Aerial 1080 poisoning in New Zealand: Reasons for concern

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Abstract
Reasons to be concerned about the widespread use of aerially distributed food baits containing 1080 poison (sodium monofluoroacetate) for pest control in New Zealand are evident in scientific publications and government reviews and reports. Many hazardous properties and a lack of scientific knowledge of the effects of 1080 were described in a comprehensive report by the Environmental Risk Management Authority in 2007. These findings are presented followed by examination of evidence of problems with aerial 1080 use: 1) Increased pest impacts following poisoning due to competitive release of rats and mice, and prey-switching by predators; 2) Reduced efficacy with repeated poisoning of rats; 3) Deaths of native birds; and 4) Lack of scientific justification and monitoring of aerial 1080 use. It is concluded that there is an urgent need to bring scientific methodology into pest management.

Introduction

Aerially delivered "1080" poison (Compound 1080 – active ingredient is sodium monofluoroacetate) has been a mainstay of pest management in New Zealand for many decades, mostly targeting the introduced possum (*Trichosurus vulpecula*) for bovine tuberculosis control and conservation purposes (Morgan & Hickling 2000). Increasingly, 1080 poison is also being used to target rats (*Rattus rattus*) and stoats (*Mustela erminea*) across vast areas of NZ's native forests (Elliot 2016) and because rat numbers recover rapidly, poisonings every two years have been suggested (Nugent & Morriss 2013; Wright 2011).

In 2007 a comprehensive reassessment of the use of 1080 was carried out by the New Zealand Government's ***Environmental Risk Management Authority*** (ERMA Review 2007). The toxin was approved by ERMA for continued aerial spreading despite the hazardous properties and deficiencies in knowledge described in their review (ERMA Review 2007). These properties and unknowns are presented below, followed by an examination of problems with 1080 use, evident in scientific publications and Department of Conservation (DoC) reports.

Hazardous properties of 1080

The dangerous nature of 1080 poison has been described many times by New Zealand toxicologist Charles Eason who warned that if 1080-poisoned food baits "*are not prepared and used with extreme care, humans, livestock, and non-target wildlife will be put at risk*" (Eason 1997, p. 157) and that "*considerable care must be taken when using 1080 to ensure that the risks of its use are outweighed by ecological benefits achieved*" (Eason et al. 2011, p. 14).

1080 acts by blocking respiration within cell mitochondria, so it is harmful to a very broad range of organisms including bacteria, fungi, plants, nematodes, insects, birds, mammals (ERMA Review 2007) and snails (Fairweather et al. 2015). Sub-lethal effects include damage to reproductive structures, birth defects and organ damage (Eason et al. 2000) and can be cumulative (Eisler 1995). Toxic effects may possibly occur at concentrations too low to detect with any validated analytical methods (USEPA 1988).

The toxin has a marked ability to spread, readily contaminating experimental controls[1] and moving within food chains, for example aphids on broad bean plants all died when the roots were immersed in 0.00005% 1080 culture solution (ERMA Review 2007, Evaluation and Review Report [ERR] p. 427). Contaminated dust from aerially-distributed cereal baits was found at a test site 1 km away, 5 days after a 1080 poisoning operation (ERMA Review 2007, ERR p. 477). 1080 is known to spread in flying and crawling insects, urine, blood, faeces, carcasses (ERMA Review 2007), and bait carried around by birds (AHB 2007, p. 39). In water, 1080 is highly soluble and mobile (Fairweather et al. 2015), and very stable in sterile conditions (ERMA Review 2007, ERR p. 439).

[1] Environmental Risk Management Authority's Assessment of 1080 (2007), Evaluation and Review Report pp. 323, 415, 416, 447, 469, 517

Breakdown of 1080 in baits and soil may take months, especially in cold or dry conditions (Eason 1997). In the bones of poisoned carcasses it might persist for even longer (Ross & McCoskery 2012). In short-term studies, contaminated fish and invertebrates still contained 1080 when the experiments ended (Booth & Wickström 1999 (ants); Champeau et al. 2014 (trout); Lyver et al. 2005 (eels); Suren & Bonnet 2006 (koura)).

It has been suggested that at very low concentrations, 1080 may persist: *"the very low concentrations of 1080 which may occur in the environment may be too low to favour microbial degradation or induce the necessary enzyme systems"* (ERMA Review 2007, ERR p. 353).

Toxic breakdown products of 1080 include fluorocitrate and fluoromethane. The amount of 1080 that breaks down into these or other harmful products, and what effects they may have, are poorly understood (Eason et al. 2011, p. 4; ERMA Review 2007, Decision p. 119; ERR pp. 360, 435; Northcott et al. 2014, p. 1057).

Bioaccumulation of 1080 occurs, at least in the short term. Due to a 'latency period' before symptoms of poisoning occur, animals feeding on the baits can become very toxic before debilitation sets in, e.g. a cave weta contained 130mg/kg (ERMA Review 2007, ERR p. 727). Plants take up 1080 from the soil (ERMA Review 2007, ERR p. 383). Ants are known to shift 1080 bait particles (Booth & Wickström 1999, p. 613) and along with other animals such as rats and stoats which cache food (Innes 2005, p. 189; King & Murphy 2005, p.271) may make stores of poisoned bait or poisoned animals.

Variability in effects (e.g. with temperature, time of day, age of animal, species, population, individual, age, poisoning operation) and unexpected findings are characteristic of 1080 research (ERMA Review 2007). Notably *"The sensitivity of a species to 1080 poison is difficult to predict from toxicity data from other, closely related species"* (McIlroy 1986, cited in ERMA Review 2007, Applicants' References p. 119).

Deficiencies in knowledge

The ERMA Review highlighted many deficiencies in knowledge of the effects of 1080 poison. Topics noted as having little or no information for the assessment panel to base its decision on are listed in Table 1. Many other effects had been very poorly researched and in the Decision section it states, "*Because of a lack of data, risks are often presented as singular results. In reality, they are better represented by 'families' of data*" (ERMA Review 2007, Decision p. 202).

Information needed to support the case of the Applicants[2] was missing in the ERMA reassessment. The ERMA panel noted that (1) there were only "*very brief*" results from monitoring of non-target effects (ERR p. 480); (2) no reference was cited to back up the claim that possums are the main maintenance hosts for bovine tuberculosis in NZ (ERR p. 540); (3) no data was available from Tb surveys the AHB claimed to have done (ERR p. 546); and (4) little factual support was provided to demonstrate efficacy of aerial compared with ground application of 1080 for possum control (ERR p. 539). In addition the Animal Health Board's economic evaluation was described as "*crude*" (ERR p. 580), with vastly overstated, questionable economic benefits from the proposed Tb control programme (ERR pp. 582, 592, 596) by the economic experts consulted by ERMA (ERMA Review 2007).

