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Opposition to aerial 1080 poisoning for control of invasive mammals in New Zealand: risk perceptions and agency responses

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Public opposition to the aerial broadcast of sodium fluoroacetate (1080) poison pellets in New Zealand is an issue for pest management agencies who use it for protecting indigenous wildlife and reducing bovine Tb levels. The first part of this study analyses a wide range of concerns expressed in 525 submissions made to the Environmental Risk Management Authority in 2007 opposing the re-registration of 1080. In the second part of this study we evaluate the information produced by pest management agencies about 1080 for its coverage of the range of perceived risks identified in the submissions. The information produced by agencies addresses most issues of technical risk, but few risks identifying ethical, economic, social, research and operational concerns. The submissions and agency responses are analysed in the framework of risk communications research and approaches to 'wicked' problems. This shows that focusing only on improving the written material on 1080 risks will not reduce critical public concerns about aerial use of 1080. Both risk communication practice and approaches to 'wicked' problems emphasize the importance of engaging in dialogue with relevant players to progress socially complex issues. We argue that a more deliberate and strategic effort to build dialogue and collaboration with key communities is needed. Agencies need to engage relevant experts and sustain initiatives over time to build trust and move forward. Science is an important voice to be at the table, but is only one among several.

Keywords: pest control; brushtail possum; *Trichosurus vulpecula*; Compound 1080; sodium fluoroacetate; risk perception; outrage factors; risk communication; wicked problems

Introduction

The brushtail possum (*Trichosurus vulpecula*) (hereafter the 'possum') has spread throughout New Zealand since its introduction from Australia in 1858 to establish a fur industry (Pracy 1974). An omnivore, the possum causes extensive damage to some native forests (Payton 2000) as well as to wildlife via competition for food and predation of eggs, chicks and birds. Predation by possums compounds the predation of native wildlife by introduced rodents and mustelids, but large-scale poisoning of possums and ship rats (*Rattus rattus*) has been shown to protect endangered species (Innes et al. 1995, 1999). Forest tree species also benefit from large-scale possum control, and recovery of palatable plants has been documented (Norton 2000). As well as negative impacts on wildlife and forests, the possum is the main wildlife vector and reservoir for bovine tuberculosis (Tb). Ongoing transmission of Tb from tuberculous possums to farmed livestock is considered the single greatest barrier to Tb reduction and eradication (Coleman & Caley 2000). To eradicate Tb from New Zealand, the Animal Health Board (AHB)

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conducts large-scale possum control programmes and, to a lesser extent, control of ferrets which is the other major Tb vector. In 2007–2008, the AHB spent NZD 55 million on vector control management (Animal Health Board 2008). This included ground control of possums over 3,100,000 ha and aerial control over 500,000 ha. Ferrets were controlled over 1,250,000 ha via ground control only. Expenditure on possum control by the Department of Conservation (DOC) during 2008–2009 was NZD 14.9 million (Department of Conservation 2009a), providing sustained control of possums over 1,099,627 ha.

Several toxins and various traps have been used for possum control (Eason et al. 2000; Montague & Warburton 2000), but the only toxin that can be applied aerially is sodium fluoroacetate (Compound 1080, hereafter '1080') in cereal baits or in chopped carrot baits. 1080 (the laboratory acquisition number assigned in the USA during screening trials in the 1940s) was first registered for use in New Zealand in 1964. 1080 is not available to the general public for use in any form in New Zealand. Only fully registered and strictly controlled operators may use ground-based or aerial 1080 products. It is only the absence of native land mammals in New Zealand, aside from two species of bat, that enables licensed operators to distribute 1080 baits from the air.

