All baits were dyed green with the exception of the one batch of repellent prefeed that was not used in any development trials (see 4.2 below). While 0.15% 1080 Pellets are always dyed green, development trials used green prefeed as well to deter kea from sampling prefeed baits and to reinforce the association between

prefeed and toxic baits. Weser and Ross (2012) found that green was the least preferred colour for captive kea.

D-pulegone 90% (CAS 89-82-7, 90% active ingredient) was imported by Connell Brothers Ltd. from Penta Manufacturing Company (Livingston New Jersey, USA). Anthraquinone (Avipel Dry® CAS-84-64-1, 95% active ingredient) was imported by Etec Crop Solutions Ltd. from Arkion Life Sciences LLC (New Castle Delaware, USA). Repellents were added after the base ingredients for RS5 baits had been combined in the ACP factory mixer. This took place at the same stage when the cinnamon lure, green dye, and 1080 (where applicable) were added. After a period of further mixing, pellets were extruded and treated with steam to improve bait cohesion.

4.1 Loss of d-pulegone in manufacture and subsequent rate of decay, when prefeed and toxic RS5 cereal baits contain a low nominal concentration (0.17% wt/wt) of d-pulegone

Booth and Fisher (2010) established and validated methods for analysing d-pulegone (TLM090) and anthraquinone (TLM078) in cereal baits. Additional validation was completed at the beginning of this study to confirm that the method for d-pulegone was unaffected by the presence of green dye and anthraquinone. The analysis method for d-pulegone has an uncertainty (95% confidence interval) of ±4%. All baits were analysed at the Landcare Research Toxicology Laboratory (Gerald Street, Lincoln).

Three batches of green repellent prefeed baits (LCR2PRE, LCR4PRE, and LCR5PRE) and two batches of green repellent 1080 baits were manufactured using 0.17% d-pulegone and sampled on receipt and about 2, 4, 8 and 16 weeks after receipt. The first of the two batches of repellent 1080 baits (1080 LCR Pentrial) also included 0.10% anthraquinone. The second of the batches of

repellent 1080 baits (1080 Otira) was sampled an additional time, a few days after aerial application at the kea monitored operation at Otira, Arthur's Pass. The time taken for baits to reach the laboratory from the factory varied from 2 to 13 days. To standardise across batches, analysis results are reported as weeks since manufacture.

Three 25 kg bags of baits were monitored for each batch, stored in conditions recommended by the manufacturer (W. Simmons ACP Ltd., pers. comm.). Baits were stored out of direct or defused sunlight and away from fuels, solvents and other potential contaminants. The facility was kept at a stable temperature, in the range of 15-25°C. Room temperature and relative humidity were monitored, and recorded at least monthly. At each sampling point, about 100 g of baits was taken from each of the 3 bags and pooled to give a composite sample. Baits were taken from midway down the bag and the open bag was folded down after sampling.

We tabulated the d-pulegone concentration in baits sampled on receipt, at 4–5 weeks and at about 12 (10–16) weeks. A time series of d-pulegone concentrations was graphed for each batch of repellent prefeed or repellent 1080 baits.

A linear regression model was fitted and graphed in the R statistical computing environment, using a log transformation of the d-pulegone concentration (R Core Team 2013). The model estimated the initial d-pulegone concentration at time of manufacture from the intercept at time zero. The regression slope was use to estimate the rate of decay of d-pulegone over the period measured (10–16 weeks after manufacture).

4.2 Loss of d-pulegone in manufacture and subsequent rate of decay, when prefeed and toxic RS5 cereal baits contain higher nominal concentrations of d-pulegone

For this study objective, we applied the same methods described in Section 4.2 to two further pairs of batches of repellent prefeed and repellent 1080 baits manufactured with higher nominal concentrations of d-pulegone. We were guided in our choice of nominal concentration by the monitoring results of all previous batches.

First, we manufactured a small batch of undyed repellent prefeed (LCR8PRE, nominal 0.225% wt/wt d-pulegone) and green repellent 1080 baits (1080 LCR8TOX, nominal 0.25% wt/wt d-pulegone). 250kg of prefeed and 500kg of toxic bait were manufactured, as minimum quantities recommended by ACP Ltd. Baits were sampled and analysed about 2, 4, 8, and 12 weeks after receipt.

Later, we manufactured and monitored an operational scale batch of green repellent prefeed (Mataketake DPAQ, nominal 0.25% d-pulegone) and green repellent 1080 baits (1080 Mataketake, nominal 0.29% d-pulegone). In addition to the standard sampling timeframes, samples were taken from stored prefeed and toxic baits on the days that baits were aerially applied at a pest efficacy field trial at Mataketake, West Coast.

4.3 Stability monitoring 1080 and repellents in 0.15% 1080 Pellets over 6 months

Three batches of repellent 1080 baits were analysed for 1080 and d-pulegone upon receipt and at 2, 4 and 6 months after receipt. The analysis method for 1080 (TLM023) has a method detection limit of 2 mg/kg and an uncertainty (95% confidence interval) of ±9%. Bait appearance and odour was recorded at each sample time.

The first batch of repellent 1080 baits was manufactured using 0.25% anthraquinone and this was also analysed in each sample. The analysis method for anthraquinone has a method detection limit of 0.05 mg/g and an uncertainty (95% confidence interval) of ±3%. The other two batches (1080 LCR8TOX, 1080 Mataketake) were manufactured with d-pulegone only.

The results were compiled as tables and assessed for any instability in appearance, odour or 1080 concentration.

5. Results

Based on exploratory analysis, we pooled all data from the first two study objectives and fitted a regression model that treated study objective (first or second) and bait type (1080 or prefeed) as fixed effects (Figure 1). We used the regression analysis to estimate the d-pulegone concentration at the time of manufacture for each batch from the intercept at time zero of the linear regression model (Table 2). We compared the estimated concentration at manufacture to the nominal concentration of 0.17% d-pulegone for each batch.

We estimated the rate of decline from the regression model, within the time period monitored. Dissipation during storage was evident in all batches and the rate of decline varied.

5.1 Loss of d-pulegone in manufacture and subsequent rate of decay, when prefeed and toxic RS5 cereal baits contain a nominal concentration of 0.17% wt/wt d-pulegone

Table 1 lists the d-pulegone concentrations analysed on receipt and at about 4 and 12 (10–16) weeks after manufacture. None of the batches met the target operational concentration for the period when baits are most likely to be applied aerially (i.e., ~0.17% ± 0.05, 4 to 12 weeks after manufacture).

In the 2 batches of 1080 baits, 79% or 97% of the nominal d-pulegone concentration was retained in manufacture; between 62% and 88% of the nominal d-pulegone concentration was retained in manufacture for the 3 batches of prefeed (Table 2).

The rate of decline was 7.0% per week for 1080 baits (with a standard error of 0.80) in this study objective and 3.2% per week for prefeed baits (with a standard error of 0.60).

5.2 Loss of d-pulegone in manufacture and subsequent rate of decay, when prefeed and toxic RS5 cereal baits contain higher nominal concentrations of d-pulegone

Despite using higher nominal concentrations of d-pulegone, none of the LCR8 or Mataketake batches met our target operational repellent concentration for the period when baits are most likely to be applied aerially (i.e., ~0.17% ± 0.05, 4 to 12 weeks after manufacture, see grey rows in Table 1).

The proportion of nominal concentration retained in manufacture was reasonably similar between batches (Figure 1, grey rows in Table 2). 1080 baits retained 60–62% of the nominal concentration whereas retention was 50% or 68% of d-pulegone for prefeed baits. These values are lower than the earlier batches prepared with a nominal concentration of 0.17% d-pulegone (see Table 2), suggesting a higher degree of loss in manufacture for the batches prepared with higher nominal concentrations.

The rate of decline was 5.2% per week for 1080 baits (with a standard error of 0.75) and 6.4% per week for prefeed baits (with a standard error of 0.96).

5.3 Stability monitoring 1080 and repellents in 0.15% 1080 Pellets over 6 months

TO REVISE WHEN FINISHED Concentrations of 1080 and repellents are listed for each batch in Table 3 and descriptions of bait appearance and odour are given in Table 4. 1080 and anthraquinone was stable over the 6 month monitoring period for all three batches. This supports the current product label recommendation (use within 3 months for best palatability) for 1080 baits. D-pulegone was much less stable, as seen in the first two study objectives.

6. Discussion

6.1 Loss of d-pulegone in manufacture and subsequent decay

There was a high degree of loss of d-pulegone in the manufacture process. Aside from the best two batches (1080 LCR Pentrial and LCR5), all other batches were less than 80% of the nominal concentration.

The odour of d-pulegone was very strong in the factory, suggesting it vaporises during manufacture (W. Simmons, pers. comm. 27 August 2013). We have discussed the problem with Bill Simmons at Animal Control Products Ltd. and we consider that there are three possible mechanisms causing this loss. One mechanism that could account for a small amount of loss is adhesion of liquid to the machinery during the mixing process. Secondly, it is possible that there could be an interaction between the d-pulegone and cinnamon lure, as the lure contains solvents and volatile carriers. We do not think this is causing loss in manufacture as there was no consistent difference between the proportion of nominal d-pulegone present in prefeed baits (lured with 0.15% cinnamon) did not and toxic baits (lured with 0.3% cinnamon). The third and most likely explanation, in our view, is that superheated steam is volatising the d-pulegone. Steam conditioning of the mixed, loose pellet ingredients immediately prior to

pelletising is essential for the formation of good quality robust pellets (W. Simmons, pers. comm. 2 September 2013), but this heat is likely to vaporise at least some d-pulegone.

For some reason, the degree of loss in manufacture was higher for the batches produced with higher nominal concentrations. Increasing the nominal concentration of d-pulegone appeared to make very little difference to the estimated proportion of d-pulegone retained in baits at the time of manufacture (Table 2). It may be that we passed some threshold concentration which is the highest level of d-pulegone that can be retained in the cereal matrix by mixing alone. Volatile compounds can reach this kind of saturation point after which any additional compound will not be held without using a 'keeper' compound or an encapsulation process (check, references needed). A small pilot trial was carried out in which RS5 baits were surface treated with a d-pulegone solution and similar or higher rates of loss were observed (unpublished data and Kane Stafford EPRO pers. comm.).

We evaluated the rate of decay from the regression model, evaluating 1080 batches separately from prefeed batches (Figure 1). For some reason, the batches of prefeed manufactured with a low nominal concentration was more stable (decaying at 3.2% per week) than the others (range of 5.2–7%).

None of the batches met the target operational concentration 4 to 12 weeks after manufacture. Two of the batches prepared with 0.17% d-pulegone came close; one batch of prefeed (LCR5) met the target operational concentration for up to 5 weeks and one batch of toxic baits (LCR5/6) met the target for 8 weeks after manufacture. We had hoped that the approach of using a higher nominal concentration would allow us to meet this target. However, the higher percentage loss in manufacture meant that these batches still did not contain the target operational concentration 4 weeks after manufacture (see Table 1).

6.2 Range of d-pulegone concentration in aviary trials

Orr-Walker et al. (2012) carried out their aviary trials over a period of 3 months (about 12 weeks) after Wanganui #7 prefeed baits were manufactured with a nominal concentration of 0.17% d-pulegone on 29 July 2009. Initial d-pulegone concentration is unknown although their baits contained 0.03% d-pulegone 7.5 months after manufacture. This figure is realistic if decay rates in our model were applied 32 weeks after manufacture. Using the 3 batches of prefeed baits manufactured with the same nominal concentration and assuming that Wanganui #7 baits behave similarly to RS5 baits, we can estimate the likely d-pulegone concentration in the aviary trial baits during the trial. On receipt, the 3 analogous batches of prefeed contained 0.10–0.15% d-pulegone. After 10–16 weeks after manufacture, these batches contained 0.081–0.095% d-pulegone.

Orr-Walker (2012) detected significant differences in consumption rates in the sequence of four treatments (untreated baits, combined repellent baits, primary repellent baits, untreated baits), pooled from 5 different aviaries visited over the 12 week period. This suggests that captive kea were repelled when presented with combined repellent cereal baits containing about 0.08%–0.15% d-pulegone, followed by primary repellent cereal baits of a similar concentration of d-pulegone. If this is the case, then the operational target for d-pulegone could be reduced to 0.08%–0.15% d-pulegone, 4 to 12 weeks after manufacture. Measured against this lower target, 4 of the 9 batches were acceptable (LCR4PRE, LCR5PRE, 1080 Mataketake, LCR8PRE).

6.3 Stability monitoring 1080 and repellents in 0.15% 1080 Pellets over 6 months

We also monitored the stability of 1080 and both repellents over 6 months. 1080 was stable during the six months we monitored repellent toxic baits (update when last two batches are finished). Given on the results of Morgan and Arrow

(2012), this suggests that the label could be amended to recommend product use for after 6 months of storage, for palatability and stable 1080. It also tells us that the inclusion of d-pulegone did not affect the stability of 1080.

Anthraquinone was also stable over 6 months in the one batch of toxic bait where it was present, in line with the observations of Booth and Fisher (2010).

As expected, d-pulegone was not stable over this time period

7. Conclusions

With current production methods, we would struggle to achieve the target operational concentration of d-pulegone at operations 4 to 12 weeks after manufacture. We think it is reasonable to lower the target operational concentration to 0.08%–0.15% d-pulegone, however even then only 4 out of 9 batches achieved this concentration 12 weeks after manufacture.

We need some means of stabilising d-pulegone before any further testing can be done of repellent strategies involving d-pulegone. This would require investment with development with engineers or chemists to find a solution, which might include encapsulation of d-pulegone, addition of a 'keeper' compound or using another production method. We could then re-test for kea repellence and pest efficacy with the stabilised manufacturing method.

Based on the three batches of toxic bait monitored for 6 months, the stability of 1080 is unlikely to be affected by the presence of either repellent. If we find a means for stabilising d-pulegone, any amendment to the registration needs to stipulate the period during which repellency could be expected, ideally 4 to 12 weeks after manufacture.

8. Acknowledgements

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Tables

Date of manu-facture	Batch	Bait type	Nominal D-P % wt/wt	D-P % wt/wt on receipt	D-P % wt/wt at ~4 weeks	D-P % wt/wt at ~12 weeks
21/2/13	1080 Landcare Pentrial	1080	0.17	0.14 (1)	0.120 (5)	0.082 (10)
31/5/13	1080 Otira	1080	0.17	0.11 (2)	0.099 (4)	0.060 (11)
21/2/13	LCR2PRE	Prefeed	0.17	0.098 (1)	0.085 (4)	0.089 (10)
21/2/13	LCR4PRE	Prefeed	0.17	0.11 (1)	0.091 (4)	0.095 (10)
12/3/13	LCR5PRE	Prefeed	0.17	0.15 (0)	0.140 (5)	0.081 (16)
16/9/13	1080 LCR8TOX	1080	0.25	0.17 (1)	0.102 (4.5)	0.079 (12.5)
5/11/13	1080 Mataketake	1080	0.29	0.21 (0)	0.11 (4)	0.11 (11)
16/9/13	LCR8PRE	Prefeed	0.225	0.143 (1)	0.10 (4.5)	0.081 (12.5)
1/11/13	Mataketake DPAQ	Prefeed	0.25	0.14 (1)	0.071 (5)	0.063 (11)

Table 1 Batches of repellent prefeed baits and two batches of repellent 1080 baits produced at the stated d-pulegone (D-P) concentration. The rows shaded grey had higher nominal concentrations. All baits were green RS5 cereal baits manufactured by ACP Ltd. All baits were dyed green except LCR8PRE. All prefeed baits contained 0.15% cinnamon lure and all 1080 baits contained 0.30% cinnamon lure. In the columns reporting the d-pulegone concentration, we report in parentheses the approximate number of weeks after manufacture when the sample was taken.

Batch	Estimated D-P % wt/wt at manufacture	95% confidence interval	Nominal D-P % wt/wt	Estimated proportion of nominal at manufacture	Mean proportion of nominal at manufacture
1080 Landcare Pentrial	0.165	0.141–0.192	0.17	97%	88%
1080 Otira	0.135	0.116–0.157	0.17	79%	
LCR2PRE	0.105	0.091–0.121	0.17	62%	73%
LCR4PRE	0.115	0.100–0.133	0.17	68%	
LCR5PRE	0.150	0.131–0.172	0.17	88%	
1080 LCR8TOX	0.155	0.133–0.181	0.25	62%	61%
1080 Mataketake	0.175	0.155–0.200	0.29	60%	
LCR8PRE	0.153	0.130–0.179	0.225	68%	59%
Mataketake DPAQ	0.124	0.108–0.143	0.25	50%	

Table 2 Estimated d-pulegone concentration at time of manufacture, as compared to the nominal concentration. Estimates were derived as the intercept at time zero of the linear regression model.

	1080 Landcare Pentrial (manufactured 21/2/13, nominal 0.17% d-pulegone and 0.25% anthraquinone)			1080 LCR8TOX (manufactured 16/9/13, nominal 0.25% d-pulegone)		1080 Mataketake (manufactured 5/11/13, nominal 0.29% d-pulegone)	
	Anthraquinone % wt/wt	D-pulegone % wt/wt	1080 % wt/wt	D-pulegone % wt/wt	1080 % wt/wt	D-pulegone % wt/wt	1080 % wt/wt
On receipt	0.24	0.14 (1)	0.17	0.17 (1)	0.14	0.21 (0)	0.13
2 months	0.22	0.082 (10)	0.15	0.09 (9)	0.12	0.11 (9)	0.14
4 months	0.24	0.042 (19)	0.15	0.065 (18)	0.13	TBC	TBC
6 months	0.24	0.042 (28)	0.13	TBC	TBC	TBC	TBC

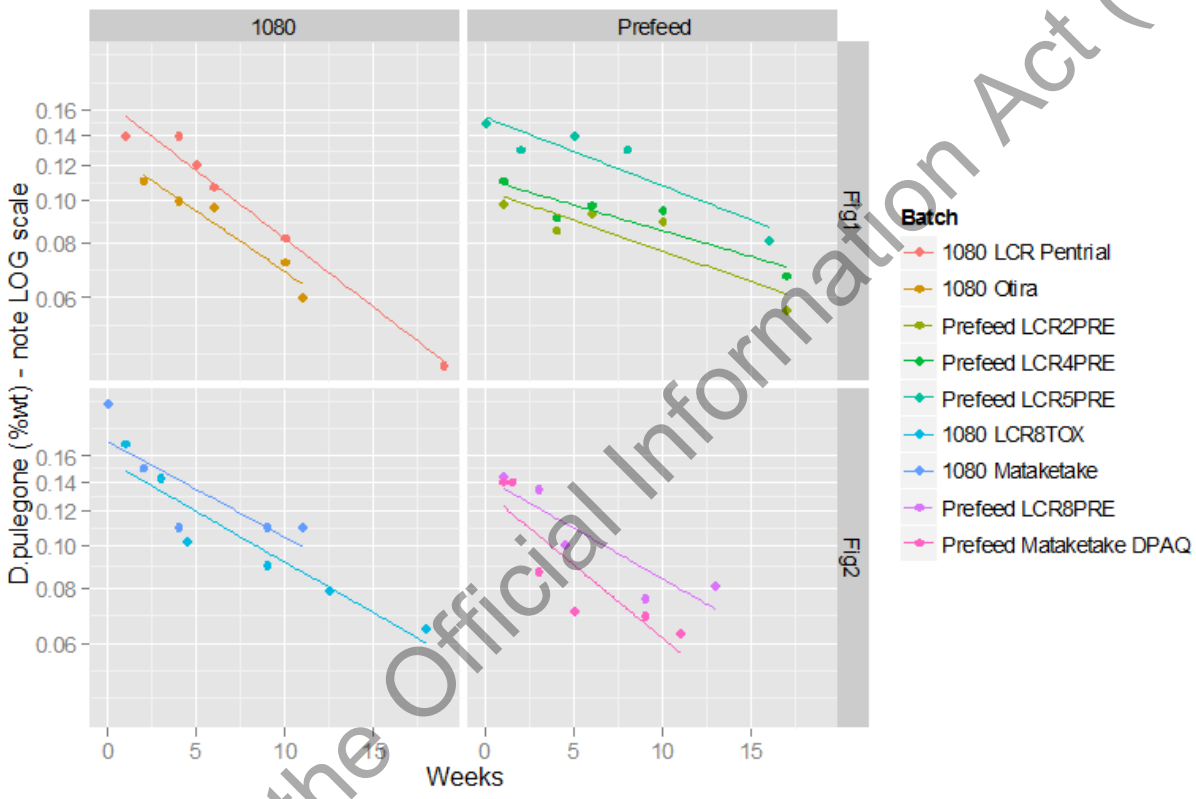
Table 3 Batches of repellent 1080 baits produced at with d-pulegone (D-P) concentration and monitored for the third study objective. All baits were green RS5 cereal baits manufactured by ACP Ltd containing contained 0.30% cinnamon lure. In the columns reporting the d-pulegone concentration, we report in parentheses the approximate number of weeks after manufacture when the sample was taken.

	1080 Landcare Pentrial (manufactured 21/2/13, nominal 0.17% d-pulegone and 0.25% anthraquinone)	1080 LCR8TOX (manufactured 16/9/13, nominal 0.25% d-pulegone)	1080 Mataketake (manufactured 5/11/13, nominal 0.29% d-pulegone)
On receipt	Bait appeared fresh, strong pulegone odour	TBC	TBC
2 months	Bait appeared fresh, no pulegone odour, but reasonable cinnamon odour		
4 months	Bait appeared normal still, no pulegone odour, but slight cinnamon odour		
6 months	Bait appeared normal still, but very hard now, slight cinnamon odour		

Table 4 Description of bait appearance and odour on receipt and at 2, 4 and 6 months after receipt. Refer to Table 3 for bait details.

Figures

Figure 1 Linear regression model of d-pulegone concentration in four batches of 1080 baits and five batches of prefeed baits manufactured with d-pulegone. Data points are the actual concentrations analysed; results have an uncertainty (95% confidence interval) of ±4%.



Appendix

Batch	Weeks	D-pulegone (%wt)	Nominal D-pulegone (% wt/wt)
Prefeed LCR2PRE	1	0.098	0.17
Prefeed LCR2PRE	4	0.085	0.17
Prefeed LCR2PRE	6	0.093	0.17
Prefeed LCR2PRE	10	0.089	0.17
Prefeed LCR2PRE	17	0.056	0.17
Prefeed LCR4PRE	1	0.11	0.17
Prefeed LCR4PRE	4	0.091	0.17
Prefeed LCR4PRE	6	0.097	0.17
Prefeed LCR4PRE	10	0.095	0.17
Prefeed LCR4PRE	17	0.067	0.17
Prefeed LCR5PRE	0	0.15	0.17
Prefeed LCR5PRE	2	0.13	0.17
Prefeed LCR5PRE	5	0.14	0.17
Prefeed LCR5PRE	8	0.13	0.17
Prefeed LCR5PRE	16	0.081	0.17
1080 LCR Pentrial	1	0.14	0.17
1080 LCR Pentrial	4	0.14	0.17
1080 LCR Pentrial	5	0.12	0.17
1080 LCR Pentrial	6	0.107	0.17
1080 LCR Pentrial	10	0.082	0.17
1080 LCR Pentrial	19	0.042	0.17
1080 Otira	2	0.11	0.17
1080 Otira	4	0.099	0.17
1080 Otira	6	0.096	0.17
1080 Otira	10	0.072	0.17
1080 Otira	11	0.06	0.17
Prefeed LCR8PRE	1	0.143	0.225
Prefeed LCR8PRE	3	0.134	0.225
Prefeed LCR8PRE	4.5	0.10	0.225
Prefeed LCR8PRE	9	0.076	0.225
Prefeed LCR8PRE	13	0.081	0.225
Prefeed Mataketake DPAQ	1	0.14	0.25
Prefeed Mataketake DPAQ	1.5	0.14	0.25
Prefeed Mataketake DPAQ	3	0.087	0.25
Prefeed Mataketake DPAQ	5	0.071	0.25
Prefeed Mataketake DPAQ	9	0.69	0.25
Prefeed Mataketake DPAQ	11	0.063	0.25
1080 LCR8TOX	1	0.17	0.25
1080 LCR8TOX	3	0.142	0.25
1080 LCR8TOX	4.5	0.102	0.25

1080 LCR8TOX	9	0.090	0.25
1080 LCR8TOX	12.5	0.079	0.25
1080 LCR8TOX	18	0.065	0.25
1080 Mataketake	0	0.21	0.29
1080 Mataketake	2	0.15	0.29
1080 Mataketake	4	0.11	0.29
1080 Mataketake	9	0.11	0.29
1080 Mataketake	11	0.11	0.29

Table A1: Complete set of d-pulegone monitoring results

Appendix 15

DOCDM-1360759 Repellent literature update February 2014

Repellent Literature update February 2014, 9(2)(a), 9(2)(g)(ii) DOC

Yellow highlights are potential problems

METHIOCARB 0.1–0.5% (plus green dye and/or perhaps up to 2% d-pulegone) recommended by Spurr 2008

Current uses	NZ: Mesurol, seed treatment Overseas: seedlings, seed treatment, was used on berries, grapes, cherries in US until registration lapsed (persistence of residues on food crops) Used to prevent avian predation of eggs (Avery et al 1995) It is a carbamate developed as an insecticide.
Mechanism	Secondary Avery 2003: post ingestional distress, inhibits acetylcholinesterase at nerve synapses Retching, vomiting, post-ingestional paralysis; recovers within 30 minutes More toxic than AQ; dead birds have been found at trials; rat LD50 is 15-35 mg/kg
Bird data	RW blackbird and boat-tailed grackle seed consumption reduced by 90-93% by 0.05% methiocarb and 92-97% by 0.1% methiocarb Dickcissels consumption of 0.05% methiocarb-treated rice reduced by 70% relative to pretreatment consumption (1 cup test)
Pest data	
Stability	
References	Avery 2003; Avery et al. 1998, 2001; Cummings et al. 1992, 1998; Dolbeer et al. 1994,1998; Guarino 1972; Porter 1977; Porter et al. 1994; Sayre and Clark 1993; various cited by Avery 2003;

TANNIC ACID 2% plus green dye, recommended by Spurr 2008

Current uses	Not registered commercially
Mechanism	probably secondary, maybe primary Avery 2003: difficult to digest
Bird data	Consumption of bottled water decreased with increasing tannin concentration for both Red winged blackbirds and starlings. RW Blackbirds consumed more tannin than starlings. 0.5%, 1%, 2.5%, 5% solutions tested
Pest data	"phenolic chemicals (tannins inparticular) are aversive to rats and probably interfere with protein uptake (Rogler et al. 1985)" Crocker et al. 1993 2% tannic acid did not reduce bait consumption by Norway rats and was recommended by Spurr et al 2001 for field testing
Stability	
References	Spurr et al 2001; Espaillat and Mason 1990

METHYL ANTHRANILATE not included in Spurr review; he cautions that it works well with a few selected species only so it is difficult to say whether kea will respond

Current uses	Rejex-iT, TP-40 and AG-36 formulations for standing pools, rye, wheat, turf grass Bird Shield Also food flavouring
Mechanism	Primary: Trigeminal nerve irritant Avery 2003 "with no alternative food, or with a relatively unattractive alternative food available, birds will persist and eat the MA-treated food" Secondary effects on gut possible
Bird data	Dickcissels consumption of treated rice not reduced when treated with 0.05% MA (Avery et al 2001) Captive Rose ringed parakeets offered the following foods treated at 0.1, 0.3, 0.5%: Sunflower seeds – no repellence, in fact more repellent-treated eaten than plain Maize—repellence at 0.3 and 0.5% Sorghum and millet—repellence observed at 0.1, 0.3, 0.5% No repellence detected in a no choice trial sparrows and pigeons at 2mL/kg pellets Free living Long billed Corellas ate significantly less oats treated with 0.8% MA than untreated oats; no significant difference in consumption between 0.4% and 0.8% MA MA had no effect on Canada geese foraging behaviour In aviary trials, feral pigeons were repelled from consuming feed or cauliflower sprouts when untreated feed was available (but not in the no choice trial). Sparrows were repelled only at 1% MA (much higher than for pigeons). Concluded that MA repellency very species specific. Feral pigeons ate less MA treated maize than untreated maize in another choice trial Northern bobwhites were deterred in 2 cup test but d-pulegone was more effective Bird Shield was not effective in deterring blackbirds from ripening rice and sunflower fields; lab analysis showed MA was below threshold levels for repellency House sparrows were not repelled from eating wheat surface coated with 0.25%, 0.5% or 1% Dimethyl anthranilate and methyl anthranilate
Pest data	Nolte et al 1993 – mice avoided 1% MA in a single bottle test In a choice trial, rats ate less food treated with dimethyl anthranilate than acetone-treated food (Crocker et al 1993) 0.25% methyl anthranilate and dimethyl anthranilate reduced bait consumption by Norway rats, although all except one rat still consumed a toxic dose (Spurr et al 2001) Food treated with 0.5% dimethyl anthranilate repelled voles in a choice test

	(Kaukeinen and Buckle cited by Spurr et al 2001) Evidence of habituation by rats – consumption increased from day 1 to day 3 of baits treated with 2.5% dimethyl anthranilate or methyl anthranilate
Stability	Volatile, exacerbated by UV and microbial activity Can be encapsulated; can cause phytotoxic effects on sprayed vegetation(Moran 2001 and Avery 2003)
References	Belant et al. 1996; Cummings et al. 1992; Esther et al 2011; Kentish et al 2003; Malhi and Kaur 2003; Mason et al. 1989; Mastrota and Mench 1995; Moran 2001; Porter 1995; Sayre and Clark 1993; Spurr et al 2001; Umeda and Sullivan 2001; Werner et al 1995; various cited in Avery 2003

CINNAMAMIDE (not included in Spurr review)

Current uses	
Mechanism	Primary 'effect was almost immediate, suggesting that [rock doves] found it distasteful or that it had fast acting post-ingestional consequences' (Crocker et al 1993)
Bird data	Repellent to rock doves at concentrations as low as 0.1% but repellency declined over 3 days Repellent to house sparrows at 2.5g/kg (Porter unpublished cited by Spurr et al 2001) Cinnamamide reduced food consumption by feral pigeons at 0.09% wt/wt; pigeons became habituated at low concentrations (<0.26%) but at high concentrations there was conditioned aversion
Pest data	In a choice trial, rats ate less food treated with 0.5% cinnamamide than acetone-treated food. In no choice tests, rats ate less food and lost more weight on cinnamamide diet than on a control diet or on a dimethyl anthranilate diet. Crocker et al 1993 concludes rats are repelled at 0.5% w/w 0.25% cinnamamide reduced bait consumption by rats compared to standard bait. 0.1% Cinnamamide did not reduce bait consumption by rats; Spurr et al caution this might have a low and short lived repellency effect for birds (but this may not matter for aerial 1080 applications?) House mouse repellence to 0.8% w/w treated baits
Stability	Comments about short lived repellency (Spurr et al 2001) 'Washes off' treated plants (Crocker et al 1993) Cotterill et al 2004 found more effective 'stickers' to improve persistence
References	Cotterill et al 2004; Crocker and Perry 1990; Crocker et al 1993 (rats); Crocker et al 1993 (rock doves); Gurney et al 1996; Spurr et al 2001

CAFFEINE ('methylxanthine' not included in Spurr review)/

Current uses	Not commercially sold as an avian repellent? Cheap and low toxicity
Mechanism	Primary (ref Werner et al 2007)
Bird data	Cage feeding trials with redwing blackbirds and brown-headed cowbirds: 2500ppm caffeine reduced consumption by up to 75%; flight pen trial with flocks resulted in 4% rice consumption in treated plots versus 43% in untreated plots; field trial on rice field >90% rice not consumed Redwing blackbird consumption of rice was reduced at 250ppm caffeine and 10000ppm caffeine and sodium benzoate; repellency was >85% for rice treated between 2500-20000ppm Redwing blackbirds consumed 13% of treated seeds (10000 ppm caffeine) and 83% of untreated seeds on broadcast rice fields Werner et al 2009
Pest data	Tested as a toxicant for pest coyotes (Johnston 2005)
Stability	Low solubility which was a problem for soaking seeds in water; Werner et al 2007 used sodium benzoate and 'Transfilm' to increase solubility
References	Avery et al 2005; Linz et al 2007; Werner et al 2007;

Others without much data:

Aluminium ammonium sulphate (Curb, Guardsman, Rezist, D-ter, Gaard, Scat): primary repellent

Lithium chloride, secondary repellent

Ortho-aminoacetophenone, recommended by Spurr et al 2001 for field testing

Fungicides Thiram and Vitavax (thiram/carboxin), tested by Werner et al 2010 with redwing blackbirds

Garlic oil (Linz et al 2007; Mason and Linz 1997; Hile et al 2004)

Suggested framework for evaluating information gaps

Repellent strategy all use green dye and cinnamon lure	Kea consume very little (if any) repellent toxic bait	Possum and rat kills continue to be high when repellent is used	no welfare concerns are raised	Effective for 4–12 weeks after bait manufacture
1. 0.17% D-pulegone in prefeed and toxic	Repellence not tested in aviary or car park trials Otira op at lower DP concentration	Met	TBC	NO: DP microencapsulation or other manufacturing improvement needed
2. 0.17% D-pulegone and 0.1% anthraquinone in prefeed 0.17% D-pulegone in toxic	Orr Walker et al 2012	Possum kills fine Secondary poisoning of stoats probably fine Rat kill not high enough	TBC	NO: DP microencapsulation or other manufacturing improvement needed
3. As for 2 except try a different primary repellent				
4. As for 2 except try a different secondary repellent				
5. 0.1% Anthraquinone in prefeed only				
6. A different secondary repellent in prefeed only				

Appendix 16

Battle for our Birds Monitoring & Research Projects: Progress to date

4 August

PROJECTS	$	Invest. No.	Invest. Leader	QUESTION
OUTPUT				
Out of Scope [redacted]				
OUTC OME				
Out of Scope [redacted]				
Kea	160k	4607	9(2)(a), 9(2)(g)(ii) [redacted]	Level of acute survival through 1080 operation? Is annual productivity and survival improved by aerial 1080 predator control? Kahurangi & Abbey Rocks
Out of Scope [redacted]				

Appendix 17

Battle for our birds monitoring

9(2)(a), 9(2)(g)(ii)

April 2014 DM-1397230

Summary

Three types of monitoring are being undertaken at the Battle for our birds (BfoB) sites: indicator monitoring which tells us where and when to undertake predator control at all sites, output monitoring which tells us whether the predators were killed at all operational sites and outcome monitoring at selected sites which tells us whether there was benefit to key at-risk species.

We have sufficient indicator and output monitoring that conforms to best practice at the BFoB sites. But most of our outcome monitoring is too coarse to quickly tell us whether our predator control has been effective. Only the existing kea monitoring programme is intensive enough to give us an answer within the 2-year timeframe requested by the Minister.

An increase in intensive outcome monitoring that includes multiple rockwren populations, whio, long-tailed bats, mohua and Haast tokoeka in addition to kea, will enable us to report on the effectiveness of BfoB for 6 key at-risk species.

In addition, there is an opportunity to extend our rodent and stoat monitoring into the alpine zone where we know that rodent and stoat irruptions occur but we are uncertain of their magnitude, the impact on native animals, and the effectiveness of aerial 1080.

The magnitude and impact of rodent and stoat irruptions in beech and mixed beech-podocarp forests in the North Island is less well known than in the South. We propose to extend the stoat and rodent monitoring network in the North Island in order to assess the magnitude and effect of rodent and stoat irruptions in these forests. We maximise the opportunity to learn about beech mast, rodent and stoat irruptions in the North Island if set up our monitoring network this year.

Some very large aerial 1080 operations are planned as part of BfoB (DM-1325967). We propose to set up a network of tracking tunnels to determine if the large size of these operations leads to slow recovery of pest populations near the middle of the operational area.

Introduction

Three types of monitoring are being undertaken at the Battle for our birds sites (Table 1):

1. Indicator monitoring which helps us determine when we need to undertake pest control – this comprises beech seed and rodent monitoring. For the purposes of this document we regard all rodent monitoring as output monitoring.

2. Output monitoring - did we kill the animals we planned to kill – rodent and stoat monitoring.

3. Outcome monitoring – did we help those species that we planned to help – bird, bat and landsnail monitoring.

The following sections outline the monitoring which conforms to best practice, that will be undertaken as part of our standard programme of work led by Operations or Science & Capability. Also included is the extra monitoring that might be undertaken in association with BFOB should there be sufficient resources available. These are summarised in Table 1 and indicative costs for proposed new work are outlined in Table 4.

Indicator monitoring

Beech seed monitoring is a joint Operations and S&C undertaking and is already funded.

Seedfall

Beech seedfall is collected at 16 of the 24 sites (Table 1). Collection is undertaken by Operations staff, seed counting is contracted to Canterbury University by S&C, data is stored in an SQL server database and data management and analysis is undertaken by S&C.

Shot-gun sampling

To provide an early indication of seedfall we also undertake shot-gun sampling of beech seeds at 16 if the 24 sites (Table 1). We shoot branches out of trees in February and March and count the seeds. The sampling is undertaken by both Operations and S&C staff and the data is collated by S&C and currently stored in a spreadsheet.

Only 3 of the 24 sites have no beech seed monitoring, but these 3 sites are in Kahurangi National Park, close to other sites within the National Park at which seed monitoring is being undertaken.

Output monitoring

Existing output monitoring

Stoat and rat abundance is indexed at all 24 BFoB sites using tracking tunnels. At all but two sites the tracking tunnels are run by Operations staff. At two sites (Abbey Rocks and Mt Stanley) tracking tunnels are run by S&C staff as part of an existing research programme. All the tracking tunnel data are currently collated by S&C and stored in an Access database managed by [redacted]. Future solutions for the management of these data are under discussion with the Planning, Monitoring and Reporting Team.

In addition, tracking tunnels are being run at 5 other sites that are not being treated with 1080 (see Table 2). Each of these sites is similar to, and geographically close to at least one of BFoB sites and will act as a control against which we can assess the success or otherwise of the planned pest control operations.

Proposed new output monitoring

Although we know that mouse irruptions occur in alpine environments in response to a masting event (beech/tussock) and that stoats and rats are present, we do not know whether stoat and rat populations irrupt in alpine environments in response to masting . Furthermore, we have no measure of the impact of any potential rodent and stoat irruptions on native animals in the alpine environment, though we know that rock wrens and perhaps other species suffer considerable losses to predators even when predators are at low densities.

A network of tracking tunnels has recently been established in the alpine environment, some at BFoB and some at non-treatment sites (Tables 1 &2), but the operation of this network is as yet

unfunded. It could appropriately be funded as part of a BFoB monitoring programme, or as Science and Capability research project, but it is important that rodent and stoat monitoring continues so we are able to determine whether or not rodents and stoats irrupt in these environments in response to masting events.

Although the magnitude, timing and impact of beech mast induced rodent and stoat irruptions in South Island beech forests is well understood, we know little about rodent and stoat irruptions in beech and beech-podocarp forests in the North Island. There are tracking tunnels at only 4 places in the North Island beech forests. It is likely that significant loss of wildlife will occur in these forests in the coming year as anecdotal evidence indicates heavy beech seeding in many places. It seems likely that BFoB might appropriately have included many North Island forests. An expanded North Island network could appropriately be funded as part of a BFoB monitoring programme, or as Science and Capability research project, but it is important that rodent and stoat monitoring starts soon so we are in the position of being able to determine the extent of the rodent and stoat irruptions in these Northern forests.

We are planning some very large 1080 operations next spring in as part of BFoB. These operations are large not only because there are cost-efficiencies in large operations, but also because the recovery time for rat, stoat and possum populations after large operations is theoretically longer than for small operations, because there is less immigration. This theory needs to be tested.

We are therefore proposing to:

1. Maintain and operate the recently established South Island alpine environment tracking tunnel networks.
2. Establish tracking tunnels at three new untreated sites in North Island forests, which have yet to be chosen.
3. Establish tracking tunnels at two sites (Kahurangi and Te Maruia) with very large (>85,000ha) 1080 operations with tracking tunnel lines in the middle of the block, near the edge and outside the block in a matched untreated area.

Outcome monitoring

We can usefully divide outcome monitoring into:

1. Coarse outcome monitoring that will indicate the success or otherwise of pest control only in the long-term and after repeated pest control operations.

2. Intensive outcome monitoring which will assess the success or otherwise of pest control within a year or two.

Coarse outcome monitoring

Birds are already being monitored at seven of the BFoB sites (Table 1) using either five minute bird counts or digital audio recordings. Bird counts are also undertaken at a further 4 matched non-treatment sites (Table 2). Seven of the sites are monitored by Operations staff, and four (Abbey Rocks, Kini, Mt Stanley and Editor Hill) as part of an S&C research programme. Operations staff store the count data in individual spreadsheets, while the S&C data are stored in 2 Access databases.

Operations staff are monitoring *Powelliphanta* land snails by counting live snails in plots at five of the BFoB sites (all identified in Table 1), and at five non-treatment sites, one of which is matched with one of the treatment sites (Table 2). The data are collated by S&C and stored in an Access database

Mohua are being monitored by counting birds along transects or within key areas at 5 BFoB sites. Operations staff undertake two of these counts (Landsborough, Catlins, Blue Mountains), the other two (Dart and South Branch Hurunui) are undertaken by S&C staff as part of an existing research programme. The data are stored in individual spreadsheets.

Whio are being monitored by Operations staff at three BFoB sites (Clinton/Arthur, Wangapeka, Oparara) by counting birds on river transects. The data are stored in individual spreadsheets.

Rather low key rockwren monitoring is undertaken by a community group at one of the BFoB sites (Cobb). Data storage practices are unknown.

The counting methods described above will detect changes over a few years and multiple 1080 operations but they are not precise enough to detect change in abundance or productivity through a single 1080 operation.

Intensive outcome monitoring

The Department has undertaken to report back to the Minister of Conservation on the success or otherwise of BFoB within two years, yet none of the existing coarse monitoring programmes are precise enough to do this (see above). We therefore propose to monitor 6 indicator species (Table 3) at sufficient intensity that we can report on the success of BFoB for these species within 2 years.

The six species are all threatened and are representative of animals that live along forested rivers, in forests or in the alpine environment. They comprise both ground and hole-nesters or roosters which are vulnerable to mammalian predation when nesting or roosting. Two large species are vulnerable only to stoat and possum predation, while all the smaller species are vulnerable to rats as well as stoats and possums (Table 3).

All species have been already been proposed as indicators of management success as part of DOC's indicator species programme.

Some populations of mohua, whio, Haast tokoeka, and long-tailed bats are already managed as part of conservation management programmes.

Table 3: Characteristics of the 6 indicator species.

Species	Habitat	Hole or ground nesting/roosting	Main predators
Mohua	Forest	Hole nesting	Stoats and rats
Whio	Riverine forests	Ground nesting	Stoats
Long-tailed bats	Forest	Hole roosting	Stoats and rats
Rock wren	Alpine	Ground nesting	Stoats
Kea	Forest & Alpine	Ground nesting	Stoats and possums
Haast tokoeka	Forest	Ground nesting	Stoats

Existing intensive outcome monitoring

Kea survival is being monitored through 1080 drops using radio-tagged birds at 6 of the BFoB sites and their productivity in the 2 subsequent breeding years will also be monitored. This is part of an existing research programme undertaken jointly by S&C and the Kea Conservation Trust. Data from this programme are stored in an Access database.

Rockwren productivity and survival is being monitored through an intensive programme of banding and remote camera nest monitoring at one of the BFoB sites (Haast Range) by S&C staff. However, the Haast Range 1080 operation is to be undertaken in August to maximise the benefit to Haast Tokoeka and will not include areas above the treeline where the rockwrens live as they will be covered in snow. Thus we will only get an indication of whether or not aerial 1080 in neighbouring forests benefits rockwren, we will not know if aerial 1080 in the alpine zone benefits rockwren. Data from this programme are stored in an Access database.

Both species of bat are being monitored intensively in the Eglinton Valley by S&C and Operations staff – but no 1080 is planned for the Eglinton – this work will provide no indication of the effect of aerial 1080 on bats. Data from this programme are stored in an Access database.

Planned intensive outcome monitoring

The existing whio monitoring at Wanagapeka and Oparara would be ramped up so that birds are radio-tagged and their nests monitored through 2 seasons. This would enable us to measure productivity and survival through a breeding season before the 1080, and a breeding season after the 1080. This work would be undertaken by Operations Staff with some oversight by S&C - it would require a injection of funds to pay for transmitters and staff time for finding ducks and monitoring nests.

Rockwren survival and productivity would be monitored at a new site in Kahurangi National Park through two seasons, one just after a 1080 drop and one a year after. This combined with the existing intensive rockwren monitoring at the Haast Range would provide a good measure of the effectiveness of aerial 1080 and protecting birds and nests from predation. The work would be undertaken by S&C staff, and the data stored in an Access database the same as used in the other rock wren programme.

Previous analyses of the impact of 1080 on the productivity of rowi at Okarito suggested that 1080 did not substantially increase their productivity, but this analysis was confounded by chick mortality caused by the monitoring. It seems likely that there is a substantial benefit to kiwi from 1080 operations that we have not yet measured properly. With this in mind the survival of Haast tokoeka chicks would be monitored through 2 seasons after a 1080 drop. This requires the Operations staff to drop their Operation Nest Egg work, and instead radio tag and monitor kiwi chicks. The work would all be undertaken by Operations Staff with some oversight by S&C . There would be an injection of funds required to catch kiwi to radio-tag them.

The existing long-tailed bat monitoring at Maruia would be ramped up so that bats can be captured and tagged continuously through the summer immediately after a 1080 drop and the subsequent season. This would provide us with monthly estimates of survival and productivity through two summers one in which there was a rat plague and 1080 drop and one normal summer. This work would be undertaken by Operations and S&C staff, the data would be managed by S&C and stored in an Access database.

Mohua survival and productivity would be monitored in the Dart Valley for two seasons, one just after the 1080 drop and one a year later. When combined with previous work this study would confirm the benefits of 1080 for mohua. This work would be undertaken by S&C staff and the data stored in the existing mohua database.

Table 1. Added Leslie Extension and Blue Mountains – need to update Output, Indicator and Outcome monitoring cells.

Table 1: Monitoring at Battle for our Birds sites.

			Output		Indicator		Outcome current/planned								
Site	Operation	Ha	Rodent & stoat tracking tunnels	Alpine tracking tunnels	Beech seedfall trays	Beech seed shooting	5mbc	Acoustic bird counts	Snail plots	Mohua	whio	bats	rock wren	kea	Haast tokoeka
Kahurangi	Cobb	61,000	✓	✓									✓	✓	
Kahurangi	Quartz Range	60,000	✓						✓					✓	
Kahurangi	Anatoki	39,000	✓			✓			✓					✓	
Kahurangi	Wangapeka	42,000	✓	✓	✓						✓			✓	
Kahurangi	Oparara	62,000	✓			✓			✓		✓		✓	✓	
Kahurangi	Leslie Extn	10,000	✓												
Mt Stanley	Mt Stanley	4,500	✓		✓	✓		✓	✓						
Te Maruia	Te Maruia	85,000	✓	✓	✓	✓	✓					✓			
Abbey Rocks	Abbey Rocks	17,000	✓		✓	✓		✓							
Landsborough	Landsborough	23,000	✓		✓	✓	✓			✓					
Haast Range	Haast Range	26,000	✓	✓		✓							✓*		✓
Waimakariri	Waimakariri	34,000	✓		✓	✓				✓				✓	
Dart	Dart	25,000	✓		✓	✓				✓					
Makarora	Makarora	15,500	✓			✓									
W. Matukituki	W. Matukituki	1,900	✓		✓	✓									
Catlins	Catlins	10,000	✓		✓	✓	✓								
Blue Mountains	Blue Mountains	5,000	✓		✓					✓					
Waikaia	Waikaia	10,000	✓			✓									
Clinton/Arthur	Clinton/Arthur	23,000	✓		✓	✓					✓				
Eglinton	Eglinton	22,000	✓	✓	✓	✓	✓*			✓*		✓*			
Hollyford	Hollyford	20,500	✓	✓	✓										
Dusky Sound	Dusky Sound	32,000	✓		✓										
Waitutu	Waitutu	30,000	✓		✓		✓								
Iris Burn	Iris Burn	11,500	✓	✓	✓	✓									
										✓					
Total		720,000	24	7	16	16	5	2	4	5	3	2	3	6	1

✓	Existing coarse outcome monitoring	✓	Existing intensive outcome monitoring	✓	Planned intensive outcome monitoring	*	No 1080

Table 2: Monitoring being carried out at non-treatment sites that will act as experimental "controls" for the Battle for our birds sites.