A major issue which came to light in the ERMA Review was the unreliability of the concentrations of 1080 measured in stored samples and in samples taken under field conditions. The ERMA Committee stated "*it is essential that the issue of stability of 1080 in stored samples is resolved...the results must be disseminated to all laboratories that undertake 1080 analyses*." (ERMA Review 2007, Decision p. 119). However this research has not been carried out (Dr P. Fisher, Landcare Research, personal communication 24 September 2015).

Whole communities of vulnerable and unique organisms such as inhabitants of ponds and tarns (Landcare Research 2015) and epiphyte mats in trees (Affield et al. 2009) were overlooked in the ERMA review.

Problems with 1080 use

1. Increased pest impacts

Vastly increased numbers of mice (almost immediately) and rats (within months) follow aerial 1080 poisoning in a response known as 'competitive release' (Caut 2007; Griffiths & Barron 2016; Ruscoe et al. 2011). These increases may have devastating ecological effects (Innes et al. 2015; Shapira 2013; Urlich et al. 2015). For example Sweetapple & Nugent (2007, p. 9) reported:

[2] DoC and the Animal Health Board, the organisations applying to continue to use 1080

At Mokau, possum control in 2002 using aerially sown 1080 baits reduced possum and rat populations to near zero…In the poisoned block, the number of large invertebrates known to be eaten by rats soared after rat numbers were reduced to near zero, and then plummeted as rat numbers exploded to very high levels. In contrast, in the unpoisoned area, the numbers of rats and of the common large invertebrates remained more or less stable.

Poisoning may favour stoats as well as rats and mice:

...in North Island forests control of ship rats leads to greatly increased abundance of house mice... stoats are specialist predators of mice, which suggests that with high mouse populations following local eradication of rats and mustelids, conditions are likely to be ideal for re-establishment of stoat populations through reinvasion. (Byrom et al. 2013, p. 7).

Predation on native fauna can also intensify after poisoning through "prey switching", as reported by King & Murphy (2005, p.270):

In mixed podocarp-hardwood North I. forest at Mapara and Kaharoa, for example, rats were the main prey of stoats ...After successful poison operations against rats, there were strong and consistent responses by stoats to eat more birds.

Stoats devastated kiwi chicks after a poisoning operation (DoC 2002, p 9):

Four months after an effective possum and rat knock-down by a 20,000-ha aerial 1080 operation over Tongariro Forest, stoats reappeared in the centre of the forest and began killing kiwi chicks. So far five of the 11 chicks have been predated, and all in the centre of the treatment area.

2. Efficacy against rats

Byrom et al. (2013) suggested that rats in repeatedly poisoned populations may become difficult to control, through becoming bait-shy or developing a higher tolerance to 1080 as seen in rabbits in Australia. Genetic selection for resistance to 1080 has been observed in laboratory rats and flies (ERMA 2007, ERR p. 535; Howard et al 1973,Tahori 1963, cited in Twigg et al. 2002, p 556).

Individual rats may develop tolerance to 1080, as reviewed by Gooneratne et al. (2008, p. 137):

Repeated exposure of rats to small doses of fluoroacetate appears to afford some protection to subsequent challenge...This is not the case in sheep, probably because even small doses of fluoroacetate result in myocardial damage in this species and this damage can be cumulative on subsequent exposure...

Reducing efficacy of 1080 in killing rats, under a regular (yearly) poisoning regime, has been observed already (Innes et al. 1995; 1999). DoC has reported poor rat kills recently:

Further refinement of aerial application of bait is needed, as recently illustrated by the variability in rat kill results from DOC's large-scale 'Battle for our birds' response to the 2015 beech forest mast...While all operations killed most rats present only 19 operations of 25 (76%) got the rats below 10% rat tracking[3], and 15 (60%) of the operations got the rats to 1% rat tracking or less (Brown et al. 2015).

3. Effects on birds

Cowan et al. (2016) drew attention to an "unacceptable" risk to kea (*Nestor notabilis*)and the vulnerability of native birds to 1080, due to bait repellents being ineffective, the minute amount of bait required to kill small birds and the likelihood that birds would eat fragments of baits and peck at whole baits. Small fragments are a problem with both carrot (Fisher 2013) and cereal (Morgan et al. 2015) baits. The commonly used bird deterrents - cinnamon flavour and green colour - are ineffective, at least for robins (*Petroica* spp.) (Clapperton et al. (2014).

Widespread mortality was recorded in the first studies on effects of 1080 on birds. Rammell & Fleming (1978, p. 93) reported *"it is clear that a wide variety of small birds commonly found in New Zealand's forests and bush are susceptible to 1080 poisoning."* Spurr (1979) listed the following species as having been found dead in areas poisoned with 1080: "*Australian harrier, weka, pukeko, kaka, kea, morepork, rifleman, NZ pipit, brown creeper, whitehead, grey warbler, fantail, tit, robin, silvereye."* Since then Spurr & Powlesland (1997) have added *kokako, tui* and *kereru* to the list, and Fairweather et al. (2015) added *kakariki* and *fernbird*.

Sub-lethal effects of 1080 on birds include damage to testicular morphology (Balcomb et al. 1983) and heart

[3] The proportion of baited tunnels with rat tracks left in them

and wing muscles (Ataria et al, 2000). The high energy requirements of avian muscle tissue may make it particularly susceptible to 1080 (Ataria et al. 2000).

The risk to many native bird species from aerial 1080 operations is unknown (Veltman et al. 2014). The most definitive studies on bird deaths due to 1080 have used radio-telemetry, and have confirmed on-going, substantial mortality of kea (Kemp & van Klink 2014 (unpublished report)) and fern birds (van Klink et al. 2013). Recently it was stated that to address the issue of 1080 poisoning of native birds objectively, *"it would be necessary to design a bespoke bird- and mammal-carcass collection study as an integral part of a 1080 pest-control operation,"* (Morriss et al. 2016, p. 369).

DoC's most commonly used method of assessing bird mortality, the five minute bird count, is notoriously unreliable (Westbrooke & Powlesland 2005; ERMA Review 2007; Green & Pryde 2012; Hartley 2012). Nesting success is also used by DoC to assess effects of poisoning and as with bird counts, it is of questionable value. Increased nesting success is claimed to indicate that aerial 1080 has had a beneficial effect (EPA 2013 pp. 13, 114, 28). But it may actually show that populations have been severely culled (Nilsson 1984; Arcese & Smith 1988). For instance in their review Eason et al. (2011) described how a population of tomtits estimated to have been culled by 79% by an aerial 1080 operation had shown enhanced nesting success the following season, with "*pairs rearing two, and in some cases, three broods*" (p. 12). Furthermore the monitoring of nesting success (e.g. O'Donnell & Elliot (1996), by climbing into trees to inspect mohua (*Mohua ochrocephala*) nests every 3-4 days) may cause predation. The visual, oral and olfactory disturbances from nest monitoring are likely to attract predators (Major 1990; Hein & Hein 1996; Ellenberg et al. 2015); stoats have followed at least one wildlife scientist around (Ellenberg et al. 2015, p. 240).