Compound 1080 is also registered and used for ship rat and rabbit (*Oryctolagus cuniculus*) control in New Zealand, and for fox (*Vulpes vulpes*), cat (*Felis catus*), wild dog (*Canis lupus familiaris*) and rabbit control in Australia. 1080 is absorbed through the gastrointestinal tract followed by conversion to fluorocitrate, leading to inhibition of the tricarboxylic acid cycle (Krebs cycle). Loss of energy and death follows usually within 6–18 hours for possums (Eason & Wickstrom 2001). Species vary widely in their sensitivity to 1080. Carnivores are the most sensitive group, and dogs are especially so, with an LD_{50} of 0.06 mg/kg bw (Chenoweth 1949). Herbivores (Atzert 1971; Robinson 1970; McIlroy 1983) and birds (McIlroy 1984) are less sensitive while reptiles and amphibians are less sensitive again (Atzert 1971). The LD_{50} for tree weta is 91 mg/kg bw (Ogilvie 1999), which is indicative of the low sensitivity of a wide range of terrestrial invertebrates to 1080 (e.g. spiders, amphipods, centipedes, cockroaches, beetles, slugs). Fish and other aquatic fauna (including invertebrates) generally have very low sensitivity to 1080 (Fagerstone et al. 1994). The New Zealand freshwater crayfish (*Paranephrops planifrons*) showed no ill effects after exposure to 1080 (Suren & Bonnett 2004), nor did native fish in freshwater streams after being treated with 1080 baits for possum control (Suren & Lambert 2004). Oral toxicities for a wide range of species are summarized in Green (2004). Twigg and Parker (2010) argued that other factors reduce the potential risk to non-target species and should be assessed as well as sensitivity to the specific toxin.

Micro-organisms found in most New Zealand soils can develop enzymes capable of degrading 1080 by defluorinating fluoroacetate within 1–2 weeks in mild weather (Eason 2002), as can common soil fungi (Walker 1994). Biodegradation of 1080 occurs even more rapidly in water, ranging from 1 day (at 23 °C in the presence of the native aquatic plant *Myriophyllum triphyllum*) to a few weeks by micro-organisms at temperatures below 7 °C (Parfitt et al. 1994; Ogilvie et al. 1995). However, since 1080 is water-soluble it is rapidly diluted in water, and hence in flowing waterways 1080 levels are quickly reduced to biologically insignificant levels without bio-degradation (Suren 2006a, b). Sub-lethal doses of 1080 are metabolized and excreted by mammals within 8–24 h (e.g. rabbits, possums, sheep, goats, mice) with few, if any, long-term effects (Mead et al 1979; Eason et al. 1994a; Gooneratne et al. 1994, 2008). 1080 is not detected in their tissues after about 7 days (Eason et al.1994b). Consequently, 1080 is not passed up the food chain, unlike the more persistent, anti-coagulant rodent poisons. 1080 degrades more slowly in carcasses, where it might persist for some

months at low temperatures, thus posing a threat to dogs.

ERMA reassessment of 1080

The Environmental Risk Management Authority (ERMA) was established under the Hazardous Substances and New Organisms (HSNO) Act 1996. The Authority makes decisions on applications to import, develop or field test new organisms, or to import or manufacture hazardous substances in New Zealand. ERMA also has a statutory role in reassessing substances for their ongoing registration and use.

In October 2006, the Animal Health Board and Department of Conservation jointly submitted an application to ERMA for reassessment of 1080. The Authority accepted the request for reassessment on the grounds that reassessment was justified by the large increase in the amount of 1080 being used and projections of increasing future use, the significant body of new research on 1080 and its environmental effects since the original registration, and the considerable public concern about the use of 1080.

The DOC and the AHB sought approval for continued use of 1080 to control possum, rabbit, stoat (*Mustela erminea*), rodents and wallaby (*Macropus eugenii eugenii*). They also sought to respond to public concern over the safety of 1080, particularly its use in aerial operations. Following a six-month assessment, public submissions and two weeks of public hearings, the Authority Chair, Neil Walter, called it the '. . . largest and most challenging exercise ever undertaken by ERMA New Zealand' (Environmental Risk Management Authority 2007a). The Authority's decision was to allow the continued use of 1080 under tighter mandatory controls, particularly for aerial use of 1080. The Authority's decision-making Committee 'found that the continued use of 1080 has significant benefits for New Zealand's environment. These benefits would not be fully realized if the use of 1080 were restricted to ground-based operations only' (Environmental Risk Management Authority 2007b, p. 18).