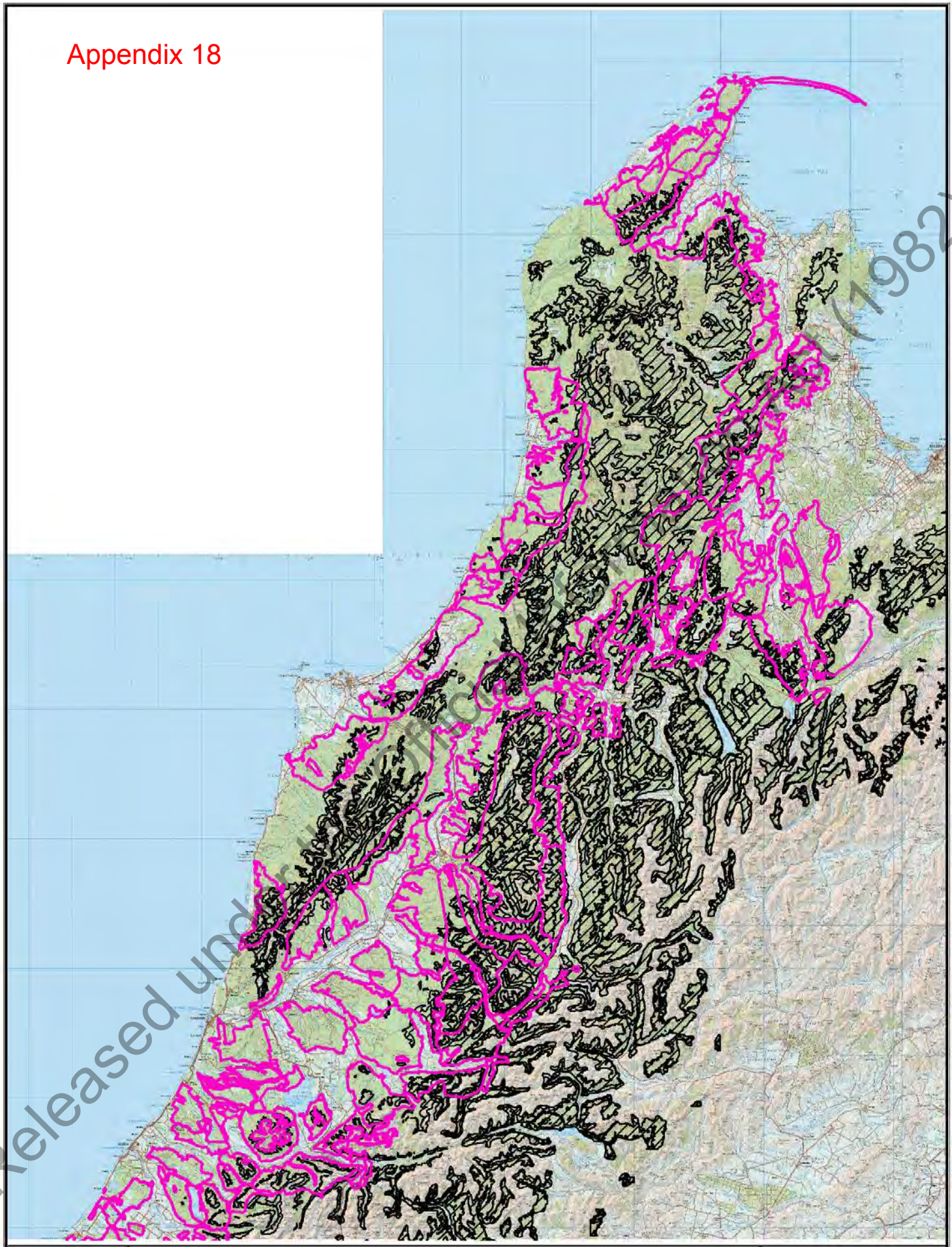
Site	Matched control for	Rodent & stoat tracking tunnels	Alpine Rodent & stoat tracking tunnels	5mbc	Acoustic bird counts	Snail plots
Rappahanock	Te Maruia	✓		✓		
Kinloch	Dart, West Matukituki, Makarora	✓				
Kini	Abbey Rocks	✓			✓	
Stafford	Haast Range			✓		
Editor Hill	Mt Stanley	✓			✓	✓
Mt Cedric	St Arnaud Range	✓	✓			
Murchison Mountains	Iris Burn	✓	✓			
Lake Roe	Dusky Sound, Iris Burn		✓			

✓	Existing coarse outcome monitoring

Table 4: Indicative costs of new work

Title	2014-15	2015-16	Dependencies
North Island tracking tunnels	$35,000	$30,000	There is an existing S&C research proposal for this work.
Alpine tracking tunnels	$78,000	$78,000	There is an existing S&C research proposal for this work.
Large 1080 block tracking tunnels	$70,000	$60,000	
Haast tokoeka	$20,000	$20,000	
Long-tailed bats	$70,000	$70,000	
Mohua	$70,000	$70,000	
Whio		$90,000	
Rock Wren	$120,000	$120,000	
Total	**$463,000**	**$538,000**	

Appendix 18



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TBfree NZ West Coast & Tasman Aerial Blocks

TBfree_Aerial_Control_Areas
Kea_habitat_Scarce_rats

Produced by: 9(2)(g)(ii)
Office: Greymouth
Date: 14/04/2014

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Appendix 19

Agenda for consultation meeting—new standards for aerial 1080 in kea habitat

Thursday 3rd April 130-330pm

TBfreeNZ: Matthew Hall, [redacted]

DOC: [redacted]

1. Check agenda and make revisions

2. Question and answers on supporting research:
   - predators of kea
   - non-target risk to kea at aerial 1080 operations
   - benefits to kea of predator control via aerial 1080 operations
   - repellents

3. Feedback on changes to existing performance standards for 0.15% 1080 cereal to reduce kea deaths

4. Feedback on new standard for 0.15% 1080 cereal to ensure kea benefit from stoat control—during and soon after mast years

5. Feedback on new standard to ensure kea benefit from stoat control—between mast years
   - Review shape file of kea habitat where rats can be scarce
   - Rat monitoring option and definition of widespread
   - Stoat control option

6. Note any follow up actions required

Appendix: Request for feedback emailed 31st March

Hello

We would like your feedback on the operational implications of the attached draft DOC Code of Practice for aerial 1080 in kea habitat. We hope for your feedback by the 9th of April, as planners of aerial 1080 operations.

This draft Code of Practice has been developed by the Pesticides Advisory Group to replace the current performance standards. We propose that the performance standards sheets for aerial 1080 permissions will say "The DOC Code of Practice for aerial 1080 in kea habitat must be followed." We decided to move to a Code of Practice, because it allows us to be clear about which standards apply to which bait types and for summarising the research behind the standards. We have also started a set of FAQs at the end of the document.

Scope of the draft Code

All aerial 1080 operations that occur where kea could be present, as defined by a map of kea distribution in Figure 1 of the Code. This includes:

-0.15% 1080 Pellets – there are 2 sets of compulsory performance standards that apply: 3 standards to reduce kea deaths and 2 standards to ensure that kea benefit from stoat control

-0.08% 1080 Pellets and 0.08% 1080 Rodent Pellets –no change, these pesticide uses continue to be prohibited for use in kea habitat (Figure 1) because they are only available in the Wanganui #7 matrix

-1080 carrot—no change, all operations must be monitored for kea survival

-0.2% 1080 Pellets (wallabies) and 0.04% 1080 Pellets (rabbits)—the Code brings these pesticide uses into line with 1080 carrot, requiring that all operations must be monitored for kea survival

Standards that apply to aerially applied 0.15% 1080 pellets

The PAG has met by phone twice since our face-to-face meeting, to try to get the most effective standards for the risks. As a result, some standards in the code differ from what I described in my emails in early March to DOC staff planning operations and TBfree NZ managers. Please read the draft Code of Practice to get the full picture, but I'd like to point out some key points that cause the Code to have a wider impact than I initially indicated.

Compulsory performance standards to reduce kea deaths:

These are the same as the current standards (cinnamon RS5s with maximum sowing rates) except that the draft Code drops the final bullet point "*avoid sowing baits in areas of low structural vegetation cover (e.g. alpine herb fields and tussock) above the tree line*." The rationale for this removal is explained in the Code. This is not to say that operations "should" include alpine and tussock; it is more that these areas can be sown where this would contribute to the operation's targets (e.g. protecting alpine species from predators) and where other risks can be managed.

Compulsory performance standards to ensure that kea benefit from stoat control:

The rationale for these new standards is explained in the Code. There are 2 situations.

-During and soon after a mast: All aerial 1080 operations in kea habitat must be between 1 July of the mast year and 31 August of the year following.

-Between masts: Aerial 1080 operations that include "*kea habitat where rats can be scarce*" that occur outside the 14 month timeframe above can only occur if:

(1) the operation is supplemented with an agreed level of stoat control; or

(2) monitoring demonstrates that rats are 'widespread,' including in areas where rats can be scarce. 'Widespread' means that at least 2 tracking tunnels record rat prints on 80% of transects monitored prior to the operation (following Gilles and Williams 2013).

"*Kea habitat where rats can be scarce"* includes:

-all kea habitat over 700m altitude, and

-all kea habitat in pure beech forest

A shapefile is in preparation which I will have on an ArcReader disc next week for meeting with TBfreeNZ on Friday 3rd. We propose to make this available in NATIS (internally) and on the web-based geoportal (so that TBfree NZ and others can access it and overlay it with their own maps).

Compliance for upcoming operations

From your preliminary responses a couple of weeks ago, I understand that there are 3 operations where the timing might put the operations into the "between mast" situation:

DOC Iris Burns (possibly late June)

DOC Leslie and TBfree NZ Mt Arthur (June)

To comply with the new performance standards, these operations would either need to demonstrate that rats are 'widespread' in pre-operational monitoring or carry out stoat control at the same operational area. I will send this message to the CSMs and DCSs involved so that they can start to look at stoat control options in the case where rats are not widespread prior to these operations.

Implementation

We hope to have conversations and correspondence with you about this over the next 10 days, closing on 9th April. I will summarise the operational implications for the DDGs (Kevin O'Connor and Felicity Lawrence), with the aim of a DDG decision by the 18th April. The draft Code of Practice would come into immediate effect for aerial 1080 operations this year.

Focus for comments

We are really looking for feedback on the operational implications of:

1. 0.15% 1080 Pellets: removal of the alpine exclusion from the standard to reduce kea deaths
2. 0.15% 1080 Pellets: introduction of the new standards to ensure kea benefit from stoat control
3. Requiring kea monitoring at all aerial 1080 carrot operations and all 1080 operations targeting rabbits and wallabies. We suspect that very few of these will occur in kea habitat, so it would be good to hear from Mark M, Paul H and Neil B to confirm our assumption.

Many thanks

9(2)(a), 9(2)(g)(ii)

[redacted]

Technical Advisor Threats (Systems Development)

Mātanga Mātai Mōrearea (Pūnaha)

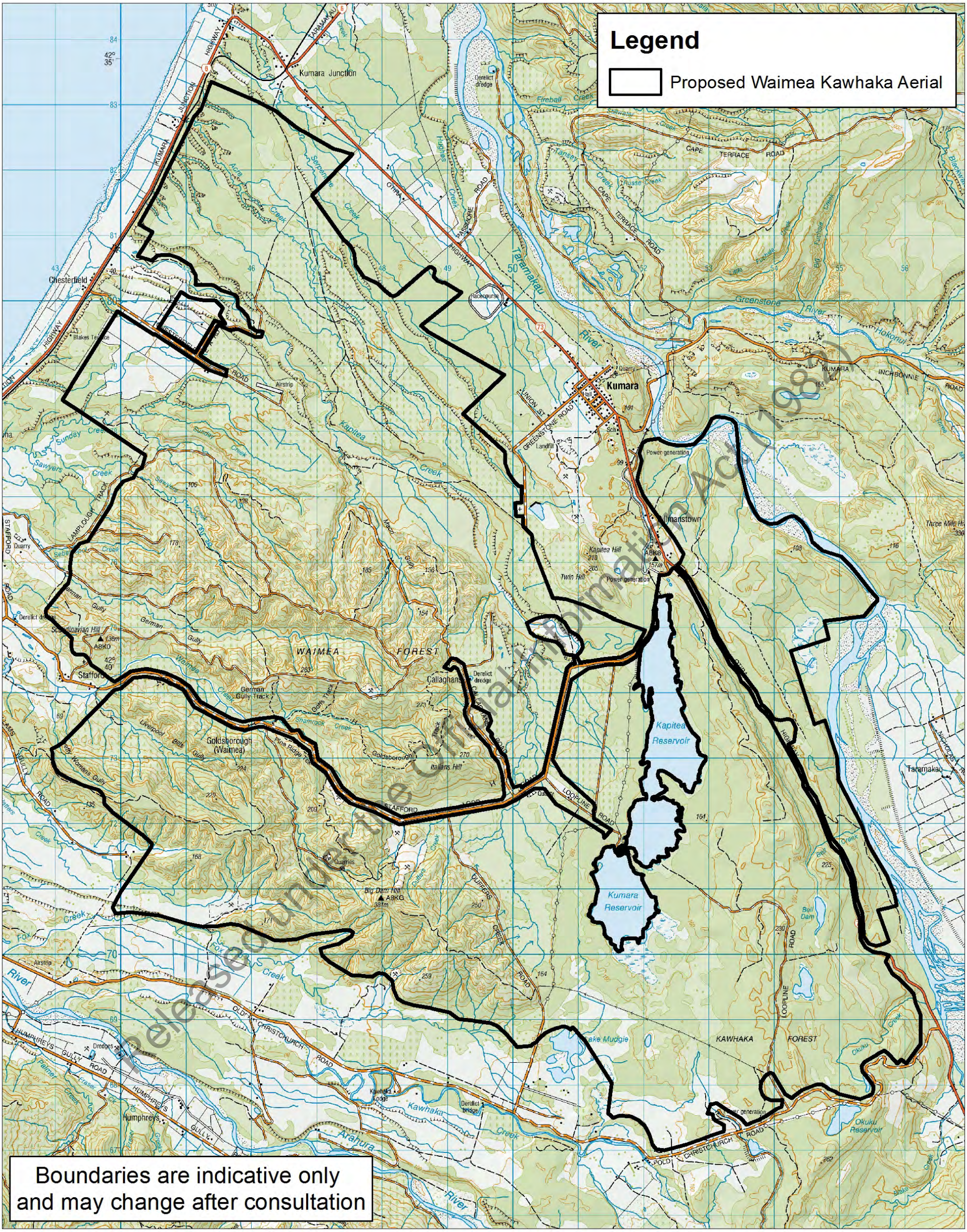
Department of Conservation - *Te Papa Atawhai*

DDI: 9(2)(a), 9(2)(g)(ii)

Conservation for prosperity *Tiakina te taiao, kia puawai*

www.doc.govt.nz

Appendix 20



TBfree New Zealand Ltd - Aerial 1080 Operation

Initial Consultation Map

Waimea Kawhaka Aerial 2015

Produced by: 9(2)(a), 9(2)(g)(ii)
Office: Greymouth
Version: Draft 1
Date: 10 November 2014

TBfree NEW ZEALAND

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Coordinate System: NZGD 2000 New Zealand Transverse Mercator

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Hokitika

Topographic Map Sourced from LINZ, Crown Copyright Reserved. Cadastral information derived from LINZ, Crown Copyright Reserved.

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Appendix 21

Summary of kea research

Non target risk to kea from aerial 1080 cereal operations

The kea is a large parrot endemic to the Southern Alps of New Zealand and is the world's only mountain parrot. Kea were re-classed from 'Not threatened' to 'Nationally Endangered' by Robertson et al. (2012); the criteria for this classification are a population estimate of 1000–5000 and an ongoing or predicted decline of 50–70% in the total population over the next 10 years. In order to prevent this decline, effective predator control is critical.

DOC is concerned about the potential population impact of the kea deaths some aerial 1080 cereal operations. Kea survival has been monitored through 10 aerial 1080 cereal operations in 9 locations (Table 1, Figure 2). Kea were captured and tagged with VHF radio transmitters prior to the operation; the transmitters were fitted with motion sensors that record the time (hour) when motion ceased. A total of 150 kea were monitored in the operational areas and 20 kea deaths resulted from consuming 1080 (Kemp and van Klink 2014). All 20 kea deaths occurred in the 3 operations where we monitored the largest samples of birds (Table 1). It may be that kea in these locations are at higher risk for some site specific reason, such as forest type or more experience with human food). It is also possible that kea deaths were not detected at the other sites due to small sample size.

It appears that most kea ignore 1080 pellets but a small number are poisoned by them. Most (16) of 20 of the detected kea deaths occurred soon (1–4 days) after the aerial 1080 operations. Bright green contents (1080 cereal remains) were found in the gizzard or crop of the 18 corpses recovered for autopsy and 1080 was detected in muscle tissue (Kemp and van Klink 2014; van Klink and Crowell 2014). This indicates direct poisoning of kea from eating 1080 cereal (as opposed to secondary poisoning from possum carcasses) and that probably more than one pellet was consumed.

Commented [m1]: Checking with [redacted] and [redacted]

Predators to kea

The kea is vulnerable to a range of introduced mammalian predators due to its ground-nesting habit and extended nesting cycle (i.e., it takes four months to fledge young, Jackson 1963). Kemp et al. (2014) attempted to identify the predators of kea using a combination of nest cameras, corpse necropsy and inference from predator density fluctuations during nest survival monitoring. Nest cameras recorded visits by stoats, possums, ship rats, house mice and weka. Stoats were identified as the predator in 3 of the 16 nest failures recorded while no positive identification was possible for the other cases. Statistical modelling of the effect of predator visitation on nest survival suggests that visits by stoats, possums and rats were predictors of nest failure, with the strongest support for stoat visits. Two predation events were confirmed by corpse necropsy; one death by stoat predation was confirmed by DNA analysis and the other kea was predated by either a falcon or stoat. Kemp et al. (2014) also analysed the survival odds of kea nests at a rimu forest before, during, and after a mast event with no predator control. Survival odds were related to changes in stoat abundance but not to changes in rat abundance, implicating stoats as the important predator following mast events.

We have photographs of a possum appearing to kill kea chicks (DOC no date). However stoats are the far important predator following mast events, which is when kea nest failure is at its greatest.

Benefits to kea populations from predator control via aerial 1080

Predator control needs to take place on a landscape scale to protect kea nests from predation by stoats and other predators, for two reasons. Stoats are the most important predator and have a large home range (e.g.; 100–200 ha, King and Murphy 2005). For example, an extensive area must be controlled to when stoat are targeted to protect Okarito brown kiwi chicks (*Apteryx australis* Okarito), based on mapping of the home range of stoats (Miller et al. 2001). Kea nests are found at a low density (Jackson 1960; Anderson 1986) so broad scale control is needed to cover even a small number of nests. For example, Bond and Diamond (1992) estimated that there were between 0.14 and 0.40 nests per hectare.

Aerial application of 1080 baits is one of the main methods of rat and possum control on a landscape scale in New Zealand and can be effective for reducing stoat numbers through by-kill. Murphy et al. (1998) first recorded a reduction in a stoat population following aerial 1080 by secondary poisoning; they observed prey remains in 12 of 13 radio-tracked stoat corpses after the operation including rat remains in 8 corpses and possum remains in a single corpse. Rats are reliable vectors for poison, based on consistent rat kills at aerial 1080 operations and on their common occurrence in the stoat diet (King and Murphy 2005). The significance of possums and mice as poison vectors for stoat control is less certain and might vary by locality. If rats aren't present in a forest (such as in the years between beech or rimu masts), we are unsure of the extent of the stoat by-kill that would be achieved.

The potential benefit to kea populations from aerial 1080 cereal operations has been investigated by Kemp et al. (2014), through long term monitoring of kea productivity and survival at sites before and for at least 2 seasons after aerial 1080 operations. This included a controlled (before-after-controlled-impact or BACI) study with a non-treatment area for a lowland rimu forest in Westland and a correlative modelling approach for 5 upland beech forests where there were no non-treatment areas.

The BACI study monitored predator dynamics and kea nests before and after an aerial 1080 operation in the spring of a mast year (2011) at Okarito forest in Westland, as compared to the same measures at nearby Fox-Paringa forest where predators were not controlled. Aerial 1080 reduced the stoat tracking index to near zero for 2 kea nesting seasons whereas the stoat tracking index increase to about 80% in the year after the mast (known as a 'stoat irruption year') at Fox-Paringa (Figure 3 –insert 9(2)(a), 9(2)(g)(ii) predator graph). Kea nest survival was estimated in the treated area as 100% in the mast year and 69% in the stoat irruption year, whereas nest survival in the untreated area was estimated as 38% and 1% respectively. During the 2 breeding seasons after the rimu mast, kea productivity was estimated at 4 times higher at the treated area (1.4 fledglings per adult female) than at the untreated area (0.32 fledglings per adult female).

Kemp et al. (2014) also monitored predator dynamics and kea productivity and survival at 5 upland beech forests, 4 of which were treated with aerial 1080 and 1 of which was kill-trapped for stoats and possums. Beech mast occurred in all five upland beech forests in 2009, followed by a stoat irruption in 2010. They concluded that kea productivity is near zero during uncontrolled stoat irruptions in beech forest (as also seen in the BACI study). Kea productivity between mast events is 0.44 fledglings per adult female on average, but this increases to 0.95 fledglings per female with effective stoat and possum control. The study included one site (Mt Arthur) where the stoat tracking

index increased in the stoat irruption year, several adult kea disappeared and no kea nests were found (Figure 4, insert [redacted] predator graph). The authors concluded that the aerial 1080 at Mt Arthur occurred too early in the mast year, when rodents were sparse, to achieve effective stoat control.

In summary, effective stoat control improves kea productivity and unchecked stoat irruptions following mast years are very bad for kea. Therefore if aerial 1080 is to make up for the few adult kea it sometimes kills, it must optimise the by-kill of stoats, particularly through irruptions over the breeding season. Effective stoat control appears more likely where rats are widespread in the operational area and best practice suggests prefeeding is essential to obtain good rat kills. We do not know for sure if this is true when rats are scarce but mice and/or possums are widespread; mouse kills with RS5 pellets appear to be inconsistent. We know lowland forests usually have rats but in upland forest they can be scarce unless there has been a mast event. Therefore aerial 1080 operations which include high altitude forest need further considerations on their design to achieve control of stoats. For example operations could be:

- Timed to coincide with high rat numbers in the winter or early spring of a mast year (Figure 3), or
- Triggered by rat monitoring, to detect a broad presence of rats at high altitudes prior to the operation

Repellents to protect kea at aerial 1080 cereal operations

The Department of Conservation is working with others to develop, register and implement an effective bird repellent to prevent kea deaths at aerial 1080 cereal operations (Crowell 2014). A number of trials have taken place in aviaries (Orr-Walker et al. 2012), pens (Cowan et al. 2013), and in the field (Kemp 2010, Crowell et al. 2014b, van Klink and Crowell 2014) since 2008, focussing on d-pulegone (which has a strong minty odour disliked by birds) and anthraquinone (which birds learn to avoid after post-ingestional discomfort). The research program is working to overcome limitations for each of these repellents. For d-pulegone, the focus is on stabilising the compound in cereal baits because monitoring has shown that it dissipates in manufacture and storage (Crowell et al. 2014a, van Klink and Crowell 2014). The addition of anthraquinone at the level used in the trials (0.1% wt/wt) seems to be detected and avoided by rats (Cowan et al. 2013). The proportional reduction in rat tracking was less in plots where both repellents were used, as compared to plots where d-pulegone or no repellents were used (Crowell et al. 2014b). The rat and kea responses to lower concentrations will be investigated; this may include using anthraquinone in blocks within an aerial 1080 cereal operation. Other repellents have been identified for preliminary screening with wild kea in 2014.

None of the repellents are ready for use in a pest operation in 2014, other than possibly anthraquinone in trial plots to gauge rat efficacy. Given that the timeframe for developing and registering a bird repellent is unknown, other immediate steps are needed to protect kea at aerial 1080 cereal operations.

Table 1 Sample size and outcomes for kea with known fates monitored before and after aerial 1080 cereal operations (from Kemp and van Klink 2014).

Operation	Number of birds followed	Deaths recorded	Probability of survival	Lower 95% confidence bound	Upper 95% confidence bound
Arawhata 2008	10	0	100%	78.7%	100%
Fox-Franz 2008	17	7	58.8%	39.3%	75.9%
Mt Arthur 2009	13	0	100%	82.8%	100%
Hawdon 2009	10	0	100%	78.7%	100%
Okarito 2011	37	8	78.4%	65.5%	87.4%
Wangapeka 2011	13	0	100%	82.8%	100%
Abbey Rocks 2011	8	0	100%	74.7%	100%
Copland 2012	2	0	100%	42.5%	100%
Hawdon 2012	6	0	100%	68.9%	100%
Otira 2013	34	5	85.3%	72.7%	92.7%
Total	150	20	86.7%		

Appendix 23

Sodium fluoroacetate

Pesticide Information Review

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Version History:

Version	*Date Written*	*Change/Reason for Change*
2014/2	12/12/2014	Formatting changes, and updates to Sections 3.2 and 6.2
2014/1	29/08/2014	New data on soil breakdown (Section 2.2.2), water samples (Section 2.3.1), native non-targets (3.2.3), and revised overview for native non-targets
2013/1	18/09/2013	New information on kea (Sections 2.5.4, 3.2.1 and 3.2.3) and morepork, kaka, robins, tomtits, grey warbler and riflemen (3.2.3).
2012/3	23/10/2012	New information on fernbirds (Sections 2.5.4, 3.2.1 and 3.2.3) & bees (4.2.1)
2012/2	17/10/2012	New information on 1080 resiudes in magpies (*Pica pica*) in 2.5.4, and LD_{50} for magpies in 4.1.1.
2012/1	12/04/2012	New information on 1080 in water 2.3.1, 2.3.2, and 2.3.3, and 3.2.1 (snails), corrected formatting and Table numbers.
2011/2	17/10/2011	New information (kea) 3.2.3
2011/1	13/1/2011	New information on fish and aquatic invertebrates 3.2.3
2010/2	31/08/2010	New information (kiwi) 3.2.3
2010/1	3/08/2010	New information 2.5.2, 3.2.2 & 3.2.3
2009/7	15/12/2009	3.2.3 (skinks and weka); 5.1.7, 6.2.4 (Rats)
2009/6	1/09/2009	Corrected number of operations monitored by Thomas et al. (2004) in section 2.1.1
2009/5	13/8/2009	New information in sections 2.5.4 (Quail) & 4.2.1 (0.2% carrot and 0.04% oat operations).
2009/4	20/7/2009	Rewrote sections 2.3.1, 2.4.2 and 2.4.3 based on new information.
2009/3	13/07/2009	New information in Section 3.2.2 (falcon); 6.2.4 (Mice)
2009/2	19/05/2009	New information in Section 6.2.2 (Mice)
2009/1	17/02/09	New information in Sections 2.5.1 & 2.5.4 (deer); 3.2.1 & 3.2.3 (Kakariki)
2008/1	18/09/08	New information in Sections 2.5.2; 2.5.4; 3.2.1 & 3.2.3 (kea); 4.1.4; 4.2.1; & 6.2.4
2006/2	10/08/06	New information in section 3.2.3 (paste baits)
2006/1	15/3/06	New information in sections 2.1.1; 2.5.5; 3.2.3; & 6.2.4.
2005/2	17/03/05	New information in sections 2.1.1; 2.4.2; 2.5.2; & 6.2.4.
2005/1	18/01/05	Up dated Section 1.4 pesticide uses

2004/2	8/10/2004	Residue and non-target native and feral animal information from Speedy (2003) included
2004/1	15/9/2004	Original document

Contents

I. Overview

Introduction

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

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

Fate in the Environment

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

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

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

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

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

Effects on Non-Target Native Species

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

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

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

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

the Vertebrate Pesticide Residue Database (VPRD) between 1994-2013 recorded only 35 poisoned individuals representing 10 native species across all bait types used in aerial poisoning. No conclusions about population effects can be drawn from this information but it is useful to focus further studies. Some native species (mainly invertebrates) have contained 1080 residues when sampled, an indication of potential risk to insectivores from secondary poisoning.

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

There have been numerous studies examining the effects of aerial poisoning on native non-target populations over the last 20 years. 21 species of native birds, particularly threatened species, have been monitored. None of the studies have identified population level mortality which threatened the viability of the species, although the only reliably calculated mortality rates are for kokako, kiwi, kaka, whio and fernbirds. The upper 95% mortality rates for kokako, kiwi, kaka, whio are all less than 3.5%. The mean mortality rate for fernbirds is 9.4%.

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

Invertebrate populations have been monitored in nine aerial poisoning operations and none have shown significant population effects on any species

studied, nor is there evidence to suggest poisoned invertebrates are a significant factor in secondary poisoning of other animals. Long term monitoring of native land snails indicates substantial benefits to threatened populations in sites treated with aerial poisoning.

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

Effects on Domestic and Feral Animals

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

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

Feral deer population mortality from aerial poisoning operations targeting possums is highly variable and does not appear to be consistently influenced by toxic loading, sowing rate, prefeeding or bait type. Most estimates of deer kill fall between 30 and 60%. Nugent et al. (2001) quote productivity figures for red deer populations of around 30% so low to moderate by-kill of deer populations is probably negated within a couple of years.

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

Although 1080 is toxic to bees, baits used in pest control are generally not attractive to bees. However this may not always be the case if bees are particularly hungry, so beekeepers should always be notified of operations.

Human Health

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

followed by respiratory distress, anxiety, agitation, muscle spasms, stupor, seizures, and coma.

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

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

Operational

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

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

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

1. Introduction

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

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

1.1 Chemical name

Sodium monofluoroacetate

1.2 Synonyms

Sodium fluoroacetate, Monofluoroacetate, Compound-1080, 1080 (‘ten-eighty’)

1.3 CAS Numbers

62-74-8

1.4 Registered pesticides containing 1080 available in New Zealand

0. 2 % 1080 Pellets (2 g kg^{-1} 1080), Pesticide use numbers: 21, 22, 23

0.15% 1080 Pellets (1.5 g kg^{-1} 1080), Pesticide use numbers: 1, 2, 3, 54, 55, 56, 98

0.08 % 1080 Pellets (0.8 g kg^{-1} 1080), Pesticide use numbers: 7, 8, 9

0.08 % 1080 Rodent Pellets (0.8 g kg^{-1} 1080), Pesticide use numbers: 10, 11, 12, 99

0.06% 1080 Pellets (0.6 g kg^{-1} 1080), Pesticide use numbers: 101, 102, 103, 104, 105, 106, 107

0.04% 1080 Pellets (0.4 g kg^{-1} 1080), Pesticide use numbers: 13, 14, 100

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

No Possums® 1080 gel (1.5 g kg^{-1} 1080), Pesticide use numbers: 91

0.1% 1080 Feral Cat Bait (1.0 g kg^{-1} 1080), Pesticide use numbers: 38, 115

10% 1080 Gel (100 g kg^{-1} 1080), Pesticide use numbers: 15, 39, 97

5% 1080 Gel (50 g kg^{-1} 1080), Pesticide use numbers: 16

Pestoff Exterminator Paste (1.5 g kg^{-1} 1080), Pesticide use numbers: 35, 36

Pestoff Professional 1080 Possum Paste 0.08% (0.8 g kg^{-1} 1080), Pesticide use numbers: 41

Pestoff Professional 1080 Possum Paste 0.15% (1.5 g kg^{-1} 1080), Pesticide use numbers: 42, 96

Pestoff Professional 1080 Possum & Rabbit Paste 0.06% (0.6 g kg^{-1} 1080), Pesticide use numbers: 44

1.5 Chemical and physical properties

1080 has an empirical formula of $C_2H_2FNaO_2$ (Figure 1) and a molecular weight of 100.3. In its pure form 1080 is an odourless, colourless, non-volatile powder that decomposes at about 200°C. Although the compound is often said to be tasteless, dilute solutions are thought to taste like weak vinegar. Sodium monofluoroacetate is very water-soluble but has low solubility in organic solvents such as ethanol and oils. Monofluoroacetates are chemically stable, hence 1080 as a pure compound in powder form—or when prepared in an aqueous stock solution—will not readily decompose.

This section is from Eason & Wickstrom (2001).

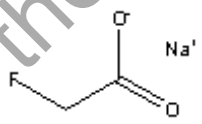

Figure 1. The chemical structure of sodium fluoroacetate.

1.6 Historical development and use

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

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

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

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

Most studies assessing monofluoroacetate concentrations in plants have focused on those species that are overtly toxic to mammals. However, it would appear that the ability of plants to synthesise monofluoroacetate is more widespread than generally supposed, since monofluoroacetate occurs at extremely low concentrations in some Finnish plants (Vartiainen & Kauranen 1980), in tea leaves (Vartiainen & Kauranen 1984) and guar gum (Vartiainen & Gynther 1984; Twigg et al. 1996b). In addition some plants, when exposed to fluoride ions, can biosynthesise fluoroacetate, albeit at very low levels. Fluorocitrate, the toxic metabolite of monofluoroacetate, has also been detected in tea leaves (Peters & Shorthouse 1972). Fluoroacetate biosynthesis can also occur in some bacteria, notably *Streptomyces cattleya* (O'Hagan & Harper 1999). Resistance in mammals, birds, and insects occurs in areas where there is continued exposure to the toxin. Interestingly, the caterpillar moth, *Sindrus albimaculatus*, which feeds on *Dichapetalum cymosum*, can not only detoxify fluoroacetate, but also accumulate it (probably in vacuoles) and uses it as a defence against predation (Meyer & O'Hagan 1992).

This section is from Eason & Wickstrom (2001).

1.7 Toxicology and pathology

1.7.1 Mode of action

Monofluoroacetate is converted within animals to fluorocitrate, which inhibits the tricarboxylic acid cycle. This results in accumulation of citrate in the tissues and plasma, energy deprivation, and death. Synthesis of fluorocitrate occurs in the mitochondria, and the fluorocitrate formed inhibits mitochondrial aconitate

hydratase. There is also evidence to suggest that fluorocitrate inhibits citrate transport into and out of mitochondria, and that fluorocitrate has an inhibitory effect on succinate dehydrogenase. The high levels of citrate concentration that occur during monofluoroacetate intoxication can also have an inhibitory effect on the glycolytic enzyme, phosphofructokinase.

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

This section is from Eason & Wickstrom (2001).

1.7.2 Pathology

Known target organs in animals following 1080 exposure include the heart, lungs, liver, kidney, testes, and foetus (Annison et al. 1960; McTaggart 1970; Buffa et al. 1977; Sullivan et al. 1979; Schultz et al. 1982; Trabes et al. 1983; Chung 1984; Savarie 1984; Twigg et al. 1988; Chi et al. 1996; Gregg et al. 1998; Eason et al. 1999). The pathological changes observed at post-mortem appear to be largely the result of progressive cardiac failure with congestion of the abdominal viscera and lungs. Examination of monofluoroacetate-poisoned mammals usually reveals cyanosis of mucous membranes and other tissues. Diffuse visceral haemorrhage has been described in some animals, particularly cattle. Subepicardial haemorrhages on the epicardium and endocardium as well as on the epiglottis and trachea have been observed in sheep and possums poisoned with monofluoroacetate. The presence or absence of tissue damage is likely to be dose-related, and subepicardial haemorrhages have been observed in rabbits receiving a lethal dose of monofluoroacetate but not in those receiving a sub-lethal dose. It is apparent that the target organs vary to some extent in different species, which may relate to the citrate response in different species, or the metabolic activity in different tissue. In birds a target organ appears to be wing muscle (Ataria et al. 2000) as well as the heart, which is a more common target in other species.

This section is from Eason & Wickstrom (2001).

1.7.3 Absorption, metabolism, and excretion

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

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

Administration of ^{14}C-labelled fluoroacetate to rats showed that fluorocitrate, the toxic metabolite of 1080, accounted for only 3% of the radioactivity (Gal et al. 1961), and this was confirmed by Schafer & Machleidt (1971). The major metabolite, unlike fluorocitrate, does not inhibit the activity of aconitase (Gal et al. 1961). Phillips & Langdon (1955) suggested that the unidentified metabolites include non-saponifiable lipids that probably serve as intermediates for cholesterol, and some radioactivity was found in fatty acids and cholesterol in the liver. Up to 3% of the radioactivity appeared as respiratory CO_2, which implied cleavage of the C-F bond (Gal et al. 1961).

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

This section is from Eason & Wickstrom (2001).

2. Fate in the Environment

1080 in baits may be defluorinated in 1–2 weeks under favourable conditions. However, under less favourable conditions breakdown may take several weeks and, in extreme cold and drought, 1080 residues could persist in baits for several months. The 1080 in certain gel block and paste baits, can still be present for up to 18.6 months, or >5000 mm of rain.

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

While the concentration of 1080 in deionised (sterile) water remains relatively constant and independent of temperature, 1080 degradation occurs within 1-2 weeks in natural water. Temperature, and the presence of aquatic plants and microbes all affect 1080 degradation in aquatic environments. Water samples have been collected from streams following numerous pest control operations using 1080. 96.9% of these samples contained no residues of 1080. Where residues were found most of these had less than 1 µg l^{-1} 1080. Where higher 1080 residues have been found in water, the samples were mostly from very small streams and/or associated with the presence of bait, during aerial operations.

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

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

2.1 Bait pathway

2.1.1 How long do baits remain toxic?

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

Pellets

On land

Booth et al. (1999a) reported that 1080 began leaching out of Wanganui #7, 6 gram, 0.15% 1080 Pellets after 20 mm of simulated rainfall and that the 1080 declined to near the limit of detection after 250 mm simulated rainfall. Bowen et al. (1995) found that both 0.08% and 0.15% 1080 6 gm RS5 cereal pellets lost

1080 more quickly than equivalent 6 gm Wanganui #7 cereal pellets under simulated rainfall. The RS5 cereal pellets were less water resistant and started to disintegrate after approximately 5 mm of rain. 1080, at both concentrations, had been completely leached out of the RS5 cereal pellets after 150 mm rain.

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

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

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

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

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

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

In water

Suren (2006) conducted laboratory experiments to examine the fate of pellet baits that fell into moving water and to quantify the rate that 1080 leached from the pellets. 0.15% 1080 Wanganui #7 pellets were placed in flow tanks that had a cobble base and water flowing through them at 20 cm s^{-1}. Eleven and 6 g baits were used in the experiment. Both bait sizes followed a similar pattern of breakdown. The baits remained relatively intact for the first 48 hours, but lost their bright green colour. After 72 hours the baits had become swollen and started to fragment. At 84 hours the baits had disintegrated. While baits

remained for up to 72 - 84 hours before they disintegrated, 1080 leached out of the baits far more rapidly. 1080 was rapidly lost from submerged baits within the first 8 - 12 hours. Fifty percent of the 1080 in the baits was lost after the baits had been submerged for 5 hours. By 24 hours, 90% of the original 1080 concentration had been lost, and no 1080 was detected in any baits after 36 hours.

Carrot

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

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

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

Blocks

Morgan (2004) reported that the concentration of 1080 in No Possums® 1080 gel blocks took 18.6 months to decline by 30% under field conditions.

Pastes

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

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

Thomson (1988) concluded that >5000 mm of rain was required to leach about 75% of the 1080 out of the baits.

Other

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

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

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

2.1.2 How soluble is 1080 in natural water?

Sodium monofluoroacetate is highly water soluble and mobile (Parfitt et al. 1994).

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

2.2 Soil and sediment

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

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

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

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

Soil from three tip/landfill sites was sampled for 1080 residues in 1996-97. The Balgownie landfill, Wanganui had 1080 residues ranged from 330 – 930 mg kg^{-1}

(n=2). Winton tip, central Southland had 1080 residues ranged from 50 - 1450 mg kg^{-1} (n=4) and at an unspecified landfill site 1080 residues ranged from 0.0008 - 3 mg kg^{-1} (n=11) (P Fisher pers. comm. 2004).

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

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

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

Northcott et al. (2014) examined the breakdown of 1080 in podzol (Orikaka Sandy Loam, West Coast, South Island), brown soil (Matiri, West Coast, South Island) and pumice soil (Kaingaroa, Taupo, North Island) under laboratory conditions. In all three soil types the degradation products produced and the rate at which these products were formed were similar. The major degradation pathway was through microbial degradation to the hydroxyl metabolite, hydroxyacetic acid, and microbial mineralisation to CO_2. The authors reported that the dominant factor affecting the rate of degradation was temperature rather than soil type or moisture content. The transformation half-life (DT50) of 1080 increased with decreasing temperature, ranging from 6-8 days at 20°C, 10-21 days at 10°C and 22-43 days at 5°C.

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

2.2.3 Are there environmental factors that affect degradation in soil?

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

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

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

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

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

2.3 Fate in water

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

Between 1990 and October 2013 2805 water samples were been collected from streams following aerial 1080 pest control operations throughout New Zealand. The samples were taken within 24 hours of the bait being laid and after subsequent heavy rain. 96.9% of these samples contained no residues of 1080. Residues ranging from 0.1 – 9.0 µg l^{-1} *were found in 88 samples but most of these had less than 1 µg* l^{-1} *1080. These samples were mostly from very small streams and/or associated with the presence of bait. Four of these six samples were likely to have been as a result of inadvertent contamination (Booth et al. 2007; L. Booth pers. comm. 2014; Parliamentary Commissioner for the Environment 2011).*

985 of the total samples were taken from water used as human or stock drinking supplies, and 4 of these contained detectable 1080 residues at 0.1 µg l^{-1} *(1 sample) and 0.2 µg* l^{-1} *(3 samples) (L. Booth, Landcare Research, pers. comm.. 2014). All the positive samples were below the Ministry of Health maximum of 3.5 µg/l for 1080 in drinking water (Ministry of Health 2008).*

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

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

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

No 1080 was detected in 36 water samples taken from six streams over a 4 month period at Waipoua following aerial possum control using 0.08% 1080 Pellets sown at 5 - 6 kg ha^{-1} in 1990. After the 1990 aerial possum control operation using 0.08% 1080 Pellets at 14 kg ha^{-1} on Rangitoto Island 24 water samples were

collected over 6 months from 2 surface water and 2 ground water sites. No 1080 was detected in any of these samples (Eason et al. 1992).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.4 Fate in plants

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

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

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

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

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

Where uptake occurs, it is unlikely to be in large amounts. Ogilvie et al. (1998) reported that rye grass took up only 0.015% of the available 1080 from pellets placed beside the grass. When single 0.15% 1080 Wanganui #7 pellets were placed at the base of käramuramu in the field, the maximum concentration of 1080 detected in the plants was 5 µg kg^{-1} of plant material. This concentration

occurred 7 days after the bait was place beside the plants, and declined to 2.5 µg 1080 kg^{-1} plant material after 14 days (Ogilvie et al. 2006). In a similar field trial, Miller et al. (2009) placed a single 0.15% 1080 Wanganui #7 pellet at the base of puha plants. The highest level of 1080 detected in puha was 15 µg kg^{-1} of leaf material 3 days after the pellets were placed at the bottom of the plants. Note: in this study 1080 residues were recorded in puha that had been used as controls (i.e. no 1080 pellets placed beside them). The authors could not rule out that 1080 occurs naturally in puha and are currently undertaking further research to confirm this.

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

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

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

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

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

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

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

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

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

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

2.5 Animal residues

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

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

When sheep and goats were orally dosed with an aqueous 1080 solution at 0.1 mg kg^{-1} bw (equivalent to one-quarter of the published LD_{50} for sheep and less than a quarter of the LD_{50} for goats) the maximum 1080 residues recorded in plasma were 0.16 - 0.33 mg l^{-1} and 0.22 - 0.26 mg l^{-1} respectively. In the sheep, 2.5 hours after dosing the mean 1080 concentrations of were 0.098 mg l^{-1} in plasma, 0.042 mg kg^{-1} in muscle, 0.052 mg kg^{-1} in the heart, 0.057 mg kg^{-1} in the kidney and 0.021 mg kg^{-1} in the liver. The mean 1080 concentrations declined to less than 0.003 mg kg^{-1} in all tissues sampled 96 hours after dosing (Eason et al. 1994a).

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

Rabbits orally administered a sub-lethal dose of 1080 at 0.1 mg kg^{-1} bw (equivalent to one-quarter of the published LD_{50}) and sampled at intervals after dosing had maximum 1080 concentrations of 0.121 – 0.167 mg l^{-1} in plasma, 0.019 – 0.025 mg kg^{-1} in muscle, 0.014 - 0.08 mg kg^{-1} in kidney and 0.001 – 0.002 mg kg^{-1} in liver (Gooneratne et al. 1995).

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

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

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

Lyver et al. (2004) reported that five out of 8 captive long-finned eels fed 1080 contaminated possum muscle had sub-lethal residues of 0.0174 ± 0.0104 mg kg^{-1}, while three out of nine eels fed gut tissue containing 1080 had residues of 0.0306 ± 0.0220 mg 1080 kg^{-1} bw.

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

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

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

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

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

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

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

SPECIES	SAMPLE TYPE	RESIDUES (mg kg^{-1})	REFERENCE
Arthropods			
Beetles	Mixed samples	<0.1	1
Invertebrates (various)	7 mixed samples	0.0-0.75	2,3

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

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

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

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

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

1080 residues in sub-lethally poisoned koura decrease by a factor of five after eight days, presumably as a result of the animals metabolising or excreting the compound (Suren & Bonnett 2006).

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

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

Data on the half-life of 1080 in blood and tissues are presented in Table 2.

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

SPECIES	SAMPLE TYPE	T ½ (hours)	REFERENCE
Sheep	Plasma	10.8	1
	Muscle	12.0	2
	Liver	3.0	2
Goat	Plasma	5.5	1
Possum	Plasma	9.1	3
Rabbit	Plasma	1.1	4
	Muscle	0.4	4
	Kidney	0.8	4
Mouse	Plasma	2.0	5
	Muscle	1.7	5

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

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

In sheep dosed with a lethal amount of 1080 (200 µg kg^{-1}), the concentration of 1080 in the muscle of sheep sacrificed post-dosing reached a maximum of 111 µg kg^{-1} in 4 hours and declined exponentially thereafter. In the liver a maximum concentration of 38 µg kg^{-1} was recorded at 2 hours with exponential decline thereafter (Rammell 1993). Sheep that died 22 – 25 hours after receiving a 0.30 mg kg^{-1} dose of 1080 had 1080 concentrations of 0.06 1- 0.75 µg g^{-1} in the heart, 0.058 - 0.72 µg g^{-1} in the skeletal muscle and 0.047 - 0.051 µg g^{-1} in the liver. In sheep that died 43 - 52 hours after dosing (0.30 mg kg^{-1}) the 1080 residues in skeletal muscle was 0.023 - 0.031 µg g^{-1}, but was undetectable in the heart and liver. The concentration of 1080 in the rumin contents of sheep that died within 24 hours of dosing was 0.15 - 0.27 µg g^{-1} (Gooneratne et al. 2008).

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

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

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

1080 residues have also been recorded in animal tissues sampled from field situations. A summary of these 1080 residues is given in Table 3.

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

SPECIES	SAMPLE TYPE	RESIDUES (mg kg^{-1})	REFERENCE
Birds			
Blackbird	Muscle	0.014–5.9	1; 2; 3
Chaffinch	Muscle	0.14–3.3	1
Hedge Sparrow	Muscle	0.03	1
Kea	Muscle	0.46 – 3.44	1
Keruru / Kukupa	Muscle	0.01	1
Morepork	Muscle	0.01	1
California Quail	Crop	18 - 76	4
Rifleman	Abdominal cavity	0.016–0.863	1
NI Robin	Muscle	0.37–3.80	5
Tomtit	Abdominal cavity	0.298–0.406	1; 2
	Muscle	0.28–4.2	
Tui	Muscle	0.012	1
Silvereye	Muscle	0.68	1
Weka	Muscle	0.012–4.3	1
Fernbird	Muscle	0.14 – 0.75	6
Marsupials			
Possum	Bone	0–0.01	1; 7; 8
	Liver	1.5–8.4	
	Muscle	0.003–2.3	
	Stomach	0.05–~70	
Mammals			
Cat	Muscle	0.06–1.24	1
Cattle	Stomach	0.04–9.1	1
	Muscle	0.003–0.46	
Deer	Stomach	8.7–35.9	1; 2; 3; 9
	Muscle	0.012–7.37	
	Heart	0. 85-8.12	
	Liver	0. 75-4.05	

SPECIES	SAMPLE TYPE	RESIDUES (mg kg^{-1})	REFERENCE
Dog	Stomach	0.079–0.7	1
	Intestine	0.44	
	Muscle	0.014–0.41	
	Vomit	1.07	
Ferret	Muscle	0.004–13	1; 10; 11
Mouse	Liver	7.8–17.6	1
	Muscle	9.1–10.3	
Pig	Muscle	0.21	1
	Stomach	56	
Sheep	Liver	0.04	1
	Muscle	0.023–0.3	
	Plasma	0.35	
	Stomach	0.009–0.27	
Stoat	Muscle	0.002–1.07	1; 9; 12; 13
	Stomach	0–0.146	
Invertebrates			
Bee	2 whole animals	0–10.8	1
Wasp	wasps	5–38	14
	larvae	66–255	
	Nest debris	17–96	

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

1 VPRD; 2 Speedy (2003); 3 Nugent et al. (2004); 4 Evans & Soulsby (1993); 5 Powlesland et al. (1999b); 6 van Klink et al. (2012); 7 Eason et al. (1991a); 8 Meenken & Booth (1997); 9 McIntosh & Staples (1959); 10 Gillies & Pierce (1999); 11 Heyworth & Norbury (1999); 12 Murphy et al. (1999); 13 Dilks & Lawrence (2000); 14 Eason et al. (1991b)

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

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

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

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

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

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

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

3. Effects on Non-Target Native Species

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

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

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

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

the Vertebrate Pesticide Residue Database (VPRD) between 1994-2013 recorded only 35 poisoned individuals representing 10 native species across all bait types used in aerial poisoning. No conclusions about population effects can be drawn from this information but it is useful to focus further studies. Some native species (mainly invertebrates) have contained 1080 residues when sampled, an indication of potential risk to insectivores from secondary poisoning.

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

There have been numerous studies examining the effects of aerial poisoning on native non-target populations over the last 20 years. 21 species of native birds, particularly threatened species, have been monitored. None of the studies have identified population level mortality which threatened the viability of the species, although the only reliably calculated mortality rates are for kokako, kiwi, kaka, whio and fernbirds. The upper 95% mortality rates for kokako, kiwi, kaka, whio are all less than 3.5%. The mean mortality rate for fernbirds is 9.4%.

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

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

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

3.1 Toxicity

3.1.1 What is the lethal dose (LD_{50}) range for each taxon?

The LD_{50} values available for native mammals, birds and arthropods are presented in Table 4. While there is no information for any native reptiles, amphibians, fish or molluscs, Section 4 has information on overseas species in these taxa which is useful.

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

SPECIES	LD_{50} (mg kg^{-1})	REFERENCES
Birds	Range: 8.00 - 9.25	
Grey duck	10.0	1
Silvereye	~ 9.25	1
Weka	~ 8.1	2
Mammals		
Short tailed bat	0.15 ('Worst case' LD value)	3
Invertebrates	Range: 42.00 - 91.00	
NZ ant	72.00 (24 h LD_{50}) 42.00 (48 h LD_{50})	4
Tree weta	91.00	4

1 McIlroy (1984); 2 McIntosh et al. (1966); 3 Lloyd and McQueen (2000); 4 Booth & Wickstrom (1999)

Aquatic Invertebrates

Based on sub-lethal exposure trials, Suren & Bonnett (2006) suggest that the 1080 LC_{50} for koura is relatively high.

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

1080 is considered a broad spectrum toxicant although variation in LD_{50}'s and body size of animals suggests that some native species could survive low exposure to 1080. The susceptibility of a specific animal is linked to its metabolic rate (McIlroy 1994), so cold-blooded animals may be more tolerant to 1080 as their metabolic rate is likely to be much lower. Fish have been found to be highly tolerant of 1080 in overseas studies (Fagerstone et al. 1994).

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

Reptiles/amphibians

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

Invertebrates

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

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

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

In compost worms, used as an surrogate for native earth worms, cocoon production and the number of live juveniles decreased progressively as 1080 concentrations increased, particularly at 1080 concentrations in the soil of ≥100 mg kg^{-1} (O'Halloran et al. 2004). These soil concentrations were well above those that normally occur following the field use of 1080.

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

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

Table 5. Amount of bait needed to be ingested to result in death based on LD_{50} for native species.

SPECIES	LD_{50} (mg kg^{-1})	AV. WEIGHT FEMALE (g)	AMOUNT OF 0.4g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 0.8g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 1.0g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 1.5g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 2.0g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 50g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 100g kg^{-1} BAIT (g) FOR LD_{50}
Birds									
Silvereye	9.25	13	0.30	0.15	0.12	0.08	0.06	0.002	0.001
Weka	8	700	14.00	7.00	5.60	3.73	2.80	0.11	0.06
Mammals									
Short-tailed bat	0.15	14	0.005	0.006	0.002	0.001	0.001	0.00004	0.00002
Arthropods									
NZ ant	42	0.002	0.00021	0.00011	0.00008	0.00006[b]	0.00004	0.000002	0.0000008
Tree weta	91	1	0.228	0.114	0.091	0.061	0.046	0.002	0.001

[a] Weights for birds from Heather and Robertson (1996) & weights of bats from Lloyd and McQueen (2000); [b] A single 6 g 0.15% 1080 pellet has enough toxin to deliver an LD_{50} dose to >100 000 ants with a mean bodyweight of 2 mg each (Booth & Wickstrom 1999).

Note: The LD_{50} values given in section 3.1.1 have been used in the calculations. The body weights used to calculate the amount of bait required for an LD_{50} are average weights of females, which are generally more susceptible to poisoning because of smaller body weight and physiological factors therefore a 'worst case scenario' for poisoning.

3.2 Exposure

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

Individual animals have been found dead after aerial, handlaying and bait station operations using 1080 carrot and cereal pellet baits (Tables 6, 7, 8). The information presented in the tables includes animals found dead, or assumed to have been lethally poisoned from the presence of 1080 residues. The information has been restricted to those operations where the basic performance standards could be verified.