In a recent review, DoC (Brown et al. 2015, p. 19) admitted that "*Few studies have monitored long-term bird population or community responses to a sustained regime of aerial 1080 application.*" This in spite of warnings such as:

> *It is clear from the available evidence that species with good reproductive and good dispersal capacities have the ability to recover from even a large reduction in numbers. It is equally clear that species with both poor reproductive and poor dispersal capacities have only a limited ability to recover.* (Spurr 1979, p. 59).

> *Net outcomes (the balance between so-called 'costs' and 'benefits') of rodent population control must be measured at the community level, because non-target deaths, secondary poisoning, diet switching, and other unexpected responses may counter-intuitively negate the benefits of reducing ship rat numbers* (Innes 2005, p. 203).

> *The effects observed in this study in key organs, such as heart and wing muscle, highlights the need to monitor individuals or populations in the medium-to-long-term*" (Ataria 2000, p 297).

Suffering of poisoned birds (and other non-target animals) was virtually overlooked by the applicants in the ERMA review, drawing criticism from the review panel's ethical consultant:

> *1080 presents a significant welfare risk - poisoned animals experience several hours of compromised welfare and death, and possible pathological effects in surviving animals. This risk, not just to possums but many other species, should be acknowledged and considered...Given that 1080 is a broad-spectrum toxin, it is essential that the broad spectrum of costs and benefits is considered and not just limited to possums* (ERMA Review 2007, ERR p. 574).

Animal welfare was *"essentially ignored"* in public information from DoC and other poisoning agencies (Green & Rohan 2012, p. 196). Suffering was trivialised by the Parliamentary Commissioner for the Environment's statements that 1080 was rated as "*moderately humane*"(Wright 2011, p 52; Wright 2013, p. 3) when the research cited actually rated it as having an "*intermediate welfare impact*"[4] consisting of severe effects, lasting for hours (Beausoliel et al. 2010).

4. Lack of science behind 1080 use by the Department of Conservation

In a 2015 overview of its own ship rat, possum and stoat control programmes (Brown et al. 2015), DoC listed many problems internal to their organisation, which included: (1) few staff had completed the

[4] The 'intermediate' rating fell between cyanide which causes suffering for minutes, and brodifacoum which causes severe to extreme suffering lasting days to weeks (Beausoliel et al., 2010).

Animal Pest Management Framework training; (2) adoption of best practise was patchy; (3) not all DoC control operations were reported; (4) failure to follow best practice; (5) insufficient toxin; (6) budget insufficient; (7) breakdown in communication between technical advisors and operational staff leading to poor design and inconclusive outcomes; (8) did not fully understand the relationship between forest mast events and rodent population responses to these; (9) had too few measures of the long-term benefits of 1080 use to different populations of native species; (10) lack of robust monitoring and follow through; (11) legal requirements not always met;(12) how variable operations had been was unknown, as not all control operations were written up; (13) average costs for ground-based trapping and toxin operations were difficult to obtain because they were not consistently recorded.

Additional problems are evident in other DoC reports. Despite claims that aerial 1080 operations must be well timed (EPA 2011, p. 28; Brown et al. 2015, p. 23) "*many logistical, political and environmental constraints can significantly affect when a treatment ultimately occurs*" (Hunter & Kemp 2015, unpublished report). Poor timing was evident in a poisoning operation in Karurangi National Park in 2014, where alpine areas were poisoned just before a snowfall which covered the baits (Elliot 2015, p. 1 (unpublished report)).

In DoC planning and reporting, the results of "nesting success" in heavily monitored nests in unpublished studies seem to be given weight and traded off against "bykill" of the species. For example:

> *An experiment in Westland provided very strong support for the notion that kea nest survival is boosted by aerial 1080 predator control in those forests, but the boost was not sufficient after one year to compensate for the bykill that occurred there. In upland beech forests, there is also evidence of a boost to nest survival but the level of nest survival achieved was not as great as in Westland.* (EPA 2011, p. 28).

> *Our study leaves little doubt that the aerial 1080 at Okarito in spring 2011 caused a substantial increase in kea productivity, via a large increase in nest survival…The main shortcomings of our study were a lack of replication, non-random assignments of the 1080 treatment among blocks and non-blind observers*. (Kemp et al. 2015, pp. 11-12 (unpublished report)).

> *We have not been able to precisely census the birds[rock wren] in our treated study areas, but given the nesting success we've observed and the number of chicks we've been able to count from some of these nests, we estimate that the population in our two 1080 treated study areas has risen from 49 to 61 birds...Even if we make the most pessimistic assumption that the 22 birds that went missing are indeed dead and were killed by 1080, we still have an overall positive result from the use of 1080 in our two treated areas...in order that we can develop further 1080 protocols to protect rock wren I recommend that we continue to use 1080 above the treeline...* (Elliot 2015, pp. 1-2 (unpublished report)).

Unaccountably, for a species near the brink of extinction[5], ongoing deaths of kea in 1080 poisoning operations are tolerated by DoC. Two examples are:

> *Our study is severely limited in terms of achieving our aims of understanding factors affecting non target risk to keas and quantifying non target risk…the level of risk at some operations is concerning…As operations continue in the face of uncertainty about risk to kea, further monitoring of kea through aerial 1080 is warranted* (Kemp & van Klink 2014, pp. 8-9 (unpublished report)).

> *While radio tagging kea at a site such as West Matukituki would help our understanding of factors influencing risk, it might also serve to substantiate claims of recklessness if kea die*. (Kemp 2014, p. 3 (unpublished report)).