As part of the new management regime, the Authority attributed some of the concerns over aerial use to poor communication and consultation by the users of 1080. It proposed that improved public information programmes would help to reduce public concerns over aerial use of 1080. ERMA encouraged users of 1080 to establish a 'best-practice model' of communication and consultation. The best-practice approach should involve explaining risks to the public in such a way as to address all concerns, present material to the public simply and clearly and to answer the public's specific concerns (Environmental Risk Management Authority 2007b).

Since announcing its decision, ERMA has developed and released communication guidelines for aerial 1080 operations (Environmental Risk Management Authority 2009) and has released two annual reports covering aerial operations and research developments. The ERMA communication guidelines primarily covered communication methods, including consultation processes and communication plans, but also referred to providing leaflets and brochures 'specific to 1080 and pest control. Fact sheets provide the backbone for communication with interested parties and organisations' (Environmental Risk Management Authority 2009:12).

Public concerns over risks and agency messages

Within the last decade public opposition to the use of 1080 has risen. A national survey in November 2001 (UMR 2001) found that 52% of the general public supported 1080 use while 32% were opposed. A UMR Omnibus survey in 2007 asked the question 'Do you support or oppose the use of 1080 poison to control the impact of possums on native forests and birds, and to control the spread of tuberculosis?' Only 45% of respondents supported use and 43% opposed, with 12% undecided (Harry Broad, pers. comm. 2009). When asked this question in

April 2009, after the ERMA hearings, 43% supported its use, 43% opposed, and 14% were undecided (Harry Broad, pers. comm. 2009). Māori were much less supportive than non-Māori. Although the applicants had hoped that presenting new information on 1080 would reduce public concerns, the extensive ERMA re-assessment process had not done so. Public opinion on any given topic can be influenced by many factors, but ERMA had identified that users of 1080 were partly responsible due to poor communication and consultation practices.

This led to the research question of whether the information provided by pest management agencies about 1080 explains the risks 'in such a way as to address all concerns' and whether it also answers 'the public's *specific* concerns' (emphasis added) (Environmental Risk Management Authority 2007b). This question was explored through two lines of enquiry. First, the submissions made to ERMA that opposed the continued use of 1080 were analysed for expressions of risk by submitters. The premise was that submissions would accurately reflect the range of risk concerns and be broadly representative of the views of the members of the New Zealand public that are opposed to 1080. The second part of the study was an in-depth analysis of publications and information sheets produced by pest management agencies to assess whether, and how, the perceived risks were being addressed.

This paper does not respond to the perceived risks with evidence for or against their scientific validity or accuracy. The decision by ERMA covers that ground extensively with respect to all the risks and benefits identified in the submissions (Environmental Risk Management Authority 2007c). We focus on how pest management agencies have addressed public perceptions of risk in written material, since such perceptions are real, regardless of whether or not scientists think the perceptions are 'accurate' (Fitzgerald et al. 1996). Where we identify failings in agency material, we propose changes to messages and behaviour by pest management agencies so they might respond more effectively to public concerns. We also identify the impediments that may make such changes difficult to achieve.

Methods

ERMA provided a copy of all the public submissions it received for the 1080 reassessment process. We identified 525 submissions out of the total of 1406 (37.3%) as expressing opposition to 1080 re-registration. These submissions (hereafter referred to as 'the submissions') were the data set for this research and were analysed for the concerns and risks expressed and the frequency with which they were mentioned.