No Possums 1080 Gel Bait in bait stations

One **Kea** was found dead approximately 60 metres away from a No Possums 1080 Gel Bait bait station with beak slash marks in the bait after a possum control operation in the Fox Valley (Stephen Robson pers. comm. 2008). **Kea** or **kaka** markings were also reported on 3 out of 170 No Possums 1080 Gel Bait bait stations removed approximately 26 months after they were placed in the field in the Perry Block, Gouland Downs (Kahurangi National Park) in 2008, although no dead birds were located (Deverell 2008).

38 **Rhytida snails** (*Rhytida patula/perampla*) and one **Powelliphanta** were found dead inside 867 No Possums 1080 Gel Bait bait stations removed approximately 26 months after they were placed in the field in the Gouland Downs (Kahurangi National Park) in 2008 (Deverell 2008).

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

Table 6. Non-target native species deaths reported during aerial operations using 0.08% 0r 0.15% carrot baits (0.08% 1080 unless stated).

SPECIES	No. FOUND DEAD	No. OF OPERATIONS	No. OF CASES WHERE RESIDUES CONFIRMED	SOWING RATE (kg ha^{-1})		REF.
				Prefeed	Toxic	
Birds						
Morepork	2	2[a]	2		15	1
Tomtit	8	4 [a]	8		10 - 15	1; 2
Tomtit	3	1[b]	3		5	3
NI Robin	3	1 [a]	3		15	4
Kereru	6	3	1		15	1; 5; 6
Rifleman	5	1	5		15	1
Grey warbler	1	1	0		15	7
Tui	1	1	1	?	?	8
Weka[c]	1	1	1		5	9

[a] 1 of these operations was at Tahae (Pureora) where there is some evidence that the carrot was not screened adequately to meet bait specifications (Powlesland et al. 1999a); [b] In this operation the carrot bait was coated with deer repellent; [c] 0.15% 1080 carrot

Records of 1 tui and 1 whitehead from Kapiti island 1984 are not included above as there is some evidence that the carrot was below specs and the birds were not residue tested (Sherley 1992).

Records of robin, grey warbler, fantail, morepork, and Tomtit from 1978/79 not included above because carrot bait not to current quality standards.

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

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

SPECIES	No. FOUND DEAD	No. OF OPERATIONS	No. OF CASES WHERE RESIDUES CONFIRMED	SOWING RATE (kg ha^{-1})		REF.
				Prefeed	toxic	
Birds						
Silvereye	1	1[a]	1		2	1
Morepork	2	1[b]	1[c]		5	2; 3
Tomtit	5+[d]	2[a]	0[e]		5 - 7	2; 4
Weka	2	2[a]	2		3 - 5	5; 6
Weka	2	2[a,f]	1[g,h]		1	7; 8
Kakariki	2	1[a]	2	3	3	9
Kakariki	1	1	0[i]	2	2	10
Kereru	4	3[a]	1[j]		2 - 3	11
Kiwi	1	1[a,f]	0[i]		1	12
Kea	20	3[a]	12	1 - 3	1 - 2.5	13
Tui	1	1	0[i]	2	2	14
Fernbird	3	1[a]	3	2	1	15
Frogs						
Hochstetter's	1	1[a]	0[i]		7	16

[a] toxic loading of baits 0.15%; [b] toxic loading of baits 0.08%; [c] the second bird was not tested; [d] number found in second operation unspecified, assumed at least 1; [e] none of these birds were tested for residues; [f] baits handlaid; [g] this bird also had cyanide residues which is thought to be the cause of death; [h] the second bird tested negative, assumed to have come from handlaid treatment block – see Pestlink report 0203SND28; [i] tested negative; [j] two other kereru tested negative.

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

1 VPRD: T1534; 2 Spurr & Powlesland (1997); 3 VPRD: T0283; 4 Calder & Deuss (1985); 5 Walker (1997); 6 VPRD: T0169 & T2061; 7 VPRD: T1370 & T1467; 8 Pestlink: 0203SND12 & 0203SND28; 9 Rhodes et al. (2008); 10 VPRD 13305; 11 VPRD: T2061; 10206 & 1427; 12 VPRD: T1283; 13 VPRD: L23934, L23949, L35852, L41021, L41026, L23948, T5227 & T5245; 14 VPRD 13306; 15 van Klink et al. (2012); 16 McNaughton & Greene (1994).

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

SPECIES	No. FOUND DEAD	No. OF OPERATIONS	No. OF CASES WHERE RESIDUES CONFIRMED	SOWING RATE (kg ha^{-1})		REF.
				Prefeed	Toxic	
Birds						
Kea	1	1	1		1	1
Tui	1	1	0[a]		?	2

[a] tested negative

1 VPRD: T0597; 2 VPRD: 8692.

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

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

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

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

The information in this section includes the results of laboratory analysis from live animals captured or killed for sampling from treatment areas. Residues from animals found dead are presented in section 3.2.1 above. The information has been restricted to those operations where the basic performance standards could be verified.

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

SPECIES	RESIDUES (mg kg^{-1})	No. OF SAMPLES	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
Birds					
Kiwi	0.011	1[d]		3[a]	1
Weka	4.35	1 [d]		5 [a]	2
Invertebrates					
Tree weta	66	1 [e]		5 [a]	3
Tree weta	8.6	1		5 [a]	4
Cave weta	32–130	4 [f]		5 [a]	3
Cave weta	4	1		5 [a]	4
Weevil	10	1			4
Kauri snails	0	4		5[b,c]	5; 6
Arthropods (mixed)	0.05–0.75	4		5[b,c]	5; 6
Spiders (mixed)	14	1g		5 [a]	3
Arthropods (mixed)	14-46	3h		5 [a]	3
Arthropods (mixed)	0-0.006	3		5[b]	7

[a] toxic loading of baits 0.15%; [b] toxic loading of baits 0.08%; [c] baits were handlaid; [d] faecal dropping sample; [e] 1 sample totalling 26 individuals collected from pitfall traps in treatment area; [f] four samples totalling 9 individuals; [g] 1 samples of 4 spiders, 2 collected from baits and 2 from pitfall traps; [h] 3 samples totalling 58 individuals collected off 1080 baits.

1 VPRD: T0819; 2 VPRD: T0169; 3 Lloyd & McQueen (2000); 4 Spurr & Berben (2004); 5 Pierce & Montgomery (1992); 6 VPRD: R004; 7 VPRD: 139 & 146

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

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

Birds

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

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1994 (Aug) Saxon River	9	0		5	1
1994 (Dec) Karamea	7	0		5	2
2009 (Sept) Gouland Downs	8	0	1	2	3
2009 (Sept) Hawdon	20	0	1	2	4

1 Walker (1997); 2 Robertson et al. (1999); 3 S. Forder pers. comm. Pestlink: 0809GDB08; 4 Veltman & Westbrooke (2011)

A total of 131 **NI brown kiwi** have been monitored during aerial and handlaid 1080 pellet operations during 5 operations and none have died from poisoning (Table 11). Kiwi call count monitoring during the Waipoua operation did not indicate significant 1080 related mortality (Pierce & Montgomery 1992).

Table 11. NI brown kiwi monitored during aerial and handlaid 1080 operations using 0.15% or 0.08% 1080 pellets.

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1990 (June) Waipoua	5	0		5[a]	1
1990 (Sept) Waipoua	6	0		5	1
1995 Rewarewa	22	0		3[b,c]	2
2001 (Sept) Tongariro Forest	29	0		3[b]	3
2006 (Sept) Tongariro Forest	69	0	2	4	4

[a] toxic loading of baits 0.8 g kg^{-1}; [b] toxic loading of baits 1.5 g kg^{-1}; [c] baits were handlaid.

1 Pierce & Montgomery (1992); 2 Robertson et al. (1999); 3 Pestlink: 0203RUA06; 4 Pestlink: 0808RUA01.

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

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

A total of 302 NI **kokako** has been exposed to this method and bait type over 13 operations and 2 have disappeared after poisoning (Table 12). Between 1986 and March 1998, 366 kokako (including 6 juveniles) have been monitored through 31

aerial poisoning operations (of all bait types and toxins combined), although the number exposed and known to have survived is greater. Of the monitored birds, 4 have disappeared after poisoning, leading to a maximum estimate for kokako mortality of 1.4% per operation with a 5% chance that it will exceed 4% (Flux & Innes 1999). Based on a meta-analysis of 129 radio tagged and banded kokako that were monitored through 8 aerial 1080 operations between 1986 and 2001, Veltman and Westbrooke (2011) calculated the upper bound of the 95% confidence interval for an estimate of zero mortaility at 2.3%.

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON[a]	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1986 Pureora Nth Block	16	0		10-12[b,d]	1
1986 Okahukura Forest	11	1		10-12[b,d]	1
1986 Meyers Farm (Pureora)	5	0		8-10[c]	1
1987 Pureora Nth Block	23	0		8[c,d]	1
1988 Mapara	3	0		10[c]	1
1988 Cowan WR/ Okahukura Forest	24	0		8-10[c]	1
1990 Waipoua	6	1[e]		5[c]	2
1990 Mapara	52	0		8[c]	3
1989 Moki Forest	12	0		9[c]	4
1990 Kaharoa Forest	24	0		[b]	5
1991 Mapara	48	0		8[c]	3
1992 Mapara	50	0		8[c]	3
1992 Kaharoa Forest	28	0		6[b]	6

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

1 Innes & Williams (1990); 2 Pierce & Montgomery (1992); 3 Bradfield (1993); 4 Spurr (1994b); 5 Speed (1992); 6 Speed (1993).

A total of 42 **weka** has been exposed to this method and bait type over 5 operations and 1 has died from poisoning (Table 13).

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1994 Saxon River	7	0		5	1
1994 Tennyson inlet	17	1		5	1
1994 Rotumanu	8	0		5	2
2000 Copland	10	0		3	3; 4

1 Walker (1997); 2 Spurr & Powlesland (1997); 3 Van Klink & Tansell (2003); 4 Pestlink: 02/03SWS22.

A total of 23 radio tagged **morepork** has been exposed to this method and bait type over 4 operations and none have died from poisoning (Table 14). Call count monitoring at Waipoua did not indicate 1significant 1080 related mortality (Pierce & Montgomery 1992).

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1990 Waipoua	2	0		5[a]	1
1994 Saxon River	6	0		5[b]	2
1994 Tennyson Inlet[c]	1	0		5[b]	2
1998 Pureora	3[d]	0		5[a]	3
2010 Waitutu	11	0	1	2[b]	4

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

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

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

In the 2010 study in Ianthe Forest, 36 radio-tagged South Island fernbirds were monitored during an aerially applied 1080 cereal pellet operation. 5 birds dropped their transmitters, 1 was killed by a predator and 3 died from 1080 poisoning. Based on this, the mortality of fernbirds due to 1080 poisoning was estimated at 9.4% (2.4-22.6% 95% CI). The authors concluded that the impact of aerial 1080 operations on fernbird numbers is small, and the survival and improved breeding success that would have resulted from introducted predators being reduced during the 1080 operation would have outweighed the losses (van Klink et al. 2012).

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

OPERATION	No. OF BIRDS EXPOSED	No.KILLED BY POISON	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1990 Waipoua	14[d]	0		5[a]	1
1994 Gouland Downs	9	4[c]		5[b]	2
2010 Ianthe Forest	36	3	1	2[b]	3

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

1 Pierce & Montgomery (1992); 2 Walker (1997); van Klink et al. (2012)

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

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

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON[a]	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1994 Saxon River	2	0		5	1
1998 Waitotara	38	10		4	2
1998 Long Ridge, Pureora	17	0		5	2
2011 Silver Peaks, Dunedin	24	0	1.5	2	3

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

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

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

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

A monitoring study in Tongariro Forest (2001) using distance sampling found no significant difference in the mortality of tomtits between the treatment (2 kg ha^{-1} prefeed followed by 3 kg ha^{-1} 0.15% 1080 pellets) and non-treatment sites (Westbrooke et al. 2003). Distance sampling of tomtits also occurred during an

aerial 1080 operation (2 kg ha^{-1} prefeed followed by 2 kg ha^{-1} 0.08% 1080 pellets) on Mt Pureora in 2003. There was no decline in male tomtits counts in this operation (Westbrooke & Powlesland 2005). These results led the Westbrooke & Powlesland (2005) to conclude that aerial poisoning operations using cereal pellets at low sowing rates causes "...little, if any..." short term impacts on tomtit populations.

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

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON[c]	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1998 Pureora	14	0		5[a]	1
2001 Tongariro	15	1		3[b]	2

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

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

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

Transect counts of **SI tomtits, grey warbler, SI robins and riflemen** were conducted before and after the 2010 Waitutu aerial 1080 operation (1 kg ha^{-1} prefeed followed by 2 kg ha^{-1} 0.15% 1080 pellets). The transects were located at five sites, three within the operational area and two in a non-treatment area. While the numbers of tomtits and grey warblers detected on the transects changed following the application of the 1080, the scale and direction of the changes (decreases for tomtits and increases for grey warbler) was similar at all five sites. The pre- and post-control counts of riflemen and SI robins were similar between the operational area and non-treatment sites. The authors therefore concluded there was no evidence for population level impacts from 1080 on any of these species (Greene et al. 2013).

Whio are unlikely to eat cereal pellet baits and their aquatic invertebrate prey are unlikely to be contaminated by 1080. However, studies have been done to determine their survival following aerial 1080 operations. There was no reduction in visual counts of whio in the Otira valley after application of 0.15% 1080 Pellets at 6 kg ha^{-1} in 1989 (Spurr & Powlesland 1997). 77 whio have been monitored through aerial 1080 pellet operations without any bird deaths (Table 18). All 19 radio-tagged whio in Waihaha survived for at least four weeks following aerial application of carrot bait (0.08%) at 15 kg ha^{-1} (Greene 1998). Based on the results of these operations and 0/ 19 whio dying during a carrot operation in Waihaha in 1998, Veltman et al. (2014) calculated the upper bound of the 95% confidence interval for an estimate of zero mortaility at 3.0%.

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
Tongariro Forest (2006)	28	0	Yes	4	1
Pukepoto-Mangetepopo (2007)	34	0	2	3 & 5	1
Oparara (2008)	15	0	2	3	2

1 Veltman et al. (2014); 2 Veltman & Westbrooke (Veltman & Westbrooke 2011)

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

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
Windbag (1998)	15	0		5	1
Waipapa (2001)	20	0		5	1
Waipapa (2008)	10	0	1	1.5	2
Waitutu (2010)	15	0	1	2	3

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

Kereru (NZ pigeon/kukupa) have not been monitored individually when exposed to this method and bait type. However none of six birds ate non-toxic cereal pellets offered in a trial on Kapiti island (Spurr & Powlesland 1997).

Monitoring of kereru during 5 aerial 1080 operations using cereal pellets did not detect population changes using the five minute count method (Spurr & Powlesland 1997). Additionally, all 15 radio tagged birds exposed to an aerial 1080 operation using carrot bait survived (Powlesland et al. 2003).

NZ falcon have not been monitored individually when exposed to this method and bait type. However falcon territories have remained occupied, presumably by the resident birds, during four aerial 1080 operations using cereal pellets (Pureora 1984, Mapara 1990-92) and one using carrot bait (Waihaha 1994) (Spurr & Powlesland 1997). The total number of falcon involved in this monitoring is about 13, although the Mapara birds (3 pair) were exposed in three consecutive years (Calder & Deuss 1985; Bradfield 1993; Greene 1998). Seaton et al. (2009) collected productivity data from 87 falcon nests in Kaingaroa pine plantation during three breeding seasons, 2003 - 2006. During this time 1080 pellets and carrots were ground laid or aerially applied in forest compartments where falcon bred. The numbers of chicks successfully fledged was not related to time since 1080 application (1 month to >3 years), application method or bait type. During the study the breeding falcon population increased from 20 to 36 pairs, leading to the authors concluding that 1080 did not have a negative impact on falcon, and probably had a positive impact by reducing predation pressure on the falcon.

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

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

A total of 145 radio tagged **Kea** have been exposed to this method and bait type over 10 operations and 20 have died from poisoning (Table 20). Additionally, 2 radio tagged birds have been exposed to 0.08% carrot baits during 1 operation and none died from poisoning (Kemp & van Klink 2008).

Table 20. Kea monitored during aerial 1080 operations using 0.15% 1080 pellets.

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
Arawata Valley (2008)	10	0	1	4	1
Franz-Fox (2008)	17	7	3	2.5	1
Mt Arthur (2009)[a]	13	0	1	2	1
Hawdon (2009)[a]	10	0	1	2	1
Okarito (2011)[a]	37	8	1	2	2
Whangapeka (2011)[a]	13	0	1	2	2
Abbey Rocks (2011)[a]	8	0	1	1	2
Copland Valley (2012) [a]	2	0	1	2	2
Hawdon Valley (2012) [a]	6	0	1	2	2
Otira (2013) [a]	29	5	1	2	2

[a] These operations were undertaken using the performance standards adopted by DOC in 2009

1 Veltman & Westbrooke (2011): 2 (J. Kemp pers. comm. 2013).

Reptiles/amphibians

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

The attractiveness of non-toxic RS5 cereal pellets (dyed green and lured with cinnamon) to wild **grand** and **Otago skinks** were tested by Marshall and Jewell (2007). The baits were offered in two sizes – small pieces no larger than 6 mm and large baits (whole pellets). The baits were offered dry or wet. All bait types were sampled (licked, nudged or bitten) by both species of skink, with small pieces sampled more often than large baits. No animals tried to consume large pieces of cereal bait. However, 1/10 grand skinks and 3/20 Otago skinks consumed small, wet pellet fragments.

Monitoring of a population of **Archeys frog** in the Coromandel Ranges before and following application of 0.15% 1080 Pellets at 5 kg ha^{-1} in 1995, showed no decline in Archeys frog (Perfect 1996). **Hochstetters frogs** were counted at 3 sites pre- and post- application at 7 kg ha^{-1}, 1994 Hunua Ranges. One frog found dead immediately following poison operation tested negative for 1080. Fluctuations in frog numbers counts were influenced so strongly by short term environmental effects that any effect of the poison drop could not be detected (McNaughton & Greene 1994).

Bats

Short-tailed bats have not been individually monitored when exposed to this method and bait type. Lloyd (1994) offered non-toxic cereal pellets to captive bats and hand broadcast baits containing a fluorescent marker throughout an area known to be inhabited by bats and concluded "...short-tailed bats are unlikely to eat carrot or grain-based baits...". However short-tailed bats are possibly vulnerable to secondary poisoning because they are known to feed on arthropods that have been recorded feeding on 1080 baits and residues in these prey can in theory be enough to kill a bat (Lloyd & McQueen 2000).

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

Fish

Native fish have not been monitored during 1080 operations. However, a field experiment has been conducted to study the impact of 1080 on **longfin eels, koaro** and **upland bullies**. Four headwater streams were selected in the Mawhera Forest in the Grey Valley, West Coast. In each stream four sites were selected – 10 m and 100 m down stream, and 10 m and 100 m upstream from where 1080 baits were to be placed in the stream. At each site 8 fish of each species were placed in individual cages. Fish mortality was recorded after 1 and 4 days. Baits (6.5 g, 0.15% 1080 Wanganui #7 pellets) were then placed in the streams at a density equivalent to a sowing rate of 25 – 30 kg ha^{-1} (this represented an extreme scenario of 10 x normal sowing rates). Fish survival was monitored 1 and 4 days after the bait was placed in the water. No fish died after the baits were added to the water, suggesting all three species were tolerant to 1080 in water at the concentrations used in the study (Suren & Lambert 2006).

Terrestrial invertebrates

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

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

Another study by Spurr & Berben (Spurr & Berben 2004) hand laid 0.15% 1080 Pellets at 5 kg ha^{-1} to simulate aerial poisoning in Tararua Forest Park in 1999 and monitored the occupancy of artificial refuges by **tree weta** and **cave weta**

(*Isoplectron sp*.). No significant impact of bait application was found for these species nor was there any effect observed on numbers of **slugs, spiders** and **cockroaches** which also commonly used the same refuges.

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

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

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

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

Aquatic invertebrates

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

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

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

Two **NI brown kiwi** followed in a 0.08% 1080 carrot operation did not die from poisoning (Table 21). Following a non-toxic bait trial on Kapiti Island in May

1993, when carrot containing the biomarker pyranine was aerially sown at 10 kg ha^{-1}, none of five **little spotted kiwi** droppings examined fluoresced (Lloyd & Hackwell 1993). Other kiwi species have not been monitored during carrot operations.

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1995 Tongariro Forest	2	0		?	1

1 Robertson et al. (1999).

A total of 44 **NI kokako** has been exposed to 0.08% 1080 carrot baits over 2 operations and none have disappeared after poisoning (Table 21). Between 1986 and March 1998, 366 kokako (including 6 juveniles) have been monitored through 31 aerial poisoning operations (of all bait types and toxins combined), although the number exposed and known to have survived is greater. Of the monitored birds, 4 have disappeared after poisoning, leading to a maximum estimate for kokako mortality of 1.4% per operation with a 5% chance that it will exceed 4% (Flux & Innes 2001).

TABLE 21. Kokako monitored during aerial 1080 operations using 0.08% carrot baits.

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON[a]	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1993 Pureora Nth Block	10	0		10	1
1996 Pureora Nth Block	34	0		15	2

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

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

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

A total of 6 **morepork** has been exposed to this method and bait type over 1 operation and one has died from poisoning (Table 22).

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1996 Tahae (Pureora)	6	1[a]		15	1

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

1 Powlesland et al. (1998).

NZ falcon have not been monitored individually when exposed to this method and bait type. However falcon territories have remained occupied, presumably by the resident birds, during one aerial 1080 operation using carrot bait (Waihaha 1994) and four using cereal pellets (Pureora 1984, Mapara 1990-92) (Spurr & Powlesland 1997). The total number of falcon involved in this monitoring was about 13 although the Mapara birds (3 pair) were exposed in three consecutive years (Calder & Deuss 1985; Bradfield 1993; Greene 1998).

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

A total of 53 colour banded **robins** has been exposed to this method and bait type over 2 operations and 15 have disappeared after poisoning (Table 23).

Table 23. Robins monitored during aerial 1080 operations using 0.08% carrot baits.

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON[a]	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1996 Tahae (Pureora)	22	12[b]		15	1
1997 Waimanoa (Pureora)	31	3[c]		10	2

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

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

[c] 1 bird also disappeared form the non-treatment site during the study period

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

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

A total of 19 colour banded **tomtit** has been exposed to this method and bait type over two operations and 16 have disappeared after poisoning (Table 24). During the 1997/98 nesting season, tomtit pairs in the 1997 treatment area had high nesting success (80% of nests fledged chicks, mean of four fledglings per nest). Even so, by the following spring it seemed that the population had not recovered to its pre-poison level. (Powlesland et al. 2000).

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON[a]	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1996 Tahae (Pureora)	5[c]	5[b]		15	1
1997 Waimanoa (Pureora)	14	11		10	1

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

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

1 Powlesland et al. (2000).

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

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

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

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

A total of 38 radio tagged **Kaka** has been exposed to this method and bait type over 2 operations and none have died from poisoning (Table 25).

Non-toxic carrot containing the biomarker pyranine was aerially sown at 10 kg ha^{-1} on Kapiti Island in May 1993. Over the 11 days following the drop, 20 kaka were caught a total of 25 times and inspected for fluorescence due to the pyranine. Only one juvenile kaka showed traces of pyranine. A large number of kaka droppings were also inspected, but no fluorescence was observed (Lloyd & Hackwell 1993).

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

OPERATION	No. OF BIRDS EXPOSED	No. KILLED BY POISON[a]	SOWING RATE (kg ha^{-1})		REF.
			Prefeed	Toxic	
1994 Waihaha (Pureora)	21	0		15	1
2000 Whirinaki	17	0		10	2

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

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

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

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

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

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

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

Reptiles/amphibians

Lizards and frogs were not monitored in any 1080 poisoning operations prior to 1994; however, none have been reported killed by 1080. There has been limited

population monitoring of aerial poisoning operations using cereal pellets but none using carrot baits.

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

Bats

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

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

Invertebrates

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

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

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

An extensive study of forest invertebrates found on 1080 baits by Sherley et al. (1999) found that at any time only a small proportion of baits had invertebrates on them, and the few individuals per bait represented a small section of the fauna present in the litter. Each month between June to October 1995 and from April to

October 1996, non-toxic carrot baits were sown at 18 kg ha^{-1} and observed for 7-10 days. Fewer invertebrates were found on non-toxic (green dyed, cinnamon lured) carrot baits than non-toxic cereal pellets. The number of invertebrates visiting the carrot baits increased as time progressed, from a low of 7% usage on day one to 17% on day three. There was no evidence that invertebrates found on baits were drawn from further than 20cm around a bait.

1080 pellets or carrot baits in bait stations

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

No Possum® 1080 gel in bait stations

No information could be found on population effects. However some testing of non-toxic bait has been done with native species. Note that this study presented bait in open dishes rather than bait stations and the behaviour of captive animals is not always typical of those in the wild. There is also some field evidence that some native species (**kea, kaka and snails**) may feed on this bait.

Birds

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

Reptiles

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

Bats

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

Invertebrates

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

Pestoff Professional Possum Paste (0.08% and 0.15%)

Birds

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

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

Bats

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

Reptiles

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

Invertebrates

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

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

10% 1080 Gel

No information could be found

Cut apple bait

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

Birds

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

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

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

Lyver et al. (2004) reported that there was no evidence captive longfinned eels would eat 1080 cereal pellets added to their water, nor was there any 1080 detected in eel tissue from water contaminated by baits. In the same study, eels did eat 1080 contaminated possum tissue but none died.

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

4. Effects on Domestic and Feral Animals

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

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

Feral deer population mortality from aerial poisoning operations targeting possums is highly variable and does not appear to be consistently influenced by toxic loading, sowing rate, prefeeding or bait type. Most estimates of deer kill fall between 30 and 60%. Nugent et al. (2001) quote productivity figures for red deer populations of around 30% so low to moderate by-kill of deer populations is probably negated within a couple of years.

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

Although 1080 is toxic to bees, baits used in pest control are generally not attractive to bees. However this may not always be the case if bees are particularly hungry, so beekeepers should always be notified of operations.

4.1 Toxicity

4.1.1 What is the lethal dose range for each taxon?

The LD_{50} values for a range of domestic and feral animals are presented in Table 26. For completeness it includes information on species not present in New Zealand.

While no LD_{50} data is available, mortality rates of pregnant ewes exposed to 1080 are higher compared to non-pregnant ewes (O'Connor et al. 1999)

Table 26. Acute oral toxicity (LD_{50} mg kg^{-1}) of 1080 for non target domestic and feral animals.

SPECIES	LD_{50} (mg kg^{-1})	REF.
Birds	Range: 2.1 - 12.6	
Mallard duck	4.8	1
Maned duck	12.6	2
Common pigeon	4.25	3
Leghorn hens	10.0	4
White leghorn chicken[a]	7.5	5
Rhode Island red chicken	6.5	6
Plymouth rock chicken	5.5	7
Eurasian magpie	2.12	8
Chukar partridge	3.51	3
Ring-necked pheasant	6.46	3
California quail	4.6	9
European goldfinch	3.5 approx	2
Australian magpie	9.9	2
House sparrow	2.5	10
Marsupials	Range: 0.210 - 0.79	
Bennett's wallaby	0.21	11
Brush-tailed possum	0.79	12
Dama wallaby	0.27	11
Mammals	Range: 0.06 - 8.3	
Dog	0.06	7
Cat	0.28	13
Ferret	1.41	3
Rabbit	0.35	14
House mouse	8.3	15
Norway rat	0.22-3.0	7
Cattle	0.393	16
Deer (not specified)	0.5	17
Horse	0.32-1.00	18
Pig	0.4	18
Sheep	0.25-0.64	18
Goat	0.3-0.7	18
Reptiles/Amphibians	Range: 43.6 - >500	

Spotted grass frog	60	19
Bullfrog	54.4	19
Leopard frog	150	19
South African clawed frog	>500	19
Blue tongued lizard	336	19
Shingle-back lizard	206[b]	19
Gould's monitor	43.6	19
Fish	Range: 54 - 3500 mg l^{-1}	
Bream & bass	> 370[c]	20
Rainbow trout	54	21
Fingerling trout	>1000[d]	17
Harlequin fish	3500[e]	22
Bluegill sunfish	>970[f]	21
Aquatic arthropods	Range: 0.05 - 3500 mg l^{-1}	
Daphnia magna	350[g]	21
Mosquito larvae (*Anopheles quadrimaculatus*)	0.05-0.1 approx	23
Terrestrial arthropods	Range: 8 - 21	
Honeybee	8	24
Housefly	21	25

[a] laying hens appeared to be more susceptible to 1080 poisoning than hens that were not laying; [b] non-tolerant populations from South Australia, Western Australian populations LD_{50} reported as 525 mg kg^{-1}; [c] survived indefinitely at this concentration; [d] survived this concentration; [e] substance tested was Fluoroacetamide (a compound related to 1080); [f] no effects observed at this level; [g] 48-hour EC_{50}

1 Hudson et al. (1972); 2 McIlroy (1984); 3 Tucker & Crabtree (1970); 4 Kalmbach (1945); 5 Cottral et al. (1947); 6 Ward & Spencer (1947); 7 Chenoweth (1949); 8 Burns & Connelly (1992); 9 Hudson et al. (1984); 10 Peacock (1964); 11 Munday (1978); 12 Bell (1972); 13 Eason & Frampton (1991); 14 McIlroy (1981); 15 McIlroy (1982); 16 Robison (1970); 17 Rammell & Fleming (1978); 18 Atzert (1971); 19 Eisler (1995); 20 King & Penfound (1946); 21 Fagerstone et al. (1994); 22 Bauermeister et al. (1977); 23 Deonier et al. (1946); 24 Booth & Wickstrom (1999); 25 Matsumura and O'Brien (1963).

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

The amount of bait needed to be ingested by non-target domestic animals for poisoning is presented in Table 27 and for feral animals in Table 28.

Fish

No information relating to bait intake (oral LD_{50} values) could be found. Force-feeding cereal pellets containing approximately 4 mg of 1080 to two fingerling trout and five adult trout, and about 8 mg of 1080 to two adult trout had no visible effect (Rammell & Fleming 1978).

All toxicity values for fish reflect concentration of 1080 in water (LC_{50} values) which is more relevant when assessing likely risks to fish from possum baits. To achieve the 96 hour LC_{50} of 54 mg l^{-1} for rainbow trout, all the 1080 in 3.6kgs of 1.5 g 1080 kg^{-1} bait would have to leach out of the bait, and then remain in 100 litres of still water, without breaking down, for 96 hours. This is highly unlikely to occur in under pest control conditions in New Zealand.

Table 27. Amount of bait needed to be ingested to result in death based on LD_{50} for non target domestic animals.

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

The LD_{50} values given in section 4.1.1 have been used in the calculations and the average weights of females have been used, as females are generally smaller and therefore a 'worst case scenario' for poisoning. Where LD values were cited as greater (>) or less (<) than a value, this value was used to make the calculations.

Table 28. Amount of bait needed to be ingested to result in death based on LD_{50} for non target feral animals.

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

The LD_{50} values given in section 4.1.1 have been used in the calculations and the average weights of females have been used, as females are generally smaller and therefore a 'worst case scenario' for poisoning. Where LD values were cited as greater (>) or less (<) than a value, this value was used to make the calculations.

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

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

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

Domestic animals

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

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

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

Glial cells in the brain are particularly sensitive to fluorocitrate (Erlichman et al. 1998; Hulsmann et al. 2000).

Feral animals

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

Spielman et al. (1973) reported that 1080 at a dose just below the maternal LD_{50} was not teratogenic to **rats**. The embryos in this study showed no macroscopic or skeletal abnormalities. This work involved only a single dose and the results contrast with Eason et al.'s (1999) investigation which followed current international guidelines that require dosing rats from day 6–17 of gestation at three dose levels. Eason et al.(1999) found the NOEL derived from their multi-dose study (0.1 mg kg^{-1} day^{-1}) was 10-fold less than the single dose NOEL (1 mg kg^{-1}) reported by Spielman et al. (1973).

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

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

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

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

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

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

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

4.2 Exposure

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

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

A number of domestic and feral non-target deaths have been reported after 1080 cereal pellets have been applied aerially (Table 29). In 2007 during aerial AHB 1080 operations horses and farmed deer were killed.

Table 29. Feral and domestic non-target animal deaths reported during aerial & handlaid operations using 0.15% or 0.08% 1080 pellets.

SPECIES	TOTAL FOUND DEAD	No. OF OPERATIONS	No. OF CASES WHERE RESIDUES CONFIRMED	SOWING RATE (kg ha^{-1})	REF.
Domestic animals					
Dog	5	3	5		1
Cat	1	1	1		2
Cattle	2	2	2		3
Pig	1	1	1		4
Feral animals					
Red deer	2	2	2		5
Introduced birds					
Blackbird	5	3	5	3-7	6
Chaffinch	5	2	5	3	7

These animals were found dead or assumed to have been lethally poisoned from the presence of 1080 residues. Reports of animals killed which were not tested for residues have been omitted. The information has been restricted to those operations where the basic performance standards could be verified. Target pests have been excluded from the data.

Blackbirds and chaffinches are commonly found dead after operations but not tested. One starling found dead near a 1080 storage area and tested negative for 1080 residues has been omitted

1. VPRD: T0891; T1694; T1720 & T1657; 2 VPRD: T0971; 3 VPRD: 170 & T1693; 4 VPRD: T0517; 5 VPRD: T1407; 6 VPRD: T1809 & T0422; 7 VPRD: T1809 & T2068.

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

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

During an aerial 1080 operation in Rotoehu Forest in October 2004, Fish and Game staff monitored **pheasant** crowing rates using five minute counts in treated and untreated blocks. There was a healthy population throughout the forest and there was no discernable difference in the crowing rates between the blocks following the 1080 operation (McDougall 2005).

Honey bees from hives located near the loading zone were observed during one operation to be gathering the green dust from toxic RS5 cereal baits. This loading zone had been used on previous occasions for aerial 1080 operations using the same bait type and no similar observations were made (N. Murray pers. comm.). AHB (2012) conducted trials to investigate the attractiveness of RS5 and Wanganui #7 pellets to bee. Bees were trained to visit wet and dry cereal baits coated with a sugar-syrup attractant. The attractiveness of the baits was determined by swirching the sugar-coated bait with standard non-toxic baits. Within 10 minutes, the bees lost interest in the standard baits. When EDR coated pellets were used, bees continued to visit the baits for approximately 30 minutes after the sugar-coated baits had been switched with the EDR coated pellets. When 1080 cereal pellets were placed within 80 metres of hives, no bees were observed visiting or landing on the baits. To test the risk of dust to honey bees, six hives were put out during an actual 1080 operation at Buller South. 1080 was not detected in bees, wax, nectar or pollen samples collected within 24 hours of the operation or when the monitoring was repeated after 15 – 16 days. Additionally, there was no evidence of 1080 dust on flowers on which bees were observed foraging (AHB 2012).

Aerial and hand laid operations using 0.15% or 0.08% 1080 carrot baits

A number of domestic and feral non-target deaths have been reported after 1080 carrot baits have been applied aerially (Table 30).

Table 30. Feral and domestic non-target animal deaths reported during aerial & handlaid operations using 0.15% or 0.08% carrot baits.

SPECIES	TOTAL FOUND DEAD	No. OF OPERATIONS	No. OF CASES WHERE RESIDUES CONFIRMED	SOWING RATE (kg ha^{-1})	REF.
Domestic animals					
Sheep	1?	1	1		1
Feral animals					
Red deer	4	1	4	5	2
Sika deer	5	1[a]	5	5	3
Introduced birds					
Blackbird	1	1	1	5	2
Chaffinch	1	1	1		4
Hedge sparrow	1	1	1		4

[a] In this operation the carrot baits were coated with deer repellent.

These animals were found dead or assumed to have been lethally poisoned from the presence of 1080 residues. Reports of animals killed which were not tested for residues have been omitted. The information has been restricted to those operations where the basic performance standards could be verified. Target pests have been excluded from the data.

Blackbirds and chaffinches are commonly found dead after operations but not tested.

1 VPRD: 050; 2 Nugent et al. (2004); 3 Speedy (2003); 4 VPRD: T1195; Pestlink: 0304RAN08

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

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

During an aerial 1080 operation in Rotoehu Forest in October 2004, Fish and Game staff monitored **pheasant** crowing rates using five minute counts in treated and untreated blocks. There was a healthy population throughout the forest and there was no discernable difference in the crowing rates between the blocks following the 1080 operation (McDougall 2005).

Aerial and handlaying operations using 0.02% 1080 carrot baits

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

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

Aerial and handlaid operations using 0.04% 1080 oat baits

Four California quail deaths were reported during two rabbit control operations using 1080 oat in the 1980-90's (Evans & Soulsby 1993).

Bait station operations using 0.15% or 0.08% 1080 Pellets

Domestic and feral non-target deaths reported after the use of 1080 cereal pellets in bait stations are reported in Table 31.

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

SPECIES	TOTAL FOUND DEAD	No. OF OPERATIONS INVOLVED	No. OF CASES WHERE RESIDUES CONFIRMED	SOWING RATE (kg ha^{-1})	REF.
Dog	2	1	1		1; 2
Cattle	16	1	2		3

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

Pestoff Professional 1080 Possum Paste (0.08 & 0.15%)

Honey bees were known to be attracted to 1080 paste baits (sometimes referred to as jam baits) used in pest control prior to 1995. Changes in formulation of 'Pestoff Professional' possum paste since then have been found to be unattractive to bees (Morgan 2000).

No Possums® gel block bait

Honey bees offered this bait near their hive appeared to be unable to penetrate the firm gel matrix with their proboscis and were seldom observed on the bait compared with control baits offered (Morgan 1999).

Cut apple bait

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

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

The information in this section includes the results of laboratory analysis from live animals captured or killed for sampling from treatment areas. Residues from animals found dead are presented in section 4.2.1 above.

Aerially applied 0.15% 1080 Pellets

Samples taken by a vet from a sick dog following application at 5 kg ha^{-1} June 1999 Nelson/Marlborough Takaka had 1.07 mg kg^{-1} 1080 in its vomit, 0.44 mg kg^{-1} 1080 in its intestine and 0.3 mg kg^{-1} 1080 in its stomach (VPRD T0891).

0.15% 1080 Pellets in bait stations

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

4.3 Treatment

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

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

5. Human Health

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

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

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

5.1 Toxicity

5.1.1 What is the oral LD_{50} (mg kg^{-1} bw)?

The oral LD_{50} for humans has been estimated as being between 0.7 and 10.0 mg kg^{-1} (Chenoweth 1949; Kaye 1970; Eisler 1995). 2.5 mg kg^{-1} is used a working LD_{50} for all the calculations in this review.

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

The information on bait consumption required for poisoning is presented in Table 32.

Table 32. Amount of 1080 bait needed to be ingested by a human to result in death based on the LD_{50}.

	LD_{50} (mg kg^{-1})	AV. WEIGHT (kg)	AMOUNT OF 0.8 g kg^{-1} 1080 BAIT (g) FOR LD_{50}	AMOUNT OF 1.5 g kg^{-1} 1080 BAIT (g) FOR LD_{50}
Child	2.5	15	46.9	25
Adolescent	2.5	30	93.8	50
Small adult	2.5	60	187.5	100
Large adult	2.5	90	281.3	150

These figures represent the amount of bait that would have to be consumed in one sitting for a 50% chance of death. This is a straightforward acute toxicity calculation without any “safety factors’ that are used to extrapolate the results of animal studies to humans.

5.1.3 What is the dermal LD_{50} (mg kg^{-1} bw)?

Monofluoroacetate is not readily absorbed through intact skin, but it can be absorbed more readily through cuts and abrasions. Fagerstone et al. (1994) estimated the dermal LD_{50} at 300 mg kg^{-1}. Exposure guidelines (Threshold Limit Values, TLV) for 1080 have been set in USA, with a Time-weighted average (TLV-TWA) of 0.05 mg/m^3 for skin exposure (Anon. 1991). In New Zealand the Occupational Health and Safety Service (OSH) has set a Biological Exposure Index (BEI) of 15 $\mu g\ l^{-1}$ (0.015 ppm) for 1080 in human urine (Occupational Safety and Health Service 2002).

5.1.4 Where the pesticide involves a gaseous form, what is the gaseous LC_{50} (ppm in air)?

This is not applicable for 1080.

5.1.5 Where there is dust or mist associated 1080 use, what is the dust and mist LC_{50} (ppm in air)?

There is no published information on the LC_{50} for 1080 in dust or mist. A Biological Exposure Index (BEI) of 15 $\mu g\ l^{-1}$ (0.015 ppm) for 1080 has been set by Occupational Health and Safety Service (OSH) New Zealand (Occupational Safety and Health Service 2002).

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

Three different complementary tests indicate that 1080 is not a mutagen and is therefore unlikely to be a carcinogen (Eason et al. 1999).

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

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

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

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

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

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

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

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

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

The onset clinical signs usually ranges from 30 minutes to about 2-3 hours (Eason & Wickstrom 2001), however, in one case of acute poisoning, onset of symptoms was described as within minutes (Williams 1948). Relatively few cases of human poisoning (accidental or deliberate) have been reported in the literature (22 cases, 16 of which were fatal) (Harrison et al. 1952; Brockmann et al. 1955; Trabes et al. 1983; Ellenhorn & Barceloux 1988; Anon. 1992).

Poisoning symptoms experienced include nausea, vomiting, and abdominal pain initially, followed by respiratory distress, anxiety, agitation, muscle spasms, stupor, seizures, and coma. Hypotension is thought to be one of the more important predictors of mortality in 1080 intoxication (Chi et al. 1996; Chi et al. 1999).

5.2 Treatment

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

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

There is ongoing research into antidotes for 1080 (e.g. Goncharov et al. 2006).

6. Operational

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

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

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

6.1 Animal Welfare

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

1080 toxicosis generally has a characteristic 'lag time' in mammalian species, where following intake of a lethal dose, the animal will show no visible signs of poisoning for up to a number of hours, before beginning to display symptoms (Eason & Wickstrom 2001). The onset clinical signs usually ranges from 30 minutes to about 2 - 3 hours with most deaths in mammals generally occurring 8 – 48 hours after ingestion of a lethal dose (Eason & Wickstrom 2001).

Possums

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

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

Rodents

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

McIlroy (1982) reported that ship rats exhibited a 0.8 - 27.8 hour latent period and died 2.4 - 36.5 hours after a lethal dose of 1080 was administered. Norway rats had a 0.4 – 2.3 hour latent period and a 2.5 – 112.0 hour time to death. Mice had a 1.3 – 2.8 hour latent period and 2.2 - 68.3 hour time to death. In rats observed syptoms included animals initially appearing depressed, often sitting quietly hunched in a corner or lying on their side, back or stomach with their eyes

partially closed: hypersensitivity to touch or sounds; and uncoordinated movement with unsteady balance. Respiration was initially very rapid, but became slower, shallower and more irregular until death occurred. Convulsions were commonly observed.

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

Cats

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

Rabbits

In rabbits the animal welfare impacts of 1080 are described as intermediate (MAFBNZ 2010). The onset of symptoms has been reported as ocurring between 1.1 - 10.1 hours after exposure to a lethal dose and death occuring after 3.0 - 44.3 hours (McIlroy 1981). Gooneratne et al. (1994) reported the time to death ranging from 1 to 7.5 hours in rabbits following a lethal dose. Lying prone, lethargy, respiratory distress, sensitivity to noise or disturbance and convulsions have been reported in poisoned rabbits (McIlroy 1981; MAFBNZ 2010).

Wallabies

McIlroy (1981) reported symptoms in poisoned wallabies included animals sitting hunched up; generally appearing non-alert, with shivering or shaking forelimbs and unsteady balance; convulsions and a white froth exuded from the mouth and nostrils. The latent period in Bennett's wallabies was <16.9 to 23.2 hours (7 wallbaies observed), and the time to death was 8.9 – 38.9 hours (23 wallabies observed). For dama wallabies the time to death was 13.8 - 37.1 hours. MAFBNZ (2010) describe the overall animal welfare impacts of 1080 on wallabies as intermediate compared to other vertebrate toxic agents.

Deer

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

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

6.2 Efficacy

6.2.1 Is 1080 effective on the target pest, based on the LD_{50}?

All the registered target species have relatively high susceptibility to 1080. The LD_{50} values are presented in Table 33.

Table 33. Acute oral toxicity (LD_{50} mg kg^{-1}) of 1080 to the target pests.

TARGET PEST	LD_{50} (mg kg^{-1})	REF.
Cat	0.28	1
Deer not specified	0.50	2
Mule deer	0.27 – 0.90	3
House mouse	8.30	4
Brush-tailed possum	0.79[a]	5
Rabbit	0.35	6
Ship rat	0.76	4
Laboratory rat	1.71	4
Norway rat (wild)	0.22-3.0	7
Bennett's wallaby	0.21	8
Dama wallaby	0.27	6; 8

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

1 Eason & Frampton(1991); 2 Rammell & Fleming (1978); 3 Tucker & Crabtree (1970); 4 McIlroy (1982); 5 Bell (1972); 6 McIlroy (1981); 7 Chenoweth (1949); 8 Munday (1978).

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

Target pests would have to eat at least the amounts given in Table 34 in one feeding session (at least three hours) to be likely to receive an acute lethal dose.

Table 34. Amount of bait a target pest needs to ingest to result in death based on LD_{50}.

SPECIES	LD_{50} (mg kg^{-1})	AV. WEIGHT FEMALE (g)	AMOUNT OF 0.2g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 0.4g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 0.6g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 0.8g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 1.0g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 1.5g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 2.0g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 50g kg^{-1} BAIT (g) FOR LD_{50}	AMOUNT OF 100g kg^{-1} BAIT (g) FOR LD_{50}
Bennetts wallaby	0.21	11000		-		-	-	1.5	1.2	0.05	0.02
Cat	0.28	2500		-		-	0.7	-	-	-	-
Dama wallaby	0.27	4300		-		-	-	0.8	0.6	0.02	0.01
House Mouse	8.30	20				0.21		0.1			
Norway rat	0.22	220		-		0.06	-	0.03	-	-	-
Possum	0.8	3000		-	4.0	3.0	-	1.6	-	-	-
Rabbit	0.35	800	1.4	0.7	0.47	-	-	-	-	-	-
Red deer	0.5	80000		-		-	-	26.67	-	-	0.4
Ship rat	0.76	140				0.13		0.07	-	-	-

Palatability

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

Possums

For possums, Morgan (2004) reported that under field conditions No Possums® 1080 gel blocks have a 20% decline in palatability after 36.4 months. In the same study, double wax coated 1080 pellets left in Philproof bait stations had a 20% decline in palatability after 4 months.

Mice

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

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

Other factors

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

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

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

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

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

Possums

Aerially distributed 1080 cereal pellets

The percentage kills obtained during aerial operations using 0.08% 1080 cereal pellets are presented in Table 35. For non-prefed aerial operations using 0.08% cereal pellets the mean kill was 69.1% (n=10). The mean kill for prefed aerial operations using 0.08% cereal pellets was 91.1% (n=2).

The percentage kills obtained during aerial operations using 0.15% 1080 cereal pellets are presented in Table 36. Based on this data, the mean possum kill for prefed operations is 93.2% (n=38), operation where cause of failure known excluded) and for non prefed operations 80.0% (N=21).

Table 35. The percentage possum kill for aerial operations using 0.08% 1080 cereal pellets.

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
100%	Station Creek A Trial, Jul 2006	-	5 (#7 12 g pellets)	1
82.2%	Station Creek B Trial, Jul 2006	2 (12 g pellets)	5 (12g #7 pellets, 7 days later)	1
0%	Mapara, October 1992	-	8	2
89%	Isolated Hill SR Nelson August 1992	-	4	2
96%	Titirangi Reserve Wanganui June 1992	-	5	2
50%	Puketi Forest Northland March 1992	-	5	2
32%	Mapara October 1991	-	5	2
91%	Whitecliffs Wanganui July 1991	-	6	2
61%	Waipapa EA June 1991	-	10	2
79%	Mapara September 1990	-	8	2
93%	Rangitoto Island October 1990	-	12	2

1 Josh Kemp per comm.; 2 Spurr (1993)

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

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
100%	Blue Mountains, June-July 2008	2 (12g #7 baits)	3 (12g #7 pellets coated with deer repellent, 21 days later)	1
91.3%	Manawatu Gorge, 20-25/7/2007	2	3 (5 days later)	2
100%	Parapara 07A Trial, May 2007	3 (6g pellets)	3 (12g RS5 pellets, 25 days later)	3
100%	Parapara 07C Trial, May 2007	-	3 (12g RS5 pellets)	3
100%	Hukarere A May 2007	2 (12g pellets)	2.5 (12g #7 pellets, 25 days later)	3
100%	Hukarere B May 2007	2 (12g pellets)	2.5 (12g #7 pellets, orange lure, 25 days later)	3
100%	Hukarere C May 2007	2 (12g pellets)	2.5 (6g RS5 pellets, 25 days later)	3
87.3%	Thomas River, 12-15/01/2007	1 (6g pellets)	3.5 (12g pellets, 3 days later)	4
89.4%	Mataketake, 12-15/01/2007	1 (6g pellets)	3.5 (12g pellets, 3 days later)	5
91.1%	Otaki Bio Site, 12/09-14/12/2006	2.11 (6g pellets)	2.11 (6g pellets, 93 days later)	6
100%	Otaki Core, 12/09-14/12/2006	2.11 (6g pellets)	2.11 (6g pellets, 93 days later)	6
100%	Wangapeka, Oct 2006	0.8 (12g pellets)	5 (12g RS5 pellets, 14 days later)	3
81.1%	Hawdon Valley, 12-28/9/2006	2 (6g pellets)	5 (6g pellets, 16 days later)	7
89.4%	Poulter Valley,12-28/9/2006	2 (6g pellets)	5 (6g pellets, 14 days later)	7
100%	Whenuakite, Aug 2006	2 (6g pellets)	3 (12g #7 pellets, 13 days later)	3
100%	Station Creek C Trial, Jul 2006	2 (12g pellets)	5 (12g #7 pellets, 7 days later)	3
78.4%	Waiohine/Tauherenikau, 29/08/2005	-	3 (#7 pellets)	8
90.2%	Pembroke - Block 1A, 25/01/2005	-	3 (#7 pellets)	9
84.6%	Matemateaonga Stage 1, 19/11/04, 11/1/05	-	4 (#7 pellets)	10
100%	St Andrews 11/11/2004 – 21/02/2005	2	3 (#7 pellets, 102 days later)	11
85.3%	Waiotauru, 7-8/09/2004	-	3 (#7 pellets)	12
75.9%	Mt Karioi, 20/05/2004 – 09/06/2004	2	4 (12g #7 pellets, 20 days later)	13
96.6%	Copeland River, 18-19/10/2003	2	3 (12g pellets)	14

28.1%	Copeland River, 18-19/10/2003	-	3 (12 g pellets)	14
87.6%	Kahurangi Point, 10/9/2003	-	3 (12 g pellets)	15
94.7%	Gouland Downs, 29/8/2003	-	3 (12 g pellets)	16
98%	Hutt River, 28/7/03	2	2 (12g pellets, 5 days later)	17
85.7%	Featherston / Waiorongomai Block 1 retreatment, 02/03 (GWRC op)	1.5	1.5 (10g pellets)	18
93%	Mt Pirongia, 27/8/2002	2	4 (12g pellets)	19
100%	Hampden, North Otago, 28/6/2002	2	2 (12g pellets)	20
89.7%	Featherston / Waiorongomai Block 3, Dec 01-Feb 02 (GWRC op)	2	2 (10g pellets)	18
95.5%	Featherston / Waiorongomai Block 2, Dec 01-Feb 02 (GWRC op)	2	2 (10g pellets)	18
38.2%[a]	Featherston / Waiorongomai Block 1, Dec 01-Feb 02 (GWRC op)	2	2 (10g pellets)	18
94.2%	Mt Bruce / Miki Miki, 01/02 (GWRC op)	2	2 (10g pellets)	18
90.4%	Mt Bruce / Miki Miki, 01/02 (GWRC op)	2	1 (10g pellets)	18
88.1%	Akatarawa valley, 01/02 (GWRC op)	2	2 (10g pellets)	18
84.7	Owhanga, 01/02 (GWRC op)	2	2 (10g pellets)	18
89.2%	Castlehill/Bideford, 01/02 (GWRC op)	2	2 (10g pellets)	18
77.3%	Otaki, 2001	-	3 (12 g pellets)	18
81.1%	Upper Waingawa, 2001	-	3 (12 g pellets)	18
88.3%	Marapara EA, 5/10/2001	2	3 (12g pellets)	21
97.7%	Tongariro Forest CA, 19/9/2001	2	3 (12g pellets)	22
82.9%	Ohau/Mangahao, 8/9/2001	-	3 (12 g pellets)	23
97.2%	Leslie/Karamea, 27/8/2001	-	4 (12 g pellets)	24
81.1%	Blue Mountains, 22/8/2001	1	2 (RS5 pellets)	25
57.6 %	Hackett, 31/5/2001	-	3 (12 g pellets)	26
94.0%	Featherston, 00/01 (GWRC op)	2	2 (10g pellets)	18
92.2%	Whakatikei, 00/01 (GWRC op)	1	1 (10g pellets)	18
93.2%	Otaki Crown, Jan 01 (GWRC op)	2	2 (10g pellets)	18
97.6%	Tinui, 00/01 (GWRC op)	2	2 (10g pellets)	18
81.5%	Moeatoa, 6/8/2000	-	5 (6 g pellets)	27
81.5%	Whareorino, 6/8/2000	-	5 (6 g pellets)	28
100%	Bideford, 99/00 (GWRC op)	2	2 (10g pellets)	18
97.9%	Pukunui, 99/00 (GWRC op)	1.2	2 (10g pellets)	18
95.5%	Owhanga, 99/00 (GWRC op)	2	2 (10g pellets)	18
94.0%	Wainuiomata, 98/99 (GWRC op)	3	3 (10g pellets)	18

87.0%	Arawhata, 26/4/1999	-	3.1 (6 g pellets)	29
18.3%	Okura, 24/4/1999	-	2.6 (6 g pellets)	30
84.0%	NE Tararua, 1999	-	4 (8 g pellets)	18
92.8%	Tauherenikau, 1998	-	4 (8 g pellets)	18
94.2%	Landsborough, 30/6/1998	-	4 (6 g pellets)	31
95.8%	Landsborough, 30/6/98	-	2 (6 g pellets)	31

[a] heavy thunderstorms on the evening treatment occurred damaged the bait.