DoC's "Battle for the Birds" programme uses widespread aerial 1080 poisoning to attempt to control expected rises in pest animals (rats, mice and stoats) associated with episodic masting (seeding) of beech trees (Elliot 2016). This idea overlooks many important ecological facts: (1) negative effects of competitor release and prey switching following poisoning (as above); (2) many different plant species (not just beech trees) mast at different times with variable responses by pest animals (Canham et al. 2014; Griffiths & Barron 2016; Innes 2005; Ruscoe & Murphy 2005); (3) mice rather than rats are expected to increase in beech forests following masting (Efford et al. 2006; Murphy & Pickard 1990; Ruscoe & Murphy 2005); (4) 1080 is usually very ineffective at killing

[5] Numbers of kea were estimated at 1000-5000 in 1986 (Anderson, 1986, cited in Bond & Diamond 1992) and sharp declines and absences have been noted in the last few years (www.1080science.co.nz/decline-in-kea-numbers/)

mice (Fisher & Airey 2009) and can be poor at controlling stoats (Dilks et al. 2011; King & Murphy 2005); (5) New Zealand's native birds and other animals have weathered massive rises in rat numbers since the time of the kiore (*Rattus exulans*) (King 1984); (6) responses to masting naturally decline on their own within a few months (King 1984; 1990); (7) in poisoning deaths, priceless genetic material (along with the potential to adapt, e.g. to predation pressure (Urlich 2015)) is lost from populations; (8) New Zealand's endemic species such as kea are long-lived, slow reproducers to whom an occasional poor nesting year is likely of little consequence provided the adults survive (King 1984).

Anderson et al. (2014, p. 26) wrote of a *"disconnect between science and management"* whereby managers used a "*trial and error"* approach without formal assessment to control pests, despite the existence of a large amount of pest-focused ecological research. The foregoing appears to verify that.

5. Lack of science behind its use by TbFree NZ

While much has been made of the issue of possums transmitting bovine tuberculosis (*Mycobacterium bovis*) to domestic cattle there is still no empirical evidence that this has ever happened and no known mechanism of transmission (Coleman & Cook 2001; Nugent et al. 2015). Nevertheless, mathematical models have been used by the Animal Health Board (now known as TbFree NZ) to guide poisoning operations on a massive scale (Nugent et al. 2015). In 2015, 10.5 million hectares were under vector pest control targeting possums, typically aerial 1080 poisoning at five-yearly intervals, to keep possums below a critical density assumed to prevent Tb transmission (Nugent et al. 2015).

According to Livingstone et al. (2015, p. 9) no proof of any Tb infection in possums in an area to be poisoned is required, it just needs to be *suspected*. The Biosecurity Act (1993) allows wide scale poisoning to be forced upon land owners wherever an authorised officer "considers" it to be "necessary or expedient".

Control measures implemented to reduce Tb infection rates in livestock have involved widespread 1080 poisoning aimed at possums, and supplemented with tuberculin testing and slaughtering of test-positive stock (Livingstone et al., 2015). Whether the use of 1080 has contributed anything is questionable given the evidence cited:

> *The unique and perverse nature of bovine tuberculosis (Tb) in New Zealand has also made it difficult to show clear benefits of poisoning possums when seeking to reduce the incidence of Tb in livestock …examples are needed as unfortunately Hohotaka*[6]*… is the only documented example with an experimental control, and most scientists will not be willing to generalise from one example. No doubt more evidence will accumulate with time* (Montague 2000, pp. 278-279).

> *Within two years of such possum control* [around farms in Buller in the 1970's] *TB in cattle had dropped to very low levels, strongly implying that possum control had largely stopped TB transmission from possums to cattle. This pattern and response to control was also observed in other places in the 1980s, leaving no need for further scientific confirmation*. (Nugent 2016, p. 17).

The foundational assumptions on which the poisoning regime is built are proving to be inappropriate, for example transmission rates between possums have been found to be far lower than assumed (Rouco et al. 2015) and possum density is not well correlated with possum Tb infection rates (Nugent et al. 2015). The goal of eradication of Tb from possums has been described as needing "*better understanding"* of *"a number of eco-epidemiological issues, all of them complex and difficult."* (Nugent et al. 2015, p. 37).

Two recent publications (Barron et al. 2015 and Byrom et al. 2015) have highlighted that other wildlife such as pigs and ferrets which can spread Tb should be considered in efforts to manage the disease. Pigs may be poorly controlled by aerial 1080 (Cowled et al. 2004, p. 16) and increase numerically due to pig hunters avoiding poisoned areas (AHB 2008, p. 32). Ferrets may increase numerically (Rammell & Fleming 1978, p. 92) and extend their ranging behaviour (Byrom et al. 2015, p. 45; Norbury & Reddex 1990, p. 147) following aerial 1080 poisoning operations.

Meanwhile management of Tb in livestock is poor due to reliance on a tuberculin skin and blood test that has the potential to produce both false positive and false negative results. False positive reactors are slaughtered unnecessarily and can cause unnecessary herd movement restrictions (Humblet et al. 2009). The false negative problem creates a risk of allowing TB to persist in a herd (AHB 2012, p. 13) and may be

[6] A study comparing three blocks of farms in the Central North Island, in which time of onset of intensive possum control in the block was concurrent with a decline in the annual incidence in Tb in cattle, from low (<3%) to very low (<1%) (Caley et al. 1999).

responsible for the sudden re-emergence of Tb (Humblet et al. 2009). Other factors which can contribute to Tb emergence include feed stress, poor hygiene (Humblet et al. 2009) and contaminated pasture (Harris 1977).

The Parliamentary Commissioner for the Environment's report on 1080 stated under "*What this report does not cover ...the Animal Health Board's action in controlling bovine tuberculosis (TB) in any detail.*" (Wright 2011, p. 12). Nevertheless the Animal Health Board released the statement: "*Hopefully such a comprehensive report will reassure the New Zealand public that the carefully-regulated use of biodegradable 1080 to control predatory pests, such as possums, is not only safe, but necessary.*" (Wright 2013, p. 6). Further clouding of the truth was evident when Tb management was reviewed in 2015 and it was claimed that two "independent" science reviews (Caley 2015; Ferguson & Hellström 2016) had been commissioned for this (National Bovine TB Plan Governance Group 2015 p. 23). In fact two of the three authors had been involved with Tb research in New Zealand (e.g. Hellström 1979; Caley et al. 1999; Caley 2006).

Alternatives
Historically, scientific publications have called for alternatives to 1080:

> *1080 is too dangerous for general use.* (Barnett & Spencer 1949[7], p. 429).
>
> *Because control operations utilising 1080 may induce bait shyness, are only temporarily effective, and often create favourable conditions for noxious animals by reducing competition, and releasing nesting sites and feeding areas this Council believes that alternative means of dealing with problem animals should be investigated* (Harris 1977, p. 2) (New Zealand Nature Conservation Council).
>
> ...*until better methods of large-scale control [for possums] are developed, 1080 is perceived to be an essential tool*...(Eason 1997, p. 57).

However in recent years authorities including the New Zealand Parliamentary Commissioner for the Environment have encouraged acceptance:

> *The only option for controlling possums, rats and stoats on almost all of the conservation estate is to drop poison from aircraft.* (Wright 2011, p. 67) (Parliamentary Commissioner for the Environment).
>
> *Emerging issues include the need for… maintenance and more public support for mammal pest control or eradication, especially where this involves toxins (e.g. the Predator Free New Zealand initiative).* (New Zealand Royal Society 2014, p. 5).