Submission analysis

Submissions varied from short statements opposing 1080 and poisons in general, to detailed submissions quoting agency reports and scientific papers. Submissions provided no personal information so the analysis could not explore submitters' profiles as had been possible in other studies. Earlier research into public beliefs and attitudes found attitudinal differences based on gender, age, location (rural vs. urban) and occupation towards pest control and use of poisons (Fitzgerald et al. 1996, 2007).

While discourse analysis has been used previously to reveal underlying ethnic, social and political perspectives of submitters for other New Zealand debates (racism and anti-racism (Kirkwood et al. 2005), homosexual law reform (McCreanor 1996) and national sports policy (Sam & Jackson 2006)) we aimed to quantify patterns in the submissions by searching for groups of concerns.

Draft categories and sub-categories for coding of perceived risks were identified from reading the first 50 submissions. These were modified and refined as new, less frequent, subcategories were subsequently identified. Five broad risk classes were defined by combining

theme-linked sub-categories and categories; poisons; environment; economic and social; human health; and anti-agency. Risk classes were sub-divided into a total of 13 categories and 35 sub-categories. Each submission was coded (present/absent) for one or more of these sub-categories; results were tabulated in an Excel spreadsheet. The results from this analysis (Table 1) provided the risk categories against which we evaluated whether the informative material from pest management agencies had addressed the main risks raised in the submissions. Sub-category descriptors were derived from comments in submissions. A mean of 4.7 sub-category concerns were scored from each submission.

We sorted submissions into four groups for further analysis based on the number of risks coded from each submission. The percentages with which different risk factors occurred within each of the four groups were plotted as bar charts to identify any emergent patterns. Although all 35 risk categories were initially included in this analysis, nine risk factors were coded infrequently and added little to the results. These nine factors had a score of 20% or less in Group 4 results (Fig. 1) and were omitted from the plotted data.

Hierarchical cluster analysis was applied to all 35 risk factors to identify groups among the risk factors. We adopted a divisive hierarchical clustering method given the binary nature of the data set to identify groups (Kaufman & Rousseeuw 2005).

Information from pest management agencies

The Animal Health Board, Department of Conservation, the 13 regional councils and the two unitary authorities (Marlborough and Tasman District Councils) were contacted and asked for the communications material they used to inform people about 1080. Their websites were also searched for any information on 1080, its use, risks and alternatives. Information on 1080 use was also obtained from the National Possum Control Agencies (NPCA). (The National Possum Control Agencies was established in the early 1990s to help coordinate possum control. It produces a number of publications intended for general use, including by pest management agencies. Most NPCA publications can be downloaded at no charge from www.npca.org.nz.) All material was analysed in the context of the categories and sub-categories of perceived risks identified from the submission analysis. Data take the form of a narrative to evaluate the extent to which the informational material addressed the perceived risks and are summarized in Results.

RESULTS

Analysis of submissions

The most common response (from 323, or 62% of the 525 submissions) was to express a general antipathy towards 1080 and poisons per se as tools for pest management (Table 1). Within this sub-category some submissions also made reference to concerns about health risks or environmental contamination, issues that were separately scored in other sub-categories. The 'poisons are unsafe' category also included comments which referred to New Zealand being the world's major user of 1080. New Zealand accounts for about 80% of global use of 1080, which is a consequence of two key factors—its effectiveness against possums and other major pests combined with the absence in New Zealand of vulnerable native land mammals found in other countries (Environmental Risk Management Authority 2007b). Other submissions considered it was inconsistent to use 1080 when other environmental poisons have been restricted or banned elsewhere, such as DDT. These two concerns together were mentioned in 27% of submissions.

> Sample submission: 'It took a long time for this country to realise the huge mistake it made with 245-T and in those days we didn't have ERMA.'

At the higher level of risk classes, however, the one mentioned most frequently was

Table 1 Perceptions of risk about 1080 use
The results are ordered from the highest scoring sub-category within a risk class to the least mentioned sub-category.