1 Morriss & Nugent (2008); 2 Pestlink:0708PNT18; 3 J Kemp per comm.; 4 Pestlink:0708SWS07; 5 Pestlink:0708SWS06; 6 Pestlink:0708KAP16; 7 Pestlink:0607WMK02; 8 Pestlink:0607WRP02; 9 Pestlink:0506TEA01; 10 Pestlink:0506WHA01; 11 Pestlink:0405BUL15; 12 Pestlink:0405KAP21; 13 Pestlink:0304WAI22; 14 Pestlink:0304SWS27; 15 Pestlink:0304GDB05; 16 Pestlink:0203GDB13; 17 Wright (2004); 18 Brown & Urlich (2005); 19 Pestlink:0203WAI05; 20 Lorigan et al. (2002); 21 Pestlink:0203MPT03; 22 Pestlink:0203RUA06; 23 Pestlink: 0304KAP12; 24 Pestlink: 0203MOT19; 25 Nugent & Yockney (2001); 26 Pestlink: 0203SWS32; 27 Pestlink: 0203MPT36; 28 Pestlink: 0203MPT04; 29 Pestlink:0203SWS17; 30 Pestlink:0203SWS18; 31 Pestlink:0304SWS05.

Aerially distributed 1080 carrots

The mean percentage possum kill for operations using 0.8 g kg^{-1} 1080 carrots (Table 37) is 91.1% (n=7).

Table 38 lists aerial operations using 1.5 g kg^{-1} 1080 carrots where the percentage kill could be calculated. The mean kill for these operations was 93.7% (n=4).

Table 37. The percentage possum kill for aerial operations using 0.8 g kg^{-1} 1080 carrot.

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
93.4%	Te Kopia SR, 11-25/7/2006	2 (6g baits)	5 (6g baits, 12 days later)	1
91.8%	Whirinaki Rata Block 30/8-8/9/2005	3	5 (8 days later)	2
87.8%	Hunua Ranges, 7-8/9/2001	5	5	3
86%	Otupaka EA, 17-18/05/2000	5	10 (6g baits)	4
96.0%	Paeroa Range, 18/08/1999	5	10-15 (6g baits)	5
88.4%	Marokopa/Tawerau, 5/7/1998	5	5 (6g baits)	6
94.2%	Marokopa/Tawerau, 5/7/1998	5	10 (6g baits)	7

1 Pestlink:0607ROT01; 2 Pestlink: 0506RAN01; 3 Pestlink: 0203AKD13; 4 Pestlink: 0304RAN08; 5 Pestlink: 0304ROT05; 6 Pestlink: 0203MPT08; 7 Pestlink: 0203MPT08.

Table 38. The percentage possum kill for aerial operations using 1.5 g kg^{-1} 1080 carrot.

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
98.1%	Matakuhia, Tataraakina, July 2003	5	5 (6g baits)	1
96.3%	Wakeman's Block, Tataraakina, July 2003	5	5 (6g baits with deer repellent)	1
86.6-100%	Hampden, North Otago, 28/6/2002	2	2 (6g baits)	2
92.5%	Lake Okataina SR, 27/7/1999	5	12 (6g baits)	3

1 Nugent et al. (2004); 2 Lorigan et al. (2002); 3 Pestlink: 0304ROT04.

1080 cereal pellets in bait stations

Table 39 contains the percentage possum kills for bait station operations using 0.15% 1080 cereal pellets. The mean kill for these operations was 93.3% (N=8).

Table 39. The percentage possum kill for 0.15% 1080 cereal pellets in bait stations.

KILL	LOCATION	METHOD	REF.
83.7%	Opuiaki, Sept-Oct 2009	100 x 100 m grid, 2 prefeeds (600g per bait station), 1 toxic fill (300 g bait per station)	1
95%	Fox Valley, April-May 2008	100 x 200 m grid, 2 prefeeds (460 g per bait station), 1 toxic fill (460 g bait per station)	2
88.9%	Fox Valley, July 2007	100 x 200 m grid, 2 prefeeds (500 g per bait station), 1 toxic fill (500 g bait per station)	2
97.1%	Rotoehu EA, Oct-Nov 2007	1 bait station/ha, 2 prefeeds (1500 g per bait station), 1 toxic fill (700 g bait per station)	3
96.2%	Mokaihaha EA, October 2001	1 bait station/ha, 3 prefeeds, 1 toxic fill (1500 g bait per station)	4
94.8%	Minganui Faces, Oct 1999	0.53 bait stations/ha, 3 prefeeds, 1 toxic fill (750 g bait per station)	5
100%	Kaharoa CA, Jan 1997	0.25 bait stations/ha, 3 prefeeds, 1 toxic fill (1000 g bait per station)	6
90.6%	Minganui Faces, Nov 1996	0.53 bait stations/ha, 3 prefeeds, 1 toxic fill	7

1 Pestlink: 0800TAU01; 2 Pestlink: 0809SWS04; 3 Pestlink 0708ROT03; 4 Pestlink: 0304ROT06; 5 Pestlink: 0304RAN12; 6 Pestlink: 0304ROT09; 7 Pestlink: 0304RAN13.

No Possums® 1080 gel (1.5 g kg^{-1} *1080) in bait stations*

The mean percentage possum kill for the operations using No Possums® 1080 gel block in Table 40 is 78.4% (N=2).

Table 40. The percentage possum kill during bait station operations using No Possums® 1080 gel block.

KILL	LOCATION	METHOD	REF.
65.6%	Whareorino, August 2003	2 bait stations/ha, 1 prefeeds, 1 toxic fill (250 g bait per station)	1
91.3%	Leslie Karamea, Jan-April 2002	0.24 bait stations/ha, 1 toxic fill (500 g bait per station), used in conjunction with feracol	2

1 Pestlink: 0304MPT03; 2 Pestlink: 0203MOT19.

Handlaid 1080 cereal pellets

The mean percentage possum kill for operations using handlaid 0.15% 1080 cereal pellets (Table 41) is 88.8% (n=6).

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

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
91.7%	Stewart Island, Dec 07 – Jan 2008	No	Not specified	1
100%	Colenso Basin, Ruahines, Sept-Oct 2007	2 (6 g pellets)	1.5 (12 g pellets, 31 days later)	2
66.7%	Awarua, 3/3/2000		0.4 (8 g pellets, traps and Feratox also used)	3
90.6%	Fox Valley, 23/9/1999		0.5 (8 g pellets, traps also used)	4
94.6%	Abbey Rocks B, 2/6/1999		0.5 (6 g pellets, traps also used)	5
89.3%	Abbey Rocks C, 3/6/1999		0.5 (6 g pellets, traps also used)	5

1 Pestlink: 0809SIS02; 2 Pestlink: 0708PNT17; 3 Pestlink: 0203SWS30; 4 Pestlink: 0203SWS34; 5 Pestlink: 0203SWS28.

1080 cereal pellets in bait bags

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

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

KILL	LOCATION	METHOD	REF.
96%	Stewart Island, Oct-Nov 2008	20 x 100 m grid (not prefed)	1
97.6%	Pegasus/Tin Range Oct-Nov 2004	Grid (not prefed)	2
85% (Range: 68.8%-100%)	Paterson Inlet Blocks, Oct 2003	Bags put on recent sign (not prefed)	3
~92.6%	Mt Anglem/Hananui, Oct-Nov 2003	4.3-5.3 bait bags/ha, 1 prefeed, 2 toxic bag placements (6 g baits).	4
53.1-73.2%	Warawara Forest Blocks, Mar-Jun 2003	Bags put on recent sign (not prefed)	5

1 Pestlink: 0809SIS03; 2 Pestlink: 0405SIS04; 3 Pestlink: 0304SIS19; 4 Pestlink: 0304SIS20; 5 Pestlink: 0203KAI12.

1080 paste in bait bags

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

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

KILL	LOCATION	METHOD	REF.
56.4%	Minganui Faces, Sept-Oct 2000	Bags placed on a 75m x 10m grid, not prefed.	1

1 Pestlink: 0304RAN09.

Handlaid 1080 paste

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

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

KILL	LOCATION	METHOD	REF.
~84%	Rangitikei Snail Area, Kaimanawa FP, 2000-2002	Prefed, set on recent sign.	1
86.6%	Mortens, Canterbury	Spits 5-6 m apart around forest edge, not prefed	2
84.7%	Steventon, Canterbury	Spits 5-6 m apart around forest edge, not prefed	2
84% (Range: 50-96%)	9 sites around NZ (1996-98) – good weather conditions	Spits 5 m apart around forest edge, prefed	3
34% (Range: 0-59%)	4 sites (1997) - where rain washed out baits or hot weather dried out the baits	Spits 5 m apart around forest edge, prefed	3
76% (Range: 68-93%)	9 sites around NZ (1996-98) – good weather conditions	Spits 5 m apart around forest edge, not prefed	3
30% (Range: 11-46%)	4 sites (1997) where rain washed out baits or hot weather dried out baits.	Spits 5 m apart around forest edge, not prefed	3

1 Pestlink: 0304RAN09; 2 Ross & Henderson (2003); 3 Thomas & Morgan (1998)

Rats

Aerially distributed 1080 cereal pellets

The percentage rat kill for the aerial operations using 0.08% cereal pellets is presented in Table 45.

The percentage rat kills obtained during aerial operations using 0.15% 1080 cereal pellets are presented in Table 46. Based on this data, the mean kill for prefed operations is 98.7% (n=30).

Table 45. The percentage rat kill for aerial operations using 0.08% 1080 cereal pellets.

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
100%	Whakapohai E, Jan 2007	5 (6g baits)	2 (12g #7 pellets, 5 days later)	1
1.2%	Station Creek A Trial, Jul 2006	-	5 (12g #7 pellets, 5 days later)	1
96.3%	Station Creek B Trial, Jul 2006	2 (12g pellets)	5 (12g #7 pellets, 7 days later)	1
<70%	Mapara, Oct 1992	-	8	2
80%	Mapara, Oct 1991	-	8	2
100%	Mapara, Sept 1990	-	8	2

1 J Kemp per comm.; 2 Bradfield. (1993).

Table 46. The percentage rat kill for aerial operations using 0.15% 1080 cereal pellets.

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
100%	Kia Wharite – Matemateaonga, Nov-Dec 2008	1 (6g pellets)	2 (12g #7 pellets, 27 days later)	1
100%	Poulter Valley, Oct 2008	1 (6g pellets)	2 (6g #7 pellets, 17 days later)	2
44.1%	Heaphy Coast A, Nov 2007	-	2 (6g #7 pellets)	3
72.7%	Heaphy Coast B, Nov 2007	-	2 (6g RS5 pellets)	3
100%	Heaphy Coast C, Nov 2007	1 (12g pellets)	2 (6g RS5 pellets, 12 days later)	3
100%	Heaphy Coast D, Nov 2007	2 (12g pellets)	2 (6g RS5 pellets, 12 days later)	3
100%	Pihanga, Nov 07	2 (12g pellets)	2 (12g #7 pellets, 8 days later)	4
100%	Catlins, Aug 2007	2 (12g pellets)	3 (12 g RS5 pellets, 29 days later)	4
100%	Parapara 07A Trial, May 2007	3 (6g pellets)	3 (12g RS5 pellets, 43 days later)	4
100%	Parapara 07B Trial, May 2007	3 (6g pellets)	3 (12g #7 pellets, 43 days later)	4
90.6%	Parapara 07C Trial, May 2007	-	3 (12g RS5 pellets)	4
0%	Parapara 07D Trial, May 2007	-	3 (12g #7 pellets)	4
100%	Hukarere A May 2007	2 (12g pellets)	2.5 (12g #7 pellets, 25 days later)	4
100%	Hukarere B May 2007	2 (12g pellets)	2.5 (12g RS5 pellets, 25 days later)	4
100%	Hukarere C May 2007	2 (12g pellets)	2.5 (12g #7 pellets, 25 days later)	4
98.1%	Whakapohai A, Jan 2007	5 (6g pellets)	2 (12g #7 pellets, 5 days later)	4
100%	Whakapohai B, Jan 2007	2 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	4
100%	Whakapohai C, Jan 2007	2 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	4
100%	Whakapohai D, Jan 2007	1 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	4
98.4%	Dart/Caples, 25-30/10/2006	2	2 (6g RS5 pellets, 5 days later)	5
100%	Otaki Bio Site, 12/09-14/12/2006	2.11 (6g pellets)	2.11 (6g #7 pellets, 93 days later)	6
98.9%	Otaki Core, 12/09-14/12/2006	2.11 (6g pellets)	2.11 (6g #7 pellets, 93 days later)	6
100%	Wangapeka, Oct 2006	0.8 (12g pellets)	2.5 (12g RS% pellets, 14 days later)	4

100%	Hawdon Valley, 12-28/9/2006	2 (6g pellets)	5 (6g pellets, 16 days later)	7
100%	Poulter Valley,12-28/9/2006	2 (6g pellets)	5 (6g pellets, 14 days later)	7
100%	South Branch Hurunui Valley, 14/9-6/10/2006	2 (6g pellets)	5 (6g pellets, 22 days later)	7
98.7%	Tongariro Forest, 30/8-15/09/2006	2	4 (12g #7 pellets, 5 days later)	8
100%	Opuiaki, 18-28/8/2006	2	3 (12g #7 pellets, 5 days later)	9
94.9%	Central Coromandel, Aug 2006	2 (6g pellets)	3 (12g #7 pellets, 13 days later)	4
96.1%	Whenuakite, Aug 2006	2 (6g pellets)	3 (12g #7 pellets, 13 days later)	4
98.8%	Station Creek C Trial, Jul 2006	2 (12g pellets)	5 (12g #7 pellets, 7 days later)	4
98.0%	Waipoua Forest, 24/09 – 12/10/2005	2	3 (12g #7 pellets, 16 days later)	10
80.2%	Waipapa East, Waipapa EA, Sept 2001	2	2	11
97.8%	Waipapa North, Waipapa EA, Sept 2001	2	2	11
100%	Kaharoa, Oct 1990	2	18	12
92.1%	Makino Forest, August 1989	-	9	13

1 Pestlink:0809WHA01; 2 Pestlink:0809WMK06; 3 Pestlink:0809BUL06; 4 J Kemp per comm.; 5 Pestlink:0708WAK04; 6 Pestlink:0708KAP16; 7 Pestlink:0607WMK02; 8 Pestlink:0708RUA01; 9 Pestlink:0607TAU05; 10 Pestlink:0506KAU09; 11 Styche et al. (2004); 12 Innes et al. (1995); 13 Warburton (1989).

Handlaid 1080 cereal pellets

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

1080 cereal pellets in bait stations

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

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

KILL	LOCATION	METHOD	REF.
97.0%	Opuiaki, Sept-Oct 2009	100 x 100 m bait station grid, 2 prefeeds (600g per bait station), 1 toxic fill (300 g bait per station)	1
91.2%	Waipapa East, Waipapa EA, Aug 2000	150 x 150 m bait station grid, 2 prefeeds, 1 toxic fill	2
87.7%	Waipapa North, Waipapa EA, Aug 2000	150 x 150 m bait station grid, 2 prefeeds, 1 toxic fill	2
85.5%	Waipapa South, Waipapa EA, Aug 2000	150 x 150 m bait station grid, 2 prefeeds, 1 toxic fill	2
100%	Trounson Kauri Park, Nov 1996	100 x 100 m bait station grid, 4 prefeeds, 1 toxic fill	3

1 Pestlink: 0800TAU01; 2 Matthew et al. (2004); 3 Gillies et al. (2003).

Mice

Aerially distributed 1080 cereal pellets

The percentage mouse kill for the aerial operations using 0.08% cereal pellets is presented in Table 48. The percentage rat kills obtained during aerial operations using 0.15% 1080 cereal pellets are presented in Table 49. Based on this data, the mean kill for prefed operations is 90.0% (n=12).

Table 48. The percentage mouse kill for aerial operations using 0.08% 1080 cereal pellets.

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
58%	Whakapohai E, Jan 2007	5 (6g pellets)	2 (12g #7 pellets, 5 days later)	1

1 J Kemp per comm.

Table 49. The percentage mouse kill for aerial operations using 0.15% 1080 cereal pellets.

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
93.4%	Poulter Valley, Oct 2008	1 (6g pellets)	2 (6g #7 pellets, 17 days later)	1
100%	Pihanga, Nov 07	2 (12g pellets)	2 (12g #7 pellets, 8 days later)	1
86.2%	Parapara 07C Trial, May 2007	-	3 (12g RS5 pellets)	1
37.3%	Parapara 07D Trial, May 2007	-	3 (12g #7 pellets)	1
97.0%	Parapara 07A Trial, May 2007	3 (6g pellets)	3 (12g RS5 pellets, 43 days later)	1
92.0%	Parapara 07B Trial, May 2007	3 (6g pellets)	3 (12g #7 pellets, 43 days later)	1
100%	Whakapohai A, Jan 2007	5 (6g pellets)	2 (12g #7 pellets, 5	1

			days later)	
66.7%	Whakapohai B, Jan 2007	2 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	1
96.4%	Whakapohai C, Jan 2007	2 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	1
86.0%	Whakapohai D, Jan 2007	1 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	1
50.0%	Dart/Caples, 25-30/10/2006	2	2 (6g RS5 pellets, 5 days later)	2
100%	Otaki Bio Site, 12/09-14/12/2006	2.11 (6g pellets)	2.11 (6g #7 pellets, 93 days later)	1
100%	Wangapeka, Oct 2006	0.8 (12g Pellets)	2.5 (12g RS5 pellets, 14 days later)	1
100%	Tongariro Forest, 30/8-15/09/2006	2	4 (12g #7 pellets, 5 days later)	1

1 J Kemp per comm.; 2 Pestlink: 0708WAK04.

1080 cereal pellets in bait stations

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

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

KILL	LOCATION	METHOD	REF.
94%	Trounson Kauri Park, Nov 1996	100 x 100 m bait station grid, 4 prefeeds, 1 toxic fill	1

1 Gillies et al. (2003).

Wallabies

The percentage kill of wallabies using aerially distributed 1.5 g kg^{-1} 1080 carrot is presented in Table 51 and in Table 52 for handlaid 5% and 10% 1080 gels.

Table 51. The percentage wallaby kill for aerially distributed 1.5 g kg^{-1} 1080 carrots.

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
93.1%	Okataina SR, 1999 (Dama wallabies)	5	12	1

1. PESTLINK: 0304 ROT04

Table 52. The percentage wallaby kill for handlaid 5% and 10% 1080 gel.

KILL	LOCATION	METHOD	REF.
86.2%	Okataina SR, 1988 (Dama wallabies)	5-10 m x 50-100 m transects, 5 baited leaves/branch (5% 1080 gel)	1
91.3%	Tasman Smith SR, Hunter hills, 1983 (Bennett's wallabies)	10 branches/ha, 25 baited leaves/branch (10% 1080 gel)	1

1. Warburton (1990)

Deer

The percentage kill of deer is presented in Table 53 for aerially distributed 1.5 g kg^{-1} 1080 carrot is and in Table 54 for handlaid 10% 1080 gel.

Table 53. The percentage deer kill for aerially distributed 1.5 g kg^{-1} 1080 carrots.

KILL	LOCATION	SOWING RATE (kg ha^{-1})		REF.
		Prefeed	Toxic	
92%	Titiraupunga, 1997	5	15	1
34%	Pureora, 1994	5	15	2
42%	Pureora, 1994	15	15	2

1 Fraser & Sweetapple (2000); 2 Fraser et al. (1995)

Table 54. The percentage deer kill for handlaid 10% 1080 gel.

KILL	LOCATION	METHOD	REF.
79%	Hauhangaroa Range, 1997	2 branches/ha, 10 baited leaves/branch	1
80%+	Stewart Island, 1981	2.5 branches/ha, 20 baited leaves/branch	2
100%	Stewart Island, 1981	5 branches/ha, 20 baited leaves/branch	2

1 Sweetapple (1997); 2 Nugent (1990).

Goats

10% 1080 gel (100 g kg^{-1} *1080), handlaid*

The percentage kill of goats using handlaid 10% 1080 gel is presented in Table 55.

Table 55. The percentage kill of goats following the use of handlaid 10% 1080 gel.

KILL	LOCATION	METHOD	REF.
88%	Whitecliffs, Buller River, Jul 2007	2.2 branch/ha in preferred habitat, 10 - 20 baited leaves/branch	1
87%	Motu River, Jan 1986	1 branch/ha in preferred habitat, 20 baited leaves/branch	2
97%	Motu River, March 1982	2.5 branches/ha, 20 baited leaves/branch	3

1 Anderson (2008) Docdm-231336; 2 Veltman & Parkes (2002); 3 Parkes (1983)

7. Glossary of Terms

µg kg^{-1}, µg l^{-1}

See ppb.

µg g^{-1}, µg ml^{-1}

See ppm.

Absciss

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

Aconitase

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

Biological Exposure Index (BEI)

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

Biosynthesis

The production of a chemical compound by a living organism.

bw

Body weight

Carcinogenic

The ability of a substance to cause cancer.

Citrate

A salt or ester of citric acid.

Cyanosis

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

Defluorination

To remove fluorine

Endocardium

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

Epicardium

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

Epiglottis

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

Fluorocitrate

The toxic metabolite of fluoroacetate that causes inhibition of aconitase.

Gastrointestinal tract

The stomach and intestine as a functional unit

Glial cells

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

Half-life

During each half life (t½ or elimination half-life) 50% of the pesticide in the body at the beginning of that half-life is eliminated. The half-life is established in laboratory trials, and is used to predict the rate of elimination of a single dose of pesticide from the body and to estimate how long the disappearance of cumulative intakes of a pesticide from the body would take.

Hypotension

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

Intravenous

Administered into a vein.

LC_{50}

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

LD_{50}

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

LOEL

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

Mitochondrial aconitate hydratase

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

Metabolites

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

mg kg^{-1}**, mg** l^{-1}

See ppm.

mmol (, mM)

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

Mutagenic

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

NOEL

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

Non-saponifiable lipids

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

Oral

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

Phosphofructokinase

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

ppb

parts per billion. This concentration unit is equivalent to 1 µg l^{-1} in water (solution) or air and 1 µg kg^{-1} in solid samples (soil/sediments/biological tissue).

ppm

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

Succinate dehydrogenase

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

Subepicardial

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

Teratogen

A compound that causes birth defects in a developing foetus.

Toxicosis

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

Toxin

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

Toxicant

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

Trachea

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

Tricarboxylic acid cycle

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

Threshold Limit Values (TLV)

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

Viscera

Body organs.

VPRD

Vertebrate Pesticide Residue Database. (DOCDM-32812)

8. Common and Scientific Names of Species

Amphibians

Archeys frog	*Leiopelma archeyi*
Bullfrog	*Rana catesbeiana*
Hochstetters frogs	*Leiopelma hochstetteri*
Leopard frog	*Rana pipiens*
South African clawed frog	*Xenopus laevis*
Spotted grass frog	*Limnodynastes tasmaniensis*

Aquatic invertebrates/Crustaceans

Daphnia	*Daphnia magna*
Koura	

Birds

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

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

Eutherian mammals

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

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

Fish

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

Marsupial mammals

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

Reptiles

Blue tongued lizard	*Tiliqua nigrolutea*

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

Terrestrial invertebrates

Cave Weta	*Pharmacus sp. and Isoplectron sp.*
Cockroaches	*Blattidae*
Compost worms	*Eisenia fetida*
Honeybees	*Apis mellifera*
Leaf-veined slugs	*Athoracophorus bitentaculatus*
tree weta	*Hemideina crassidens*
Ground Weta	*Hemideina thoracica*

Plants

cabbage	*Brassica oleracea*
gifblaar	*Dichapetalum cymosum*
käpuka (New Zealand broadleaf)	*Griselinia littoralis*
käramuramu	*Coprosma robusta*
peanut	*Archis hypogeae*
perennial ryegrass	*Lolium perenne*
puha	*Sonchus* spp.
pikopiko	*Asplenium bulbiferum*
rat weed	*Palicourea margravi*i
ratsbane	*Dichapetalum toxicarium*
sugar cane	*Saccharum spp.*

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Appendix 24

DOC code of practice for aerial 1080 in kea habitat

Version 1.0 approved for use effective from 1 June 2014.

The code will be reviewed by 1 February 2016. The code is a working draft and will be finalised when the supporting research is published.

Approved by

Suzanne Edwards
Acting Deputy Director-General Science and Capability
Date: 5 May 2014

Supported by

Kevin O'Connor
Deputy Director-General Conservation Services
Date: 23 April 2014

Date	Amendment details	Version Number
7 May 2014	Working draft of the Code released	1.0
10 October 2014	New DOCgis shapefile of kea habitat; minor typo corrected in flowchart, missing reference added	1.1

1. Purpose

This code of practice sets out the compulsory performance standards that must be followed for aerial 1080 operations in areas where kea may be present on land managed by the Department of Conservation (DOC). These compulsory performance standards apply throughout the distribution of kea (Appendix 1). This includes new standards to achieve effective control of stoats with all aerial 1080 operations, so that any potential kea deaths are offset by improved productivity and survival. By designing operations to control stoats, we can reverse the decline of kea at managed sites.

This code is based on our current understanding of the risks and benefits of aerial 1080 to kea. Relevant research is summarised in four areas: predators of kea; non-target risk to kea at aerial 1080 cereal operations; benefits to kea from predator control via aerial 1080 cereal operations; and repellents to protect kea at aerial 1080 cereal operations.

2. Summary of kea research

2.1 Predators of kea

The kea is a large parrot endemic to the Southern Alps of New Zealand and is the world's only mountain parrot (Higgins 1999). Kea were re-classed from 'Not threatened' to 'Nationally Endangered' by Robertson et al. (2012); the criteria for this classification are a population estimate of 1000–5000 and an ongoing or predicted decline of 50–70% in the total population over the next 10 years due to recruitment failure. In order to prevent this decline, effective predator control is critical.

The kea is vulnerable to a range of introduced mammalian predators due to its ground-nesting habit and extended nesting cycle (i.e., it takes four months to fledge young, Jackson 1963). Kemp et al. (2014) identified the key predators of kea using a combination of nest cameras, corpse necropsy and inference from predator density fluctuations during nest survival monitoring. Nest cameras recorded visits by stoats, possums, ship rats, house mice and weka. Stoats were identified as the predator in 3 of the 16 nest failures recorded while no positive identification was possible for the other cases. Statistical modelling of the effect of predator visitation on nest survival suggests that visits by stoats, possums and rats were predictors of nest failure, with the strongest support for stoat visits. Two predation events were confirmed by corpse necropsy; one death by stoat predation was confirmed by DNA analysis and the other kea was predated by either a falcon or stoat. Kemp et al. (2014) also analysed the survival odds of kea nests at a rimu forest before, during, and after a mast event with

no predator control. Survival odds were related to changes in stoat abundance but not to changes in rat abundance, implicating stoats as the important predator.

We have photographs of a possum appearing to kill kea chicks (DOC no date). However stoats are the far more important predator, particularly following mast events when kea nest failure and predation of juveniles and adults are at their greatest.

2.2 Non target risk to kea from aerial 1080 cereal operations

DOC is concerned about the potential population impact of kea deaths observed at some aerial 1080 cereal operations. Kea survival has been monitored through 10 aerial 1080 cereal operations in 9 locations (Appendix 2). Kea were captured and tagged with VHF radio transmitters prior to the operation; the transmitters were fitted with motion sensors that record the time (hour) when motion ceased. A total of 150 kea were monitored and 20 kea deaths resulted from consuming 1080 (Kemp and van Klink 2014). All 20 kea deaths occurred in the 3 operations where we monitored the largest samples of birds (Appendix 2). It may be that kea in these locations are at higher risk for some site specific reason. It is also possible that kea deaths were not detected at the other sites due to small sample size.

It appears that most kea ignore 1080 pellets but a small number are poisoned by them. Half (10) of 20 of the detected kea deaths occurred the day after 1080 baits were sown; 6 occurred within 2–5 days and 3 occurred within 10–14 days. One bird died 35 days after the operation but 1080 poisoning could not be confirmed by the time the corpse was recovered. Bright green contents (1080 cereal remains) were found in the gizzard or crop of the 18 corpses recovered in time for autopsy (Kemp and van Klink 2014; van Klink and Crowell 2014). This indicates direct poisoning of kea from eating 1080 cereal (as opposed to secondary poisoning from possum carcasses) and that probably more than one pellet was consumed. 1080 was detected in muscle tissue for all of the 11 birds tested.

2.3 Benefits to kea populations from predator control via aerial 1080

Predator control needs to take place on a landscape scale to protect kea nests from predation by stoats for two reasons:

- Kea breeding pairs and nests are found at a low density (Jackson 1960) so broad scale control is needed to cover even a small number of nests. For example, Bond and Diamond (1992) estimated that there were between 0.14 and 0.40 nests per hectare.
- Stoats have a large home range and dispersing young are capable of long distance travel (King and Murphy 2005). Stoats are short lived with high productivity (up

to 13 young per year when food supply allows) so localised small scale control measures are quickly undone by immigration. Methods must target female stoats are essential to achieving effective control. For example, an extensive area must be controlled to when stoats are targeted to protect other threatened bird species, such as Okarito kiwi (Miller et al. 2001).

Aerial application of 1080 baits is one of the main methods of rat and possum control on a landscape scale in New Zealand and can be effective for reducing stoat numbers through secondary poisoning. Murphy et al. (1998) first recorded a reduction in a stoat population following aerial 1080 by secondary poisoning; they observed prey remains in 12 of 13 radio-tracked stoat corpses after the operation including rat remains in 8 corpses and possum remains in a single corpse. Rats are reliable vectors for poison, based on consistent rat kills at aerial 1080 cereal pellet operations which are pre-fed (Fairweather et al. 2013) and on their common occurrence in the stoat diet (King and Murphy 2005). The significance of possums and mice as poison vectors for stoat control is less certain and has not been directly measured (i.e., in the absence of rats). Data on mouse kill from aerial 1080 cereal pellet operations appears to be variable, although we do not know if this will affect stoat kill (Fairweather et al 2013). If rats aren't present in a forest, such as at high altitudes or in pure beech forests, we are unsure of the extent of the stoat by-kill that would be achieved.

The potential benefit to kea populations from aerial 1080 cereal operations has been investigated by Kemp et al. (2014), through long term monitoring of kea productivity and survival at sites before and for 2 kea breeding seasons after aerial 1080 operations. This included a controlled (before-after-controlled-impact or BACI) study with a non-treatment area for a lowland rimu forest in Westland and a correlative modelling approach for 5 upland beech forests.

The BACI study monitored predator dynamics and kea nests before and after an aerial 1080 operation in the spring of a mast year (2011) at Okarito forest in Westland, as compared to the same measures at nearby Fox-Paringa forest where predators were not controlled. Aerial 1080 reduced the stoat tracking index to near zero for 2 kea nesting seasons whereas the stoat tracking index increased to about 80% in the year after the mast (the 'post seedfall year') at Fox-Paringa (Appendix 3). Kea nest survival was estimated in the treated area as 100% in the mast (seedfall) year and 69% in the post seedfall year, whereas nest survival in the untreated area was estimated as 38% and 1% respectively. During the 2 breeding seasons after the rimu mast, kea productivity was estimated at 4 times higher at the treated area (1.4 fledglings per adult female) than at the untreated area (0.32 fledglings per adult female).

Kemp et al. (2014) also monitored predator dynamics and kea productivity and survival at 5 upland beech forests, 3 of which were treated with aerial 1080 (including stoat trapping at one site). Beech mast (seedfall) occurred in all five upland beech forests in 2009, followed by a stoat irruption in early 2010. They

concluded that kea productivity is near zero during uncontrolled stoat irruptions in beech forest, as it was in rimu forest. In the years between mast events, kea productivity is 0.44 fledglings per adult female on average, but this increases to 0.95 fledglings per female with effective stoat and possum control. Again, this was similar to what was observed in rimu forest.

Operations need to occur when rodents are widespread in order to achieve effective stoat control. At Mt Arthur, the operation took place in May 2009, when rodent numbers were still climbing following beech mast seeding (Appendix 3). Monitoring showed that the stoat irruption was not prevented (Appendix 3), several adult kea disappeared and no kea nests were found despite extensive searches.

In summary, effective stoat control improves kea productivity and survival whereas unchecked stoat irruptions following mast years are strongly negative to kea populations. In order to make up for the few adult kea sometimes killed in aerial 1080 cereal operations, all operations should be designed to achieve stoat control. This can be achieved easily during and soon after a mast year, provided operations are timed for when rats are widespread. However it is less clear cut between mast years. For example:

- Effective stoat control appears more likely where rats are widespread in the operational area, but we do not know for sure if this is true when rats are scarce but mice and/or possums are widespread. Mice can be very patchy in their distribution in non-mast years.
- We know lowland mixed forests usually have rats but in upland pure beech forests they can be scarce between mast events. The transition from prevalent to low rat densities is likely to happen somewhere between 500 and 700m in mixed forests depending on the site and the season.

2.4 Repellents to protect kea at aerial 1080 cereal operations

The Department of Conservation is working with others to develop, register and implement an effective bird repellent to prevent kea deaths at aerial 1080 cereal operations (Crowell 2014). A number of trials have taken place in aviaries (Orr-Walker et al. 2012), pens (Cowan et al. 2013), and in the field (Kemp 2010, Crowell et al. 2014b, van Klink and Crowell 2014) since 2008, focussing on d-pulegone (which has a strong minty odour disliked by birds) and anthraquinone (which birds learn to avoid after post-ingestional discomfort). The research program is working to overcome limitations for each of these repellents. For d-pulegone, the focus is on stabilising the compound in cereal baits because monitoring has shown that it dissipates in manufacture and storage (Crowell et al. 2014a, van Klink and Crowell 2014). The addition of anthraquinone at the level used in the trials (0.1% wt/wt) seems to be detected and avoided by rats (Cowan et al. 2013). The proportional

reduction in rat tracking was less in plots where both repellents were used, as compared to plots where d-pulegone or no repellents were used (Crowell et al. 2014b). The rat and kea responses to lower concentrations will be investigated; this may include using anthraquinone in experimental plots within an aerial 1080 cereal operation. Other repellents have been identified for preliminary screening with wild kea in 2014.

We are preparing for an aviary trial to test whether kea can be repelled from eating cereal pellets that contain anthraquinone (without d-pulegone). If successful, we will look at the feasibility of feeding kea non-toxic repellent cereal pellets prior to some operations, such as at car parks and huts, as part of the risk management.

None of the repellents are ready for operational use in 2014, other than a possible trial of anthraquinone in plots to monitor rat kills and a possible kea bait aversion programme at some operations should aviary trials provide strong evidence of efficacy. Whilst an effective repellent would prevent deaths of kea at aerial 1080 operations, we still need to reduce stoat predation in order to reverse the decline of this species.

3. Compulsory performance standards in kea habitat

This code of practice states and explains the compulsory performance standards that will apply to all pest operations aerially applying 1080 within the distribution of kea (Appendix 1) on land managed by DOC, using one of the following registered methods:

- Aerially applied 0.15% 1080 Pellets (pesticide use #1 on the DOC Status List)
- Aerially applied 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets (pesticide uses #7 and #10)
- Aerially applied 0.2% 1080 Pellets (targeting wallabies, pesticide use #22) or 0.04% 1080 Pellets (targeting rabbits, pesticide use #14) and aerially applied 1080 carrot (pesticide uses #25, 30, 33)

3.1 Aerially applied 0.15% 1080 Pellets

There are two sets of compulsory performance standards for all operations using aerially applied 0.15% 1080 Pellets within the distribution of kea (Appendix 1). The first set aims to reduce kea deaths and the second aims to ensure benefit to kea from stoat control.

3.1.1 Compulsory performance standards to reduce kea deaths:

Standard 1: Only use cinnamon-lured RS5 pellets.

Standard 2: Use a maximum of 2kg/ha of prefeed bait for 12g baits (or 1kg/ha for 6g baits).

Standard 3: Use a maximum of 2kg/ha of toxic bait for 12g baits (or 1kg/ha for 6g baits).

RS5 pellets are required because both Luey (2009) and Blyth (2011) observed a preference for Wanganui #7 baits amongst captive kea. The lure must be cinnamon because all kea monitoring has followed aerial operations using this lure. We do not know how other lures would affect bait attractiveness to kea.

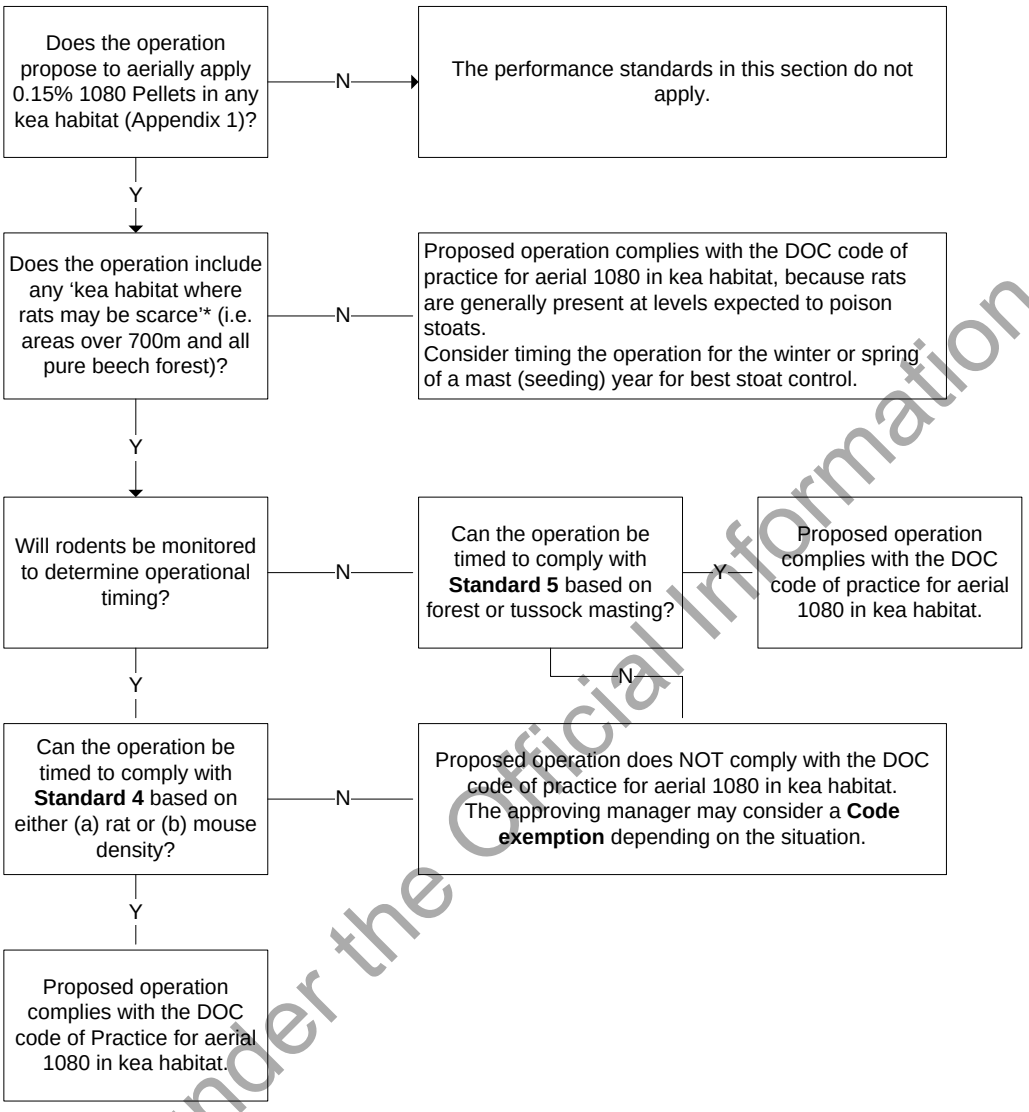
We restrict the prefeed sowing rate in order to limit kea encounters with prefeed pellets. Kea consumption of prefeed pellets could increase the likelihood that kea eat toxic bait.

We restrict the toxic sowing rate in order to limit kea encounters with toxic pellets.

A previous standard has been removed, which prevented baits being sown in areas of low structural vegetation cover (e.g. alpine herb fields and tussock) above the tree line. This was intended to protect kea by keeping baits out of open areas that could be easily avoided. Subsequent kea deaths at Okarito and Otira suggest that most kea ignore 1080 pellets but a small number will find and eat them whether they are highly visible or not. This draws into question the effectiveness of the alpine exclusion standard. At the same time, a need for predator control in alpine environments is emerging (O'Donnell 2013). Stoats and mice are prevalent predators in the alpine zone and possums are significant predators of snails.

3.1.2 Compulsory performance standards to ensure that kea benefit from stoat control:

This flow chart is designed to determine whether Standard 4, Standard 5 or neither standard applies to a proposed 0.15% 1080 cereal operation in kea habitat.



*A shape file of kea habitat (Appendix 1) is available to DOC staff on DOC gis:
http://intmaps/richmapviewer/?Viewer=DOCgis&Project=7d6f3bb6-aaf2-4aa2-8c1f-d9391e0ee504

Shape files of 'kea habitat where rats may be scarce' are available to DOC staff on:
DOC gis (http://intmaps/richmapviewer/?Viewer=DOCgis&Project=dc59ec29-b795-4321-b030-a7c642a16558)

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It can also be viewed on the DOC geoportal by searching on the keyword "kea" on:
http://geoportal.doc.govt.nz/geoportal/catalog/main/home.page

Standard 4: Toxic bait application can occur when either (a) or (b) are met:

(a) Within 6 months prior to the operation, the tracking index for **rats** is 20% or higher on 8 out of 10 transects monitored in the operational area (following Gillies and Williams 2013).

Or

(b) Within 6 months prior to the operation, the tracking index for **mice** is 20% or higher on 8 out of 10 transects monitored in the operational area (following Gillies and Williams 2013). In this case, rats and mice must be monitored (ideally 2 weeks) before and after the operation; this monitoring should also include stoats where suitable transects are in place. Monitoring results must be reported and raw data made available, including any pre- and post-operational monitoring of possums (where completed, to allow the role of possums in secondary poisoning of stoats to be evaluated).

In both (a) and (b) where operations occur in the year following a forest or tussock mast, toxic bait application must occur prior to 31st August in the post-seedfall year (i.e. prior to kea nesting, see Appendix 3, Figure 3).

The above rodent-based thresholds are based on our current understanding of stoat poisoning via aerial 1080 operations. Stoats do not eat 1080 baits but can be poisoned when they prey on rats (and possibly mice and possums) that have taken bait. These thresholds will be revised over time as we learn from future operations.

Because stoats are the main predators of kea, we expect that nest survival and kea productivity to improve in the two years following an effective stoat knockdown (Kemp et al. 2014). Timing operations to benefit kea should offset any kea deaths that might occur at some operations.

Standard 5: Where rodent monitoring has not been done, toxic bait application can occur when the operation includes forest or tussock in a mast (seedfall) year or in the year following (post-seedfall), as determined either by seed monitoring or by expert judgement. In this case toxic bait must be applied in the 14 month period between 1st July of the mast (seeding) year and 31st August of the following year.

This standard allows mast seeding to be used as a proxy for rodent density where rodent monitoring data is not available, such as for some possum operations. The timeframe is based on the trend of rodent and stoat abundance observed in previous beech and rimu masts (Appendix 3, Figures 1-3).

Code exemption: Where standard 4 or 5 have not been met, aerial operations using 0.15% 1080 Pellets can only proceed in kea habitat where rats can be scarce at the discretion of the manager approving the permission. The approving manager will take the following factors into consideration:

- Potential number of kea put at risk
- Existing data on pest numbers (possum, stoat, rat, mouse)
- Other measures in place to control stoats
- Any early indications of upcoming mast seeding events

Handlaid 0.15% 1080 Pellets

In most cases, handlaying is used in conjunction with aerial application and all the same standards will be compulsory. For operations that are entirely handlaid, the above performance standards are recommended. Some or all of these standards may be compulsory for a specific operation, at the discretion of the DOC manager who approves the DOC permission for the operation.

3.2 Aerially applied 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets

These pesticide uses are subject to a **compulsory restriction:** Aerial application of 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets is **PROHIBITED** in areas of kea habitat (Appendix 1) on land managed by the Department of Conservation (DOC).

This product is only available in the Wanganui #7 formulation, which was preferred over RS5 pellets by captive kea in 2 aviary trials (Luey 2009; Blythe 2011).

Handlaid 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets

It is recommended that 0.08% 1080 Pellets and 0.08% Rodent Pellets are not handlaid where kea are present, given that it is only available in the Wanganui #7 cereal formulation. The decision to prohibit or allow handlaying of 0.08% 1080 Pellets or 0.08% Rodent Pellets lies with DOC manager who approves the DOC permission for the operation.

3.3 Aerially applied 0.2% 1080 Pellets or 0.04% 1080 Pellets and aerially applied 1080 carrot

These pesticide uses are subject to a **compulsory information need**: Any aerial 1080 operation in kea habitat (Appendix 1) using 0.2% 1080 Pellets, 0.04% 1080 Pellets or 1080 carrot must be monitored for kea survival (with support from DOC Science & Capability and following Kemp and van Klink 2014 or van Klink and Crowell 2014).

Kea monitoring requires specialist skills, involving capture of kea and tagging them with VHF radio transmitters weeks or months before poison baiting. Telemetry surveys are carried out during the risk period following the operation, on foot and from aircraft.

No aerial 1080 operations using these cereal baits have been monitored for kea survival so the risk is unknown. The cereal baits used to target wallabies (0.2%) and rabbits (0.04%) are different from either RS5s or Wanganui #7s and neither is lured with cinnamon.

Two kea were monitored and survived in one aerial 0.08% 1080 carrot operation in 2007 (Kemp and van Klink 2008). This method is seldom used in kea habitat, but any future operations need to be monitored to help quantify the risk to kea. Carrot is eaten by captive kea and may be attractive to wild kea.

Handlaid 0.2% 1080 Pellets, 0.04% 1080 Pellets or 1080 carrot

It is recommended that any handlaid 1080 operation in kea habitat (Appendix 1) using 0.2% 1080 Pellets, 0.04% 1080 Pellets or 1080 carrot is monitored for kea survival.

4. Frequently asked questions

1) When using 0.15% 1080 Pellets, the 'performance standards to reduce kea deaths' refer to a maximum sowing rate of 2kg/ha for 12g baits. Our target sowing rate is 2 kg/ha but we allow for 3–4 kg/ha to allow for overlapping swathes. Does this comply?

   Yes. The maximum sowing rate in the standard is an average or nominal sowing rate.

2) The 'performance standards to reduce kea deaths' no longer include a standard to avoid sowing open areas above the tree line. Is sowing above the tree line encouraged to protect kea?

   No. The standard was removed for two reasons. First, kea have found and consumed toxic bait in two operations where this standard was applied. We now question the importance of vegetation cover in preventing kea from consuming toxic baits. Second, the previous standard prevents application of bait in alpine and tussock areas for predator control to protect threatened alpine species like rock wren. The benefit of predator control in alpine environments could outweigh the potential non-target risk of visible toxic baits in some places. This balance will be evaluated on a case by case basis in the DOC permission process for each aerial 1080 operation where sowing is proposed to occur above the tree line.

3) We are planning to sow 0.15% 1080 Pellets in some open alpine areas to protect rock wren. What is the best timing to achieve this, considering that there could be snow for some of the year? Should rocky areas above the tussock be excluded?

   Avoid sowing toxic baits on snow. With regard to rocky outcrops, these should be evaluated along with other timing and boundary decisions in operational planning. Seek advice from technical and science advisors for your situation.

4) Our aerial 1080 operation using 0.15% 1080 Pellets targets possums not rats. Do the 'performance standards to ensure kea benefit from stoat control' apply to this operation?

   Yes, the performance standards apply throughout kea habitat irrespective of the target pest. Follow the flow chart to see how your operation is affected.

5) I have checked the 'Kea habitat where rats can be scarce' shape file and only 10% of our operational area overlaps with the shape file. Do we need to comply with the 'performance standards to ensure kea benefit from stoat control'?

This should be discussed with the assessor at the time of application for DOC permission. Any decision to exempt a DOC permission from the Code is at the discretion of the approving manager for the DOC permission.