The current drive for continued aerial poisoning disregards the success of ground control operations in quelling rat plagues (Brown et al. 2015, p. 10), the wide uptake of "Goodnature" self-resetting traps (Priestly 2014), new technology (e.g. image recognition, GPS, remote) and developments in species-specific ground control (Campbell et al. 2015; Russell et al. 2015). There is excellent potential for ground-based commercial pest harvesting to carry out initial control, thereby reducing overall costs and supporting local communities (Jones et al. 2012). A strong market exists for possum fur (Jones et al. 2012) and pest meat for pet food was identified as a particular niche where New Zealand has strength and opportunity (Coriolis Ltd. 2014, p. 43).

TbFree NZ had contingencies to use bTB vaccines for livestock and wildlife, developed in case poisoning was banned (AHB 2007; 2008). Tb in livestock could be managed along with other livestock diseases by the Ministry for Primary Industries, possibly by culling the few remaining infected herds and providing management advice on preventing re-infection[8], along with monitoring focussed largely at abattoirs and the freezing works (FATE 2016).

Regardless of the technique used to manage invasive pests, a sound ecological approach with robust monitoring is required (King 1984, pp. 131-132, 185-186; Caut et al. 2007, p. 865; Baber et al. 2008, pp. 8-9). Without this even ground control of pests may have devastating effects. For

[7] After investigating the use of 1080 as a rat poison in Britain.

[8] Including ground control of Tb-susceptible wildlife in bush-pasture margins and strict livestock movement control regardless of animal age (Mary Molloy, FATE, personal communication 25 July 2016.)

example, rats became very abundant after DoC implemented stoat trapping in the Eglinton Valley (Innes 2005, p. 202; Efford et al. 2006, p. 291), and stoat trapping in the Hurunui and Hawdon areas was followed by rat plagues and declines in rare mohua and parakeet (*Cyanoramphus malherbi*) numbers (Brown et al. 2015 p. 5; Elliot & Suggate 2007, pp. 35-40).

There is compelling evidence that the science underpinning the aerial use of 1080, for either Tb control or conservation, is unsound.

Much of New Zealand's ecological heritage is probably far better left alone:

"*The hardy species are the ones that have survived on the main islands for at least a hundred years in company with the whole range of predators and other habitat changes, and therefore are able to come to some sort of terms with them.... What conditions do they require? Simply to be left alone in their natural habitat, and enough of it. In the long run, the continued survival of any species genotype is impossible outside the habitat to which it is adapted: conservation of species and of habitat are the same thing*" (King 1984, p. 183).

Conclusions and Recommendations

There is much unknown about 1080 poison but it is clear that the practice of aerial spreading it with food baits kills rare birds and causes severe ecological upheaval, favouring invasive, fast breeding pest species. There is an urgent need to bring scientific methodology into pest management. The following course of action is suggested:

1. Cease aerial 1080 poisoning immediately.
2. Commission independent reviews of:
   a) Current threats to native ecological systems.
   b) Options for bovine tuberculosis management in NZ.
3. Establish a wholly independent scientific advisory board to:
   a) Develop management plans for native ecological systems.
   b) Oversee the implementation of management plans.
   c) Oversee independent, landscape-scale, on-going monitoring to assess effects of management on ecological systems.

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References

Affeld, K, Worner, SP, Didham, RK, Sullivan, J, Henderson, RC, Olarte, JM, Thorpe, S, Clunie, L, Early, J, Emberson, R, Johns, P, Dugdale, J, Mound, L, Smithers, C, Pollard, S & Ward, J 2009. The invertebrate fauna of epiphyte mats in the canopy of northern rata (Myrtaceae: *Metrosideros robusta* A. Cunn.) on the West Coast of the South Island, New Zealand. *New Zealand Journal of Zoology 36:* 177-202.

AHB 2007. *Vaccine Programme. Animal Health Board Annual Research Report 2006-2007*: 18-19.

AHB 2008. *Vaccine Programme. Animal Health Board Annual Research Report 2007-2008:* 19-20.

AHB 2012. *Identification of risk factors associated with new and persistent infection in cattle herds at Karamea. Animal Health Board Annual Research Report 2011/2012*: 13

Anderson, D, Byrom, A, Baxter, P, Cassey, P, Ramsey, D & Woolnough, A 2014. How can science guide best-practice pest management? *Kararehe Kino 24*: 26.

Arcese, P & Smith, JM 1988. Effects of population density and supplemental food on reproduction in song sparrows. *Journal of Animal Ecology 57*: 119-136.

Ataria, JM, Wickström, M, Arthur, D & Eason, CT 2000. Biochemical and histopathological changes induced by sodium monofluoroacetate (1080) in mallard ducks. *New Zealand Plant Protection 53*: 293-298.

Baber, M, Babbitt, K, Brejaart, R, Ussher, G, DiManno, N & Sexton, G 2008. "Does mammalian pest control benefit New Zealand's Hochstetter's frog (*Leiopelma hochstetteri*)?"In B Clarkson, P Kurian, T Nachowitz & H Rennie (eds). Proceedings of the Conserv-Vision Conference. 14 pp.

Balcomb, R, Bowen, CA, Williams, HO 1983. Acute and sublethal effects of 1080 on starlings. *Bulletin of Environmental Contamination and Toxicology 31*: 692-698.

Barnett, SA & Spencer, MM 1949. Sodium fluoroacetate (1080) as a rat poison. *The Journal of Hygiene 47*: 426-430.

Barron, MC, Tompkins, DM, Ramsey, DSL & Bosson, MAJ 2015. The role of multiple wildlife hosts in the persistence and spread of bovine tuberculosis in New Zealand. *New Zealand Veterinary Journal 63 (Supplement 1)*: 68-76.

Beausoliel, N, Fisher, P, Warburton, B, Mellor, D 2010. *How humane are our pest control tools? (09-11326). MAF Biosecurity New Zealand Technical Paper no: 2011/01.* 149 pp.

Bond, A & Diamond, J 1992. Population estimates of Kea in Arthur's Pass National Park. *Notornis 39*: 151-160.

Booth, LH & Wickström, ML 1999. The Toxicity of Sodium Monofluoroacetate (1080) to *Huberia striata*, a New Zealand Native Ant. *New Zealand Journal of Ecology 23(2):* 161-165.

Brown, K, Elliott, G, Innes, J & Kemp, J 2015. *Ship rat, stoat and possum control on mainland New Zealand. An overview of techniques, successes and challenges.* Department of Conservation report. 40 pp.