Risk class and category	Sub-category	Percentage in submissions
1. Risks of using poisons for pest control		
Poisons are unsafe	Non-specific concerns about use of poison including risks to people's health and contamination of forests and waterways	62
	NZ should follow other countries and ban or severely control 1080 use	15
	Use is inconsistent with banning other poisons, e.g. DDT, 245-T, Agent Orange	12
2. Risks to the environment		
Deaths of non-target animals	By-kill or secondary poisoning of only native species	47
	By-kill or secondary poisoning of wild animals including deer, pig and game birds	30
	Risks to hunting, farm or pet dogs	25
	Indiscriminate application/ indiscriminate kill	18
	By-kill or secondary poisoning of farmed or domestic animals (other than dogs)	14
	No known antidote (usually implied for dogs)	7
Ethical concerns	Causes inhumane death, or suffering due to sub-lethal doses	25
	All animal life is sacred, should be equally valued	2
Ecological	Oppose aerial use, but support ground use of 1080	18
	Impacts on aquatic life	3
	Changes to forest structure caused by wild animals may be beneficial (or not necessarily bad)	1
3. Economic and social risks		
New Zealand's international reputation	Inconsistent with clean, green image	23
	Impacts on exports from residues (in meat, milk, etc.) and from overseas consumer's concerns about animal welfare	19
Preferable alternatives	Alternatives (aside from a bounty) are available that are safer or more effective or cost less	23
	Reintroduction of bounty advocated to address the problem	8
	Better enforcement of Tb stock movement controls would address all or a majority of Tb outbreaks	4
Employment opportunities foregone	Loss of existing jobs and export opportunities (or future opportunities forgone) with aerial spraying (e.g. deer hunters, venison exporters, possum ground control contractors)	4
	Waste of fur and food resource	4
	Measures to develop possum fur, yarn and pelt industry would help address the problem	3
Threats to hunting	Adverse impacts on recreational hunting	17
4. Human health risks		
Direct threats	Eating poisoned animal products (meat, milk, honey)	15
	Drinking contaminated water	11

Table 1 (*Continued*)

Risk class and category	Sub-category	Percentage in submissions
	Inadvertent skin contact with 1080 or with poisoned pests or domestic animals	3
5. Anti-agency		
Research	Research and monitoring insufficient, poor quality, ignored or not impartial	10
	No significant gains after 40+ years using 1080. It is not as effective as claimed	5
	Damage to forests by wild animals or threat posed by Tb is overstated or not proven	4
Vested interests	Government departments have vested interest in promoting or approving use	10
Operations	Poor process (inadequate consultation, lack of transparency, etc.)	8
	Non-compliance with consents (or manufacturer's instructions) or current consent conditions are inadequate	8
	Operational mistakes or poor operational planning	7
	Risk of terrorists or environmental activists getting access to 1080	4
6. Māori cultural values	Impacts on Māori values	4

Note: Percentages do not add to 100% because a mean of 4.7 concerns was identified from each submission.

'environment', followed by 'economic and social'. Within 'environment' the dominant issue was people's concerns about by-kill or secondary poisoning, most particularly of native species (47%). This was followed by concerns over by-kill of wild animals (introduced species such as deer, pigs, game birds) (30%) and risks to dogs (25%). Risks to animals or by-kill were scored 741 times in the 525 submissions.

> Sample submission: 'How regularly are native species exposed to sub-lethal doses of 1080 poison? If a rat lying on the ground from 1080 is seen by a native falcon and eaten is that falcon exposed to a sub-lethal dose of 1080? Falcon numbers are declining! Or native fish, moreporks, snails, kakapo, skinks, geckos and weta – is this affecting them?'

The 'indiscriminate' nature of aerial distribution of 1080 baits with consequential risk of 'indiscriminate kills' was specifically mentioned in 18% of submissions. The same percentage opposed aerial distribution, but supported the ground use of 1080 (via use in bait stations and other formulations).

Ethical concerns that a lethal dose of 1080 is inhumane due to alleged suffering prior to death, or that sub-lethal doses adversely affect animals, were mentioned in 25% of submissions. These submissions also said that animal welfare issues are relevant to pests, despite the environmental damage they may cause.