6) For standard 4, do we need to establish monitoring transects in all high altitude (>700m) or pure beech forest areas included in the operation? Does the operational area need to be stratified when designing the monitoring?

   Gillies and Williams (2013) state that "it is very important to ensure that representative environments are sampled within the areas you are interested in (e.g. a rodent control block). The easiest way to do this is to consider the gross environment types that make up your study site or management block and what proportion of the area they make up. So, for example, if 50% of your study area is red beech forest, then 50% of your sampling effort should include that environment." Apply this protocol to your monitoring design. This would provide coverage of all major habitat types in your operation including any at higher altitudes. Formal stratification is not usually necessary.

7) For standards 4 and 5, the 'deadline' for operations in the year following the mast (i.e., the post-seedfall year) is 31st August. What if we plan our operation for June or July, but sustained poor weather means that we miss this deadline?

   The intention is to time the operation to achieve stoat control prior to kea nesting (see Appendix 3, Figure 3). If all practical steps have been taken to achieve this but this deadline is still not met, the operation should proceed as early as possible thereafter.

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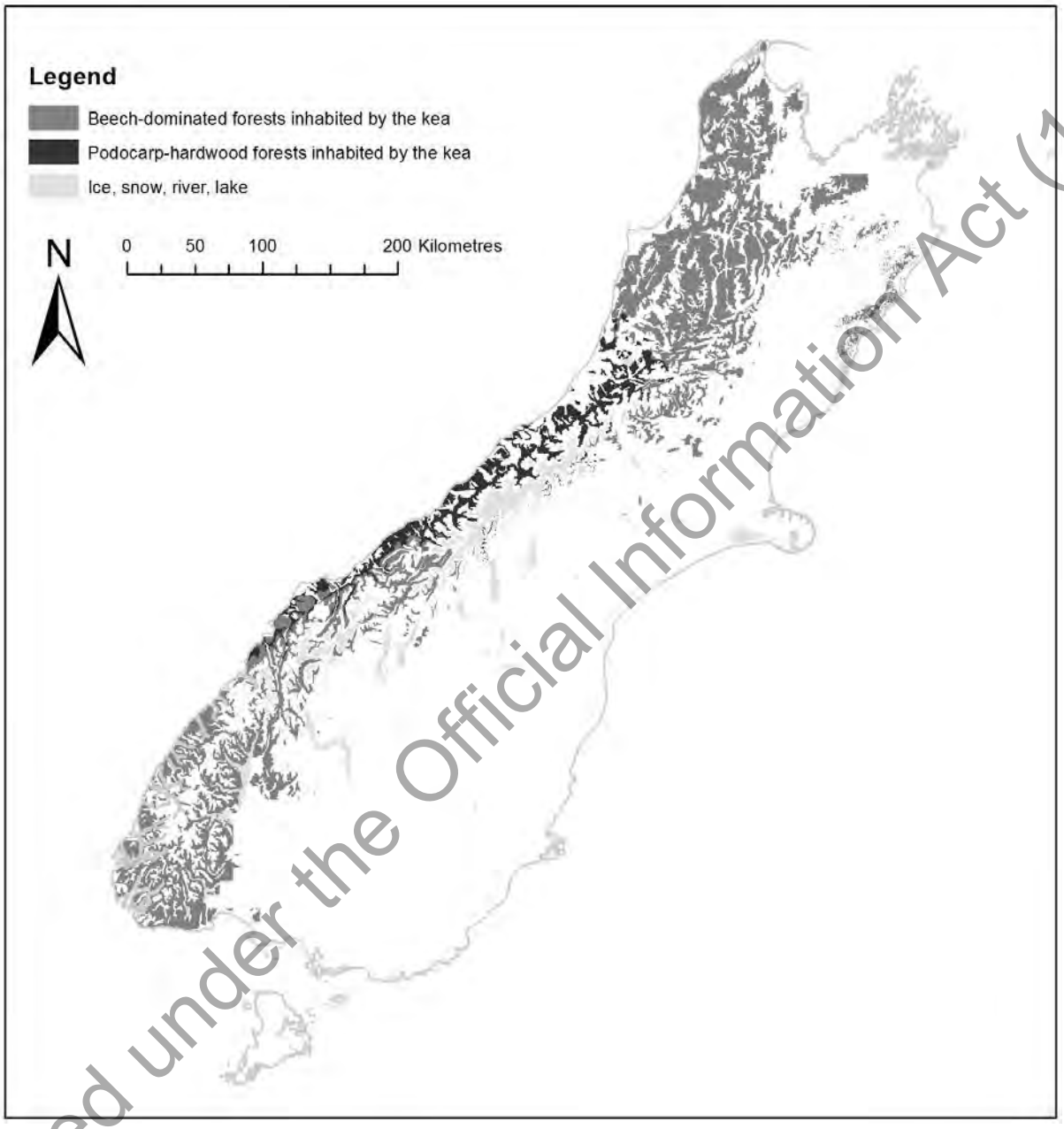
Van Klink, P.; Crowell, M. 2014: Kea (*Nestor notabilis*) survivorship through a 1080 cereal operation with the bird repellent d-pulegone at Otira, Central Westland. Department of Conservation (unpublished). 26p.

Appendix 1: Map of kea distribution



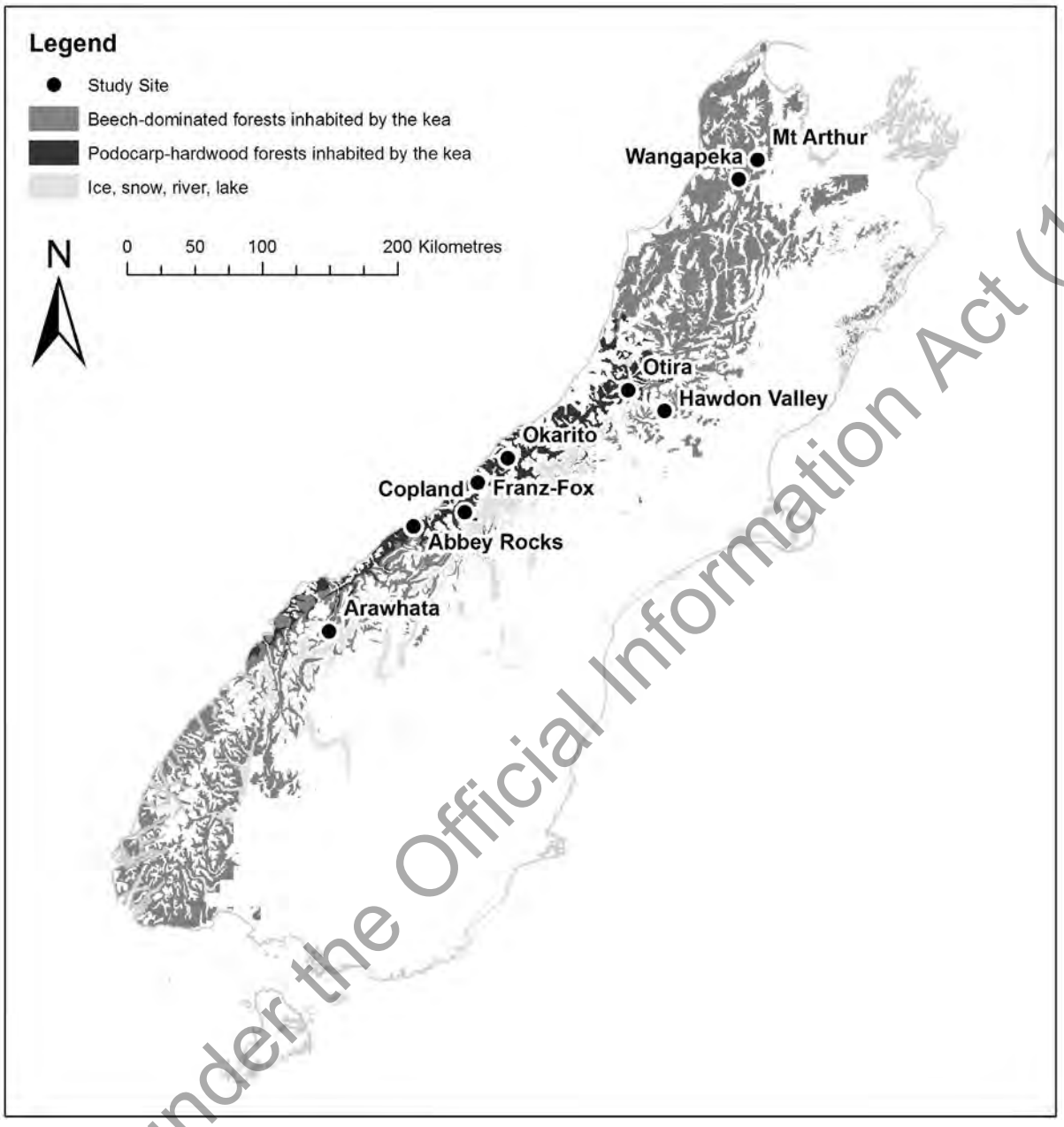
The distribution of kea in the South Island of New Zealand. A shape file is available to DOC staff on DOC gis:

http://intmaps/richmapviewer/?Viewer=DOCgis&Project=7d6f3bb6-aaf2-4aa2-8c1f-d9391e0ee504

Appendix 2: Kea monitoring

Operation	Number of birds followed	Deaths recorded	Probability of survival	Lower 95% confidence bound	Upper 95% confidence bound
Arawhata 2008	10	0	100%	74.1%	100%
Fox-Franz 2008	17	7	58.8%	32.9%	81.6%
Mt Arthur 2009	13	0	100%	79.4%	100%
Hawdon 2009	10	0	100%	74.1%	100%
Okarito 2011	37	8	78.4%	61.8%	90.2%
Wangapeka 2011	13	0	100%	79.4%	100%
Abbey Rocks 2011	8	0	100%	68.8%	100%
Copland 2012	2	0	100%	22.4%	100%
Hawdon 2012	6	0	100%	60.7%	100%
Otira 2013	34	5	85.3%	68.9%	95%
Total	150	20	86.7%		

Sample size and outcomes for kea with known fates monitored before and after aerial 1080 cereal operations (from Kemp and van Klink 2014).



Location of the 9 aerial 1080 cereal operations where kea survival was monitored between 2008 and 2013.

Appendix 3: Pest abundance graphs

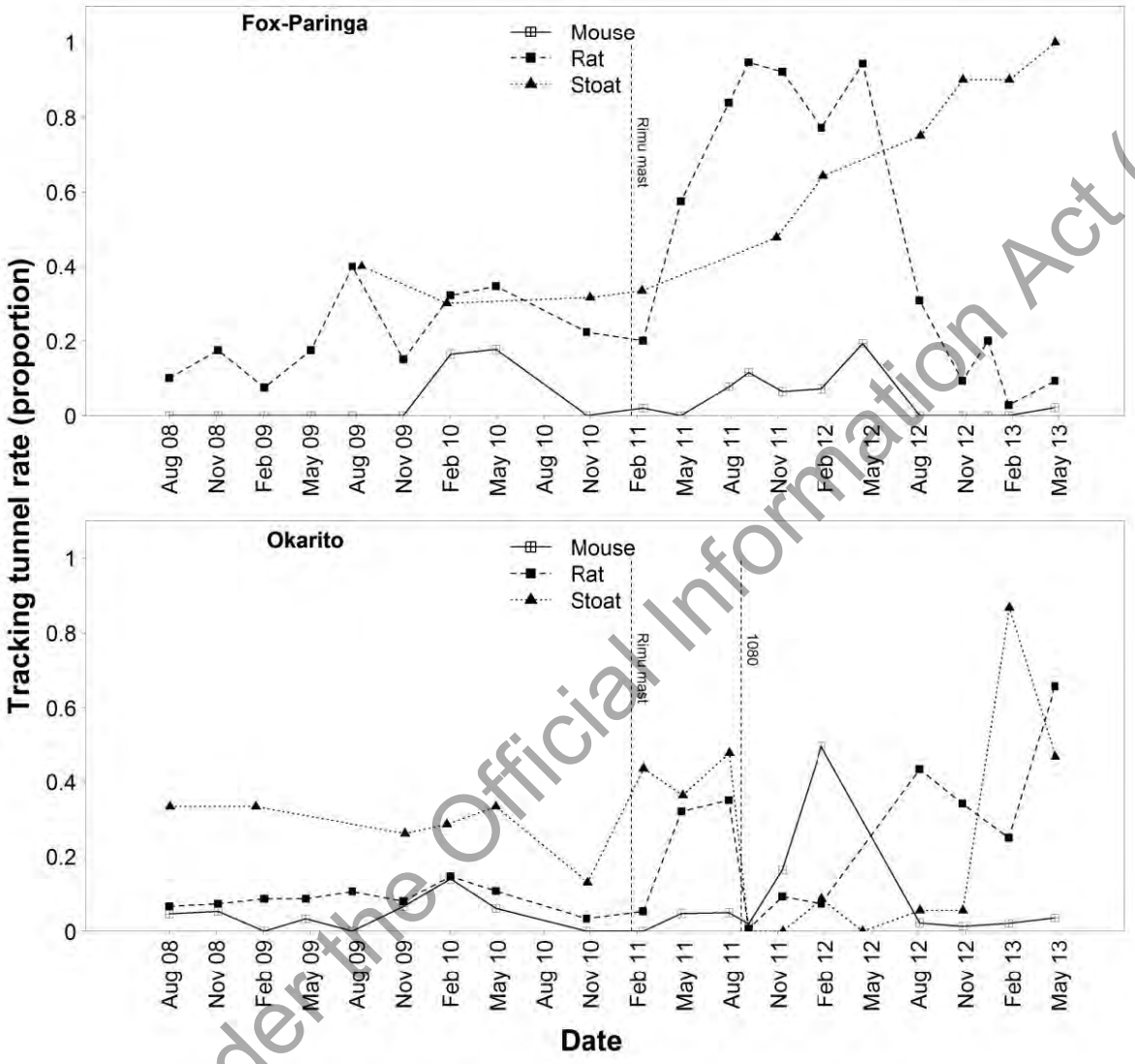


Figure 1 Relative abundance of stoats, rats and mice in a rimu mast year and in the following ('post-seedfall') year. An aerial 1080 cereal operation occurred at Okarito whereas Fox-Paringa received no predator control.

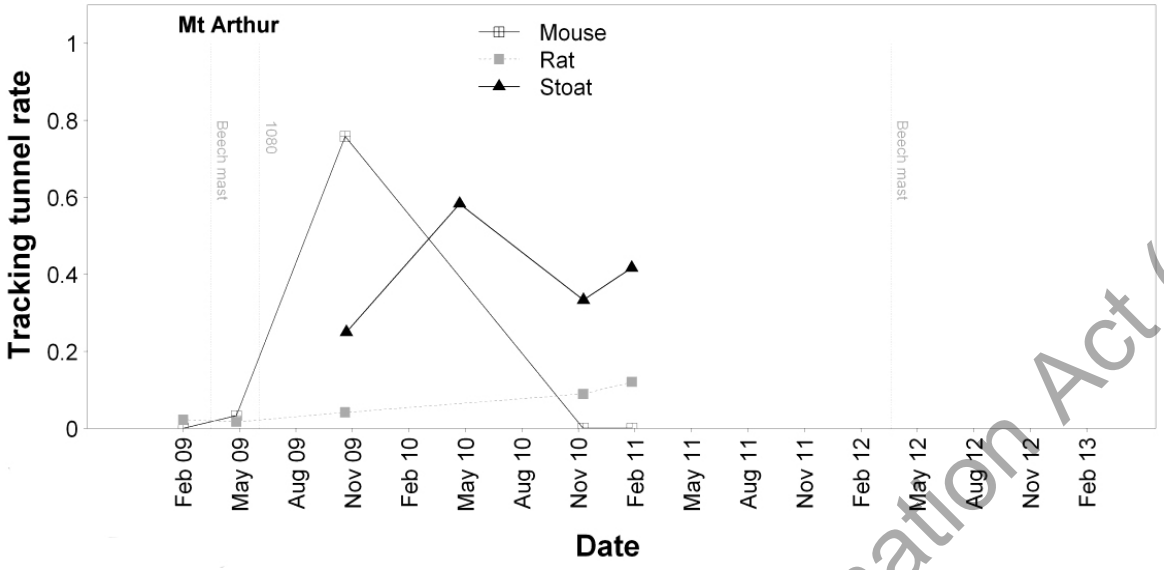


Figure 2 Relative abundance of stoats, rats and mice in a beech forest. An aerial 1080 cereal operation occurred at Mt Arthur in a beech mast year before rodents were abundant.

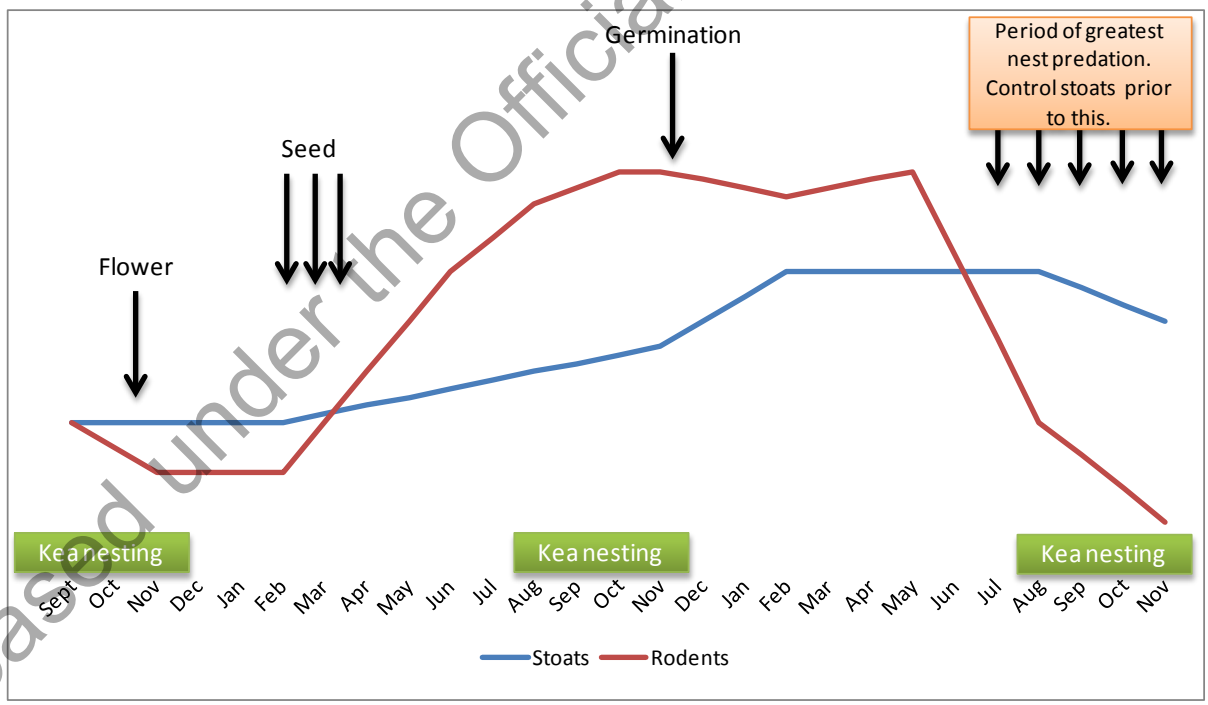


Figure 3 Illustration of how rodent and stoat tracking indices fluctuate during and after a beech or rimu mast. See also King and Murphy (2005) for a 4-year generalised model of the beech mast cycle with respect to mice and stoats.

Appendix 25

Workshop summary
5 July 2013

Developing an alpine biodiversity research programme: a review of issues and management solutions

2013-onwards

Attendees: [redacted]

Workshop aims
The aim of this meeting was to discuss the scope and content of an alpine biodiversity research programme. Specifically:

1. Summarise the strategic needs and management problems
2. Discuss significance, current knowledge and gaps in relation to biodiversity and predator impacts
3. Develop a conceptual model for managing alpine biodiversity
4. Identify the scope of the programme
5. List priority questions
6. Discuss synergies with other 'higher altitude' research and management projects
7. Identify work plan tasks for the 2013-2014 financial year

1. Strategic needs and management problems
Alpine ecosystems (i.e. high altitude ecosystem types above the timberline) form some of the most extensive and significant environments in New Zealand (>30%).They support some of the richest areas of biodiversity in the country and for some species, the last refuge. New Zealand's alpine fauna has traditionally been thought of as relatively secure from the impacts of introduced mammalian predators because cold temperatures limit activity of mammals above the treeline. However, increasingly, data are being collected that indicate that introduced predators are contributing to significant declines in threatened birds, reptiles and invertebrates including our only truly alpine bird, the rock wren. In addition, browsing by introduced herbivores is seen as having significant impacts on endemic plants and ecosystem integrity.

The Department of Conservation has identified a set of priority ecosystem types for management nationally (Ecosystem Management Units, EMUs). These include 14 alpine ecosystem types, which collectively form about 25% or 700,000 ha of EMUs However, we currently have no best practice management tools to undertake effective pest control to reverse declines in biodiversity at high altitude. Nor do we have much understanding of how predation risk varies in seasonally, annually or geographically.

2. Significance of high altitude ecosystems for biodiversity
Participants discussed a wide range of topics around threatened biodiversity, impacts of predators, browsers and climate change. A range of presentations were used to focus the discussion:

1. Introduction to alpine biodiversity, issues and priorities DOCDM-1242642 ([redacted]): In this presentation we discussed the characteristics of unique biodiversity of the alpine zone and the threatening processes that have been identified. We focused on the bird, invertebrate and reptiles, and particularly the growing evidence for unsustainable impacts of predators. Stoats and mice are prevalent predators in the alpine zone and possums are significant predators of snails but there is uncertainty about importance of other predators (e.g., pigs, hedgehogs). Case studies, including kea, alpine weta, lizards and Hutton's shearwater were discussed.

2. Impacts of stoats on rock wrens DOCDM-1233648 ([redacted]): We conducted a nesting study of rock wrens during the 2012/13 summer season in the Homer and Gertrude Valleys, Fiordland. All 20 nests we monitored failed; ten were attributable to stoat predation and cause could not be determined with certainty for the other ten. Adult birds were killed on the nest in at least three (up to seven) predation events. However, only low numbers of both stoats and mice were detected through tracking tunnel monitoring. Our results point to the episodic nature of predation on rock wrens, which can occur even when predators are at low density.

3. Significance of predators for *Powelliphanta* snails DOCDM-1243188 ([redacted] A large number of threatened *Powelliphanta* snails live above or near the timberline. Possums in particular, but also pigs and thrushes, are significant predators. Predator control programmes have showed some positive but slow recovery responses. Possum control operations need to be extended upwards from forest areas to improve protection of alpine snails.

4. Climate change and alpine invertebrates DOCDM-1242590 ([redacted]): Two major predictions of climate change scenarios for alpine invertebrates are (a) increased predation risk as predators expand their range and numbers and (b) increased fragmentation and the chance of local extinctions as snow pack and vegetation community changes occur. Long term research is needed to evaluate these predictions and develop management strategies.

5. Research on rats and climate change DOCDM-1209088 ([redacted]): Historic evidence that suggests ship rats are limited by temperature and altitude but as climate warms, it has been predicted that there will be increased occurrence and impacts of rodents at high altitude. From a DOC operational perspective, if rats are moving up the hillside we need to know when and to what extent and develop control strategies.

6. Other topics discussed included:

    a. The need for a landscape-level approach to stoat management for protection of species (such as kea) that use a variety of habitats including the alpine zone ([redacted]). Pest control techniques need to be evaluated for non-target risk prior to deployment. Current work investigating kea repellents in 1080 bait will determine whether this toxin can be aerially broadcast in the alpine zone.

b. Evaluating drivers of distribution of 'alpine' lizard species ([redacted]). Work in Sinbad Gully suggests a correlation between relict lizard distributions and prevalence of mice. The role of mice in lizard (and invertebrate) declines in the alpine zone needs evaluating.
c. Vulnerable invertebrates as indicators in the alpine zone [redacted] Grasshoppers appear to be a non-preferred food source in the diet of stoats and would not be a good indicator of the impacts of mice. In contrast, wētā are a preferred food item and have strong potential as an indicator.

3. A conceptual model for restoring alpine ecosystems

Participants reviewed and refined a conceptual model developed for high altitude habitats in the Eglinton Valley (Slides 26-29 in DOCDM-1242642), then used the model and previous presentations as a catalyst to identify information needs and focus on key objectives and threats. The broad conservation targets for the alpine/subalpine zone are to maintain and restore:

- Alpine community structure
- Browse-sensitive flora
- Predator-sensitive fauna

Discussions exposed a very large number of questions about the impacts of predators on alpine biodiversity, relative predation risk and highlighted the lack of predator control tools.

4. Scope of the research programme

The proposed research programme will focus on understanding the impacts of introduced predators on alpine biodiversity and developing management techniques though adaptive management experiments. Research on climate change mitigation and on impacts and control of browsers is also warranted. However, based on the evidence of which threats are the most significant and the amount of indicative funding for the programme, it is prudent to focus on developing predator control tools in the first instance.

5. Priority questions

1. How do we manage predator threats and at what scale (time and space)?
   - Principle – control should be at broad landscape scale control (>1000 ha scale; likely to need to trial efficacy of toxins).
   - We need to adopt an adaptive management approach.
   - We likely need different scales for different target taxa or high value biodiversity 'hotspots'.
2. What are the specific impacts of predators on different taxa?
   - We have some information about impacts on birds and *Powelliphanta* snails, and some inferences about impacts on reptiles. However, more detailed information about impacts on long-term viability of populations of threatened species and specific information on impacts on other invertebrates and lizards is needed.
3. How does predation risk vary spatially (altitude and geographically) and with time (short and long term)?
   - Predation risk probably varies in time and space, possibly in cycles. We need to identify patterns so can target management effectively.

- Alpine predation risk is likely to be affected by what's going on in adjacent forest habitats.
- We may need to monitor browser numbers too if they constitute significant alternative food sources for predators.

4. How do we measure and monitor predators and biodiversity at high altitude (tool development)?
   - We need to modify monitoring methods used in other habitat types so we can monitor predators effectively.
5. Where are the biodiversity hotspots and what are their characteristics?
   - Examine idea that biodiversity values are patchy in alpine zones.
6. How will climate change influence predation risk?
   - Predator numbers, particularly rodents are forecast to increase significantly with climate warming, implying a need to increase capability for predator control at high altitudes. Species that currently occur rarely in alpine habitats may invade and become problems (e.g., hedgehogs, wasps).
7. What are the risks posed by new invasives/ invasion ecology
   - Similarly, climate change may increase invasion of weeds or other invasives into these alpine zone.

6. Synergies and collaborations

There are a large number of synergies and potential collaborations that can be used to develop a comprehensive and integrated research programme. These include:

- Existing DOC species programmes (e.g., takahē, Haast tokoeka, rock wren, snails, kea, Hutton's shearwater etc)
- DOC threats programmes (rats and climate change, bird repellents)
- University programmes
- Community groups (e.g., Friends of the Cobb)
- Landcare Research climate change research (rats and climate change – [redacted] etc)

7. Work plan 2013-2014

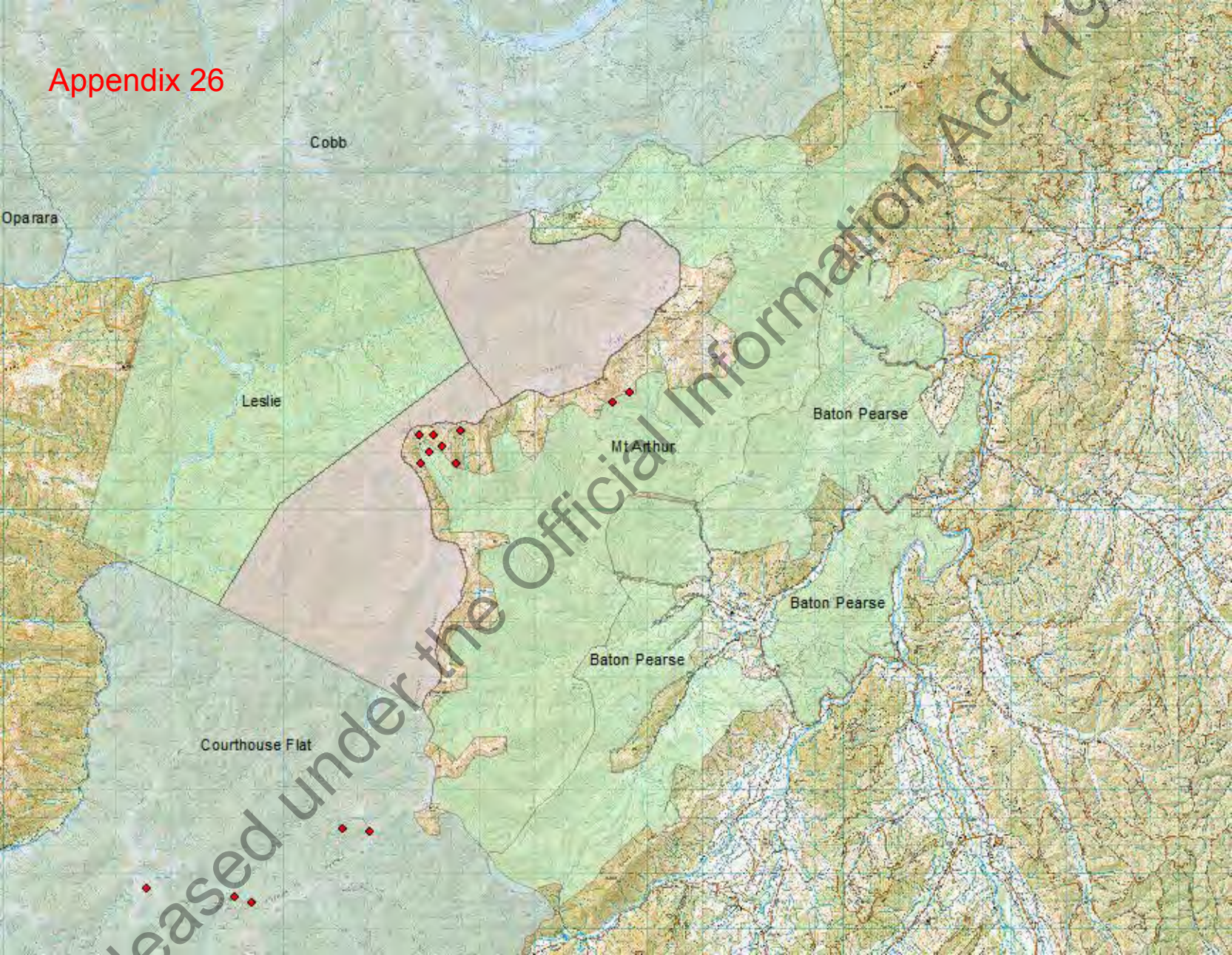
1. Conduct a review of significance of alpine ecosystems for fauna, knowledge of impacts of predators, gaps and priorities to guide development of the programme.
2. Continue rock wren nesting success study.
3. Develop several low cost pilot studies for implementing 2013/14 that lead towards designing pest control experiments. Potential candidates include:
   a. Mouse ecology
   b. Monitoring Barrier skinks (see Slides 30-31 in DOCDM-1242642)
   c. Developing monitoring methods for scree wētā
4. Identify locations of all alpine EMUs and management actions proposed in order to look for potential alpine study areas to trial landscape scale experimental pest control in future years.
5. Set up a network of monitoring sites in study areas selected in (4) above that monitor predator levels and associated ecological factors (e.g., fruit and seed phenology, climate etc). Complement the network with input from other research programmes.
6. Develop detailed work and business plans for future years to answer priority questions.

Programme co-ordinators

9(2)(a), 9(2)(g)(ii) [redacted] and 9(2)(a), 9(2)(g)(ii) [redacted]
Terrestrial Ecosystems and Species Unit
Department of Conservation — *Te Papa Atawhai*
PO Box 4715, Christchurch 8140

16 July 2013

Appendix 26



Appendix 27

Appendix 28

Comments on Project R-80719-03, Pest efficacy of bird repellent at an aerial 1080 cereal operation

A well designed, executed and analysed field trial.

The project report identified that d-pulegone when included in cereal prefeed and 1080 baits at ~0.17%wt/wt was not quite as effective at killing rats as standard baits (still achieved 96 – 100% reduction), but was better than the combined repellents (d-pulegone and anthroquinone) when used in prefeed and d-pulegone in the 1080 baits. There didn't appear to be any significant difference in effects on possum kill, though in five out of six blocks, possum kill was less than 90%.

Under the treatment, it identifies that a buffer was created around each block in an effort to provide independence of treatments. It is assumed that the buffer received the same treatment as the block, but no monitoring lines were allowed to fall into the buffer areas. Is that assumption correct?

With respect to the Recommendations, I question whether the second question is worth pursuing, as the lower the concentration to reduce rat avoidance, the less likely it is to have an effect on kea. With respect to the first question this should be investigated, but it needs to be realised that any reduction in volatility of d-pulegone may impact on the likely repellent effect. I suggest as an additional recommendation, the need to investigate other potential chemicals (similar to d-pulegone?) that maybe less volatile, but still repellent to kea and non-repellent to rats and possums.

9(2)(a), 9(2)(g)(i)

This report presents the results of a field trial to test whether the addition of bird repellents to cereal pellets affects the kills of pest species during aerial 1080 operations. The trial was well designed and the results are clearly reported. It is a pity that the results suggest that in addition to volatility issues with the d-pulegone, the addition of the repellents to cereal pellets affects their efficacy on rats.

This report will ultimately be published as a DOC science publication. I have no concerns with the results or the way they are presented. My comments are of a minor nature:

- The title appears a little stilted. I suggest it is reworded.
- Sentence 4 of abstract and first sentence of paragraph 3 of the introduction 'Repellents were used … of New Zealand'. Change the word treatments to treatment.
- The reference Orr-Walker et al. 2012 is in the text, but not in the reference list.
- The operational area is on the true right of the Haast River, not the true left as stated in the 'Trial location' (page 6).
- Second sentence of paragraph 2 on page 10 (in data analysis section) 'Given the two … of observing a possum track or a bite mark … is evaluated as:'. It should read 'Given the two … *of observing a rat track or a possum bite mark* … is evaluated as:'
- Second sentence of paragraph 5 on page 10: Insert (DIC) after the words

'Deviance Information Criterion'. In the next sentence add the words 'Akaike Information Criterion' before 'AIC'.

- References: delete 'b' after the date 2011 in reference Werner et al 2011.

The poor efficacy of cereal pellets on rats does not necessarily negate the use of the repellents during TBfree operations where possums are the only target pest. However, the volatility of the d-pulegone remains an issue. If further research into d-pulegone is going to be undertaken, then a method reducing the volatility of the compound needs to be found.

9(2)(a), 9(2)(g)(ii)

Good report, robust statistical treatment has been applied. Good monitoring of the d-pulegone concentration during storage and operation. The drop of levels is well documented here and questions around stability prior to operation use are brought up.

The conclusion that neither repellent treatment could effectively used in operation indicates that further research is required.

9(2)(a), 9(2)(g)(ii)

Appendix 29

Mokihinui
Aerial possum control
Spring 2014

What are we doing?

TBfree New Zealand manages our national programme to control and eradicate bovine tuberculosis (TB) in cattle and deer herds.

In New Zealand, the main carriers and transmitters of TB to livestock are possums. This means possum control is a vital part of the TBfree programme, along with regular herd testing, slaughter of suspect livestock TB cases and controls on the movement of cattle from herds and areas of high TB risk.

Annually, TBfree New Zealand plans and implements a possum control programme on the West Coast which takes into consideration information from surveys of wildlife density, recent and historic findings of TB in wildlife, herd testing results and the operational history of the region. As a part of the 2014/15 programme, the Mokihinui aerial possum control operation is planned for September/October 2014. The Mokihinui operation is part of a strategy where TBfree New Zealand will continue to keep infected herd numbers down through ongoing targeted control of possums. The operation will cover about 48,200 hectares (see map overleaf).

[Insert operational map]

Why are we doing it?

TBfree New Zealand's goal is to eradicate bovine tuberculosis (TB) – a highly infectious disease that affects domestic cattle and deer herds, and which can cause tuberculosis in humans. TB-infected wild animals, mainly possums, are responsible for most new herd infections on the West Coast, as shown by investigation of new TB cases and by the dramatic impact possum control has had on reducing the number of infected herds. TB-infected wild animals are known to inhabit nearly 40 per cent of New Zealand, including most of the West Coast. Controlling the disease is vital to prevent livestock production losses and protect the international reputation of the country's dairy, beef and deer exports.

[Insert West Coast timeline – 1967 to 2013]

Why are we targeting possums?

In order to eradicate bovine TB from infected populations, possum numbers need to be kept extremely low – around one to two animals over 10 hectares, which can be measured as a trap catch rate of no more than 2%. Regular control (both ground and aerial 1080) has been undertaken in parts of the Mohikinui block over the last 10 years with the northern part of the block last flown in 2008. Further possum control is now required to maintain a low possum density so as to minimise the risk of disease spread, and to prevent infection of farmed cattle and deer.

What happens next?

All landowners/occupiers within and adjacent to the proposed control area will be contacted and visited by the TBfree New Zealand contactor well ahead of the operation to discuss boundary issues, water supply safety and management of any risks to dogs and livestock.

TBfree New Zealand is required to obtain consents for the operation from West Coast Regional Council and the Ministry of Health.

Affected landowners/occupiers will be contacted again before the operation starts, notices will be published in local newspapers and warning signs will be placed at all likely access points to the operational area.

What will it involve?

The operation will begin with helicopter distribution of non-toxic, tan-coloured cereal pellets at a rate of 1kg per hectare. This "pre-feed" gives possums a taste for the pellets and overcomes potential bait shyness. About one to two weeks later, toxic, green cereal pellets containing biodegradable sodium fluoroacetate (also known as 1080) will then be applied by helicopter at a rate of 2kg of bait pellets per hectare (roughly one bait to every 60 square metres).

This operation will have strict requirements for safety, quality assurance and monitoring. GPS navigational equipment will be used to make sure bait is placed accurately. This technique has historically been very successful in controlling possum numbers to extremely low levels.

[Insert photo of bait – prefeed and toxic]

Why have we chosen this method?

The majority of TBfree New Zealand possum control work on the West Coast is done by local contractors, using traps and hand-laid toxins. The remaining control work – including the Mokihinui operation – involves the aerial application of biodegradable 1080 cereal baits.

Aerial bait application is the preferred control method for areas such as Mokihinui, given the size of the area to be treated and the rugged nature of the terrain. It is a highly efficient, cost-effective and safe method of controlling possums.

1080 is biodegradable and does not persist in the environment or in animals that consume a non-lethal dose. In June 2011, the Parliamentary Commissioner for the Environment strongly endorsed its continued use in New Zealand.

TBfree New Zealand's contribution to conservation has been commended by the country's biggest conservation organisation, Forest & Bird.

Biodiversity benefits

The Mokihinui operation will have conservation benefits for native flora and fauna. Threatened species are struggling to breed under normal predator pressures, but this year they will struggle even more due to the anticipated beech mast and resultant high predator numbers.

Mammalian pests are the greatest threat to ecosystem functioning and species conservation in NZ. Possums, ship rats and stoats are all implicated in the incremental and sometimes catastrophic degrading of forest ecosystem condition and species loss.

Possums eat the forest canopy and are one of the major predators of forest birds, preying on eggs, chicks and adults. Possums are a significant predator of *Powelliphanta* snails. Biodegradable 1080 is also very effective at controlling the other two major forest predators: ship rats and stoats, both of which are a major source of predation on forest birds and eggs.

Reducing these predators will enable a higher nesting success for a range of forest bird species found in the Mohikinui area such as blue duck (whio), great spotted kiwi, kea, kaka and kakariki. The control work will also protect populations of threatened long-tailed bats and *Powelliphanta* snail species found in the area.

To learn more about the biodiversity benefits of pest control visit www.doc.govt.nz/battleforourbirds

[insert 2 x images – 1 x native land snail; 1 x blue duck or great spotted kiwi]

Important Information

Warning signs will be placed at all main access points to the operational area and everyone must follow the cautions on these signs. There is no health risk in using this area if the following precautions are observed:

- **DO NOT** handle any bait. Cereal baits containing 1080 are dyed green.
- **DO NOT** allow children to wander unsupervised.
- **DO NOT** hunt or take game from within a 2km radius of the poison area for either human or pet consumption. It is an offence to sell meat products which have been exposed to 1080. Hunting can resume four months after control or after two months if 100mm of rain has fallen.
- **DO NOT** take dogs into this area until the warning signs have been removed. Dogs are very susceptible to 1080 poisoning – even a tiny amount will kill them. It is critical that they do not have access to bait and are not allowed to scavenge carcasses, which remain toxic to dogs until they are fully decomposed.

Please observe these rules whenever you see warning signs about the pesticide. Warning signs indicate that pesticide residues may still be present in the baits or animals. When signs are removed, this means that you can resume normal activities in the area. These signs will remain in position for at least six months following the operation.

[insert no dog symbol]

Is there any risk to public drinking water during or after the operation?

No. 1080 is highly soluble in water and biodegradable, and does not persist in water or soil.

Local health authorities apply strict conditions to all aerial 1080 operations to make sure drinking water supplies are not contaminated. Safety has been confirmed by tests on several thousand water samples taken after aerial 1080 operations over many years.

What do I do if I suspect poisoning?

- Contact your local doctor or hospital, or dial 111
- National Poisons Centre 0800 POISON – 0800 764766
- In the case of a domestic animal being poisoned, contact a local veterinarian.

Further Information

If you require any further information please contact:

TBfree New Zealand West Coast office
P.O. Box 535
Greymouth 7840
Tel: 03 769 9098
Email: vectornsi@tbfree.org.nz
Website: www.tbfree.org.nz

Contractor
XXXX Contractor
Tel:
Email:

For more information on how and why sodium fluoroacetate is used in New Zealand please visit **www.1080facts.co.nz**

Appendix 30

Recommended next steps in repellent research (from Kea repellent wrap up meeting 230714)

A list of five research areas were identified by the group as the recommended next steps toward developing a bird repellent to protect kea in aerial 1080 cereal operations. We used the earlier 'next steps' list from the March stakeholder meeting as a starting point, and amended this in light of the aviary trial results. This list of research areas should be used to guide the choice of research to complete as funds become available.

Before further trials are completed with kea, we need to define that an acceptable level of kea mortality in an aerial 1080 operation. This would give us a threshold of how effective the repellent needs to be in order to prevent the decline of the local kea population. This should be defined using [redacted] modelling. In general terms the current model suggests that mortality in the order of 10% of the local population would still have a positive benefit (assuming good nest survival post-operation for 2 years). This figure needs to be refined through some further analysis using [redacted] model.

An effective repellent would eliminate kea deaths from consuming 1080 baits, however this will not reverse the decline in kea without sustained stoat control. Research is required to increase the scale, frequency and effectiveness of stoat control. This includes:

- Refining our understanding of the conditions required for effective stoat control in aerial 1080 operations (e.g., are mice an effective vector for 1080 poisoning of stoats in the absence of rats?)

- Developing other broad scale stoat control tools that can be used between aerial 1080 operations (e.g. best practice for PAPP in bait stations, new methods for using PAPP such as the spit fire or aerial application, improvements to stoat trapping regimes)

The research list is not in priority order as it may be that the funding, personnel or time frames available dictate which project is tackled first.

1. Continued investigation of anthraquinone as a secondary repellent, for situations where:

- Possums are the only target (e.g., TBfree NZ) or

- Rats are absent from the site or not the priority target

For example, we need to define the maximum concentration of anthraquinone that could be used without affecting possum kills (noting that 0.25% AQ is the maximum we can use without affecting the current EPA approval for 1080 pellets or causing prefeed pellets to become hazardous). Further trials could be completed pairing anthraquinone with other cues. We recommend that green prefeed is used in further trials, as it is the least preferred colour for kea and provides consistency with the appearance of toxic baits. If anthraquinone is not used in both phases of an operation, further work would be needed to either mask the appearance of anthraquinone in prefeed or to add a compound to 1080 baits that looks the same to a parrot.

2. Seek advice from food technologists and chemists (e.g., Food Technology Massey, Plant & Food Ltd.) on likelihood and pathway for developing a stabilisation method for d-pulegone in cereal

matrix. This advice would be reviewed to decide whether to pursue the repellence trials outlined in 3 and whether to invest in stabilisation.

3. This research would be carried out if the stabilisation advice is favourable. Carry out a kea behavioural trial using d-pulegone RS5 cereal pellets, to confirm whether d-pulegone acts as a primary repellent in its own right. If it is a repellent, then we need to invest in stabilisation. If it is just a cue we could use something else with anthraquinone. The trial involves a second visit to look for evidence of habituation. We note that the trials to date would suggest it is a acting as a cue for secondary repellent at the concentrations we have been working with. For this reason, a higher nominal concentration of d-pulegone should be used for this trial.

4. Carry out preliminary field screening of other potential repellents. Put the repellent on known attractive bait (butter, cheese, live huhus) and see how wild kea react. Huhus have benefit that it would be recognised as a food. We can rule out any repellents where kea seem to feed on the food readily. Small quantities would need to be sourced of the candidate repellents:

- Tannic acid
- Caffeine (LCR)
- Cinnamamide
- Garlic oil

5. Test whether the Willowbank aviary kea would readily consume 0.14% anthraquinone baits if re-presented with the baits in several months time. Given that three of the kea learned to avoid these baits it would be interesting to see how they respond to the baits after a period of non-exposure.

Appendix 31

DOC code of practice for aerial 1080 in kea habitat

Approved for use effective from DATE 2014
This code is a working draft and will be finalised when the supporting research is published.

Approved by
Felicity Lawrence
Deputy Director-General Science & Capability
Date:

Supported by
Kevin O'Connor
Deputy Director-General Services
Date:

Executive summary

Kea were re-classed from 'Not threatened' to 'Nationally Endangered' by Robertson et al. (2012); the criteria for this classification are a population estimate of 1000–5000 and an ongoing or predicted decline of 50–70% in the total population over the next 10 years due to recruitment failure. The main agent of decline for kea is stoat predation, which occurs on at all life stages from eggs and nestlings to juveniles and adults. Stoat predation on kea is greatest in the year following mast events, when stoat numbers peak. Stoats need to be controlled at a landscape scale to prevent the decline of kea, such as through aerial 1080 cereal operations. Where aerial 1080 operations reduce stoat numbers through by-kill, we have observed better kea nest survival and productivity for up to 2 seasons. On the other hand, operations that took place when rodents or stoats were scarce are unlikely to have benefited kea. Kea have been poisoned in 3 of the 10 aerial 1080 cereal operations monitored since 2008.

This code sets out the compulsory performance standards that must be followed for aerial 1080 operations in areas where kea (*Nestor notabilis*) may be present on land managed by the Department of Conservation (DOC). This includes new standards to achieve effective control of stoats with all aerial 1080 operations, so that any potential kea deaths are offset by improved productivity and survival. By designing operations to control stoats, we can reverse the decline of kea at managed sites.

The code of practice summarises supporting research in four areas.

Predators of kea: Researchers identified the key predators using nest cameras, corpse necropsy and inference from predator density fluctuations during nest survival monitoring. This research indicates that stoats are the most important predator of kea and the impacts are most severe following mast events, which is when stoats occur in high numbers.

Non-target risk to kea at aerial 1080 cereal operations: A total of 150 kea have been monitored in 10 aerial 1080 operations. 20 kea deaths resulted from consuming 1080 in 3 of these operations. Autopsies indicated that kea were directly poisoning by eating 1080 cereal (as opposed to secondary poisoning from possum carcasses) and that probably more than one pellet was consumed. The timing of most of those deaths, soon after bait was laid, indicates those kea that died readily ate the bait.

Benefits to kea from predator control via aerial 1080 cereal operations: Effective stoat control improves kea productivity and survival whereas unchecked stoat irruptions following mast years can

drive kea productivity to near zero. If we are to avoid kea declining to Nationally Critical and then towards extinction, and in order to make up for the few adult kea sometimes killed in aerial 1080 cereal operations, all operations in kea habitat must be designed to achieve or be supplemented by stoat control.

Repellents to protect kea: The Department of Conservation is working with others to develop, register and implement an effective bird repellent to prevent kea deaths at aerial 1080 cereal operations. The research program is working to overcome limitations: one of the repellents dissipates in manufacture and storage and the other seems to be detected and avoided by rats. Whilst an effective repellent would prevent deaths of kea at aerial 1080 operations, we still need to reduce stoat predation in order to reverse the decline of this species.

Purpose

This code sets out the compulsory performance standards that must be followed for aerial 1080 operations in areas where kea (*Nestor notabilis*) may be present on land managed by the Department of Conservation (DOC). These compulsory performance standards apply throughout the distribution of kea (Figure 1).

This code of practice is based on our current understanding of the risks and benefits of aerial 1080 to kea. Relevant research is summarised to make it easier to understand the reasons for the standards.

Summary of kea research

Predators of kea

The kea is a large parrot endemic to the Southern Alps of New Zealand and is the world's only mountain parrot (Higgins 1999). Kea were re-classed from 'Not threatened' to 'Nationally Endangered' by Robertson et al. (2012); the criteria for this classification are a population estimate of 1000–5000 and an ongoing or predicted decline of 50–70% in the total population over the next 10 years due to recruitment failure. In order to prevent this decline, effective predator control is critical.

The kea is vulnerable to a range of introduced mammalian predators due to its ground-nesting habit and extended nesting cycle (i.e., it takes four months to fledge young, Jackson 1963). Kemp et al. (2014) identified the key predators of kea using a combination of nest cameras, corpse necropsy and inference from predator density fluctuations during nest survival monitoring. Nest cameras recorded visits by stoats, possums, ship rats, house mice and weka. Stoats were identified as the predator in 3 of the 16 nest failures recorded while no positive identification was possible for the other cases. Statistical modelling of the effect of predator visitation on nest survival suggests that visits by stoats, possums and rats were predictors of nest failure, with the strongest support for stoat visits. Two predation events were confirmed by corpse necropsy; one death by stoat predation was confirmed by DNA analysis and the other kea was predated by either a falcon or stoat. Kemp et al. (2014) also analysed the survival odds of kea nests at a rimu forest before, during, and after a mast event with no predator control. Survival odds were related to changes in stoat abundance but not to changes in rat abundance, implicating stoats as the important predator.

We have photographs of a possum appearing to kill kea chicks (DOC no date). However stoats are the far more important predator, particularly following mast events when Kea nest failure and predation of juveniles and adults are at their greatest.

Non target risk to kea from aerial 1080 cereal operations

DOC is concerned about the potential population impact of kea deaths observed at some aerial 1080 cereal operations. Kea survival has been monitored through 10 aerial 1080 cereal operations in 9 locations (Table 1, Figure 2). Kea were captured and tagged with VHF radio transmitters prior to the operation; the transmitters were fitted with motion sensors that record the time (hour) when motion ceased. A total of 150 kea were monitored and 20 kea deaths resulted from consuming 1080 (Kemp and van Klink 2014). All 20 kea deaths occurred in the 3 operations where we monitored the largest samples of birds (Table 1). It may be that kea in these locations are at higher risk for some site specific reason. It is also possible that kea deaths were not detected at the other sites due to small sample size.