Byrom, A, Banks, P, Dickman, C & Pech, R 2013. Will reinvasion stymie large-scale eradication of invasive mammals in New Zealand? *Kararehe Kino 21*: 6-7.

Byrom, AE, Caley, P, Paterson, BM & Nugent, G 2015. Feral ferrets (*Mustela furo*) as hosts and sentinels of tuberculosis in New Zealand. *New Zealand Veterinary Journal 63(Supplement 1)*: 42-53.

Caley, P 2006. Bovine tuberculosis in brushtail possums: models, dogma and data. *New Zealand Journal of Ecology 30(1)*: 25-34.

Caley, P 2015. *A review of science underpinning eradication of TB from New Zealand. Commissioned by the TB Plan Review Plan Governance Group*. 28 pp.

Caley, P, Hickling, GJ, Cowan, PE & Pfeiffer, DU 1999. Effects of sustained control of brushtail possums on levels of Mycobacterium bovis infection in cattle and brushtail possum populations from Hohotaka, New Zealand. *New Zealand Veterinary Journal 47(4)*: 133-142.

Campbell, KJ, Beek, J, Eason, CT, Glen, AS, Godwin, J, Gould, F, Holmes, ND, Howald, GR, Madden, FM, Ponder, J, Threadgill, DW, Wegmann, AS & Baxter, GS 2015. The next generation of rodent eradications: Innovative technologies and tools to improve species specificity and increase their feasibility on islands. *Biological Conservation 185*: 47-58.

Canham, CD, Ruscoe, WA, Wright, EF & Wilson, DJ 2014. Spatial and temporal variation in tree seed production and dispersal in a New Zealand temperate rainforest. *Ecosphere 5(4)*: Article 49. 14 pp.

Caut, S, Casanovas, JG, Virgos, E, Lozano, J & Witmer, GW, Courchamp, F 2007. Rats dying for mice: Modelling the competitor release effect. *Austral Ecology 32(8)*: 858-868.

Champeau, O, Knight, B &Tremblay, L 2014. *1080 uptake and elimination in the rainbow trout. Cawthron Institute report no. 2611.* Cawthron Institute, Nelson. 32 pp.

Clapperton, BK, Morgan, DKJ, Day, TD, Oates, KE, Beath, AM, Cox, NR & Matthews, LR 2014. Efficacy of bird repellents at deterring North Island robins (*Petroica australis longipes*) and tomtits (*P. macrocephala toitoi*) from baits. *New Zealand Journal of Ecology 38(1)*: 116-123.

Coleman, JD & Cooke, MM 2001. *Mycobacterium bovis* infection in wildlife in New Zealand. *Tuberculosis 81(3)*: 191-202.

Coriolis Ltd. 2014. *Investment opportunities in the New Zealand pet food industry. V1.00c. February 2014*. 81 pp.

Cowan, P, Booth, L & Crowell, M 2016. Repellents with potential to protect kea and other native birds from aerial poisoning for possum and rat control. *New Zealand Journal of Ecology 40(1)*: 29-41.

Cowled, B, Parkes, J & Lapidge, S 2004. *A project that investigates current options for managing feral pigs in Australia and assesses the need for the development of more effective and humane techniques and strategies. Stage 4 Report*. Pest Animal Control Cooperative Research Centre, Canberra, Australia. 30 pp.

Dilks, P, Shapiro, L, Greene, T, Kavermann, MJ, Eason, CT & Murphy EC 2011. Field evaluation of para-aminopropiophenone (PAPP) for controlling stoats (*Mustela erminea*) in New Zealand. *New Zealand Journal of Zoology 38(2)*: 143-150.

DoC 2002. *Rare Bits* Newsletter 44, April 2002: 9.

Eason, C 1997. Sodium monofluoroacetate toxicology in relation to its use in New Zealand *Australasian Journal of Ecotoxicology 3*: 57-64.

Eason, C, Miller, A, Ogilvie, S & Fairweather, A 2011. An updated review of the toxicology and ecotoxicology of sodium fluoroacetate (1080) in relation to its use as a pest control tool in New Zealand. *New Zealand Journal of Ecology 35(1)*: 1-20.

Eason, C, Warburton, B, Henderson, R 2000. Toxicants used for possum control. Techniques Used for Poisoning Possums, in TL Montague (ed). *The brushtail possum: biology, impact and management,* Manaaki Whenua Press, Lincoln, pp. 154-163.

Efford, MG, Fitzgerald, BM, Karl, BJ & Berben, PH 2006. Population dynamics of the ship rat *Rattus rattus* L. in the Orongorongo Valley, New Zealand. *New Zealand Journal of Zoology 33*: 273-297.

Ellenberg, U, Edwards, E, Mattern, T, Hiscock, JA, Wilson, R & Edmonds, H 2016. Assessing the impact of nest searches on breeding birds - a case study on Fiordland crested penguins (*Eudyptes pachyrhynchus*). *New Zealand Journal of Ecology 39(2)*: 231-244.

Elliot, G, Suggate, R 2007. *Operation Ark. Three year progress report. Department of Conservation Report.* 86 pp.

Elliot, G 2015 (unpublished report). *Rock wren and 1080 in Kahurangi National Park*. Department of Conservation report. 5 pp.

Elliot, G 2016. *The science behind the Department of Conservation's predator control response*. Department of Conservation, 10 pp.

Eisler, R 1995. *Sodium monofluoroacetate (1080) hazards to fish, wildlife in invertebrates: a synoptic review. Patuxent Environmental Science Centre, U.S. National Biological Service Biological Report 27*. 52 pp.

EPA 2011. *New Zealand Environmental Protection Authority Annual Report on the Aerial Use of 1080 for the year ended 31 December 2011*: 28.

EPA 2013. *New Zealand Environmental Protection Authority Annual Report on the Aerial Use of 1080 for the year ended 31 December*: 13.

ERMA Review 2007. *Environmental Risk Management Authority's reassessment of 1080, 2007, Application HRE05002*.

Fairweather, A, Broome, K & Fisher, P 2015. *Sodium fluoroacetate pesticide information review. Department of Conservation Report Docdm-25427.* 103 pp.

FATE [Farmers Against Ten Eighty] 2016. Federated Farmers challenged over Tb-Free rort. *Scoop News,* 13 May 2016. http://www.scoop.co.nz/stories/PO1605/S00171/federated-farmers-challenged-over-tb-free-rort.htm

Ferguson, I & Hellström, J 2015. *Review of the science undertaken for the purpose of managing Bovine Tuberculosis in New Zealand.* 16 pp.

Fisher P 2013. *Non-target risks of using 1080 and pindone for rabbit control. Landcare Research. Envirolink Advice Grant 1250-MLDC82.* 34 pp.