> Sample submission: 'The cruelty of 1080 poison is well known . . . It is barbaric in the extreme to continue such behaviour. Even pests don't deserve such treatment.'

Two concerns dominated the 'economic and social' risk class—perceived impacts on New Zealand's reputation and arguments in favour of preferred alternatives to 1080. New Zealand's image was considered threatened either through a tarnishing of the country's 'clean green' image or through supposed impacts on exports (via residues in animal products or

concerns about animal welfare). These concerns were expressed by 23% and 19% of submissions respectively.

> Sample submission: '1080 in NZ's export food chain is a bigger risk to NZ meat and food exports that Tb.'

Many submitters wanted alternatives to 1080 (23%), with some preferring the re-introduction of a bounty system (8%) for possum control. Many said ground control could be used more frequently, that there was less justification for aerial use of 1080. A few submissions (3%) proposed using possum as a resource (fur, food, or pelts) to help reduce possums.

> Sample submission: 'The cost of using people to control pests may be slightly higher but has lots of other benefits. Look at the opportunities to reduce the unemployment numbers and also create meaningful work for our troubled youth . . . '

Adverse impacts on recreational hunting were scored for 17% of the submissions. Common complaints concerned the stand-down times from hunting in areas after aerial 1080 operations, increased travel times to hunting areas, distrust between hunting groups and pest management organizations, and insufficient use of deer repellent on baits (which reduces deer mortality).

> Sample submission: 'An area I hunted for many years is now no longer worth hunting as animals are few and far between, birdlife is non-existent and areas I traveled are overgrown and difficult to transit.'

The most common criticisms of pest management agencies were that the research and monitoring were insufficient to justify the safety and use of 1080, monitoring of water quality was not independent of agencies, and pest agencies have a vested interest in using 1080. While this indicated a lack of trust in agencies, criticisms under the heading 'operations' were scored 23% of the time and may or may not have reflected on poor operational process in specific instances. Inadequate consultation prior to 1080 use (8%) often cited a 'big brother knows best' attitude.

> Sample submission: 'The powers using 1080 when facing the public are so pumped up with the necessary information to achieve what they want, they are not taking in, or the least bit interested in the points being raised.'

The least mentioned category of concerns was human health, although some of the general 'anti-poison' comments were concerned about health risks. Given the general publicity over protecting water supplies and concerns by some people about 1080 impacts on water supplies, it was perhaps surprising that concerns about eating potentially poisoned animal products, such as meat, scored more frequently (15%) than concerns over drinking potentially contaminated water (11%).

Groupings between risk categories

There was a changing pattern of concerns depending on the number of risks identified in the submissions (Fig. 1). For this analysis we defined four groups based on the number of risks identified in the submission (Table 2). When few risks were expressed (Group 1) only two stood out—general concern about poisons and concern at the risk of by-kill of native species. In Group 2 general concern over poisons and by-kill of natives still dominated and the new risks that emerged (mentioned by about 30%) were: by-kill of wild species (introduced wild game animals, excluding native spp.); ground use of 1080 is acceptable but not aerial; 1080 is inhumane; and 1080 use affects New Zealand's international image.

In Group 3 the dominant risks mentioned by over 50% of submissions were, in priority order: poisons in general, by-kill of natives, then by-kill of wild species. Risks to image and risks to dogs were coded from 40% of submissions. Over 30% of submissions in this group identified: 1080 is inhumane; exports are