It appears that most kea ignore 1080 pellets but a small number are poisoned by them. Half (10) of 20 of the detected kea deaths occurred the day after 1080 baits were sown; 6 occurred within 2–5 days and 3 occurred within 10–14 days. One bird died 35 days after the operation but 1080 poisoning could not be confirmed by the time the corpse was recovered. Bright green contents (1080 cereal remains) were found in the gizzard or crop of the 18 corpses recovered in time for autopsy (Kemp and van Klink 2014; van Klink and Crowell 2014). This indicates direct poisoning of kea from eating 1080 cereal (as opposed to secondary poisoning from possum carcasses) and that probably more than one pellet was consumed. 1080 was detected in muscle tissue for all of the 11 birds tested.

Benefits to kea populations from predator control via aerial 1080

Predator control needs to take place on a landscape scale to protect kea nests from predation by stoats for two reasons:

- Kea breeding pairs and nests are found at a low density (Jackson 1960) so broad scale control is needed to cover even a small number of nests. For example, Bond and Diamond (1992) estimated that there were between 0.14 and 0.40 nests per hectare.
- Stoats have a large home range and dispersing young are capable of long distance travel (King and Murphy 2005). Stoats are short lived with high productivity (up to 13 young per year when food supply allows) so localised small scale control measures are quickly undone by immigration. Methods must target female stoats are essential to achieving effective control. For example, an extensive area must be controlled to when stoats are targeted to protect other threatened bird species, such as Okarito kiwi (Miller et al. 2001).

Aerial application of 1080 baits is one of the main methods of rat and possum control on a landscape scale in New Zealand and can be effective for reducing stoat numbers through secondary poisoning. Murphy et al. (1998) first recorded a reduction in a stoat population following aerial 1080 by secondary poisoning; they observed prey remains in 12 of 13 radio-tracked stoat corpses after the operation including rat remains in 8 corpses and possum remains in a single corpse. Rats are reliable vectors for poison, based on consistent rat kills at aerial 1080 cereal pellet operations which are pre-

fed (Fairweather et al. 2013) and on their common occurrence in the stoat diet (King and Murphy 2005). The significance of possums and mice as poison vectors for stoat control is less certain and has not been directly measured (i.e., in the absence of rats). Data on mouse kill from aerial 1080 cereal pellet operations appears to be variable, although we do not know if this will affect stoat kill (Fairweather et al 2013). If rats aren't present in a forest, such as in the years between beech masts, we are unsure of the extent of the stoat by-kill that would be achieved.

The potential benefit to kea populations from aerial 1080 cereal operations has been investigated by Kemp et al. (2014), through long term monitoring of kea productivity and survival at sites before and for 2 kea breeding seasons after aerial 1080 operations. This included a controlled (before-after-controlled-impact or BACI) study with a non-treatment area for a lowland rimu forest in Westland and a correlative modelling approach for 5 upland beech forests where non-treatment areas were not paired with treatment areas.

The BACI study monitored predator dynamics and kea nests before and after an aerial 1080 operation in the spring of a mast year (2011) at Okarito forest in Westland, as compared to the same measures at nearby Fox-Paringa forest where predators were not controlled. Aerial 1080 reduced the stoat tracking index to near zero for 2 kea nesting seasons whereas the stoat tracking index increased to about 80% in the year after the mast (known as a 'stoat irruption year') at Fox-Paringa (Figure 3). Kea nest survival was estimated in the treated area as 100% in the mast year and 69% in the stoat irruption year, whereas nest survival in the untreated area was estimated as 38% and 1% respectively. During the 2 breeding seasons after the rimu mast, kea productivity was estimated at 4 times higher at the treated area (1.4 fledglings per adult female) than at the untreated area (0.32 fledglings per adult female).

Kemp et al. (2014) also monitored predator dynamics and kea productivity and survival at 5 upland beech forests, 3 of which were treated with aerial 1080, 1 of which was kill-trapped for stoats and possums, and 1 of which was treated with aerial 1080 and kill-trapped for stoats. Beech mast occurred in all five upland beech forests in 2009, followed by a stoat irruption in 2010. They concluded that kea productivity is near zero during uncontrolled stoat irruptions in beech forest, as it was in rimu forest. In the years between mast events, kea productivity is 0.44 fledglings per adult female on average, but this increases to 0.95 fledglings per female with effective stoat and possum control. Again, this was similar to what was observed in rimu forest.

In a mast year, operations need to occur when rodents are widespread in order to achieve effective stoat control. At Mt Arthur, the operation took place in May 2009, when rodent numbers were still climbing (Figure 4). Monitoring showed that the stoat irruption was not prevented (Figure 4), several adult kea disappeared and no kea nests were found despite extensive searches.

Between mast years, aerial 1080 operations may not benefit kea, if rodents are not present. Figure 4 also shows the predator dynamics at Wangapeka, where aerial 1080 cereal operation took place between mast events when stoats were already very low. The effect of the aerial 1080 cereal operation on stoats and kea at Wangapeka is unclear. Survival of kea nests after the Wangapeka 1080 operation was slightly higher than would be expected without control but may not be significant.

In summary, effective stoat control improves kea productivity and survival whereas unchecked stoat irruptions following mast years are strongly negative to kea populations. In order to make up for the few adult kea sometimes killed in aerial 1080 cereal operations, all operations must be designed to achieve stoat control. This can be achieved easily during and soon after a mast year, provided the timing is right. However it is less clear cut between mast years. For example:

- Effective stoat control appears more likely where rats are widespread in the operational area, but we do not know for sure if this is true when rats are scarce but mice and/or possums are widespread. Mice can be very patchy in their distribution in non-mast years.

- We know lowland mixed forests usually have rats but in upland pure beech forests they can be scarce between mast events. The transition from prevalent to low rat densities is likely to happen somewhere between 500 and 700m in mixed forests depending on the site and the season.

Repellents to protect kea at aerial 1080 cereal operations

The Department of Conservation is working with others to develop, register and implement an effective bird repellent to prevent kea deaths at aerial 1080 cereal operations (Crowell 2014). A number of trials have taken place in aviaries (Orr-Walker et al. 2012), pens (Cowan et al. 2013), and in the field (Kemp 2010, Crowell et al. 2014b, van Klink and Crowell 2014) since 2008, focussing on d-pulegone (which has a strong minty odour disliked by birds) and anthraquinone (which birds learn to avoid after post-ingestional discomfort). The research program is working to overcome limitations for each of these repellents. For d-pulegone, the focus is on stabilising the compound in cereal baits because monitoring has shown that it dissipates in manufacture and storage (Crowell et al. 2014a, van Klink and Crowell 2014). The addition of anthraquinone at the level used in the trials (0.1% wt/wt) seems to be detected and avoided by rats (Cowan et al. 2013). The proportional reduction in rat tracking was less in plots where both repellents were used, as compared to plots where d-pulegone or no repellents were used (Crowell et al. 2014b). The rat and kea responses to lower concentrations will be investigated; this may include using anthraquinone in experimental plots within an aerial 1080 cereal operation. Other repellents have been identified for preliminary screening with wild kea in 2014.

We are preparing for an aviary trial to test whether kea can be repelled from eating cereal pellets that contain anthraquinone (without d-pulegone). If successful, we will look at the feasibility of feeding kea non-toxic repellent cereal pellets prior to some operations, such as at car parks and huts, as part of the risk management.

None of the repellents are ready for operational use in 2014, other than a possible trial of anthraquinone in plots to monitor rat kills and a possible kea bait aversion programme at some operations should aviary trials provide strong evidence of efficacy. Whilst an effective repellent would prevent deaths of kea at aerial 1080 operations, we still need to reduce stoat predation in order to reverse the decline of this species.

Compulsory performance standards in kea habitat

This code of practice states and explains the compulsory performance standards that will apply to all pest operations aerially applying 1080 within the distribution of kea (Figure 1) on land managed by DOC, using one of the following registered methods:

- Aerially applied 0.15% 1080 Pellets (pesticide use #1 on the DOC Status List)
- Aerially applied 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets (pesticide uses #7 and #10)
- Aerially applied 0.2% 1080 Pellets (targeting wallabies, pesticide use #22) or 0.04% 1080 Pellets (targeting rabbits, pesticide use #14) and aerially applied 1080 carrot (pesticide uses #25, 30, 33)

Aerially applied 0.15% 1080 Pellets

There are two sets of compulsory performance standards for all operations using aerially applied 0.15% 1080 Pellets within the distribution of kea (Figure 1). The first set aims to reduce kea deaths and the second aims to ensure benefit to kea from stoat control. The rationale for each performance standard is given in italics.

Compulsory performance standards to reduce kea deaths:

Only use cinnamon-lured RS5 pellets. *RS5 pellets are required because both Luey (2009) and Blyth (2011) observed a preference for Wanganui #7 baits amongst captive kea. The lure must be cinnamon because all kea monitoring has followed aerial operations using this lure. We do not know how other lures would affect bait attractiveness to kea.*

Use a maximum of 2kg/ha of prefeed bait for 12g baits (or 1kg/ha for 6g baits). *We restrict the sowing rate in order to limit kea encounters with prefeed pellets. Kea consumption of prefeed pellets could increase the likelihood that kea eat toxic bait*.

Use a maximum of 2kg/ha of toxic bait for 12g baits (or 1kg/ha for 6g baits). *We restrict the sowing rate in order to limit kea encounters with toxic pellets.*

A previous standard has been removed, which prevented baits being sown in areas of low structural vegetation cover (e.g. alpine herb fields and tussock) above the tree line. This was intended to protect kea by keeping baits out of open areas that could be easily avoided. Subsequent kea deaths at Okarito and Otira suggest that most kea ignore 1080 pellets but a small number will find and eat them whether they are highly visible or not. This draws into question the effectiveness of the alpine exclusion standard. In the meantime, a need for predator control in alpine environments is emerging (O'Donnell 2013). Stoats and mice are prevalent predators in the alpine zone and possums are significant predators of snails.

Compulsory performance standards to ensure that kea benefit from stoat control:

There are two situations.

Situation during and soon after mast years, i.e.;

1. **Aerial 1080 operation includes kea habitat (Figure 1), and**
2. **The forest or tussock is in a mast year or soon after**

Standard: Timing of bait application must be between 1 July of the mast year and 31 August of the year following. *This is the preferred timing for aerial 1080 operations in kea habitat. The stoat irruption can be prevented, which can otherwise drive kea productivity to near zero.*

Stoats do not eat 1080 baits but can be poisoned when they prey on rats (and possibly mice and possums) that have taken bait. Because stoats are the main predators of kea, we expect that nest survival and kea productivity to improve in the two years following an effective stoat knockdown (Kemp et al. 2014). Timing operations to benefit kea should offset any kea deaths that might occur at some operations. The 'default' timing in a mast year and the year following the mast is based on the trend of rodent and stoat abundance observed in previous beech and rimu masts (Figure 5).

Situation between mast events, i.e.;

1. **Aerial 1080 operation includes area shown on the Kea habitat where rats can be scarce shape file (will be available on the GIS portal on the DOC website), and**
2. **The operation will occur outside of the 14 month timeframe in the above standard for during and soon after mast events**

Standard: Bait may only be applied in kea habitat where rats can be scarce if: (1) the operation is supplemented with an agreed level of stoat control; or (2) monitoring demonstrates that rats are 'widespread,' including in areas where rats can be scarce. 'Widespread' means that at least 2 tracking tunnels record rat prints on 80% of transects monitored prior to the operation (following Gilles and Williams 2013).

Between mast events, there is less certainty of a significant stoat by-kill to protect kea in areas where rats can be scarce. This includes all high altitude (>700m) kea habitat and all pure beech forest where kea may be present. To offset any potential kea deaths, the only options are to carry out stoat control at the same operational area or to ensure that rats are prevalent enough to achieve a stoat knockdown. Monitoring for rat prevalence must include the areas shown on the Kea habitat where rats can be scarce shape file.

Handlaid 0.15% 1080 Pellets

In most cases, handlaying is used in conjunction with aerial application and all the same standards will be compulsory. For operations that are entirely handlaid, the above performance standards are recommended. Some or all of these standards may be compulsory for a specific operation, at the discretion of the DOC manager who approves the DOC permission for the operation.

Aerially applied 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets

Aerial application of 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets is prohibited in areas of kea habitat (Figure 1) on land managed by the Department of Conservation (DOC). *This product is only*

available in the Wanganui #7 formulation, which was preferred over RS5 pellets by captive kea in 2 aviary trials (Luey 2009; Blythe 2011).

Handlaid 0.08% 1080 Pellets or 0.08% 1080 Rodent Pellets

It is recommended that 0.08% 1080 Pellets and 0.08% Rodent Pellets are not handlaid where kea are present, given that it is only available in the Wanganui #7 cereal formulation. The decision to prohibit or allow handlaying of 0.08% 1080 Pellets or 0.08% Rodent Pellets lies with DOC manager who approves the DOC permission for the operation.

Aerially applied 0.2% 1080 Pellets or 0.04% 1080 Pellets and aerially applied 1080 carrot

Any aerial 1080 operation in kea habitat (Figure 1) using 0.2% 1080 Pellets, 0.04% 1080 Pellets or 1080 carrot must be monitored for kea survival (with support from DOC Science & Capability and following Kemp and van Klink 2014 or van Klink and Crowell 2014).

No aerial 1080 operations using these cereal baits have been monitored for kea survival so the risk is unknown. The cereal baits used to target wallabies (0.2%) and rabbits (0.04%) are different from either RS5s or Wanganui #7s and neither is lured with cinnamon.

Two kea were monitored and survived in one aerial 0.08% 1080 carrot operation in 2007 (Kemp and van Klink 2008). This method is seldom used in kea habitat, but any future operations need to be monitored to help quantify the risk to kea. Carrot is eaten by captive kea so may be attractive to wild kea.

Frequently asked questions

1. This operation targets possums not rats. Do the 'performance standards to ensure kea benefit from stoat control' apply to this operation?

   Yes, the performance standards apply throughout kea habitat irrespective of the target pest. Between mast events, the performance standard only affects operations that include area shown on the Kea habitat where rats can be scarce shape file (i.e., all areas above 700m plus all pure beech forest). Operations at podocarp or mixed forests below 700m are not affected between mast years, because rats are generally widespread in these situations.

2. I have checked the Kea habitat where rats can be scarce shape file and only 10% of one polygon is included in our operational area. Do we need to comply with the 'performance standards to ensure kea benefit from stoat control'?

   This should be discussed with the assessor at the time of application for DOC permission. Any decision to exempt a small area from the compulsory performance standards is at the discretion of the approving manager for the DOC permission.

3. Next question: add questions that are asked during consultation

Tables

Table 1 Sample size and outcomes for kea with known fates monitored before and after aerial 1080 cereal operations (from Kemp and van Klink 2014).

Operation	Number of birds followed	Deaths recorded	Probability of survival	Lower 95% confidence bound	Upper 95% confidence bound
Arawhata 2008	10	0	100%	74.1%	100%
Fox-Franz 2008	17	7	58.8%	32.9%	81.6%
Mt Arthur 2009	13	0	100%	79.4%	100%
Hawdon 2009	10	0	100%	74.1%	100%
Okarito 2011	37	8	78.4%	61.8%	90.2%
Wangapeka 2011	13	0	100%	79.4%	100%
Abbey Rocks 2011	8	0	100%	68.8%	100%
Copland 2012	2	0	100%	22.4%	100%
Hawdon 2012	6	0	100%	60.7%	100%
Otira 2013	34	5	85.3%	68.9%	95%
Total	150	20	86.7%		

Figures

Figure 1 The distribution of kea in the South Island of New Zealand.

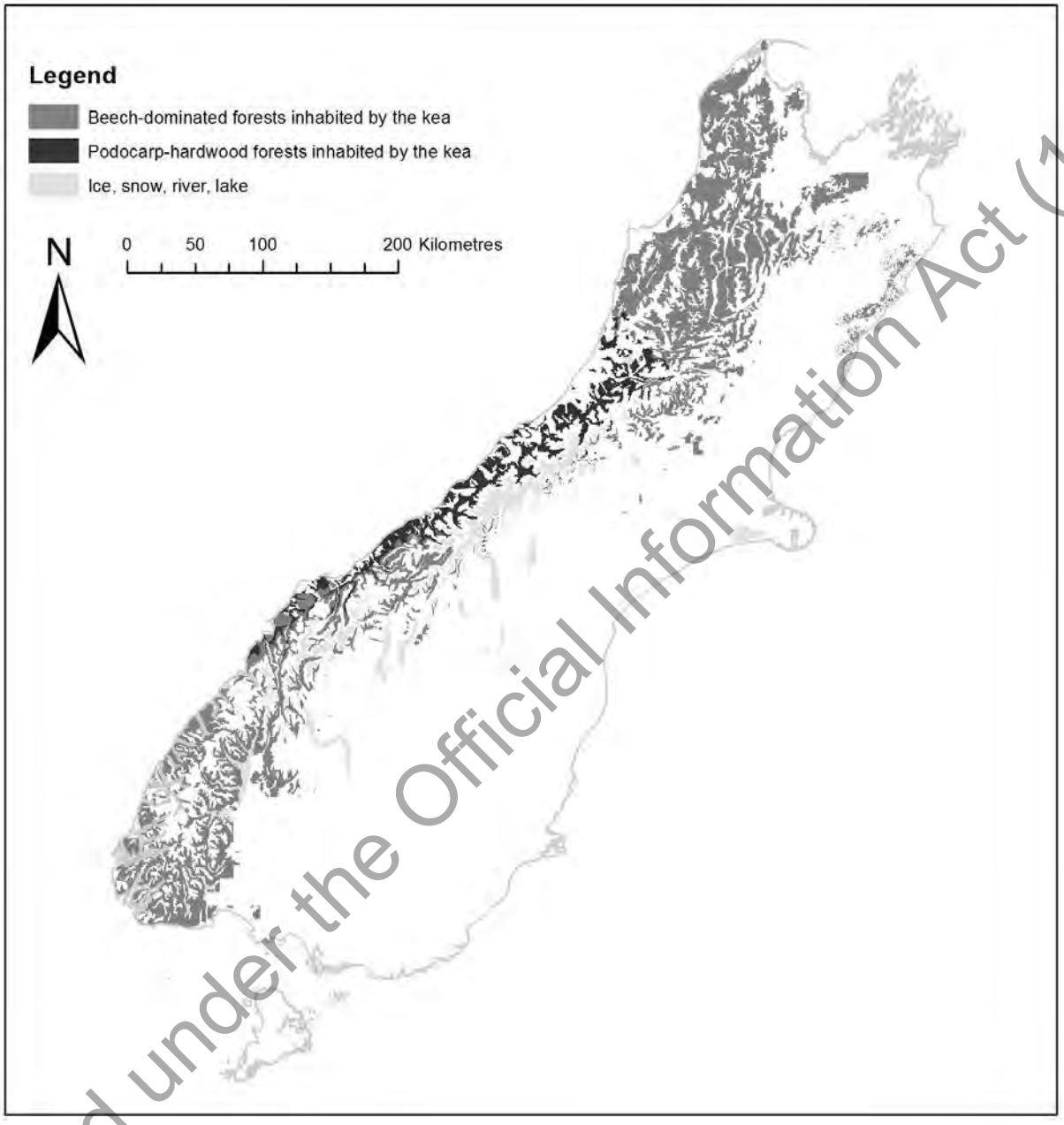


Figure 2 Location of the 9 aerial 1080 cereal operations where kea survival was monitored between 2008 and 2013.

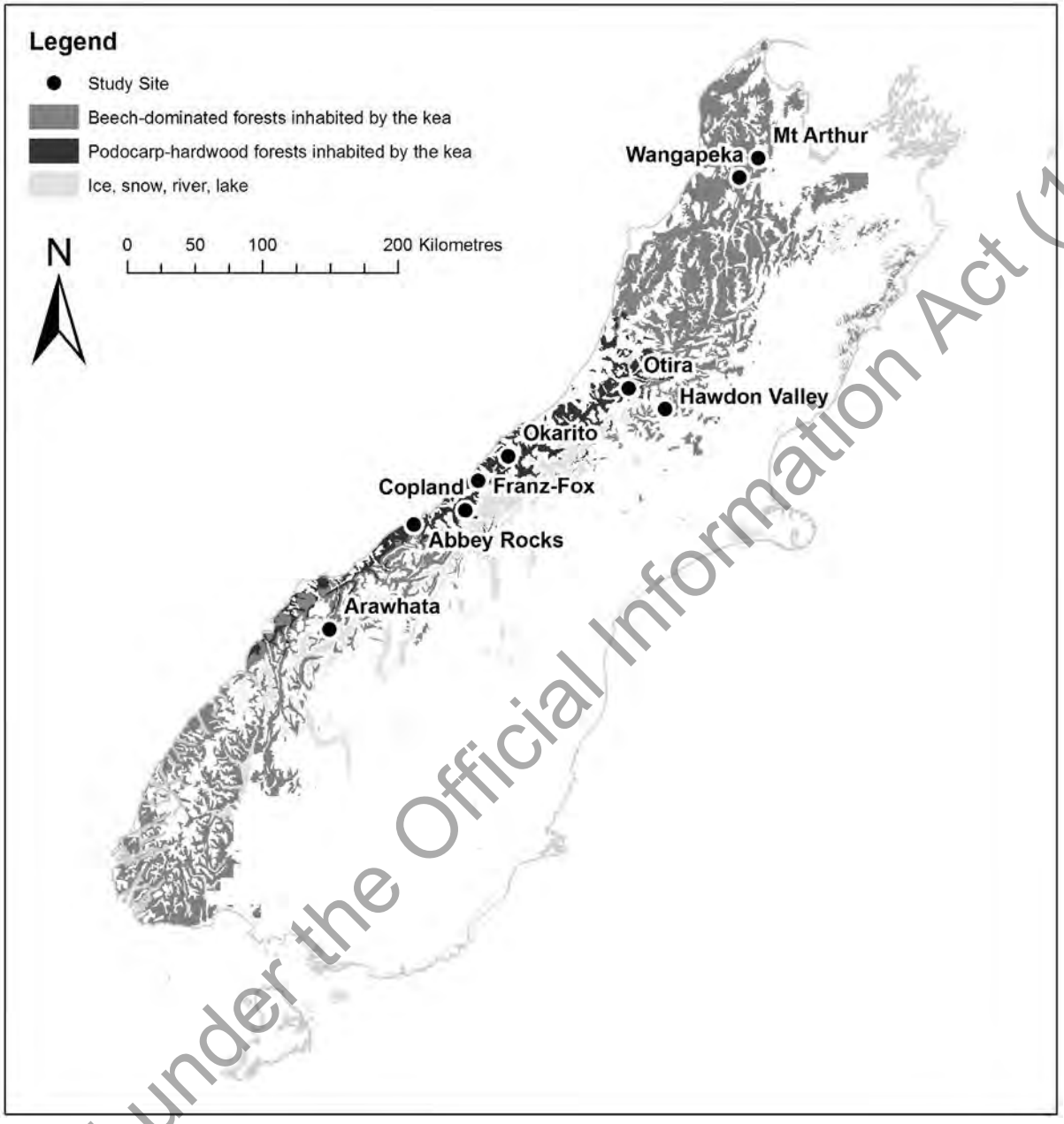


Figure 3 Relative abundance of stoats, rats and mice in a rimu mast year and in the following ('stoat irruption') year. An aerial 1080 cereal operation occurred at Okarito whereas Fox-Paringa received no predator control.

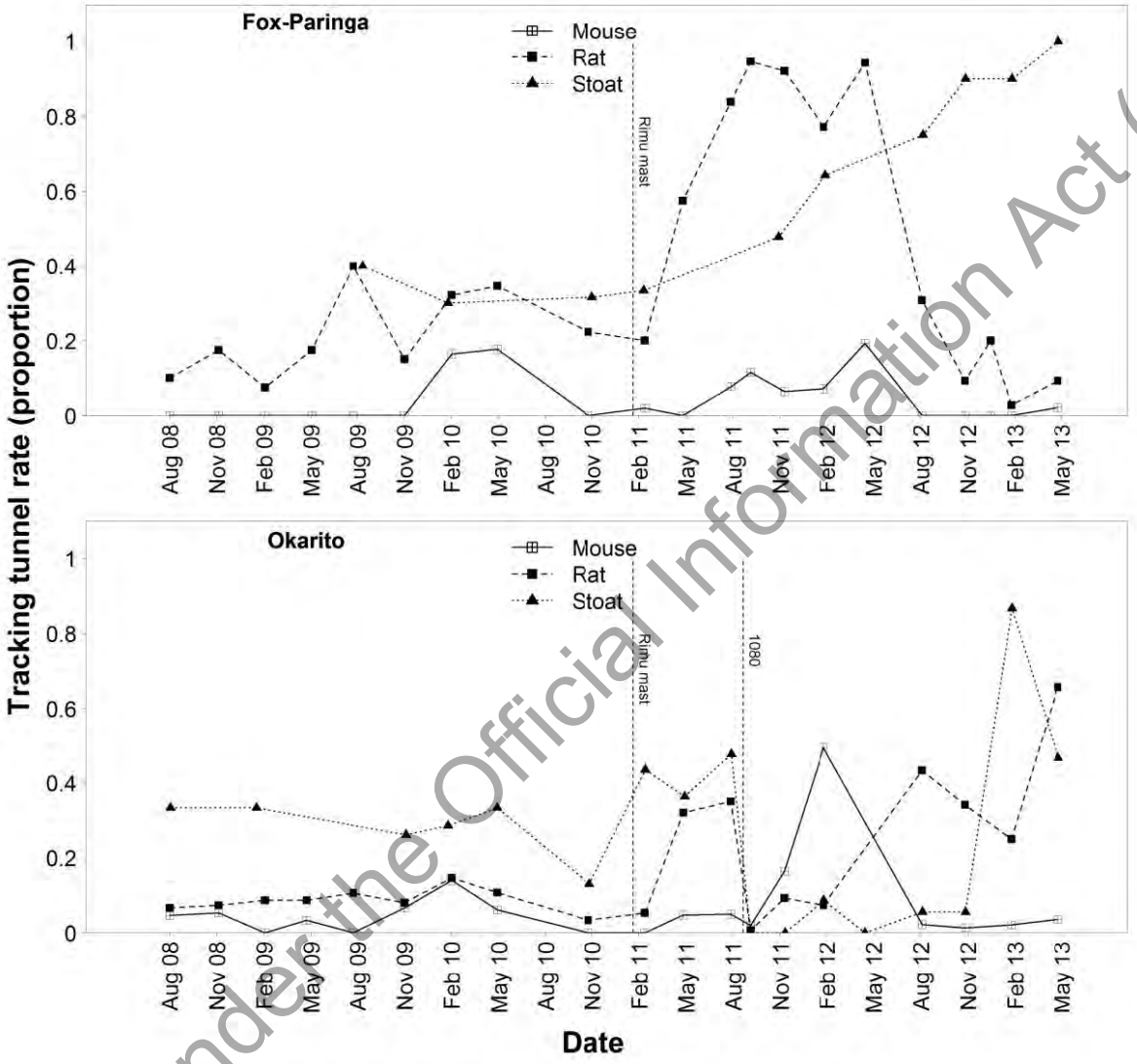


Figure 4 Relative abundance of stoats, rats and mice in 2 beech forests. An aerial 1080 cereal operation occurred at Mt Arthur in a beech mast year before rodents were abundant. At Wangapeka, an aerial 1080 cereal operation took place between beech masts.

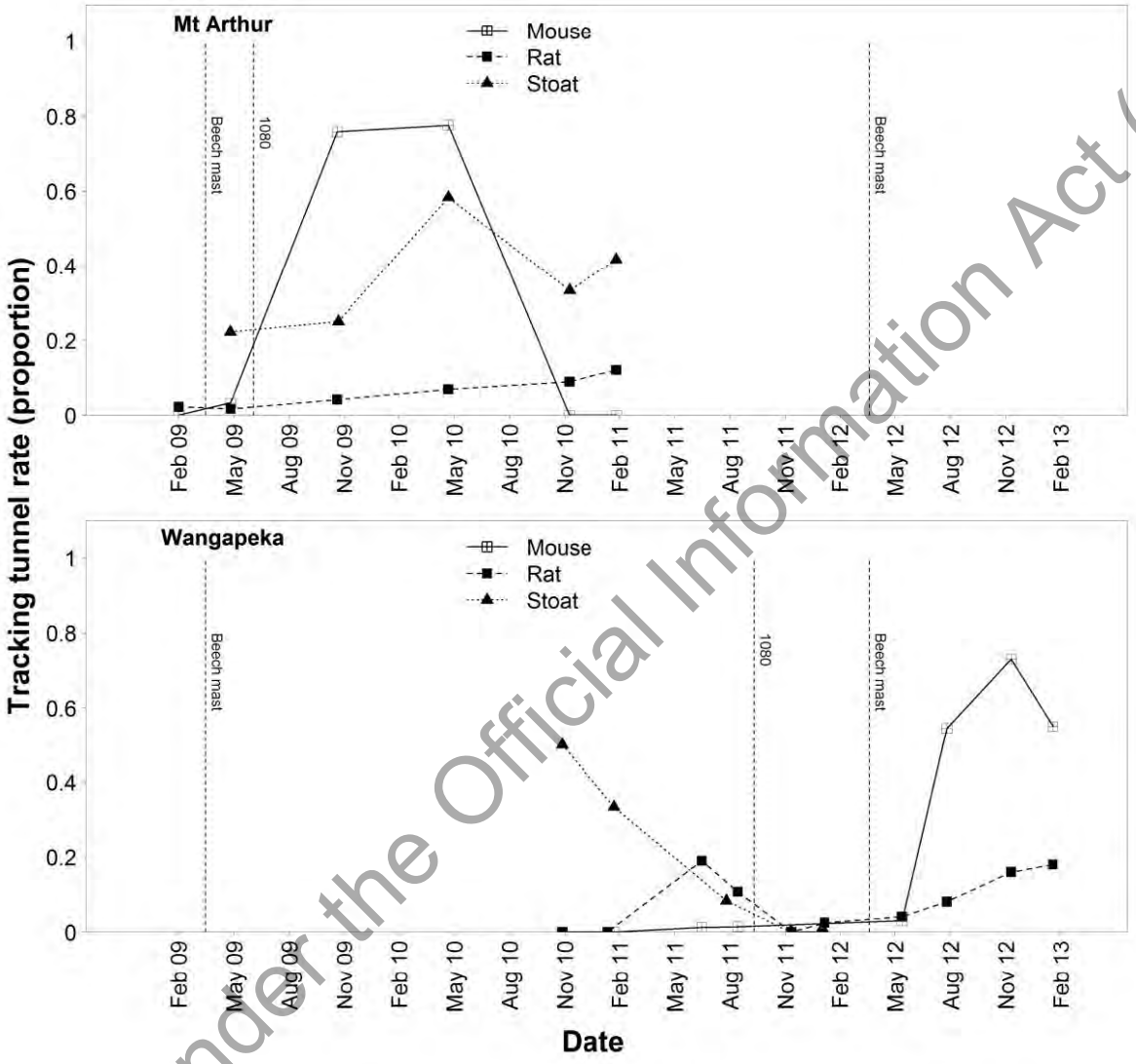
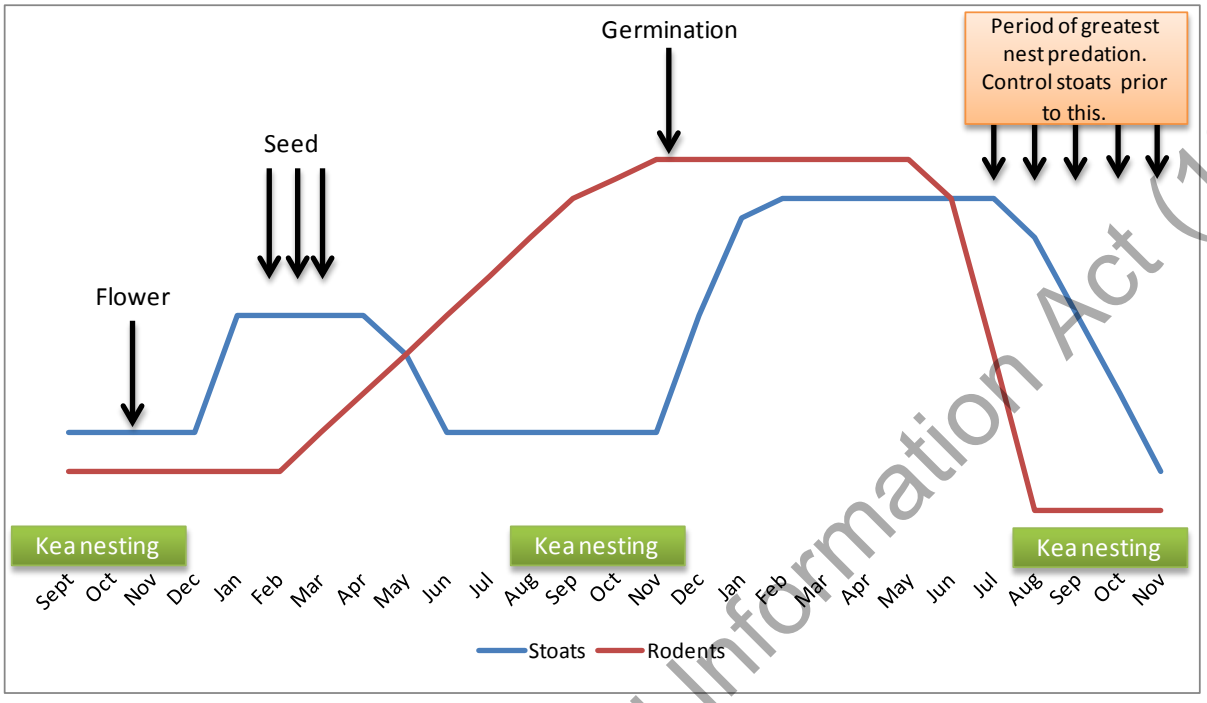


Figure 5 Illustration of how rodent and stoat tracking indices fluctuate during and after a beech or rimu mast. See also King and Murphy (2005) for a 4-year generalised model of the beech mast cycle with respect to mice and stoats.



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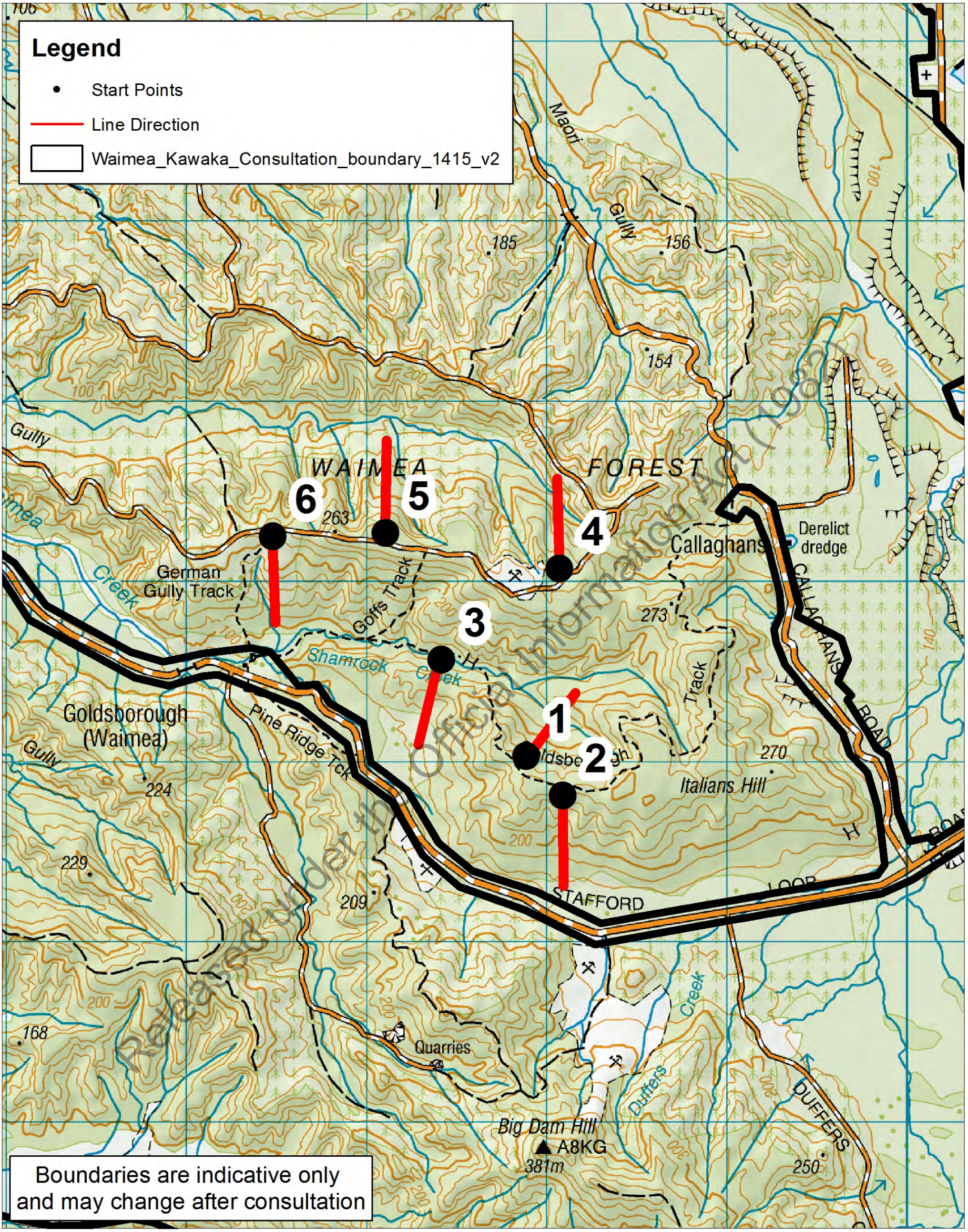
Appendix 32



TBfree New Zealand Ltd - Aerial 1080 Operation

Rat Monitoring

Waimea Kawhaka Aerial 2015

Produced by: 9(2)(a), 9(2)(g)(ii)
Office: Greymouth
Version: Draft 1
Date: 28 November 2014

TBfree NEW ZEALAND

0 0.4 0.8 km

1:20,000

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

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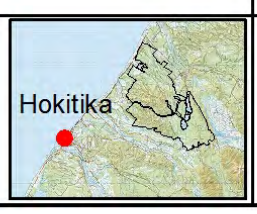

Appendix 33

Sodium fluoroacetate

Pesticide Information Review

Authors/Compilers:

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This report may be cited as:

Fairweather, A.A.C.; Broome, K.G. 2018: Sodium Fluoroacetate Pesticide Information Review. Version 2019/1. Unpublished report docdm-25427, Department of Conservation, Hamilton, NZ. 134p.

Version History:

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

2016/1	15/08/2016	Updated information in Section 3.2.3 about Archey's frogs.
2015/2	23/12/2015	Noted that No Possums® 1080 gel has been de-registered
2015/1	30/06/2015	Efficacy data in Section 6.2.4 for possums, rats, mice, rabbits and stoats updated.
2014/3	15/12/2014	New data on trout in Sections 2.5.1.and 2.5.2
2014/2	12/12/2014	Formatting changes, and updates to Sections 3.2 and 6.2
2014/1	29/08/2014	New data on soil breakdown (Section 2.2.2), water samples (Section 2.3.1), native non-targets (3.2.3), and revised overview for native non-targets
2013/1	18/09/2013	New information on kea (Sections 2.5.4, 3.2.1 and 3.2.3) and morepork, kaka, robins, tomtits, grey warbler and riflemen (3.2.3).
2012/3	23/10/2012	New information on fernbirds (Sections 2.5.4, 3.2.1 and 3.2.3) & bees (4.2.1)
2012/2	17/10/2012	New information on 1080 residues in magpies (*Pica pica*) in 2.5.4, and LD_{50} for magpies in 4.1.1.
2012/1	12/04/2012	New information on 1080 in water 2.3.1, 2.3.2, and 2.3.3, and 3.2.1 (snails), corrected formatting and Table numbers.
2011/2	17/10/2011	New information (kea) 3.2.3
2011/1	13/1/2011	New information on fish and aquatic invertebrates 3.2.3
2010/2	31/08/2010	New information (kiwi) 3.2.3
2010/1	3/08/2010	New information 2.5.2, 3.2.2 & 3.2.3
2009/7	15/12/2009	3.2.3 (skinks and weka); 5.1.7, 6.2.4 (Rats)
2009/6	1/09/2009	Corrected number of operations monitored by Thomas et al. (2004) in section 2.1.1
2009/5	13/8/2009	New information in sections 2.5.4 (Quail) & 4.2.1 (0.2% carrot and 0.04% oat operations).
2009/4	20/7/2009	Rewrote sections 2.3.1, 2.4.2 and 2.4.3 based on new information.
2009/3	13/07/2009	New information in Section 3.2.2 (falcon); 6.2.4 (Mice)
2009/2	19/05/2009	New information in Section 6.2.2 (Mice)

2009/1	17/02/09	New information in Sections 2.5.1 & 2.5.4 (deer); 3.2.1 & 3.2.3 (Kakariki)
2008/1	18/09/08	New information in Sections 2.5.2; 2.5.4; 3.2.1 & 3.2.3 (kea); 4.1.4; 4.2.1; & 6.2.4
2006/2	10/08/06	New information in section 3.2.3 (paste baits)
2006/1	15/3/06	New information in sections 2.1.1; 2.5.5; 3.2.3; & 6.2.4.
2005/2	17/03/05	New information in sections 2.1.1; 2.4.2; 2.5.2; & 6.2.4.
2005/1	18/01/05	Up dated Section 1.4 pesticide uses
2004/2	8/10/2004	Residue and non-target native and feral animal information from Speedy (2003) included
2004/1	15/9/2004	Original document

Contents

Overview

Introduction

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

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

Fate in the Environment

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

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

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

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

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

Effects on Non-Target Native Species

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

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

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

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

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

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

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

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

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

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

Effects on Domestic and Feral Animals

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

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

Feral deer population mortality from aerial poisoning operations targeting possums is highly variable and does not appear to be consistently influenced by toxic loading, sowing rate, prefeeding or bait type. Most estimates of deer kill fall between 30 and 60%. Nugent et al. (2001) quote productivity figures for red deer populations of around 30% so low to moderate by-kill of deer populations is probably negated within a couple of years.

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

Although 1080 is toxic to honeybees, baits used in pest control are generally not attractive to honeybees. However, this may not always be the case if honeybees are particularly hungry, so beekeepers should always be notified of operations.

Human Health

The estimated lethal dose of 1080 in humans lies in the range of 0.7 and 10.0 mg kg^{-1}. Sodium monofluoroacetate (1080) is absorbed through the gastrointestinal tract or via the lungs if inhaled. Monofluoroacetate is not readily absorbed through intact skin, but it can be absorbed more readily through cuts and abrasions. The onset clinical signs usually range from 30 minutes to about 2-3 hours. Signs of poisoning include

nausea, vomiting, and abdominal pain initially, followed by respiratory distress, anxiety, agitation, muscle spasms, stupor, seizures, and coma.

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

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

Operational

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

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

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

1. Introduction

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

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

1.1. Chemical name

Sodium monofluoroacetate

1.2. Synonyms

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

1.3. CAS Numbers

62-74-8

1.4. Registered pesticides containing 1080 available in New Zealand

0. 2 % 1080 Pellets (2 g kg^{-1} 1080), Pesticide use numbers: 21, 22, 23

0.15% 1080 Pellets (1.5 g kg^{-1} 1080), Pesticide use numbers: 1, 2, 3, 98

0.08 % 1080 Pellets (0.8 g kg^{-1} 1080), Pesticide use numbers: 7, 8, 9

0.08 % 1080 Rodent Pellets (0.8 g kg^{-1} 1080), Pesticide use numbers: 10, 11, 12

0.04% 1080 Pellets (0.4 g kg^{-1} 1080), Pesticide use numbers: 13, 14

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

0.10% 1080 Feral Cat Bait (1.0 g kg^{-1} 1080), Pesticide use numbers: 38, 115

10% 1080 Gel (100 g kg^{-1} 1080), Pesticide use numbers: 15

5% 1080 Gel (50 g kg^{-1} 1080), Pesticide use numbers: 16

Pestoff Exterminator Paste (1.5 g kg^{-1} 1080), Pesticide use numbers: 35, 36

Pestoff Professional 1080 Possum Paste 0.08% (0.8 g kg^{-1} 1080), Pesticide use numbers: 41

Pestoff Professional 1080 Possum Paste 0.15% (1.5 g kg^{-1} 1080), Pesticide use numbers: 42, 96

Pestoff Professional 1080 Possum & Rabbit Paste 0.06% (0.6 g kg^{-1} 1080), Pesticide use numbers: 44

Pestex (1.5 g kg^{-1} 1080), Pesticide use numbers: 140, 141, 142

Note: **No Possums® 1080 gel** was de-registered in 2015. Information about this product is contained in Appendix 1 (doc-2534486).

1.5. Chemical and physical properties

The empirical formula of 1080 is $C_2H_2FNaO_2$ (Figure 1). It has a molecular weight of 100.3. In its pure form 1080 is an odourless, colourless, non-volatile powder that decomposes at about 200ºC. Although the compound is often said to be tasteless, dilute solutions are thought to taste like weak vinegar. Sodium monofluoroacetate is very water-soluble but has low solubility in organic solvents such as ethanol and oils. Monofluoroacetates are chemically stable, hence 1080 as a pure compound in powder form — or when prepared in an aqueous stock solution — will not readily decompose.

This section is from Eason and Wickstrom (2001).

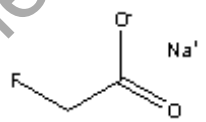

Figure 1. **The chemical structure of sodium fluoroacetate.**

1.6. Historical development and use

Sodium monofluoroacetate was first patented as a rodenticide in the late 1930's, with commercial use starting in the United States in 1944 to control gophers, ground squirrels, prairie dogs, field mice, and commensal rodents. In New Zealand the first trials were carried out in 1954, and by 1957 its use had become widespread. Currently in New Zealand the principal target species is possums and rodents. It is also

registered for use against rabbits, wallabies, deer, goats and cats. 1080 was also used in a fish-based paste to control wasps in the late 1990s.

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

1.7. Natural Occurrence

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

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

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

While most studies assessing monofluoroacetate concentrations in plants have focused on those species that are highly toxic to mammals, it would appear that the ability of plants to synthesise monofluoroacetate is more widespread than generally supposed. Monofluoroacetate occurs at extremely low concentrations in some Finnish plants (Vartiainen and Kauranen, 1980), in tea leaves (Vartiainen and Kauranen, 1984) and guar gum (Twigg et al., 1996b; Vartiainen and Gynther, 1984) and puha (Ogilvie et al., 2006). Additionally, some plants when exposed to fluoride ions, can biosynthesise low levels of fluoroacetate. Fluorocitrate, the toxic metabolite of monofluoroacetate, has also been detected in tea leaves (Peters and Shorthouse, 1972). Fluoroacetate biosynthesis can also occur in some bacteria, notably *Streptomyces cattleya* (O'Hagan and Harper, 1999). In parts of Australia where fluoroacetate contain plants are common, native herbivores and seed-eaters have developed a high level of

resistance to fluoroacetate compared to the same species elsewhere in Australia were plant species do not contain fluoroacetate. In South Africa the caterpillar of the moth, *Sindrus albimaculatus* (which feeds on *Dichapetalum cymosum*), can not only detoxify fluoroacetate, but also accumulates it and uses it as a defence against predation (Meyer and O'Hagan, 1992).

1.8. Toxicology and pathology

1.8.1. Mode of action

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

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

This section is from Eason and Wickstrom (2001).

1.8.2. Pathology

Known target organs in animals following 1080 exposure include the heart, lungs, liver, kidney, testes, and foetus (Annison et al., 1960; Buffa et al., 1977; Chi et al., 1996; Chung, 1984; Eason et al., 1999; Gregg et al., 1998; McTaggart, 1970; Savarie, 1984; Schultz et al., 1982; Sullivan et al., 1979; Trabes et al., 1983; Twigg et al., 1988). The pathological changes observed at post-mortem appear to be largely the result of progressive cardiac failure with congestion of the abdominal viscera and lungs. Examination of monofluoroacetate-poisoned mammals usually reveals cyanosis of mucous membranes and other tissues. Diffuse visceral haemorrhage has been described in some animals, particularly cattle. Subepicardial haemorrhages on the epicardium and endocardium as well as on the epiglottis and trachea have been observed in sheep and possums poisoned with monofluoroacetate. The presence or absence of tissue damage is likely to be dose-related, and subepicardial haemorrhages have been observed in rabbits receiving a lethal dose of monofluoroacetate but not in those receiving a sub-lethal dose. It is apparent that the target organs vary to some extent in different species, which may relate to the citrate response in different species, or the metabolic activity in different tissue. In birds a target organ appears to be wing muscle (Ataria et al., 2000) as well as the heart, which is a more common target in other species.

This section is from Eason and Wickstrom (2001).

1.8.3. Absorption, metabolism, and excretion

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

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

Administration of ^{14}C-labelled fluoroacetate to rats showed that fluorocitrate, the toxic metabolite of 1080, accounted for only 3% of the radioactivity (Gal et al., 1961), and this was confirmed by Schaefer and Machleidt (1971). The major metabolite, unlike fluorocitrate, does not inhibit the activity of aconitase (Gal et al., 1961). Phillips and Langdon (1955) suggested that the unidentified metabolites include non-saponifiable lipids that probably serve as intermediates for cholesterol, and some radioactivity was found in fatty acids and cholesterol in the liver. Up to 3% of the radioactivity appeared as respiratory CO_2, which implied cleavage of the C-F bond (Gal et al., 1961).

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

This section is from Eason and Wickstrom (2001).

2. Fate in the Environment

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

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

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

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

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

2.1. Bait pathway

2.1.1. How long do baits remain toxic?

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

Pellets

On land

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

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

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

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

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

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

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

0.15% 1080 cereal pellets in bait bags stapled to trees four months after a possum control operation in Patterson Inlet, Stewart Island contained 188 - 475 mg kg^{-1} 1080. 1080 residues in two 1080 cereal pellets in bait bags found lying on the ground were below the method detection limit (MDL) (VPRD & Pestlink 0809SIS02).

In water

Suren (2006) conducted laboratory experiments to examine the fate of pellet baits that fell into moving water and to quantify the rate that 1080 leached from the pellets. 0.15% 1080 Wanganui #7 pellets were placed in flow tanks that had a cobble base and water flowing through them at 20 cm s^{-1}. Eleven and 6 g baits were used in the experiment. Both bait sizes followed a similar pattern of breakdown. The

baits remained relatively intact for the first 48 hours but lost their bright green colour. After 72 hours the baits had become swollen and started to fragment. At 84 hours the baits had disintegrated. While baits remained for up to 72 - 84 hours before they disintegrated, 1080 leached out of the baits far more rapidly. 1080 was rapidly lost from submerged baits within the first 8 - 12 hours. Fifty percent of the 1080 in the baits was lost after the baits had been submerged for 5 hours. By 24 hours, 90% of the original 1080 concentration had been lost, and no 1080 was detected in any baits after 36 hours.

Dust

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

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

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

During an aerial 1080 operation (0.15% 1080 RS5 cereal pellets sown at a rate of 2 kg/ha) at Kumara in 2015, 1080 dust levels were monitored at 5 sites located within, at the boundary, and at 180 metres, 330 metres and 415 metres downwind of the operational area. Total suspended particulate (TSP) gauges were used to collect the dust and monitoring occurred for 1 day following the operation. 1080 was only detected at the monitoring site 180 metres outside the operational area at a concentration of 0.0048 µg 1080 m^{-3} (Wickham and Baynham, 2016).