Fisher, P & Airey, AT 2009. *Factors affecting 1080 pellet bait acceptance by house mice (Mus musculus). Department of Conservation Research & Development Series 306.* 23 pp.

Gooneratne, SR, Eason, CT, Milne, L, Arthur, DG, Cook, C & Wickström, M 2008. Acute and long-term effects of exposure to sodium monofluoroacetate (1080) in sheep. *Journal of Veterinary Research 75*: 127-139

Greene, TC & Pryde, MA 2012. Three population estimation methods compared for a known South Island robin population in Fiordland, New Zealand. *New Zealand Journal of Ecology 36(3)*: 340-252.

Green, W & Rohan, M 2012. Opposition to aerial 1080 poisoning for control of invasive mammals in New Zealand: risk perceptions and agency responses. *Journal of the Royal Society of New Zealand 42(3)*: 185-213.

Griffiths, JW, Barron, MC 2016. Spatiotemporal changes in relative rat (*Rattus rattus*) abundance following large-scale pest control. *New Zealand Journal of Ecology 40(3):* 371-380.

Harris, G 1977. *New Zealand Nature Conservation Council Report on the Use of Sodium Fluoroacetate (1080)*. 20 pp.

Hartley, LJ 2012. Five-minute bird counts in New Zealand. *New Zealand Journal of Ecology 36(3)*: 268-278.

Hein, EW & Hein, WS 1996. Effect of flagging on predation of artificial duck nests. *Journal of Field Ornithology 67(4)*: 604-611.

Hellström J 1979. Tuberculosis in deer. *New Zealand Veterinary Journal 27*: 151.
Humblet, MF, Boschiroli, ML, & Saegerman, C, 2009. Classification of worldwide bovine tuberculosis risk reactors in cattle: a stratified approach. *Veterinary Research 40(5)*: 50-69.

Hunter C & Kemp, J 2015 (unpublished report). *Draft Report for PAG meeting assessing Kea population responses to aerial 1080 treatment.* Department of Conservation report. 6 pp.

Innes, J 2005. Ship Rat. In CM King (ed). *The Handbook of New Zealand Mammals (2nd Edition)*. Oxford University Press, Melbourne, pp 187-203.

Innes, J, Hay, R, Flux, I, Bradfield, P, Speed, H, Jansen, P 1999. Successful recovery of North Island kokako *Callaes cinerea wilsoni* populations, by adaptive management. *Biological Conservation 87*: 201-214.

Innes, J, King, C, Bartlam, S, Forrester, G, & Howitt, R 2015. Predator control improves nesting success in Waikato forest fragments. *New Zealand Journal of Ecology 39(2)*: 245-253.

Innes, J, Warburton, B, Williams, D, Speed, H & Bradfield, P 1995. Large-scale poisoning of ship rats (*Rattus rattus*) in indigenous forests of the North Island, New Zealand. *New Zealand Journal of Ecology 19(1)*: 5-17.

Jones, C, Barron, M, Warburton, B, Coleman, M, Lyver, P O'B & Nugent, G 2012. Serving two masters: Reconciling economic and biodiversity outcomes of brushtail possum (*Trichosurus vulpecula*) for fur harvest in an indigenous New Zealand Forest. *Biological Conservation 153*: 143-152.

Kemp, J 2014 (unpublished report). *Battle for our birds kea tracking plan 2014-2015.* Department of Conservation report. 7 pp.

Kemp, J, Cunninghame, F, Barrett, B, Makan, T, Fraser, J, Mosen, C, 2015 (unpublished report). Effect of an aerial 1080 operation on the productivity of the kea (*Nestor notabilis*) in a West Coast rimu forest. Department of Conservation report. 15 pp.

Kemp, J & van Klink, P 2014 (unpublished report). *Non target risk to the kea from aerial 1080 poison baiting for the control of invasive mammals in New Zealand forests.* Department of Conservation report. 19 pp.

King, C 1984. *Immigrant Killers. Introduced Predators and the conservation of birds in New Zealand* Oxford University Press. 224 pp.

King, C, 1990. Stoats. In CM King (ed). *The Handbook of New Zealand Mammals.* Oxford University Press, Oxford, pp. 288-312.

King, C & Murphy, E 2005. Stoat. In CM King (ed). *The Handbook of New Zealand Mammals (2nd Edition)*. Oxford University Press, Melbourne, pp. 204-221.

Landcare Research, 2016. *Tarns*. http://www.landcareresearch.co.nz/publications/factsheets/rare-ecosystems/wetlands/tarns

Livingstone, PG, Hancox, N, Nugent, G & de Lisle, GW 2015. Toward eradication: the effect of Mycobacterium bovis infection in wildlife on the evolution and future direction of bovine tuberculosis management in New Zealand. *New Zealand Veterinary Journal 63(Supp 1)*: 4-18.

Lyver, P O'B, Ataria, J, Trought, K & Fisher, P 2005. Sodium fluoroacetate (1080) residues in longfin eels, *Anguilla dieffenbachii*, following exposure to contaminated water and food. *New Zealand Journal of Marine and Freshwater Research 39:* 1243-1252.

Major, RE 1990. The effect of human observers on the intensity of nest predation. *Ibis 132 (4)*: 608-612.

Montague, TL 2000. Editor's Conclusion - the beginning of the end or the end of the beginning. In TL Montague (ed). *The brushtail possum: biology, impact and management.* Manaaki Whenua Press, Lincoln, pp. 278-279.

Morgan, D & Hickling, G 2000. Techniques Used for Poisoning Possums, in TL Montague (ed. *The brushtail possum: biology, impact and management,* Manaaki Whenua Press, Lincoln, pp. 143-153.

Morgan, D, Warburton, B & Nugent, G 2015. Aerial prefeeding followed by ground based toxic baiting for more efficient and acceptable poisoning of invasive small mammalian pests. *PLOS One 10(7)*: e0134032.

Morriss, GA, Nugent, G, Whitford, J 2016. Dead birds found after aerial poisoning operations targeting small mammal pests in New Zealand 2003-14. *New Zealand Journal of Ecology 40(3)*: 361-370.

Murphy, E & Pickard, C 1990. House Mouse. In CM King (ed). *The Handbook of New Zealand Mammals*. Oxford University Press, Oxford. pp 99-113.

National Bovine TB Plan Governance Group 2015. *National Bovine TB Plan Review Full Consultation Document, June 2015*. 78 pp.

Nilsson, SG 1984. The evolution of nest-site selection among hole-nesting birds: The importance of nest predation and competition. *Ornis Scandinavica 15(3)*: 167-175.

Norbury G & Reddiex, B 1990. European rabbit. In CM King (ed). *The Handbook of New Zealand Mammals.* Oxford University Press, Oxford, pp. 131-150.

Northcott, G, Jensen, D, Ying, L & Fisher, P 2014. Degradation rate of sodium fluoroacetate in three New Zealand soils. *Environmental Toxicology and Chemistry 33(5)*: 1048-1058.

Nugent, G 2016. The main host of TB is … possum! *Kararehe Kino 27*: 16-17.

Nugent, G, Buddle, BM & Knowles, G 2015. Epidemiology and control of Mycobacterium bovis infection in brushtail possums (*Trichosurus vulpecula),* in the primary wildlife host of bovine tuberculosis in New Zealand. *New Zealand Veterinary Journal 63 (Supp 1)*: 28-41.

Nugent, G & Morriss, GA 2013. Delivery of toxic bait in clusters: a modified technique for aerial poisoning of small mammal pests. *NZ Journal of Ecology 37(2)*: 246-255.

O'Donnell, CFJ & Elliot, GP 1996. Control of a stoat (*Mustela erminea*) population irruption to enhance mohua (yellowhead) (*Mohoua ochrocephala*) breeding success in New Zealand *New Zealand Journal of Zoology 23*: 279-286.

Priestly, R 2014. Weapons of mass destruction. *The New Zealand Listener, October 4*: 52-53.

Rammell, CG & Fleming, PA 1978. *Compound 1080. Properties and use of sodium monofluoroacetate in New Zealand.* Wellington, New Zealand. Animal Health Division, Ministry of Agriculture & Fisheries. 111 pp.

Ross, J, McCoskery, H 2012. *Deer carcass breakdown monitoring. Report prepared for the Animal Health Board*. Wellington, New Zealand. 7 pp.

Rouco, C, Richardson, K, Tompkins, D 2015. Estimating TB transmission rates among possums in the wild. *Kararehe Kino 26:* 12.

Ruscoe, W & Murphy, E 2005. House mouse. In CM King (ed). *The Handbook of New Zealand Mammals (2nd Edition).* Oxford University Press, Melbourne, pp. 204-221.

Ruscoe, WA, Ramsey, DSL, Pech, RP, Sweetapple, PJ, Yockney, I, Barron, MC, Perry, M, Nugent, G, Carran, R, Warne, R, Brausch, C & Duncan, RP 2011. Unexpected consequences of control: Competitive vs. predator release in a four-species assemblage of invasive mammals. *Ecology Letters 14*: 1035-1042.

Russell, JC, Innes, JG, Brown, PH & Byrom, AE 2015. Predator-Free New Zealand: Conservation Country. *Bioscience 65(5)*: 520-525.

Shapira, I, Walker, E, Brunton, DH & Raubenheimer, D, 2013. Responses to direct versus indirect cues of predation and competition in naïve invasive mice: implications for management. *New Zealand Journal of Ecology 37(1)*: 33-40.

Spurr EB 1979. A Theoretical Assessment of the Ability of Bird Species to Recover from an Imposed Reduction in Numbers, with Particular Reference to 1080 Poisoning. *New Zealand Journal of Ecology 2*: 46-63.

Spurr, E & Powlesland, RG 1997. *Impacts of aerial application of 1080 on non-target native fauna. Department of Conservation Science for Conservation 62.* 31pp.

Suren, AM & Bonnet, ML 2006. Consumption of baits containing sodium fluoroacetate (1080) by the New Zealand freshwater crayfish (*Paranephrops planifrons*). *New Zealand Journal of Marine and Freshwater Research 40*: 169-178.

Sweetapple, P & Nugent, G 2007 Secondary Effects of Possum Control. *Kararehe Kino 11*: 9-10.

Twigg, LE, Martin, GR & Lowe TJ 2002. Evidence of pesticide resistance in medium-sized mammalian pests: a case study with 1080 poison and Australian rabbits. *Journal of Applied Ecology 39*: 549-560.

Urlich, SC 2015. What's the end-game for biodiversity: is it time for conservation evolution? *New Zealand Journal of Ecology 39*: 133-142.

USEPA 1988. *United States Environmental Protection Agency Pesticide Fact Sheet Sodium Fluoroacetate (compound 1080) Cancellation/denial/suspension/data call-in*.

van Klink, P, Kemp, J & O'Donnell, CFJ 2013. The effect of aerial application of 1080 cereal baits on radio-tagged South Island fernbirds (*Bowdleria punctata punctata*). *New Zealand Journal of Zoology 40(2)*: 145-153.

Veltman, CM, Westbrooke, IM, Powlesland, RG & Greene, TC 2014. A principles-based decision tree for future investigations of native New Zealand birds during aerial 1080 operations. *New Zealand Journal of Ecology 38(1)*: 103-109.

Westbrooke, IM & Powlesland, RG 2005. Comparison of impact between carrot and cereal 1080 baits on tomtits (*Petroica macrocephala*). *New Zealand Journal of Ecology 29(1)*: 143-147.

Wright, J 2011. *Evaluating the use of 1080: Predators, poisons and silent forests.* Parliamentary Commissioner for the Environment, Wellington. 85 pp.

Wright, J 2013. *Update Report. Evaluating the use of 1080: Predators, poisons and silent forests.* Parliamentary Commissioner for the Environment, Wellington. 15 pp.

Table 1. Unknown properties of 1080 poison as noted in the Environmental Risk Management Authority's Reassessment (2007, Evaluation and Review Report)*

Effect	Page	Wording
Acute inhalation toxicity	300	*"...represents a data gap..."*
Respiratory sensitisation	304	*"...unable to locate any studies..."*
Contact sensitisation	304	*"...unable to locate any studies..."*
Carcinogenicity in any mammalian species	306	*"...did not find any studies..."*
Adsorption/desorption in a range of soils	349	*"Data Gap"* (no definitive studies)
Reproductive toxicity to birds	349	*"Data Gap"* (no definitive studies)
Toxicity to algae	349	*"Data Gap"* (no definitive studies)
Toxicity to aquatic invertebrates	349	*"Data Gap"* (no definitive studies)
Chronic aquatic toxicity	349	*"Data Gap"* (no definitive studies)
Biodegradation in aquatic systems and soils at varying pH, soil type and temperature	349	*"Data Gap"* (no definitive studies)
Toxicity to terrestrial invertebrates (p. 350)	350	*"Data Gap"* (no definitive studies)
Toxicity of the breakdown product fluorocitrate in water or soil (p. 360)	360	*"The applicants did not provide, and the Agency was not able to locate, any data..."*
Toxicity to native NZ reptiles (p. 416)	416	*"No data are available..."*
Presence of residues in cow milk (p. 561)	561	*"No information was available..."*
Presence of residues in the main human meat sources, such as cattle, pigs, and deer (p. 562)	562	*"The Agency did not find data..."*

*This list is not exhaustive