Carrot

Thomas et al. (2004) subjected 12 g carrot baits containing 1.5 g kg^{-1} 1080 two different simulated rainfall treatments. The first treatment involved subjecting

carrot baits to 20 mm hr^{-1} simulated rainfall starting 1 hour after the 1080 was applied. The 1080 in the carrot leached out of the carrot rapidly, with the carrot losing approximately 74% of the 1080 after 10 mm of simulated rainfall. In the second treatment, which was designed to be more representative of field operations, involved starting the simulated rainfall started 48 hours after the 1080 was applied to the carrot. The carrot in this treatment retained more than 60% of its 1080 concentration after 500 mm of simulated rainfall.

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

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

Pastes

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

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

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

Degradation of fishmeal feral cat bait pellets containing 1g/kg 1080 was assessed on Auckland Island in winter 2019. The bait was placed directly on the ground under pest proof mesh cages in habitat including scrub, rata forest, tussock and coastal herbfield at nine separate sites. After 14 days with 38.4mm of accumulated rainfall the concentration of 1080 in sampled baits from each site had declined by 88-100%. At this point baits were intact and most were firm and free of visible mould. After 32 days with 110.4 mm of accumulated rainfall the 1080 levels had declined by 100% (to <MDL) at six sites and by >95% at the remaining three sites. By this point baits were soft and mouldly and some had become mushy. After 98 days baits were tested from four of the sites and all had 1080 <MDL (Cox et al., 2019).

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

Other

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

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

2.1.2. How soluble is 1080 in natural water?

Sodium monofluoroacetate is highly water soluble and mobile (Parfitt et al., 1994).

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

2.2. Soil and sediment

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

Soil

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

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

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

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

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

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

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

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

Sediments

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

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

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

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

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

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

Northcott et al. (2014) examined the breakdown of 1080 in podzol (Orikaka Sandy Loam, West Coast, South Island), brown soil (Matiri, West Coast, South Island) and pumice soil (Kaingaroa, Taupo, North Island) under laboratory conditions. In

all three soil types the degradation products produced and the rate at which these products were formed were similar. The major degradation pathway was through microbial degradation to the hydroxyl metabolite, hydroxyacetic acid, and microbial mineralisation to CO_2. The authors reported that the dominant factor affecting the rate of degradation was temperature rather than soil type or moisture content. The transformation half-life (DT_{50}) of 1080 increased with decreasing temperature, ranging from 6 - 8 days at 20°C, 10 - 21 days at 10°C and 22 - 43 days at 5°C.

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

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

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

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

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

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

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

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

2.3. *Fate in water*

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

Water monitoring during operations

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

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

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

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

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

No 1080 was detected in 36 water samples taken from six streams over a 4-month period at Waipoua following aerial possum control using 0.08% 1080 Pellets sown at 5 - 6 kg ha^{-1} in 1990. After the 1990 aerial possum control operation using 0.08% 1080 Pellets at 14 kg ha^{-1} on Rangitoto Island 24 water samples were collected over 6 months from 2 surface water and 2 ground water sites. No 1080 was detected in any of these samples (Eason et al., 1992).

Field trials

Meenken et al. (2000) monitored water in a stream at the bottom of 14 ha catchment for the presence of 1080 after 0.15% Wanganui #7 pellets had been handlaid in a at a rate of 10.7 kg ha^{-1}. Monitoring occurred at regular intervals over the 17 hours

after the bait was applied and during a rain event two days after the bait was laid. No 1080 was detected in any of the 52 water samples taken.

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

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

Landfill disposal

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

1080 breakdown products

Fluoride is a principal breakdown product of 1080. In addition to the 1080 water sampling undertaken by Fowles and Williams (1997) following the aerial 1080

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

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

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

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

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

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

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

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

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

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

(1994) reported that the rate of 1080 degradation was dependent on the species of bacteria present.

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

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

2.4. Fate in plants

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Ogilvie et al. (2004) reported that after käramuramu took up 1080 during field trials, the concentration of 1080 in the plants decreased to zero at 28 days. The

authors recommended that a withholding period of 30 days after an aerial application of 1080 could be adopted for plants within the operational area that are used for rongoa (medicinal) purposes.

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

2.5. Animal residues

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

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

When sheep and goats were orally dosed with an aqueous 1080 solution at 0.1 mg kg^{-1} b.w. (equivalent to one-quarter of the published LD_{50} for sheep and less than a quarter of the LD_{50} for goats) the maximum 1080 residues recorded in plasma were 0.16 - 0.33 mg l^{-1} and 0.22 - 0.26 mg l^{-1} respectively. In the sheep, 2.5 hours after dosing the mean 1080 concentrations of were 0.098 mg l^{-1} in plasma, 0.042 mg kg^{-1} in muscle, 0.052 mg kg^{-1} in the heart, 0.057 mg kg^{-1} in the kidney and 0.021 mg kg^{-1} in the liver. The mean 1080 concentrations declined to less than 0.003 mg kg^{-1} in all tissues sampled 96-hours after dosing (Eason et al., 1994a).

Rabbits orally administered a sub-lethal dose of 1080 at 0.1 mg kg^{-1} b.w. (equivalent to one-quarter of the published LD_{50}) and sampled at intervals after dosing had maximum 1080 concentrations of 0.121 – 0.167 mg l^{-1} in plasma, 0.019 – 0.025 mg kg^{-1} in muscle, 0.014 - 0.08 mg kg^{-1} in kidney and 0.001 – 0.002 mg kg^{-1} in liver (Gooneratne et al., 1995).

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

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

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

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

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

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

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

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

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

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

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

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

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

Species	Sample Type	Residues (mg kg^{-1})	Reference
Arthropods			

Species	Sample Type	Residues (mg kg^{-1})	Reference
Beetles	Mixed samples	<0.1	1
Invertebrates (various)	7 mixed samples	0.0-0.75	2,3
Weta	Whole body	2.7	1

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

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

Mammals

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

Birds

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

Invertebrates

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

Aquatic organisms

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

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

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

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

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

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

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

Species	Sample Type	T ½ (hours)	Reference
Sheep	Plasma	10.8	1
	Muscle	12.0	2
	Liver	3.0	2
Goat	Plasma	5.5	1
Possum	Plasma	9.1	3
Rabbit	Plasma	1.1	4
	Muscle	0.4	4
	Kidney	0.8	4
Mouse	Plasma	2.0	5
	Muscle	1.7	5

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

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

In sheep dosed with a lethal amount of 1080 (200 µg kg^{-1}), the concentration of 1080 in the muscle of sheep sacrificed post-dosing reached a maximum of 111 µg kg^{-1} in 4 hours and declined exponentially thereafter. In the liver a maximum concentration of 38 µg kg^{-1} was recorded at 2 hours with exponential decline thereafter (Rammell, 1993). Sheep that died 22 – 25 hours after receiving a 0.30 mg kg^{-1} dose of 1080 had 1080 concentrations of 0.06 1- 0.75 µg g^{-1} in the heart, 0.058 -

0.72 µg g^{-1} in the skeletal muscle and 0.047 - 0.051 µg g^{-1} in the liver. In sheep that died 43 - 52 hours after dosing (0.30 mg kg^{-1}) the 1080 residues in skeletal muscle was 0.023 - 0.031 µg g^{-1}, but was undetectable in the heart and liver. The concentration of 1080 in the rumen contents of sheep that died within 24 hours of dosing was 0.15 - 0.27 µg g^{-1} (Gooneratne et al., 2008).

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

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

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

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

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

Species	Sample Type	Residues (mg kg^{-1})	Reference
Birds			
Blackbird	Muscle	0.01–32.0	1; 2; 3; 4
Chaffinch	Muscle	0.14–5.80	1; 4
Dunnock	Muscle	0.28–1.75	4
Hedge Sparrow	Muscle	0.03	1
Kea	Muscle	0.46 – 3.44	1
Keruru/Kukupa	Muscle	0.01	1
Morepork/ruru	Muscle	0.01	1
California Quail	Crop	18 - 76	5

Species	Sample Type	Residues (mg kg^{-1})	Reference
Rifleman	Abdominal cavity	0.016–0.863	1
NI Robin	Muscle	0.37–3.80	6
Silvereye	Muscle	0.68	1
Thrush	Muscle	2.01	4
Tomtit	Abdominal cavity	0.298–0.406	1; 2; 4
	Muscle	0.23–4.2	
Tui	Muscle	0.012	1
Weka	Muscle	0.012–4.3	1
Fernbird	Muscle	0.14 – 0.75	7
Marsupials			
Possum	Bone	0–0.01	1; 8; 9
	Liver	1.5–8.4	
	Muscle	0.003–2.3	
	Stomach	0.05–~70	
Mammals			
Short-tailed bat	Muscle	0.013	10
Cat	Muscle	0.06–1.24	1
	Stomach	0.36	
Cattle	Muscle	0.003–0.46	1
	Stomach	0.04–9.1	
Deer	Muscle	0.012–7.37	1; 2; 3; 11
	Stomach	8.7–35.9	
	Heart	0. 85-8.12	
	Liver	0. 75-4.05	
Dog	Muscle	0.014–0.41	1
	Stomach	0.028–0.7	
	Intestine	0.44	

Species	Sample Type	Residues (mg kg^{-1})	Reference
	Vomit	1.07	
Ferret	Muscle	0.004–13	1; 12; 13; 14
Mouse	Whole body	0.001–55	1
	Muscle	9.1–10.3	
	Liver	7.8–17.6	
Pig	Muscle	0.03–0.21	1
	Stomach	56	
Sheep	Muscle	0.021–0.3	1
	Liver	0.04	
	Plasma	0.35	
	Stomach	0.001–1.3	
Stoat	Muscle	0.002–1.07	1; 11; 15; 16
	Stomach	0–0.146	
Invertebrates			
Honeybee	2 whole animals	0–10.8	1
Wasp	wasps	5–38	17
	larvae	66–255	
	Nest debris	17–96	

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

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

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

While 1080 is metabolised and eliminated from living animals it can persist in carcasses for months where it will degrade more slowly than indicated by the half-

life in living mammalian metabolism. The rate of degradation of 1080 in carcasses will depend on moisture, temperature and the presence of micro-organisms.

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

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

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

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

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

3. Effects on Non-Target Native Species

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

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

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

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

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

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

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

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

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

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

3.1. Toxicity

3.1.1. What is the lethal dose (LD_{50}) range for each taxon?

The LD_{50} values available for native mammals, birds and arthropods are presented in Table 4. While there is no information for any native reptiles, amphibians, fish or molluscs, Section 4 has information on overseas species in these taxa which is useful.

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

Species	LD_{50} (mg kg^{-1})	References
Birds	Range: 8.00 - 9.25	
Grey duck	10.0	1
Silvereye	~ 9.25	1
Weka	~ 8.1	2
Mammals		
Short tailed bat	0.15 ('Worst case' LD value)	3
Invertebrates	Range: 42.00 - 91.00	
NZ ant	72.00 (24 hr LD_{50})	4
	42.00 (48 hr LD_{50})	4
Wellington tree weta	91.00	4

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

Aquatic Invertebrates

Based on sub-lethal exposure trials, Suren and Bonnett (2006) suggest that the 1080 LC_{50} for koura is relatively high.

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

1080 is considered a broad-spectrum toxicant although variation in LD_{50}'s and body size of animals suggests that some native species could survive low exposure to 1080. The susceptibility of a specific animal is linked to its metabolic rate (McIlroy, 1994), so cold-blooded animals may be more tolerant to 1080 as their metabolic rate is likely to be much lower. Fish have been found to be highly tolerant of 1080 in overseas studies (Fagerstone et al., 1994).

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

Reptiles/amphibians

An Australian study of shingleback lizards found a decrease in testosterone levels in the plasma in study animals and a degeneration of seminiferous tubules in some

individuals when high sublethal doses of 1080 were administered intraperitoneally (Twigg et al., 1988).

Invertebrates

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

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

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

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

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

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

Table 5. Amount of bait needed to be ingested to result in death based on LD_{50} for native species.

Species	LD_{50} (mg kg^{-1})	Av. Weight Female (g)	Amount of 0.4g kg^{-1} Bait (g) for LD_{50}	Amount of 0.8g kg^{-1} Bait (g) for LD_{50}	Amount of 1.0g kg^{-1} Bait (g) for LD_{50}	Amount of 1.5g kg^{-1} Bait (g) for LD_{50}	Amount of 2.0g kg^{-1} Bait (g) for LD_{50}	Amount of 50g kg^{-1} Bait (g) for LD_{50}	Amount of 100g kg^{-1} Bait (g) for LD_{50}
Birds									
Silvereye	9.25	13	0.30	0.15	0.12	0.08	0.06	0.002	0.001
Weka	8	700	14.00	7.00	5.60	3.73	2.80	0.11	0.06
Mammals									
Short-tailed bat	0.15	14	0.005	0.006	0.002	0.001	0.001	0.00004	0.00002
Arthropods									
NZ ant	42	0.002	0.00021	0.00011	0.00008	0.00006[b]	0.00004	0.000002	0.0000008
Tree weta	91	1	0.228	0.114	0.091	0.061	0.046	0.002	0.001

[a] Weights for birds from Heather and Robertson (1996) & weights of bats from Lloyd and McQueen (2000); [b] A single 6 g 0.15% 1080 pellet has enough toxin to deliver an LD_{50} dose to >100 000 ants with a mean bodyweight of 2 mg each (Booth and Wickstrom, 1999).

Note: The LD_{50} values given in section 3.1.1 have been used in the calculations. The body weights used to calculate the amount of bait required for an LD_{50} are average weights of females, which are generally more susceptible to poisoning because of smaller body weight and physiological factors therefore a 'worst case scenario' for poisoning.

3.2. *Exposure*

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

Aerial and Handlaid Operations

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

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

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

[a] 1 of these operations was at Tahae (Pureora) where there is some evidence that the carrot was not screened adequately to meet bait specifications (Powlesland et al., 1999a); [b] In this operation the carrot bait was coated with EDR deer repellent; [c] 0.15% 1080 carrot

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

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

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

Species	No. Found Dead	No. of Operations	Cases Where Residues Confirmed	Sowing Rate (kg ha^{-1})		Ref.
				Prefeed	toxic	
Birds						
Silvereye	1	1[a]	1		2	1
	1	1[a]	0[i]	?	1.5 – 2.5	16
Morepork	2	1[b]	1[c]		5	3; 4
	2	2	0[i]	1	2	5
Tomtit	5+[d]	3[a]	0[e]		5 - 7	3; 6
	2	1[a]	2	Yes	3	7
Weka	2	2[a]	2		3 - 5	8; 9
	2	2[a,f]	1[g,h]		1	10; 11
Kakariki	2	1[a]	2	3	3	12
	1	1	0[i]	2	2	13
Kereru	4	3[a]	1[j]		2 - 3	14
Kiwi	1	1[a,f]	0[i]		1	15
Kea	33	9[a]	21	1 - 3	1 - 4	16; 24
Tui	1	1	0[i]	2	2	17
	1	1	0[i]	?	2	18
	1	1	0[i]	1	1	19
Fernbird	3	1[a]	3	2	1	20
Grey warbler	3	1[a]	0[i]	?	1.5 – 2.5	2
Whio	2	1	1	2	2	23
Mammals						

Short-tailed bat	1	1	1	1	1	21
Frogs Hochstetter's	1	1[a]	0[i]		7	22

[a] toxic loading of baits 0.15%; [b] toxic loading of baits 0.08%; [c] the second bird was not tested; [d] number found in second operation unspecified, assumed at least 1; [e] none of these birds were tested for residues; [f] baits handlaid; [g] this bird also had cyanide residues which is thought to be the cause of death; [h] the second bird tested negative, assumed to have come from handlaid treatment block – see Pestlink report 0203SND28; [i] tested negative; [j] two other kereru tested negative.

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

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

Bait stations

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

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

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

[a] tested negative

1 VPRD: T0597; 2 VPRD: 8692.

Other methods

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

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

Aerial and Handlaying Operations

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

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

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

The information in this section includes the results of laboratory analysis from live animals captured or killed for sampling from treatment areas. Residues from animals found dead are presented in section 3.2.1 above. The information has been restricted to those operations where the basic performance standards could be verified.

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

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

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

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

Species	Residues (mg kg^{-1})	No. Of Samples	Sowing Rate (kg ha^{-1})		Ref.
			Prefeed	Toxic	
Birds					
Kiwi	0.011	1[d]		3[a]	1
Weka	4.35	1 [d]		5 [a]	2
Whio	0.06-1.51	3 [d]	2x at 4 & 2	4	10
	0.003-0.198	19 [d]	2	2	11
	0.081	1 [d]	1.5	1.5	12
Mammals					
Short-tailed bat	0.013	1	1	1	3
Invertebrates					
Bush weta	2.7	1	1.5	1.5[a]	4
Tree weta	66	1 [e]		5 [a]	5
	8.6	1		5 [a]	6
Cave weta	32–130	4 [f]		5 [a]	5
	4	1		5 [a]	6
Weevil	10	1			6
Kauri snails	0	4		5[b,c]	7; 8
Arthropods (mixed)	0.05–0.75	4		5[b,c]	7; 8
Spiders (mixed)	14	1[g]		5 [a]	5
Arthropods (mixed)	14-46	3[h]		5 [a]	5
	0-0.006	3		5[b]	9

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

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

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

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

Birds

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

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

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

1 Walker (1997); 2 Robertson et al. (1999); 3 S. Forder pers. comm. Pestlink: 0809GDB08; 4 Veltman and Westbrooke (2011)

A total of 243 **NI brown kiwi** have been monitored during aerial and handlaid 1080 pellet operations during 5 operations and none have died from poisoning (Table 11). Kiwi call count monitoring during the Waipoua operation did not indicate significant 1080 related mortality (Pierce and Montgomery, 1992).

Table 11. NI brown kiwi monitored during aerial and handlaid 1080 operations using 0.15% or 0.08% 1080 pellets.

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

[a] toxic loading of baits 0.8 g kg^{-1}; [b] toxic loading of baits 1.5 g kg^{-1}; [c] baits were handlaid.

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

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

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

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

and Westbrooke (2011) calculated the upper bound of the 95% confidence interval for an estimate of zero mortality at 2.3%.

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

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha^{-1})		Ref.
			Prefeed	Toxic	
1986 Pureora Nth Block	16	0		10-12[b,d]	1
1986 Okahukura Forest	11	1		10-12[b,d]	1
1986 Meyers Farm (Pureora)	5	0		8-10[c]	1
1987 Pureora Nth Block	23	0		8[c,d]	1
1988 Mapara	3	0		10[c]	1
1988 Cowan WR/ Okahukura Forest	24	0		8-10[c]	1
1990 Waipoua	6	1e		5[c]	2
1990 Mapara	52	0		8[c]	3
1989 Moki Forest	12	0		9[c]	4
1990 Kaharoa Forest	24	0		[b]	5
1991 Mapara	48	0		8[c]	3
1992 Mapara	50	0		8[c]	3
1992 Kaharoa Forest	28	0		6[b]	6
1994 Rotoehu	26	0		2 [b]	7
2001 Mapara	16	0	yes	2 [b]	7

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

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

A total of 42 **weka** has been exposed to this method and bait type over 5 operations and 1 has died from poisoning (Table 13).

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

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha^{-1})		Ref.
			Prefeed	Toxic	
1994 Saxon River	7	0		5	1
1994 Tennyson inlet	17	1		5	1
1994 Rotumanu	8	0		5	2
2000 Copland	10	0		3	3; 4

1 Walker (1997); 2 Spurr and Powlesland (1997); 3 van Klink and Tansell (2003); 4 Pestlink: 02/03SWS22.

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

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

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

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

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

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

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

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

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

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

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

A total of 55 colour banded **NI robins** have been exposed to this aerial 1080 pellets over 2 operations and 10 have disappeared after poisoning (Table 16).

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

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

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

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

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

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

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

A monitoring study in Tongariro Forest (2001) using distance sampling found no significant difference in the mortality of **tomtits** between the treatment (2 kg ha^{-1} prefeed followed by 3 kg ha^{-1} 0.15% 1080 pellets) and non-treatment sites (Westbrooke et al., 2003). Distance sampling of tomtits also occurred during an aerial 1080 operation (2 kg ha^{-1} prefeed followed by 2 kg ha^{-1} 0.08% 1080 pellets) on Mt Pureora in 2003. There was no decline in male tomtits counts in this operation (Westbrooke and Powlesland, 2005). These results led the Westbrooke and Powlesland (2005) to conclude that aerial poisoning operations using cereal pellets at low sowing rates causes "…little, if any…" short term impacts on tomtit populations.

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

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

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

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

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

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

Transect counts of **SI tomtits, grey warbler, SI robins and riflemen** were conducted before and after the 2010 Waitutu aerial 1080 operation (1 kg ha^{-1} prefeed followed by 2 kg ha^{-1} 0.15% 1080 pellets). The transects were located at five sites, three within the operational area and two in a non-treatment area. While the numbers of tomtits and grey warblers detected on the transects changed following the application of the 1080, the scale and direction of the changes (decreases for tomtits and increases for grey warbler) was similar at all five sites. The pre- and post-control counts of riflemen and SI robins were similar between the operational area and non-treatment sites. The authors therefore concluded there was no evidence for population level impacts from 1080 on any of these species (Greene et al., 2013).

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

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

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

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

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

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

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

[b] These operations did not have bait application exclusions over the rivers where monitored whio were present.

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

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

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

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

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

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

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

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

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

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

Kakariki (parakeet) nests have been monitored during two aerial cereal 1080 operations. Fifteen nests were monitored during the October 2007 Hurunui Valley operation and a further seven nests were monitored during a 1080 operation in the

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

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

A total of 276 radio tagged **Kea** have been exposed to this method and bait type over 25 operations and 33 have died from poisoning (Table 20). Additionally, 2 radio tagged birds have been exposed to 0.08% carrot baits during 1 operation and none died from poisoning (Kemp and van Klink, 2008).

Table 20. Kea monitored during aerial 1080 operations using 0.15% 1080 pellets.

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha^{-1})		Ref.
			Prefeed	Toxic	
Arawata Valley (2008)	10	0	1	4	1, 2
Franz-Fox (2008)	17	7	3	2.5	1, 2
Mt Arthur (2009)[a]	13	0	1	2	1, 2
Hawdon (2009)[a]	10	0	1	2	1, 2
Okarito (2011)[a]	37	8	1	2	2
Whangapeka (2011)[a]	13	0	1	2	2
Abbey Rocks (2011)[a]	8	0	1	1	2
Copland Valley (2012) [a]	2	0	1	2	2
Hawdon Valley (2012)[a]	6	0	1	2	2
Otira (2013)[a]	34	5	1	2	2

Mt Arthur (2014)[a]	7	0	1		2
Anatoki (2014) [a]	2	0	6	1-2	2
Whangapeka (2014)[a]	8	0	1	2	2
Abbey Rocks (2014)[a]	21	1	1	1	2
Hawdon Andrews (2014)[a]	4	0	1	1	2
Oparara (2014)[a]	5	2	1	2	2
Rotoiti (2014)[a]	2	1	1	1	2
Oparara (2016)[a]	5	0	1.5	1.5	2
Whangapeka (2016)[a]	18	0	1.5	1.5	2
Hawdon (2017) [a]	5	0	2	2	4
Perth Valley 1 (2019)	13	2	2 & 2	4	3
Perth Valley 2 (2019)	12	0	2 & 2	2	4
Arthurs Pass (2019) [a]	6	1	3	3	4
Hawdon-Poulter (2019) [a]	6	0	1.5	1.5	4
Matukituki (2020) [a]	12 [b]	6	2 & 2	2	4

[a] These operations were undertaken using the performance standards adopted by DOC in 2009

[b] The sample of kea monitored comprised of birds that were habituated to feeding on human provided foods

1 Veltman and Westbrooke (2011): 2 Kemp et al. (2019); 3 (ZIP, 2019); 4 J. Kemp pers. comm.

Reptiles/amphibians

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

The attractiveness of non-toxic RS5 cereal pellets (dyed green and lured with cinnamon) to wild **grand** and **Otago skinks** were tested by Marshall and Jewell (2007). The baits were offered in two sizes – small pieces no larger than 6 mm and large baits (whole pellets). The baits were offered dry or wet. All bait types were sampled (licked, nudged or bitten) by both species of skink, with small pieces sampled more often than large baits. No animals tried to consume large pieces of

cereal bait. However, 1/10 grand skinks and 3/20 Otago skinks consumed small, wet pellet fragments.

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

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

Bats

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

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

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

Fish

Native fish have not been monitored during 1080 operations. However, a field experiment has been conducted to study the impact of 1080 on **longfin eels, köaro** and **upland bullies**. Four headwater streams were selected in the Mawhera Forest in the Grey Valley, West Coast. In each stream four sites were selected – 10 m and 100 m downstream, and 10 m and 100 m upstream from where 1080 baits were to be placed in the stream. At each site 8 fish of each species were placed in individual cages. Fish mortality was recorded after 1 and 4 days. Baits (6.5 g, 0.15% 1080 Wanganui #7 pellets) were then placed in the streams at a density equivalent to a

sowing rate of 25 – 30 kg ha^{-1} (this represented an extreme scenario of 10 x normal sowing rates). Fish survival was monitored 1 and 4 days after the bait was placed in the water. No fish died after the baits were added to the water, suggesting all three species were tolerant to 1080 in water at the concentrations used in the study (Suren and Lambert, 2006).

Terrestrial invertebrates

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

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

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

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

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

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

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

Aquatic invertebrates

In the early 1990's, the Taranaki Regional Council monitored aquatic invertebrates in streams before and after two aerial 1080 operations. No effect of the aerial 1080 operations on the invertebrate communities could be demonstrated. However, the

post control samples were collected between 32 and 42 days after the aerial operation, and the sampling protocol could have resulted in any short-term reductions in invertebrate numbers being missed (Suren and Lambert, 2006).

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

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

Birds

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

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

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

1 Robertson et al. (1999).

A total of 44 **NI kokako** has been exposed to 0.08% 1080 carrot baits over 2 operations and none have disappeared after poisoning Table 22). Between 1986 and March 1998, 366 kokako (including 6 juveniles) have been monitored through 31 aerial poisoning operations (of all bait types and toxins combined), although the number exposed and known to have survived is greater. Of the monitored birds, 4 have disappeared after poisoning, leading to a maximum estimate for kokako

mortality of 1.4% per operation with a 5% chance that it will exceed 4% (Flux and Innes, 2001).

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

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

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

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

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

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

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

Operation	No. of Birds Exposed	No. Killed by Poison	Sowing Rate (kg ha^{-1})		Ref.
			Prefeed	Toxic	
1996 Tahae (Pureora)	6	1[a]		15	1

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

1 Powlesland et al. (1998).

16 marked (15 radio-tagged and 1 banded) adult **NZ falcon** were monitored through two 0.08% 1080 carrot operations undertaken in Kaingaroa Forest during 2013-2014

by Horikoshi et al. (2018). One of the falcon was found dead following an operation but no 1080 residues were detected in its tissues. Using the live-recaptures model in Program MARK 8.1, the researchers estimated of the 95% C.I. survival of adult falcon through the operations at 68-100%.

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

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

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

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

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

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

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

[c] 1 bird also disappeared form the non-treatment site during the study period

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

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

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

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

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

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

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

1 Powlesland et al. (2000)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Reptiles/amphibians

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

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

Bats

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

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

Invertebrates

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

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

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

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

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

1080 pellets or carrot baits in bait stations

Birds

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

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

Reptiles

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

Bats

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

Invertebrates

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

Pestoff Professional Possum Paste (0.08% and 0.15%)

Birds

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

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

Bats

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

Reptiles

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

Invertebrates

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

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

10% 1080 Gel

No information could be found

Cut apple bait

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

Birds

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

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

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

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

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

4. Effects on Domestic and Feral Animals

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

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

Feral deer population mortality from aerial poisoning operations targeting possums is highly variable and does not appear to be consistently influenced by toxic loading, sowing rate, prefeeding or bait type. Most estimates of deer kill fall between 30 and 60%. Nugent et al. (2001) quote productivity figures for red deer populations of around 30% so low to moderate by-kill of deer populations is probably negated within a couple of years.

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

Although 1080 is toxic to honeybees, baits used in pest control are generally not attractive to honeybees. However, this may not always be the case if honeybees are particularly hungry, so beekeepers should always be notified of operations.

4.1. Toxicity

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

The LD_{50} values for a range of domestic and feral animals are presented in Table 27. For completeness, it includes information on species not present in New Zealand.

While no LD_{50} data is available, mortality rates of pregnant ewes exposed to 1080 are higher compared to non-pregnant ewes (O'Connor et al., 1999)

Table 27. Acute oral toxicity (LD_{50} mg kg^{-1}) of 1080 for non target domestic and feral animals.

Species	LD_{50} (mg kg^{-1})	Ref.
Birds	Range: 2.1 - 12.6	
Mallard duck	4.8	1
Maned duck	12.6	2
Common pigeon	4.25	3
Leghorn hens	10.0	4
White leghorn chicken[a]	7.5	5
Rhode Island red chicken	6.5	6
Plymouth rock chicken	5.5	7
Eurasian magpie	2.12	8
Chukar partridge	3.51	3
Ring-necked pheasant	6.46	3
California quail	4.6	9
European goldfinch	3.5 (approx.)	2
Australian magpie	9.9	2
House sparrow	2.5	10
Marsupials	Range: 0.210 - 0.79	
Bennett's wallaby	0.21	11
Brush-tailed possum	0.79	12
Dama wallaby	0.27	11
Mammals	Range: 0.06 - 8.3	
Dog	0.06	7
	0.07 (LD_{100}: 0.1)	14
Cat	0.28	14
Ferret	1.41	3
Rabbit	0.35	15

House mouse	8.3	16
Norway rat	0.22-3.0	7
Cattle	0.393	17
Deer (not specified)	0.5	14
Horse	0.32-1.00	18
Pig	0.4	18
Sheep	0.25-0.64	18
Goat	0.3-0.7	18
Reptiles/Amphibians	Range: 43.6 - >500	
Spotted grass frog	c. 60	19
American Bullfrog	54.4	3
Leopard frog	150	7
South African clawed frog	>500	20
Blotched blue-tongued lizard	336.4	19
Shingle-back lizard	205.9[b]	19
Gould's monitor	43.6	19
Fish	Range: 54 - 3500 mg l^{-1}	
Bream & bass	> 370[c]	21
Rainbow trout	54	22
Fingerling trout	>1000[d]	14
Harlequin fish	3500[e]	23
Bluegill sunfish	>970[f]	22
Aquatic arthropods	Range: 0.05 - 3500 mg l^{-1}	
Daphnia magna	350[g]	22
Mosquito larvae (*Anopheles quadrimaculatus*)	0.05-0.1 (approx.)	24
Terrestrial arthropods	Range: 8 - 21	

Honeybee	8	25
Housefly	21	26

[a] laying hens appeared to be more susceptible to 1080 poisoning than hens that were not laying; [b] non-tolerant populations from South Australia, Western Australian populations LD_{50} reported as 524 mg kg^{-1}; [c] survived indefinitely at this concentration; [d] survived this concentration; [e] substance tested was Fluoroacetamide (a compound related to 1080); [f] no effects observed at this level; [g] 48-hour EC_{50}

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

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

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

Fish

No information relating to bait intake (oral LD_{50} values) could be found. Force-feeding cereal pellets containing approximately 4 mg of 1080 to two fingerling trout and five adult **trout**, and about 8 mg of 1080 to two adult trout had no visible effect (Rammell and Fleming, 1978).

All toxicity values for fish reflect concentration of 1080 in water (LC_{50} values) which is more relevant when assessing likely risks to fish from possum baits. To achieve the 96-hour LC_{50} of 54 mg l^{-1} for rainbow trout, all the 1080 in 3.6kgs of 1.5 g 1080 kg^{-1} bait would have to leach out of the bait, and then remain in 100 litres of still water, without breaking down, for 96-hours. This is highly unlikely to occur in under pest control conditions in New Zealand.

Table 28. Amount of bait needed to be ingested to result in death based on LD_{50} for non target domestic animals.

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

The LD_{50} values given in section 4.1.1 have been used in the calculations and the average weights of females have been used, as females are generally smaller and therefore a 'worst case scenario' for poisoning. Where LD values were cited as greater (>) or less (<) than a value, this value was used to make the calculations.

Table 29. Amount of bait needed to be ingested to result in death based on LD_{50} for non target feral animals.

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

The LD_{50} values given in section 4.1.1 have been used in the calculations and the average weights of females have been used, as females are generally smaller and therefore a 'worst case scenario' for poisoning. Where LD values were cited as greater (>) or less (<) than a value, this value was used to make the calculations.

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

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

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

Domestic animals

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

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

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

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

Feral animals

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

Spielmann et al. (1973) reported that 1080 at a dose just below the maternal LD_{50} was not teratogenic to **rats**. The embryos in this study showed no macroscopic or skeletal abnormalities. This work involved only a single dose and the results contrast with the investigation by Eason et al. (1999) which followed current international guidelines that require dosing rats from day 6–17 of gestation at three dose levels. Eason et al. (1999) found the NOEL derived from their multi-dose study (0.1 mg kg^{-1} day^{-1}) was 10-fold less than the single dose NOEL (1 mg kg^{-1}) reported by Spielmann et al. (1973).

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

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

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

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

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

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

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

4.2. *Exposure*

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

Aerial and hand laid operations

Pets

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

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

Livestock

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

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

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

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

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

Honeybees from hives located near the loading zone were observed during one operation to be gathering the green dust from toxic RS5 cereal baits. This loading zone had been used on previous occasions for aerial 1080 operations using the same bait type and no similar observations were made (N. Murray pers. comm.). AHB (2012) conducted trials to investigate the attractiveness of RS5 and Wanganui #7 pellets to honeybees. The bees were trained to visit wet and dry cereal baits coated with a sugar-syrup attractant. The attractiveness of the baits was determined by switching the sugar-coated bait with standard non-toxic baits. Within 10 minutes, the bees lost interest in the standard baits. When EDR coated pellets were used, bees continued to visit the baits for approximately 30 minutes after the sugar-coated baits had been switched with the EDR coated pellets. When 1080 cereal pellets were placed within 80 metres of hives, no bees were observed visiting or landing on the baits. To test the risk of dust to honey bees, six hives were put out during an actual 1080 operation at Buller South. 1080 was not detected in honeybees, wax, nectar or pollen samples collected within 24 hours of the operation or when the monitoring was repeated after 15 – 16 days. Additionally, there was no evidence of 1080 dust on flowers on which honeybees were observed foraging (AHB, 2012).

Feral animals

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

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

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

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

During the 2017 TBfree aerial 1080 operation at Paemahi (Kaimanawa Forest Park), the impact of ***EDR*** deer repellent coated cereal pellets on **sika deer** was studied.The

study involved pre- and post monitoring using camera traps in four 600 ha blocks, two within and two outside the operational area. 730 deer were sighted during the pre-monitoring and the deer density was estimated at 20 deer km^{-1}. There was a decline in deer sighted post control, however, the decline was highest in the two blocks outside the operational area. The reduction in deer sightings was attributed to a decline in deer activity in winter rather than as a result of the 1080 operation. 11 deer were found dead by searchers, giving a by-kill of 1.6 deer km^{-1} . This is equivalent to <10% of the deer population that was present (TBfree, 2017).

Game birds

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

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

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

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

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

Other birds

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

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

Bait station operations using 0.15% or 0.08% 1080 Pellets

Domestic and feral non-target deaths reported after the use of 1080 cereal pellets in bait stations are reported in Table 31.

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

Species	Total Found Dead	No. of Operations Involved	No. of Cases Where Residues Confirmed	Sowing Rate (kg ha^{-1})	Ref.
Dog	2	1	1		1; 2
Cattle	16	1	2		3
Australasian magpie	1	1	0		1

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

Pestoff Professional 1080 Possum Paste (0.08 & 0.15%)

Honey bees were known to be attracted to 1080 paste baits (sometimes referred to as jam baits) used in pest control prior to 1995. Changes in formulation of 'Pestoff Professional' possum paste since then have been found to be unattractive to bees (Morgan, 2000).

Cut apple bait

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

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

Aerial and hand laid operations

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

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

Species	Sample Type	Residues (mg kg^{-1})	Ref.
Mammals			
Cat	Muscle	0.06–1.24	1
	Stomach	0.36	
Dog	Muscle	0.014–0.41	1
	Stomach	0.028–0.7	
	Intestine	0.44	
	Vomit	1.07	
Cattle	Muscle	0.003–0.46	1
	Stomach	0.04–9.1	
Sheep	Muscle	0.021-0.3	1; 2
	Stomach	0.001-1.3	
Deer	Muscle	0.012–7.37	1; 3; 4; 5
	Stomach	8.7–35.9	
	Heart	0. 85-8.12	
	Liver	0. 75-4.05	
Pig	Muscle	0.03–0.21	1
	Stomach	56	
Birds			
Blackbird	Muscle	0.01–32.0	1; 3; 4; 6
Chaffinch	Muscle	0.14–5.80	1; 6
Dunnock	Muscle	0.28–1.75	6
Hedge Sparrow	Muscle	0.03	1
Thrush	Muscle	2.01	6
California Quail	Crop	18 - 76	7

Species	Sample Type	Residues (mg kg^{-1})	Ref.
Invertebrates			
Honeybee	2 whole animals	0–10.8	1

1 VPRD; 2 Parliamentary Commissioner for the Environment (1994); 3 Speedy (2003); 4 Nugent et al. (2004); 5 McIntosh and Staples (1959); 6 Morriss et al. (2016); 7 Evans and Soulsby (1993)

0.15% 1080 Pellets in bait stations

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

4.3. *Treatment*

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

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

5. Human Health

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

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

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

5.1. Toxicity

5.1.1. What is the oral MDL (mg kg^{-1} b.w.)?

The oral MDL (Minimum Lethal Dose) for humans has been estimated at 0.6 mg kg^{-1} (TERA 2006). The oral LD_{50} is estimated at being between 0.7 and 10.0 mg kg^{-1} (Chenoweth, 1949; Eisler, 1995; Kaye, 1970).

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

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

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

Table 33. Amount of 1080 bait needed to be ingested by a human to result in death based on the LD_{50}.

	MLD (mg kg^{-1})	Av. Weight (kg)	Amount of 0.8 g kg^{-1} 1080 Bait (g) for MDL	Amount of 1.5 g kg^{-1} 1080 Bait (g) for MDL
Child	0.6	15	11.25	6
Adolescent	0.6	30	22.5	12
Small adult	0.6	60	45	24
Large adult	0.6	90	67.5	36

5.1.3. What is the dermal MDL (mg kg^{-1} b.w.)?

Monofluoroacetate is not readily absorbed through intact skin, but it can be absorbed more readily through cuts and abrasions. An MDL has not been estimated, but Fagerstone et al. (1994) estimated the dermal LD_{50} at 300 mg kg^{-1}. Exposure guidelines (Threshold Limit Values, TLV) for 1080 have been set in USA, with a Time-weighted average (TLV-TWA) of 0.05 mg/m^3 for skin exposure (Anon., 1991).

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

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

This is not applicable for 1080.

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

There is no published information on the LC_{50} for 1080 in dust or mist. A Biological Exposure Index (BEI) of 15 µg l^{-1} (0.015 ppm) for 1080 has been set by Occupational Health and Safety Service (OSH) New Zealand (Occupational Safety and Health Service, 2002).

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

Three different complementary tests indicate that 1080 is not a mutagen and is therefore unlikely to be a carcinogen (Eason et al., 1999).

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

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

It is a male reproductive toxicant with effects on testes of mammals (Eason and Turck, 2002; Shinoda et al., 2000; Wolfe, 1998). In a 90 day study, Wolfe (1998) reported a decreased weight of testes and epididymides, and abnormal sperm formation in male rats. In a 90 day toxicology study of 1080, Eason and Turck

(2002) reported hypospermia in the epididymides and degeneration of the seminiferous tubules of the testes of male rats dosed with 1080 at 0.25 mg kg^{-1} day^{-1}. The NOEL for rats administered 1080 via oral gavage for 90 days was 0.075 mg kg^{-1} day^{-1}.

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

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

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

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

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

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

The onset clinical signs usually ranges from 30 minutes to about 2-3 hours (Eason and Wickstrom, 2001), however, in one case of acute poisoning, onset of symptoms was described as within minutes (Williams, 1948). Relatively few cases of human poisoning (accidental or deliberate) have been reported in the literature (22 cases, 16 of which were fatal) (Anon., 1992; Brockmann et al., 1955; Ellenhorn and Barceloux, 1988; Harrison et al., 1952; Trabes et al., 1983).

Poisoning symptoms experienced include nausea, vomiting, and abdominal pain initially, followed by respiratory distress, anxiety, agitation, muscle spasms, stupor, seizures, and coma. Hypotension is thought to be one of the more important predictors of mortality in 1080 intoxication (Chi et al., 1999; Chi et al., 1996).

5.2. Treatment

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

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

There is ongoing research into antidotes for 1080 (e.g. Goncharov et al., 2006; Hoyos et al., 2018).

6. Operational

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

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

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

6.1. Animal Welfare

6.1.1. What are the animal welfare impacts of 1080 on the target pest?

1080 toxicosis generally has a characteristic 'lag time' in mammalian species, where following intake of a lethal dose, the animal will show no visible signs of poisoning for up to a number of hours, before beginning to display symptoms (Eason and Wickstrom, 2001). The onset clinical signs usually ranges from 30 minutes to about 2 - 3 hours with most deaths in mammals generally occurring 8 – 48 hours after ingestion of a lethal dose (Eason and Wickstrom, 2001).

Possums

Littin et al. (2009) reported that the onset of symptoms in eight unhandled lethally dosed possums occurred at 1 hour 50 minutes (±0:09 s.e.m) with animals exhibiting abnormal appearances and postures. Seven of the animals showed retching, and three vomited starting at 2 hours 53 minutes. Lack of coordination began at 3 hours 37 minutes, after which possums spent most of the time until death lying, showing spasms and tremors. Five of the possums had seizures while lying prostrate. The mean time to death was 11 hours 26 minute (±1:55 s.e.m).

In possums the animal welfare impacts of 1080 is described as intermediate when compared to other vertebrate toxic agents used to kill possums in New Zealand (Littin et al., 2009; MAFBNZ, 2010).

Rodents

Cook (1998) reported laboratory rats orally dosed with 1080 exhibited hypersensitivity to light and sound, an increased incidence of grooming or scratching of the abdomen, increased cage pacing and increased curled-but-awake posture. Five of the ten rats dosed with 1080 showed convulsive behaviour between 4 to 10 hours after the 1080 was administered.

McIlroy (1982b) reported that ship rats exhibited a 0.8 - 27.8 hour latent period and died 2.4 - 36.5 hours after a lethal dose of 1080 was administered. Norway rats had a 0.4 – 2.3 hour latent period and a 2.5 – 112.0 hour time to death. Mice had a 1.3 – 2.8 hour latent period and 2.2 - 68.3 hour time to death. In rats observed symptoms

included animals initially appearing depressed, often sitting quietly hunched in a corner or lying on their side, back or stomach with their eyes partially closed: hypersensitivity to touch or sounds; and uncoordinated movement with unsteady balance. Respiration was initially very rapid, but became slower, shallower and more irregular until death occurred. Convulsions were commonly observed.

In rats the animal welfare impacts of 1080 is described as intermediate when compared to other vertebrate toxic agents used to kill rats in New Zealand (MAFBNZ, 2010).

Cats

The main poisoning symptoms in cats are lethargy and disorientation, which are unusual for carnivores and more closely resemble those seen in herbivores. Other symptoms include uncoordinated movements and occasional vocalisation (Eason and Frampton, 1991). Neurological signs associated with 1080 exposure are generally less severe in cats than in dogs (Eason and Wickstrom, 2001). McIlroy reported a latent period of 1.0 - 5.6 hours and time to death between 20.7 - 21.0 hours. In cats the animal welfare impacts of 1080 are described as intermediate when compared to other vertebrate toxic agents (MAFBNZ, 2010).

Rabbits

In rabbits the animal welfare impacts of 1080 are described as intermediate (MAFBNZ, 2010). The onset of symptoms has been reported as occurring between 1.1 - 10.1 hours after exposure to a lethal dose and death occurring after 3.0 - 44.3 hours (McIlroy, 1982a). Gooneratne et al. (1994) reported the time to death ranging from 1 to 7.5 hours in rabbits following a lethal dose. Lying prone, lethargy, respiratory distress, sensitivity to noise or disturbance and convulsions have been reported in poisoned rabbits (MAFBNZ, 2010; McIlroy, 1982a).

Wallabies

McIlroy (1982a) reported symptoms in poisoned wallabies included animals sitting hunched up; generally appearing non-alert, with shivering or shaking forelimbs and unsteady balance; convulsions and a white froth exuded from the mouth and nostrils. The latent period in Bennett's wallabies was <16.9 to 23.2 hours (7 wallabies observed), and the time to death was 8.9 – 38.9 hours (23 wallabies observed). For dama wallabies the time to death was 13.8 - 37.1 hours. MAFBNZ (2010) describe the overall animal welfare impacts of 1080 on wallabies as intermediate compared to other vertebrate toxic agents.

Deer

In general, herbivores experience cardiac failure, whereas carnivores experience central nervous system disturbances and convulsions then die of respiratory failure (Egeheze and Oehme, 1979).

Daniel (1966) reported that deer became lethargic and lay down quietly without any of the convulsions or leg-thrashing commonly reported in Canidae. He reported that deer died between 2 and 30 hours after eating a lethal dose.

6.2. *Efficacy*

6.2.1. Is 1080 effective on the target pest, based on the LD50?

All the registered target species have relatively high susceptibility to 1080. The LD_{50} values are presented in Table 34.

Table 34. Acute oral toxicity (LD_{50} mg kg^{-1}) of 1080 to the target pests.

Target Pest	LD_{50} (mg kg^{-1})	Ref.
Cat	0.28	1
Deer not specified	0.50	2
Mule deer	0.27 – 0.90	3
House mouse	8.30	4
Brush-tailed possum	0.79[a]	5
Rabbit	0.35	6
Ship rat	0.76	4
Laboratory rat	1.71	4
male	2.08 (95% CI 1.73, 2.49)	7
female	1.85 (95% CI 1.56, 2.19)	7
Norway rat (wild)	0.22-3.0	8
Stoat	0.49 (LD_{90} = 0.70)	9
Bennett's wallaby	0.21	10
Dama wallaby	0.27	6; 10

[a] Ambient temperature may affect the acute toxicity of 1080 to possums, with increased toxicity at low temperatures (Veltman and Pinder, 2001).

1 Eason & Frampton(1991); 2 Rammell & Fleming (1978); 3 Tucker & Crabtree (1970); 4 McIlroy (1982b); 5 Bell (1972); 6 McIlroy (1982a); 7 (McCranor et al., 2019); 8 Chenoweth (1949); 9 Spurr (2000b); 10 Munday (1978).

6.2.2. How much bait does the target pest have to ingest in order to be poisoned, within what timeframe?

Target pests would have to eat at least the amounts given in Table 35 in one feeding session (at least three hours) to be likely to receive an acute lethal dose.

Table 35. Amount of bait a target pest needs to ingest to result in death based on LD_{50}.

Species	LD_{50} (mg kg^{-1})	Av. Weight Female (g)	Amount of 0.2g kg^{-1} Bait (g) for LD_{50}	Amount of 0.4g kg^{-1} Bait (g) for LD_{50}	Amount of 0.6g kg^{-1} Bait (g) for LD_{50}	Amount of 0.8g kg^{-1} Bait (g) for LD_{50}	Amount of 1.0g kg^{-1} Bait (g) for LD_{50}	Amount of 1.5g kg^{-1} Bait (g) for LD_{50}	Amount of 2.0g kg^{-1} Bait (g) for LD_{50}	Amount of 50g kg^{-1} Bait (g) for LD_{50}	Amount of 100g kg^{-1} Bait (g) for LD_{50}
Bennetts wallaby	0.21	11000		-		-	-	1.5	1.2	0.05	0.02
Cat	0.28	2500		-		-	0.7	-	-	-	-
Dama wallaby	0.27	4300		-		-	-	0.8	0.6	0.02	0.01
House Mouse	8.30	20				0.21		0.1			
Norway rat	0.22	220		-		0.06	-	0.03	-	-	-
Possum	0.8	3000		-	4.0	3.0	-	1.6	-	-	-
Rabbit	0.35	800	1.4	0.7	0.47	-	-	-	-	-	-
Red deer	0.5	80000		-		-	-	26.67	-	-	0.4
Ship rat	0.76	140				0.13		0.07	-	-	-

Palatability

Palatability of a bait will also influence the whether the target pest will ingest a lethal dose.

Possums

Morgan (2004) reported that under field conditions double wax coated 1080 pellets left in Philproof bait stations had a 20% decline in palatability after 4 months.

Mice

Wild caught mice demonstrate marked avoidance of baits containing 1080 in pen studies (Fisher et al., 2009; Morriss et al., 2008). In paired choice tests (using toxic pellets and non-toxic rodent pellets), only 8% of mice died when offered 0.15% 1080 baits. Pellet type (Wanganui #7 or RS5), the presence or absence of green dye, the presence or absence of 0.3% cinnamon and bait size (2g and 12g) did not have any effect on the amount of toxic bait eaten by mice (Morriss et al., 2008). In similar paired choice tests, Fisher et al. (2009) reported that mice had a low acceptance of 0.08% and 0.15% 1080 pellets and mortality rates were similar (25%) for both concentrations of 1080. The authors also found that pre-feeding with non-toxic pellets did not improve the acceptance of 0.15% 1080 pellets by mice.

Based on the marked avoidance of 1080 by mice, O'Connor et al. (2005) recommended that 1080 should not be used for mouse control operations until new methods are developed to improve 1080 bait acceptance by mice.

Other factors

Parkes (1991) noted that the when 10% 1080 gel with a carbopol carrier was applied to mahoe leaves, the baits had a maximum life of about 60 days because phytotoxicity caused most leaves to absciss within 46 days. When mahoe leaves were smeared with 10% 1080 gel in a petrolatum carrier, the baits could remain effective as baits for at least 110 days, after which time most leaves had abscissed. However, abscissed leaves could remain toxic to animals that eat leaf-fall for at least 300 days.

6.2.3. What is the latent period between bait ingestion and onset of symptoms?

The latent period is hours. Possums receiving a sub-lethal dose of 1080 have been known to develop bait shyness (O'Connor and Matthews, 1999; Ogilvie et al., 2000) and this can persist for at least three years (O'Connor and Matthews, 1999). Conditioned food aversion to diets containing 1080 has been reported in rats (Nachman and Hartley, 1975).

Note: A short latent period increases the likelihood of the target pest developing poison shyness.

6.2.4. What field evidence is there that this pesticide use causes a population decline of the target pest species at sites where it is used?

Possums

Aerially distributed 1080 cereal pellets

The percentage kills obtained during aerial operations using 0.15% 1080 cereal pellets between 2010 and 2017 are presented in Table 36. The mean percentage kill was 89.1% (±2.0% s.e., n=37). The results for earlier operations are in Appendix 1.

The percentage kills obtained during aerial operations using 0.08% 1080 cereal pellets are presented in Table 37. For non-prefed aerial operations using 0.08% cereal pellets the mean kill was 69.1% (±10.4% s.e., n=10). The mean kill for prefed aerial operations using 0.08% cereal pellets was 82.2% (n=1).

Table 36. The percentage possum kill for aerial operations using 0.15% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	
100%	Otahu, Coromandel, Nov 2017	1.5 (6g pellets)	2 (12g #7 pellets, 21 days later)	1718HAU 01
100%	Hollyford BfoB, Oct 2017	1 (6g pellets)	2 (12g RS5 pellets, 13 days later)	1718TEA 01
97.5%	Papakai, Coromandel, Oct 2017	1.5 (6g pellets)	2 (12g #7 pellets, 19 days later)	1718WH T04
95.2%	Moehau, Coromandel, Oct 2017	1.5 (6g pellets)	2 (12g #7 pellets, 26-40 days later)	1718WH T01
88.6%	Cleddau BfoB, Sept 2017	1 (6g pellets)	2 (12g RS5 pellets, 16 days later)	1718TEA 02
94.3%	Rotoehu Forest, Sept 2017	1.5 (6g pellets)	2.5 (12g #7 pellets, 8 days later)	1718TAU 01
94.0%	Whareorino, Jul 2017	1.5 (6g pellets)	2 (12g #7 pellets, 14 days later)	1617MPT 06
58.1% (est.)	Egmont NP, Dec 2016	1 (6g pellets)	2 (6g RS5 pellets, 59 days later)	1617TAR 01

100%	Waitutu BfoB, Nov 2016	1 (6g pellets)	1 (12g RS5 pellets, 13 days later)	1617TEA 01
85%	Tawarau Management Area, Oct 2016	1.5 (6g pellets)	1.5 (12g #7 pellets, 24 days later)	1617MPT 01
98.1%	Abel Tasman BfoB, Aug 2016	1.5 (6g pellets)	3 (10g RS5 pellets, 25 days later)	1718MO T06
66.7%	Kia Wharite Project - Mangapurua Block, Whanganui, Oct 2015	0.5 (6g pellets)	0.5 (6g #7 pellets, 31	1516WH A01
91.1%	Mokaihaha Ecological Area, Rotorua, Aug 2015	2 (12g pellets)	2 (12g #7 pellets, 15 days later)	1516ROT 02
78.9%	Rotoiti BfoB, Dec 2014	1 (6g pellets)	1 (6g RS5 pellets, 25 days later)	1415STA 02
100%	Eglinton Valley BfoB, Dec 2014	1 (6g pellets)	1 (12g RS5 pellets, 48 days later)	1314TEA 05
73.7%	Matukituki BfoB Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 26 days later)	1415WA N01
91.1%	Lower Holyford BfoB, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 38 days later)	1314TEA 06
99.9%	Iris Burn BfoB, Sept 2014	1 (6g pellets)	2 (12g RS5 pellets, 8 days later)	1415TEA 01
98.6%	Waitutu BfoB, Aug 2014	1 (12g pellets)	2 (12g RS5 pellets, 6 days later)	1314TEA 07
93.1%	Pirongia FP, Aug 2014	2 (6g pellets)	2 (12g RS5 pellets, 30 days later)	1415WAI 02
63.6%	Project Kaka, Tararuas, Dec 2013	1 (6g pellets)	1 (12g #7 pellets, 10 days later)	1314WRP 02
67.7%	South Hurunui, Dec 2013	1 (6g pellets)	2 (12g RS5 pellets, 21 days later)	1314WM K03

87.1%	Poulter Valley, Dec 2013	1 (6g pellets)	2 (12g RS5 pellets, 21 days later)	1314WMK03
79%	Mataketake block 2, Haast, Nov 2013	1 (6g pellets)	2 (12g RS5 pellets, 11 days later)	1314SWS
82%	Mataketake block 5, Haast, Nov 2013	1 (6g pellets)	2 (12g RS5 pellets, 11 days later)	1314SWS
80.8%	Tennyson Inlet Reserve - Mt Stanley, Nov 2013	1 (6g pellets)	1 (6g RS5 pellets, 13 days later)	1314SND02
94.0%	Waitaanga, Oct 2013	1 (8g pellets)	2 (12g #7 pellets, 16 days later)	1314TAR10
80.5%	Waitaanga, Oct 2013	1 (8g pellets)	1 (6g #7 pellets, 16 days later)	1314TAR10
100%	Central Coromandel-Papakai, Jun 2013	2 (12g pellets)	2 (12g #7 pellets, Orange lure, 7 days later)	1314HAU02
100%	Moehau, Jun 2013	2 (12g pellets)	2 (12g #7 pellets, Orange lure, 6 days later)	1314HAU01
100%	Te Kopia SR, Dec 2012	2 (6g pellets)	2 (12g #7 pellets, 16 days later)	1213ROT03
75.2%	Waipoua Forest, Sept 2011	1 (6g pellets)	2 (12g #7 pellets, 22 days later)	1112KAU01
94.4%	Waihaha Ecological Area, May 2011	1.5 (12g pellets)	1.5 (12g #7 pellets, Orange lure, 19 days later)	1112MPT05
95.3%	Project Kaka, Tararuas, Nov 2010	1.4 (6g pellets)	2 (12g #7 pellets, 16 days later)	11011PON20
95.1%	Ruahine Corner, Oct 2010	1.1 (8g pellets)	2.03 (12g #7 pellets, 13 days later)	1011PNT09
99.6%	Waitutu, Oct 2010	1 (12g pellets)	2 (12g RS5 pellets, 26 days later)	1011MRH03
100%	Tawarau, Aug 2010	2 (12g pellets)	2 (12g RS5 pellets, 33 days later)	1011MPT02

Table 37. The percentage possum kill for aerial operations using 0.08% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	
100%	Station Creek A Trial, Jul 2006	-	5 (12g #7 pellets)	Josh Kemp pers. comm.
82.2%	Station Creek B Trial, Jul 2006	2 (12g pellets)	5 (12g #7 pellets, 7 days later)	Josh Kemp pers. comm.
0%	Mapara, October 1992	-	8	Spurr (1993)
89%	Isolated Hill SR Nelson August 1992	-	4	Spurr (1993)
96%	Titirangi Reserve Wanganui June 1992	-	5	Spurr (1993)
50%	Puketi Forest Northland March 1992	-	5	Spurr (1993)
32%	Mapara October 1991	-	5	Spurr (1993)
91%	Whitecliffs Wanganui July 1991	-	6	Spurr (1993)
61%	Waipapa EA June 1991	-	10	Spurr (1993)
79%	Mapara September 1990	-	8	Spurr (1993)
93%	Rangitoto Island October 1990	-	12	Spurr (1993)

Aerially distributed 1080 carrots

The mean percentage possum kill for operations using 0.8 g kg^{-1} 1080 carrots (Table 38) is 91.1% (±1.4% s.e., n=7).

Table 39 lists aerial operations using 1.5 g kg^{-1} 1080 carrots where the percentage kill could be calculated. The mean kill for these operations was 93.7% (n=4).

Table 38. The percentage possum kill for aerial operations using 0.8 g kg^{-1} 1080 carrot.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	
93.4%	Te Kopia SR, 11-25/7/2006	2 (6g baits)	5 (6g baits, 12 days later)	0607ROT01
91.8%	Whirinaki Rata Block 30/8-8/9/2005	3	5 (8 days later)	0506RAN01
87.8%	Hunua Ranges, 7-8/9/2001	5	5	0203AKD13
86%	Otupaka EA, 17-18/05/2000	5	10 (6g baits)	0304RAN08
96.0%	Paeroa Range, 18/08/1999	5	10-15 (6g baits)	0304ROT05
88.4%	Marokopa/Tawerau, 5/7/1998	5	5 (6g baits)	0203MPT08
94.2%	Marokopa/Tawerau, 5/7/1998	5	10 (6g baits)	0203MPT08

Table 39. The percentage possum kill for aerial operations using 1.5 g kg^{-1} 1080 carrot.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	
98.1%	Matakuhia, Tataraakina, July 2003	5	5 (6g baits)	Nugent et al. (2004)
96.3%	Wakeman's Block, Tataraakina, July 2003	5	5 (6g baits with EDR deer repellent)	Nugent et al. (2004)
86.6-100%	Hampden, North Otago, 28/6/2002	2	2 (6g baits)	Lorigan et al. (2002)
92.5%	Lake Okataina SR, 27/7/1999	5	12 (6g baits)	0304ROT04

1080 cereal pellets in bait stations

Table 40 contains the percentage possum kills for bait station operations using 0.15% 1080 cereal pellets. The mean kill for these operations was 93.3% (±1.9% s.e., n=8).

Table 40. The percentage possum kill for 0.15% 1080 cereal pellets in bait stations.

Kill	Location	Method	Ref.
83.7%	Opuiaki, Sept-Oct 2009	100 x 100 m grid, 2 prefeeds (600g per bait station), 1 toxic fill (300gbait per station)	0800TAU01
95%	Fox Valley, Apr-May 2008	100 x 200 m grid, 2 prefeeds (460g per bait station), 1 toxic fill (460g bait per station)	0809SWS04
88.9%	Fox Valley, July 2007	100 x 200 m grid, 2 prefeeds (500g per bait station), 1 toxic fill (500g bait per station)	0809SWS04
97.1%	Rotoehu EA, Oct-Nov 2007	1 bait station/ha, 2 prefeeds (1500g per bait station), 1 toxic fill (700g bait per station)	0708ROT03
96.2%	Mokaihaha EA, Oct 2001	1 bait station/ha, 3 prefeeds, 1 toxic fill (1500g bait per station)	0304ROT06
94.8%	Minganui Faces, Oct 1999	0.53 bait stations/ha, 3 prefeeds, 1 toxic fill (750g bait per station)	0304RAN12
100%	Kaharoa CA, Jan 1997	0.25 bait stations/ha, 3 prefeeds, 1 toxic fill (1000g bait per station)	0304ROT09
90.6%	Minganui Faces, Nov 1996	0.53 bait stations/ha, 3 prefeeds, 1 toxic fill	0304RAN13

Handlaid 1080 cereal pellets

The mean percentage possum kill for operations using handlaid 0.15% 1080 cereal pellets (Table 41) is 88.8% (±4.7% s.e., n=6).

Table 41. The percentage possum kill for operations using handlaid 0.15% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	
91.7%	Stewart Island, Dec 07 – Jan 2008	No	Not specified	0809SIS02
100%	Colenso Basin, Ruahines, Sept-Oct 2007	2 (6g pellets)	1.5 (12g pellets, 31 days later)	0708PNT17
66.7%	Awarua, 3/3/2000		0.4 (8g pellets, traps and	0203SWS30

			Feratox also used)	
90.6%	Fox Valley, 23/9/1999		0.5 (8g pellets, traps also used)	0203SWS34
94.6%	Abbey Rocks B, 2/6/1999		0.5 (6g pellets, traps also used)	0203SWS28
89.3%	Abbey Rocks C, 3/6/1999		0.5 (6g pellets, traps also used)	0203SWS28

1080 cereal pellets in bait bags

The percentage kills obtained following the use of 1080 cereal pellets in bait bags are presented in Table 42. The mean is 82.9%.

Table 42. The percentage possum kill for operations using 0.15% 1080 cereal pellets in bait bags.

Kill	Location	Method	Ref.
96%	Stewart Island, Oct-Nov 2008	20 x 100 m grid (not prefed)	0809SIS03
97.6%	Pegasus/Tin Range Oct-Nov 2004	Grid (not prefed)	0405SIS04
85% (Range: 68.8%-100%)	Paterson Inlet Blocks, Oct 2003	Bags put on recent sign (not prefed)	0304SIS19
~92.6%	Mt Anglem/Hananui, Oct-Nov 2003	4.3-5.3 bait bags/ha, 1 prefeed, 2 toxic bag placements (6g baits).	0304SIS20
53.1-73.2%	Warawara Forest Blocks, Mar-Jun 2003	Bags put on recent sign (not prefed)	0203KAI12

1080 paste in bait bags

See Table 43 for the percentage kill during operations using 0.15% 1080 paste in bait bags.

Table 43. The percentage possum kill for operations using 0.15% 1080 paste in bait bags.

Kill	Location	Method	Ref.
56.4%	Minganui Faces, Sept-Oct 2000	Bags placed on a 75m x 10m grid, not prefed.	0304RAN09

Handlaid 1080 paste

The mean percentage possum kill for operations using handlaid 0.15% 1080 paste under good weather conditions is 83.1% (n=5) (Table 44).

Table 44. The percentage possum kill for operations using handlaid 0.15% 1080 paste.

Kill	Location	Method	Ref.
~84%	Rangitikei Snail Area, Kaimanawa FP, 2000-2002	Prefed, set on recent sign.	0304RAN09
86.6%	Mortens, Canterbury	Spits 5-6m apart around forest edge, not prefed	Ross & Henderson (2003)
84.7%	Steventon, Canterbury	Spits 5-6m apart around forest edge, not prefed	Ross & Henderson (2003)
84% (Range : 50-96%)	9 sites around NZ (1996-98) – good weather conditions	Spits 5m apart around forest edge, prefed	Thomas & Morgan (1998)
34% (Range : 0-59%)	4 sites (1997) - where rain washed out baits or hot weather dried out the baits	Spits 5m apart around forest edge, prefed	Thomas & Morgan (1998)
76% (Range : 68-93%)	9 sites around NZ (1996-98) – good weather conditions	Spits 5m apart around forest edge, not prefed	Thomas & Morgan (1998)
30% (Range : 11-46%)	4 sites (1997) where rain washed out baits or hot weather dried out baits.	Spits 5m apart around forest edge, not prefed	Thomas & Morgan (1998)

Rats

Aerially distributed 1080 cereal pellets

The percentage rat kills obtained during aerial operations using 0.15% 1080 cereal pellets between 2010 and 2015 are presented in Table 45. Based on this data, the mean kill for prefed operations is 93.0% (n=87). The results for earlier operations are presented in Appendix 1.

The percentage rat kill for the aerial operations using 0.08% cereal pellets is presented in Table 46.

Table 45. The percentage rat kill for aerial operations using 0.15% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	
100%	Northern Ruahine BfoB, Nov 2017	2 (6g pellets)	2 (6g RS5 pellets, 25 days later)	1718PNT01
100%	Kahurangi West and Kahurangi North BfoB, Nov 2017	1.5 (6g pellets)	1.5 (6g RS5 pellets, 28 days later)	1718GDB01
100%	Hollyford BfoB, Oct 2017	1 (6g pellets)	2 (12g RS5 pellets, 13 days later)	1718TEA01
97.4%	Abel Tasman NP, Oct 2017	2 (6g pellets)	2 (6g RS5 pellets, 7 days later)	1718MOT09
95.2%	Moehau, Coromandel, Oct 2017	1.5 (6g pellets)	2 (12g #7 pellets, 26-40 days later)	1718WHT01
100%	Matemateaonga, Whanganui, Oct 2017	0.5 (6g pellets)	0.5 (6g RS5 pellets, 30 days later)	1718WHA01
97.4%	Waitotara, Whanganui, Oct 2017	0.5 (6g pellets)	0.5 (6g RS5 pellets, 30 days later)	1718WHA01
100%	East & West Matukituki BfoB, Oct 2017	1.5 (6g pellets)	1.5 (6g RS5 pellets, 9 days later)	1718CNO06
88.6%	Cleddau BfoB, Sept 2017	1 (6g pellets)	2 (12g RS5 pellets, 16 days later)	1718TEA02
96.4%	Rotoehu Forest, Sept 2017	1.5 (6g pellets)	2.5 (12g #7 pellets, 8 days later)	1718TAU01

95.7%	Whitecliffs/Parininihi, Sept 2017	3 (6g pellets)	3 (6g RS5 pellets, 29 days later)	1718TAR02
90.6%	Dart/Routeburn BfoB, Sept 2017	1.5 (6g pellets)	1.5 (6g RS5 pellets, 7 days later)	1718WAK01
100%	Whirinaki Te Pua a Tane BfoB, Sept 2017	1.5 (6g pellets, with EDR)	1.5 (6g RS5 pellets with EDR, 16 days later)	1718WHK01
100%	Whirinaki Te Pua a Tane BfoB, (EDR Block), Sept 2017	1.5 (6g pellets, no EDR)	1.5 (6g RS5 pellets no EDR, 16 days later)	1718WHK01
100%	Paparoa North BfoB, Oct 2017	1.5 (6g pellets)	3 (12g RS5 pellets, 9 days later)	1718BUL01
100%	ZIP Jackson Arawhata #1, Jul 2017	2 (6g pellets, 2 prefeeds 11 days apart, Orange lure)	4 (6g RS5 pellets, 19 days later, Orange lure)	1718SWS01
100%	Whareorino, Jul 2017	1.5 (6g pellets)	2 (12g #7 pellets, 14 days later)	1617MPT06
100%	Makarora-Wilkins BfoB, Feb 2017	1 (6g pellets)	1 (6g RS5 pellets, 7 days later)	1617CNO04
86.4%	Beresford Range (Catlins) BFOB Dec 2016	1 (6g pellets)	1 (6g RS5 pellets, 41 days later)	1617MRH03
91.8%	Pukaha/Mt Bruce, Dec 2016	1 (6g pellets)	1 (6g RS5 pellets, 9 days later)	1617WRP03
96.8%	Landsborough BfoB, Dec 2016	2 (6g pellets)	2 (6g RS5 pellets, 32 days later)	J. Kemp pers. comm, 1617SWS04
85.4% (est.)	Egmont NP, Dec 2016	1 (6g pellets)	2 (6g RS5 pellets, 59 days later)	1617TAR01

97.4% (est.)	Waitutu BfoB, Nov 2016	1 (6g pellets)	1 (12g RS5 pellets, 13 days later)	J. Kemp pers. comm, 1617TEA01
94.1%	Te Maruia BfoB, Nov 2016	1 (6g pellets)	1 (6g RS5 pellets, 9 days later)	1617GRY01
100%	Waikaia Forest BfoB, Nov 2016	1 (6g pellets)	1 (6g RS5 pellets, 26 days later)	1617MRH02
100%	Hawdon BfoB, Nov 2016	2 (6g pellets)	2 (6g RS5 pellets, 7 days later)	1617WMK01
0%	Poulter BfoB, Nov 2016	2 (6g pellets)	2 (6g RS5 pellets, 7 days later)	1617WMK01
99.5% (est.)	Wangapeka, Oct 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 38 days later)	J. Kemp pers. comm, 1617MOT01
100% (est.)	Clinton BfoB, Oct 2016	1 (6g pellets)	1 (6g RS5 pellets, 26 days later)	J. Kemp pers. comm, 1617TEA04
100%	Whareorino Frog Protection Area Oct 2016	1.5 (6g pellets)	1.5 (6g Whanganui #7 pellets, 24 days later)	1617MPT01
84.9% (est.)	Dart-Caples BfoB, Oct 2016	1 (6g pellets)	1 (6g RS5 pellets, 29 days later)	J. Kemp pers. comm, 1617WAK01
80.7% (est.)	Eglington Valley BfoB, Oct 2016	1 (6g pellets)	2 (12g RS5 pellets, 25 days later)	J. Kemp pers. comm, 1617TEA05
96.3% (est.)	Oparara BfoB D+E, Sept 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 10 - 13 days later)	J. Kemp pers. comm, 1617MOT01
88.7% (est.)	Oparara BfoB A, Sept 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 10 - 13 days later)	J. Kemp pers. comm, 1617MOT01

100% (est.)	Arthur-Sinbad BfoB, Sept 2016	1 (6g pellets)	2 (12g RS5 pellets, 42 days later)	J. Kemp pers. comm, 1617TEA02
100%	Okarito South, Sept 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 11 days later)	J. Kemp pers. comm, 1617SWS03
90.7% (est.)	Kepler BfoB, Sept 2016	1 (6g pellets)	2 (12g RS5 pellets, 12 days later)	J. Kemp pers. comm, 1617TEA03
99.1% (est.)	Haast Kiwi Sanctuary BfoB, Aug 2016	1.5 (6g pellets)	3 (12g RS5 pellets, 11 days later)	J. Kemp pers. comm, 1617SWS01
100% (est.)	Arawhata BfoB, Aug 2016	1.5 (6g pellets)	3 (12g RS5 pellets, 11 days later)	J. Kemp pers. comm, 1617SWS01
100% (est.)	Abbey Rocks BfoB, Aug 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 12 days later)	J. Kemp pers. comm, 1617SWS02
100%	Waipapa Pureora BfoB Jul 2016	1 (6g pellets)	2 (12g #7 pellets, 24 days later)	1617MPT04
87.3%	Kia Wharite Project - Mangapurua Block, Whanganui, Oct 2015	0.5 (6g pellets)	0.5 (6g #7 pellets, 31	1516WHA01
100%	Mokaihaha Ecological Area, Rotorua, Aug 2015	2 (12g pellets)	2 (12g #7 pellets, 15 days later)	1516ROT02
97.9%	Mt Bruce/Pukaha, Wairarapa, Jul 2015	1 (12g pellets)	1 (12g #7 pellets, 12 days later)	1516WRP01
100%	South Branch Hurunui BfoB, Feb 2015	1.5 (6g pellets)	1.5 (6g RS5 pellets, 6 days later)	1314WMK04
100%	Poulter Valley BfoB, Feb 2015	1.5 (6g pellets)	1.5 (6g RS5 pellets, 6 days later)	1415WMK05
76.4%	Rotoiti BfoB, 170m flight path, Dec 2014	1 (6g pellets)	1 (6g RS5 pellets, 25 days later)	1415STA02

100%	Rotoiti BfoB, 150m flight path, Dec 2014	1 (6g pellets)	1.18 (6g RS5 pellets, 25 days later)	1415STA02
38.5%	Hawdon & Andrews Valleys BfoB, Dec 2014	1 (6g pellets)	1 (6g RS5 pellets, 8 days later)	1415WMK01
100%	Eglinton Valley BfoB, Dec 2014	1 (6g pellets)	1 (12g RS5 pellets, 48 days later)	1314TEA05
100%	Blue Mountains BfoB, Dec 2014	1 (6g pellets)	1.5 (6g RS5 pellets, 25 days later)	1314MRH03
100%	Abbey Rocks, Nov 2014	1 (6g pellets)	1 (6g RS5 pellets, 13 days later)	1314SWS06
100%	Landsborough/Clark BfoB, Nov 2014	1 (6g pellets)	1 (6g RS5 pellets, 15 days later)	1314SWS04
87.2%	Tennyson Inlet Reserve - Mt Stanley BfoB, Nov 2014	1 (6g pellets)	1 (6g RS5 pellets, 44 days later)	1314SND03
100%	Catlins BfoB, Nov 2014	1 (6g pellets)	1.1 (6g RS5 pellets, 15 days later)	1415MRH01
100%	Oparara BfoB Kahurangi NP, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 22 days later)	1415GDB04
77.1%	Pukaha Mt Bruce, Nov 2014	1 (6g pellets)	1 (6g RS5 pellets, 16 days later)	1415WRP04
100%	Mataraua/Waipoua, Nov 2014	1 (6g pellets)	2 (12g #7 pellets, 25 days later)	1415KAU02
96.2%	Cobb BfoB, Kahurangi NP, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 24 days later)	1415GDB02
100%	Lower Holyford BfoB, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 38 days later)	1314TEA06
100%	Clinton BfoB, Nov 2014	1 (6g pellets)	2 (12g RS5 pellets, 24 days later) some EDR	1415TEA02

			deer repellent used	
98.8%	Anatoki BfoB Kahurangi NP, Oct 2014	1 (6g pellets)	1 (6g RS5 pellets, 16 days later)	1415GDB01
60.9%	Gouland BfoB Kahurangi NP, Oct 2014	1 (6g pellets)	2 (12g RS5 pellets, 14 days later)	1314GDB01
77.5% Gibbs	Wangapeka BfoB Kahurangi NP, Oct 2014	1 (6g pellets)	1 (6g RS5 pellets, 14 days later)	1415MOT05
73.3% Fyfe	Wangapeka BfoB Kahurangi NP, Oct 2014	1 (6g pellets)	2 (12g RS5 pellets, 14 days later)	1415MOT05
38.8%	Te Maruia North BfoB Oct 2014	1 (6g pellets)	1 (6g RS5 pellets, 24 days later)	1314GRY03
100%	Iris Burn BfoB, Sept 2014	1 (6g pellets)	2 (12g RS5 pellets, 8 days later)	1415TEA01
100%	Kia Wharite – Matemateaonga & Waitotara, Sept 2014	1 (8g pellets)	2 (8g RS5 pellets, 9 days later)	1415WHA01
100%	Waitutu BfoB, Aug 2014	1 (12g pellets)	2 (12g RS5 pellets, 6 days later)	1314TEA07
96.8%	Waikaia BfoB Aug 2014	1 (6g pellets)	1 (6g RS5 pellets, 7 days later)	1314MRH02
97.3%	Abel Tasman BfoB, Aug 2014	1 (6g pellets)	2 (12g RS5 pellets, 7 days later)	1415MOT01
91.7%	Tongariro Forest, Aug 2014	0.75 (6g pellets)	0.75 (6g RS5 pellets, 9 days later)	1415RUA01
91.7%	Dart, Routeburn, Caples BfoB, Aug 2014	1 (6g pellets)	1 (6g RS5 pellets, 5 days later)	1415WAK01
64.6%	Te Kauri, Pirongia FP, Aug 2014	2 (6g pellets)	2 (12g RS5 pellets, 30 days later)	1415WAI02

100%	Project Kaka, Tararuas, Dec 2013	1 (6g pellets)	1 (12g #7 pellets, 10 days later)	1314WRP02
100%	Mataketake block 2, Haast, Nov 2013	1 (6g pellets)	2 (12g RS5 pellets, 11 days later)	1314SWS
100%	Mataketake block 5, Haast, Nov 2013	1 (6g pellets)	2 (12g RS5 pellets, 11 days later)	1314SWS
70.1%	Whitecliffs/Parininihi, Nov 2013	1 (8g pellets)	2 (12g #7 pellets, 47 days later)	1314TAR09
100%	Tennyson Inlet Reserve - Mt Stanley, Nov 2013	1 (6g pellets)	1 (6g RS5 pellets, 13 days later)	1314SND02
92.8% - 100%	Catlins Maclennan Forest, Aug 2013	0.75 (6g pellets)	1 (12g RS5 pellets, 9 days later)	1314COT02
97.5%	Moehau, Jun 2013	2 (12g pellets)	2 (12g #7 pellets, Orange lure, 6 days later)	1314HAU01
100%	Hawdon Valley, Athurs Pass NP, Dec 2013	1 (6g pellets)	2 (12g RS5 pellets, 15 days later)	1213WMK02
100%	Lewis Pass – Station Creek, Nov 2012	1 (6g pellets)	1 (6g RS5 pellets, 7 days later)	1213GRY02
95.8%	Tongariro Forest, Sept 2011	1.5 (6g pellets)	2 (12g #7 pellets, Orange lure+EDR, & cinnamon 20 days later)	1112RUA02
98.2%	Waipoua Forest, Sept 2011	1 (6g pellets)	2 (12g #7 pellets, 22 days later)	1112KAU01
97.3%	Waihaha Ecological Area, May 2011	1.5 (12g pellets)	1.5 (12g #7 pellets, Orange lure, 19 days later)	1112MPT05

94.7%	Project Kaka, Tararuas, Nov 2010	1.4 (6g pellets)	2 (12g #7 pellets, 16 days later)	11011PON20

Table 46. The percentage rat kill for aerial operations using 0.08% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	
100%	Whakapohai E, Jan 2007	5 (6g baits)	2 (12g #7 pellets, 5 days later)	J Kemp pers. comm.
1.2%	Station Creek A Trial, Jul 2006	-	5 (12g #7 pellets, 5 days later)	J Kemp pers. comm.
96.3%	Station Creek B Trial, Jul 2006	2 (12g pellets)	5 (12g #7 pellets, 7 days later)	J Kemp pers. comm.
<70%	Mapara, Oct 1992	-	8	Bradfield. (1993)
80%	Mapara, Oct 1991	-	8	Bradfield. (1993)
100%	Mapara, Sept 1990	-	8	Bradfield. (1993)

Handlaid 1080 cereal pellets

During the Rotoiti Battle for our Birds (BfoB) in December 2014 part of the operational area was handlaid with 0.15% 1080 pellets. The area was aerially prefed at 1 kg ha^{-1} (6g pellets). 25 days later 6g RS5 toxic pellets were hand broadcast at 1 ha^{-1}. The operation achieved a 66.7% rat kill (Pestlink reference: 1415STA02).

A 61% rat kill was achieved at Beam Head, Northland, in October 2008 when 0.08% 1080 rodent pellets were laid in clusters 50 metres apart along an existing track system. The operational area was prefed at a rate of 1 kg ha^{-1} and 30 days later the toxic bait was laid at a rate of 0.8 kg ha^{-1} (Pestlink reference: 0809WNG05).

1080 cereal pellets in bait stations

Table 47 contains the percentage rat kills for bait station operations using 0.15% 1080 cereal pellets.

Table 47. The percentage rat kill for 0.15% 1080 cereal pellets in bait stations.

Kill	Location	Method	Ref.
59.5%	Aislabies Block, Kaharoa, Sept 2012	Bait stations 100m arpart along ridges/spurs. 1 prefeed (1500g per bait station), 1 toxic fill (500g bait per station)	1213ROT02
30.4%	Mataraua, Jan 2010	120 x 100 m bait station grid, 1 prefeed (200g per bait station), 1 toxic fill (100g bait per station)	0910KAU04
91.3%	Mataraua, Oct 2009	120 x 100 m bait station grid, 2 prefeeds (1000g per bait station), 1 toxic fill (500g bait per station)	0910KAU04
97.0%	Opuiaki, Sept-Oct 2009	100 x 100 m bait station grid, 2 prefeeds (600g per bait station), 1 toxic fill (300g bait per station)	0800TAU01
91.2%	Waipapa East, Waipapa EA, Aug 2000	150 x 150 m bait station grid, 2 prefeeds, 1 toxic fill	Matthew et al. (2004)
87.7%	Waipapa North, Waipapa EA, Aug 2000	150 x 150 m bait station grid, 2 prefeeds, 1 toxic fill	Matthew et al. (2004)
85.5%	Waipapa South, Waipapa EA, Aug 2000	150 x 150 m bait station grid, 2 prefeeds, 1 toxic fill	Matthew et al. (2004)
100%	Trounson Kauri Park, Nov 1996	100 x 100 m bait station grid, 4 prefeeds, 1 toxic fill	Gillies et al. (2003)

Mice

Aerially distributed 1080 cereal pellets

The percentage mice kills obtained during aerial operations using 0.15% 1080 cereal pellets are presented in Table 48. Based on this data, the mean kill for prefed operations is 78.3% (n=26). The percentage mouse kill for the aerial operations using 0.08% cereal pellets is presented in Table 49.

Table 48. The percentage mouse kill for aerial operations using 0.15% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	

96.6%	East & West Matukituki BfoB, Oct 2017	1.5 (6g pellets)	1.5 (6g RS5 pellets, 9 days later)	1718CNO06
57.7%	Makarora-Wilkins BfoB, Feb 2017	1 (6g pellets)	1 (6g RS5 pellets, 7 days later)	1617CNO04
98.5%	South Branch Hurunui, Feb 2017	2 (6g pellets)	2 (6 g RS5 pellets, 10 days later)	1617WMK02
99.8%	Landsborough BfoB, Dec 2016	2 (6g pellets)	2 (6g RS5 pellets, 32 days later)	J. Kemp pers. comm, 1617SWS04
50% (est.)	Clinton BfoB, Oct 2016	1 (6g pellets)	1 (6g RS5 pellets, 26 days later)	J. Kemp pers. comm, 1617TEA04
100% (est.)	Arthur-Sinbad BfoB, Sept 2016	1 (6g pellets)	2 (12g RS5 pellets, 42 days later)	J. Kemp pers. comm, 1617TEA02
0% (est.)	Kepler BfoB, Sept 2016	1 (6g pellets)	2 (12g RS5 pellets, 12 days later)	J. Kemp pers. comm, 1617TEA03
97.3% (est.)	Abbey Rocks BfoB, Aug 2016	1.5 (6g pellets)	1.5 (6g RS5 pellets, 12 days later)	J. Kemp pers. comm, 1617SWS02
0% (est.)	Eglington Valley BfoB, Oct 2016	1 (6g pellets)	2 (12g RS5 pellets, 25 days later)	J. Kemp pers. comm, 1617TEA05
60%	Beresford Range (Catlins) BFOB Dec 2016	1 (6g pellets)	1 (6g RS5 pellets, 41 days later)	1617MRH03
66%	Poulter Valley BfoB, Feb 2015	1.5 (6g pellets)	1.5 (6 g RS5 pellets, 6 days later)	1415WMK051
100%	Abbey Rocks, Nov 2014	1 (6g pellets)	1 (6 g RS5 pellets, 13 days later)	1314SWS06
81.1%	Matukituki BfoB Nov 2014	1 (6g pellets)	2 (12 g RS5 pellets, 26 days later)	1415WAN01

82.5%	Clinton BfoB, Nov 2014	2 (6g pellets)	2 (12 g RS5 pellets, 24 days later)	1415TEA02
100%	Catlins BfoB, Nov 2014	1 (6g pellets)	1.1 (6 g RS5 pellets, 15 days later)	1415MRH01
72.7%	Iris Burn BfoB, Sept 2014	1 (6g pellets)	2 (12 g RS5 pellets, 8 days later)	1415TEA01
50.0%	Dart, Routeburn, Caples BfoB, Aug 2014	1 (6g pellets)	1 (6 g RS5 pellets, 5 days later)	1415WAK01
92.0%	Waikaia BfoB Aug 2014	1 (6g pellets)	1 (6 g RS5 pellets, 7 days later)	1314MRH02
93.4%	Poulter Valley, Oct 2008	1 (6g pellets)	2 (6g #7 pellets, 17 days later)	J Kemp pers. comm.
100%	Pihanga, Nov 07	2 (12g pellets)	2 (12g #7 pellets, 8 days later)	J Kemp pers. comm.
86.2%	Parapara 07C Trial, May 2007	-	3 (12g RS5 pellets)	J Kemp pers. comm.
37.3%	Parapara 07D Trial, May 2007	-	3 (12g #7 pellets)	J Kemp pers. comm.
97.0%	Parapara 07A Trial, May 2007	3 (6g pellets)	3 (12g RS5 pellets, 43 days later)	J Kemp pers. comm.
92.0%	Parapara 07B Trial, May 2007	3 (6g pellets)	3 (12g #7 pellets, 43 days later)	J Kemp pers. comm.
100%	Whakapohai A, Jan 2007	5 (6g pellets)	2 (12g #7 pellets, 5 days later)	J Kemp pers. comm.
66.7%	Whakapohai B, Jan 2007	2 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	J Kemp pers. comm.
96.4%	Whakapohai C, Jan 2007	2 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	J Kemp pers. comm.

86.0%	Whakapohai D, Jan 2007	1 (6g pellets)	2.5 (12g #7 pellets, 5 days later)	J Kemp pers. comm.

Table 49. The percentage mouse kill for aerial operations using 0.08% 1080 cereal pellets.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	
58%	Whakapohai E, Jan 2007	5 (6g pellets)	2 (12g #7 pellets, 5 days later)	J Kemp pers. comm.

1080 cereal pellets in bait stations

Table 50 contains the percentage mouse kills for bait station operations using 0.15% 1080 cereal pellets.

Table 50. The percentage mouse kill for 0.15% 1080 cereal pellets in bait stations.

Kill	Location	Method	Ref.
94%	Trounson Kauri Park, Nov 1996	100 x 100 m bait station grid, 4 prefeeds, 1 toxic fill	Gillies et al. (2003)

Rabbits

The majority of rabbit operations have operational targets based on the Modified Mclean Rabbit Infestation Scale. The Mclean Scale is not suitable for estimating a percent kill because it is not linearly related to rabbit population density. However, during aerial 1080 carrot field trials by Landcare Research in Otago and Hawkes Bay between 2011 and 2014, based on pre- and post-control spotlight counts of rabbits, kills of greater than 90% were achieved. These operations were prefed twice and the toxic carrot was either broadcast or strip sown. The actual sowing rate varied depending on the pre-control estimate of rabbit density (Latham et al., 2015).

Wallabies

The percentage kill of wallabies using aerially distributed 1.5 g kg^{-1} 1080 pellets is presented in Table 51, in Table 52 for 1.5 g kg^{-1} 1080 carrots and in Table 53 for handlaid 5% and 10% 1080 gels.

Table 51. The percentage wallaby kill for aerially distributed 1.5 g kg^{-1} 1080 pellets.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
96.9%	Rotoehu Forest, Sept 2017	1.5 (6g pellets)	2.5 (12g #7 pellets, 8 days later)	1718TAU01, & Commins (2017)

Table 52 The percentage wallaby kill for aerially distributed 1.5 g kg^{-1} 1080 carrots.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	
93.1%	Okataina SR, 1999 (Dama wallabies)	5	12	0304ROT04

Table 53. The percentage wallaby kill for handlaid 5% and 10% 1080 gel.

Kill	Location	Method	Ref.
86.2%	Okataina SR, 1988 (Dama wallabies)	5-10 m x 50-100 m transects, 5 baited leaves/branch (5% 1080 gel)	Warburton (1990)
91.3%	Tasman Smith SR, Hunter hills, 1983 (Bennett's wallabies)	10 branches/ha, 25 baited leaves/branch (10% 1080 gel)	Warburton (1990)

Deer

The percentage kill of deer is presented in Table 54 for aerially distributed 1.5 g kg^{-1} 1080 carrot is and in Table 55 for handlaid 10% 1080 gel.

Table 54. The percentage deer kill for aerially distributed 1.5 g kg^{-1} 1080 carrots.

Kill	Location	Sowing Rate (kg ha^{-1})		Ref.
		Prefeed	Toxic	
92%	Titiraupunga, 1997	5	15	Fraser & Sweetapple (2000)
34%	Pureora, 1994	5	15	Fraser et al. (1995)
42%	Pureora, 1994	15	15	Fraser et al. (1995)

Table 55. The percentage deer kill for handlaid 10% 1080 gel.

Kill	Location	Method	Ref.
79%	Hauhangaroa Range, 1997	2 branches/ha, 10 baited leaves/branch	Sweetapple (1997)
80%+	Stewart Island, 1981	2.5 branches/ha, 20 baited leaves/branch	Nugent (1990)
100%	Stewart Island, 1981	5 branches/ha, 20 baited leaves/branch	Nugent (1990)

Goats

10% 1080 gel (100 g kg-1 1080), handlaid

The percentage kill of goats using handlaid 10% 1080 gel is presented in Table 56.

Table 56. The percentage kill of goats following the use of handlaid 10% 1080 gel.

Kill	Location	Method	Ref.
88%	Whitecliffs, Buller River, Jul 2007	2.2 branch/ha in preferred habitat, 10 - 20 baited leaves/branch	Anderson (2008)
87%	Motu River, Jan 1986	1 branch/ha in preferred habitat, 20 baited leaves/branch	Veltman & Parkes (2002)
97%	Motu River, March 1982	2.5 branches/ha, 20 baited leaves/branch	Parkes (1983)

Stoats (bykill)

Aerially distributed 1080 cereal pellets

The percentage by-kill of stoats during aerial 1080 operations is recorded in Table 57

Table 57. The percentage stoat bykill for aerial operations targetting rats, mice and possums with 0.15% 1080 cereal pellets.

Stoat Bykill	Location	Kill Of Target Pest			Ref.
		Possums	Rats	Mice	
87.8%	Whirinaki Te Pua a Tane BfoB (EDR Block), Sept 2017		100%		1718WHK01

100%	Whirinaki Te Pua a Tane BfoB, Sept 2017		100%		1718WHK01
100%	Makarora-Wilkins BfoB, Feb 2017		100%	57.7%	1617CNO04
100%	Okarito South, Sept 2016		100%		1617SWS03
100%	Kia Wharite Project - Mangapurua Block, Whanganui, Oct 2015	66.7%	87.3%		1516WHA01
50.0%	Dart, Routeburn, Caples BfoB, Aug 2014		100%	100%	1314SWS06
100%	Catlins BfoB, Nov 2014		100%	100%	1415MRH01
100%	Tongariro Forest, Aug 2014		91.7%		1415RUA01
90%	Project Kaka, Tararuas, Dec 2013	63.6%	100%		1314WRP02
95.8%	Tongariro Forest, Sept 2011		95.8%		1112RUA02

7. Appendix 1

The efficacy data for possum and rat aerial 0.15% 1080 pellet operations that occurred before 2010 along with information about de-registered 1080 products (No Possums® 1080 gel) is stored in DOC-2534486.

8. Glossary of Terms

µg kg^{-1}, **µg** l^{-1}

See ppb.

µg g^{-1}, **µg** ml^{-1}

See ppm.

Absciss

Part of a plant breaking off naturally (e.g. leaves dying)

Aconitase

An enzyme occurring in many animal and plant tissues that accelerates the conversion of citric acid first into aconitic acid and then into isocitric acid.

Biological Exposure Index (BEI)

A reference value below which exposure to a substance will not create an unreasonable risk of disease or injury. BEIs are set by the American Conference of Governmental Industrial Hygienists (ACGIH).

Biosynthesis

The production of a chemical compound by a living organism.

b.w.

Body weight

Carcinogenic

The ability of a substance to cause cancer.

Citrate

A salt or ester of citric acid.

Cyanosis

Blueness of the skin and mucous membrane due to insufficient oxygen in the blood.

Defluorination

To remove fluorine

Endocardium

The lining of the interior surface of the heart chambers. The endocardium consists of a layer of endothelial cells and an underlying layer of connective tissue. a thin serous membrane lining the cavities of the heart.

Epicardium

The inner layer of the pericardium, a conical sac of fibrous tissue that surrounds the heart and the roots of the great blood vessels / the visceral part of the pericardium that closely envelops the heart

Epiglottis

The flap that covers the trachea during swallowing so that food does not enter the lungs.

Fluorocitrate

The toxic metabolite of fluoroacetate that causes inhibition of aconitase.

Gastrointestinal tract

The stomach and intestine as a functional unit

Glial cells

A supportive cell in the central nervous system. Glial cells do not conduct electrical impulses (as opposed to neurons, which do). The glial cells surround neurons and provide support for them and insulation between them.

Half-life

During each half life (t½ or elimination half-life) 50% of the pesticide in the body at the beginning of that half-life is eliminated. The half-life is established in laboratory trials, and is used to predict the rate of elimination of a single dose of pesticide from the body and to estimate how long the disappearance of cumulative intakes of a pesticide from the body would take.

Hypotension

Abnormally low pressure of the blood -- called also low blood pressure

Intravenous

Administered into a vein.

LC_{50}

Lethal Concentration 50%. The calculated concentration of a gas/liquid that kills 50% of the test organisms

LD_{50}

Lethal Dose 50%. The estimated dose that kills 50% of the test organisms.

LOEL

Least Observable Effect Level. The lowest dose in a study in which there was an observed toxic or adverse effect

MLD

Minimum Lethal Dose. The smallest amount of a toxin required to kill and individual.

Mitochondrial aconitate hydratase

An iron-dependent enzyme that catalyzes conversion of citrate to cis-aconitate in the tricarboxylic acid cycle within the mitochondrion.

Metabolites

The breakdown of compounds resulting from the metabolism of a parent compound.

mg kg^{-1}**, mg** l^{-1}

See ppm.

mmol (mM)

millimole: a unit of metric measurement that is equal to one thousandth (10-3) of a mole. It is the amount of a substance that corresponds to its formula mass in milligrams. [mol l^{-1}]x[mL] = mmol.

Mutagenic

The ability of a substance to cause damage to DNA and produce alterations or loss of genes or chromosomes

NOEL

No Observable Effect Level. A dosage of a toxicant that fails to produce any discernible signs of toxicosis, which may include a lack of morphological, biochemical, or physiological change

Non-saponifiable lipids

Non-polar compounds that cannot be broken down by a simple hydrolytic reaction. They include steroids and hormones.

Oral

Given or taken through or by way of the mouth, as in an oral solution.

Phosphofructokinase

An enzyme that functions in carbohydrate metabolism and especially in glycolysis by catalysing the transfer of a second phosphate to fructose.

ppb

parts per billion. This concentration unit is equivalent to 1 µg l^{-1} in water (solution) or air and 1 µg kg^{-1} in solid samples (soil/sediments/biological tissue).

ppm

parts per million. This concentration unit is equivalent to 1 mg l^{-1} (or µg ml^{-1}) in water (i.e. solutions) or air and 1 mg kg^{-1} (or µg g^{-1}) in solid samples (i.e. soil/sediments/biological tissue).

Succinate dehydrogenase

An iron-containing flavoprotein enzyme that catalyses, often reversibly, the dehydrogenation of succinic acid to fumaric acid in the presence of a hydrogen acceptor and that is widely distributed especially in animal tissues, bacteria, and yeast -- called also succinic dehydrogenase.

Subepicardial

Under the serious membrane which covers the heart situated or occurring beneath the epicardium or between the epicardium and myocardium.

Teratogen

A compound that causes birth defects in a developing foetus.

Toxicosis

A pathological condition caused by the action of a poison or toxin.

Toxin

A natural occurring poison, e.g. 1080, cyanide.

Toxicant

A synthetic man-made poison, e.g. brodifacoum.

Trachea

The tube-like portion of the respiratory tract that connects the "voice box" (larynx) with the bronchial parts of the lungs. called also windpipe.

Tricarboxylic acid cycle

A sequence of reactions in the living organism in which oxidation of acetic acid or acetyl equivalent provides energy for storage in phosphate bonds - called also citric acid cycle, Kreb cycle.

Threshold Limit Values (TLV)

Recommended values for the highest level of exposure to airborne chemical concentrations in the workplace that does not produce adverse health effects. They are set by the American Conference of Governmental Industrial Hygienists (ACGIH).

Viscera

Body organs.

VPRD

Vertebrate Pesticide Residue Database. (DOCDM-32812)

9. Common and Scientific Names of Species

Amphibians

Archeys frog	*Leiopelma archeyi*
American Bullfrog	*Rana catesbeiana*
Hochstetters frogs	*Leiopelma hochstetteri*
Leopard frog	*Rana pipiens*
South African clawed frog	*Xenopus laevis*
Spotted grass frog	*Limnodynastes tasmaniensis*

Aquatic invertebrates/Crustaceans

NZ cockle	*Austrovenus stutchburyi*
Daphnia	*Daphnia magna*
Koura	*Paranephrops planifrons*
Mussel (freshwater)	*Echyridella menziesii*
Mussel (green lipped marine)	*Perna canaliculus*

Birds

Australasian harrier	*Cirus approximans*
Bellbird	*Anthornis melanura*
Blackbird	*Turdus merula*
Chaffinch	*Fringilla coelebs*
Chicken	*Gallus gallus*
Whio (Blue duck)	*Hymenolaimus malacorhynchos*
Duck (Grey)	*Anas superciliosa*
Duck (Mallard)	*Anas platyrhynchos*
Duck (Maned)	*Chenonetta jubatta*
Fantail	*Rhipidura fuliginosa*
Fernbird	*Bowdleria punctata*
European goldfinch	*Carduelis carduelis*
Grey warbler	*Gerygone igata*
Kaka	*Nestor meridionalis*

Kakariki	*Cyanoramphus sp.*
Kea	*Nestor notabilis*
Kereru / kukupa	*Hemiphaga novaeseelandiae*
Kiwi (Haast tokoeka)	*Apteryx australis* 'Haast'
Kiwi (NI brown)	*Apteryx mantelli*
Kiwi (Little spotted)	*Apteryx owenii*
Kiwi (Rowi)	*Aptreyx rowi*
Kiwi (Great spotted)	*Apteryx haastii*
Kokako (NI)	*Callaeas cinerea wilsoni*
Magpie (Australian)	*Gymnorhina tibicen*
Magpie (Eurasian)	*Pica pica*
Morepork/ruru	*Ninox novaeseelandiae*
N.Z. Falcon	*Falco novaeseelandiae*
partridge (Chukar)	*Alectoris graeca*
Pheasant (Ring-necked)	*Phasianus colchicus*
Common pigeon	*Columba livia*
Quail (California)	*Callipepla californica*
Rifleman	*Acanthisitta chloris*
Robin (North Island)	*Petroica australis longipes*
Robin (South Island)	*Petroica australis australis*
Silvereye	*Zosterops lateralis*
Sparrow (Hedge)	*Prunella modularis*
Sparrow (House)	*Passer domesticus*
starlings	*Sturnus vulgaris*
Tomtit (NI)	*Petroica macrocephala toitoi*
Tomtit (SI)	*Petroica macrocephala macrocephala*
Tui	*Prosthemadera novaeseelandiae*
Weka	*Gallirallus australis*

Eutherian mammals

Bat (Short-tailed)	*Mystacina tuberculata*
Cat	*Felis catus*

Cattle	*Bos taurus*
Deer (red)	*Cervus elephus*
Deer (fallow)	*Dama dama*
Deer (mule)	*Odocoileus hemionus*
Deer (sika)	*Cervus nippon*
Dog	*Canis familiaris*
Ferret	*Mustela furo/ Mustela putorious*
Goat	*Capra hircus*
Horse	*Equus caballus*
Mink	*Mustela vison*
House mouse	*Mus musculus*
Pig	*Sus scrofa*
Rabbit	*Oryctolagus c. cuniculus*
Rat (Laboratory/Norway)	*Rattus norvegicus*
Rat (Ship/Brown)	*Rattus rattus*
Sheep	*Ovis aries*
Stoat	

Fish

longfin eels	*Anguilla dieffenbachia*
koaro	*Galaxias brevipinnis*
Harlequin fish	*Rasbara heteromorpha*
upland bullies	*Gobiomorphus breviceps*
Bluegill sunfish	*Lepomis macrochirus*
Trout (Rainbow)	*Oncorhynchus mykiss*

Marsupial mammals

Brushtail possum	*Trichosurus vulpecula*
Wallaby (Bennett's)	*Macropus rufogriseus*
Wallaby (Dama)	*Macropus eugenii*

Reptiles

Blotched blue-tongued lizard	*Tiliqua nigrolutea*
Common Skinks	*Oligosoma nigriplantare*
Gould's monitor	*Varanus gouldi*
Grand skink	*Oligosoma grande*
MacCann's skink	*Oligosoma maccanni*
Otago skink	*O. otagense*
Shingle-back lizard	*Tiliqua rugosa*

Terrestrial invertebrates

Cockroaches	*Blattidae*
Compost worms	*Eisenia fetida*
Honeybees	*Apis mellifera*
Housefly	*Musca domestica*
Leaf-veined slugs	*Athoracophorus bitentaculatus*
Wasp	*Vespula spp.*
Weta (bush)	*Hemideina broughi*
Weta (Cave)	*Pharmacus sp. and Isoplectron sp.*
Weta (tree)	*Hemideina spp.*
Weta (Auckland tree)	*Hemideina thoracica*
Weta (Wellington tree)	*Hemideina crassidens*

Plants

Broad bean	*Vicia faba*
box poison	*Gastrolobium parviflorum*
cabbage	*Brassica oleracea*
gifblaar	*Dichapetalum cymosum*
heart-leaf poison	*Gastrolobium bilobum*
käpuka (New Zealand broadleaf)	*Griselinia littoralis*
käramuramu	*Coprosma robusta*
lettuce	*Lactuca sativa*
Mahoe	*Melicytus ramiflorus*

peanut	*Archis hypogeae*
perennial ryegrass	*Lolium perenne*
puha	*Sonchus* spp.
pikopiko	*Asplenium bulbiferum*
rat weed	*Palicourea margravii*
ratsbane	*Dichapetalum toxicarium*
sugar cane	*Saccharum spp.*

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