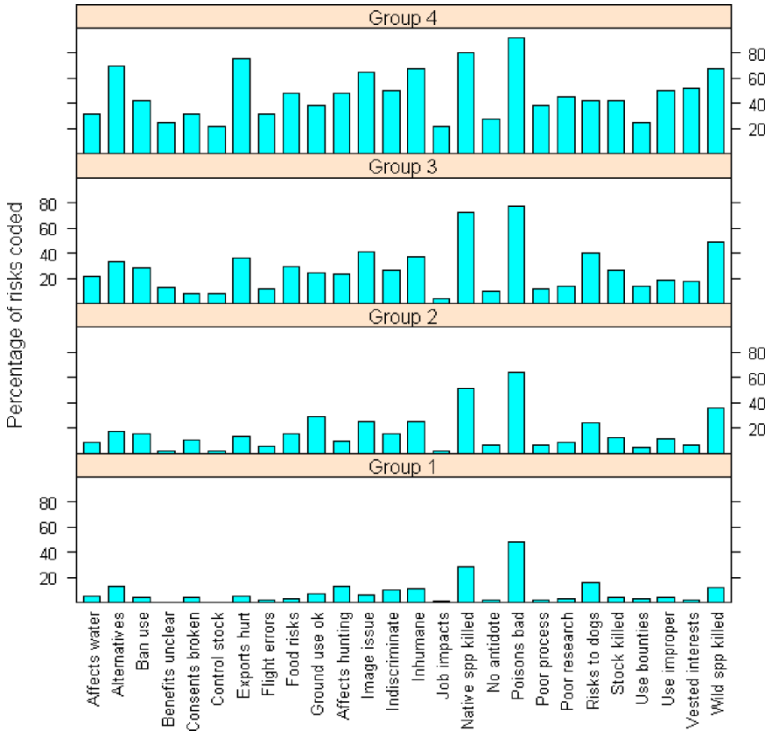

Figure 1 Percentage of perceived risks identified by submitters grouped by the number of risks scored from submissions. Key: Groups are defined in Table 2. Twenty-six risk factors that scored over 20% in Group 4 were plotted for each group.

affected; alternatives are preferable. Concerns over poisons and by-kill of native species occurred in over 80% of Group 4 submissions and still dominated the risk factors. 'Exports are affected' and 'alternatives' both occurred in over 70% of Group 4 submissions. '1080 is inhumane', 'by-kill of wild species' and 'risks to image' were all mentioned in over 65% in this group. Three risks that were scored from around 50% were '1080 promoted by vested interests', '1080 is used improperly' and 'effects are indiscriminate'. The first two of these risks were part of the 'anti-agency' risk class (Table 1). The risk that ranked third in Groups 2 and 3, namely by-kill of wild species, dropped to fifth-ranked risk in Group 4 behind 'exports are affected' and 'alternatives are better', but the percentage of this risk identified in Group 4 is much higher than rest of the groups. The concern that '1080 affects hunting' did not emerge as a risk until Group 3 (25%) and Group 4 (47%).

Overall, the pattern was of consistently top rankings in all four groups for two risks: 'poisons are bad' and 'by-kill of native species'. Groups 1 and 2 made up 70% of all submissions. Hence the four most frequently scored risks for most submitters, in addition to the two just men-

Table 2 Allocation of submissions to groups based on number of risks identified in each submission

Group	Number of risks identified	Number of submissions
1	1–3	245 (47%)
2	4–5	122 (23%)
3	6–10	118 (22%)
4	11 +	40 (8%)

tioned, were 'by-kill of wild species' and 'ground use of 1080 is acceptable but not aerial'. The hierarchical cluster analysis for all 35 identified risks showed groupings that were dominated by a few of the perceived risks (Fig. 2). We chose to classify the first five clusters to focus on the major patterns that emerged. The largest cluster was defined by the single perceived risk that poisons are bad and accounted for 62% of submissions. The risks of by-kill of native species and risks of by-kill of wild species were closely clustered (54%). Risks to dogs and inhumaneness of 1080 were also closely clustered (39%) while 'alternatives are better' constituted the fourth cluster (23%) by itself, indicating a particular group of submissions. The remaining 29 risks fell into the large fifth cluster and covered a wide range of risks. The results of the cluster analysis were consistent with the groupings we made of the sub-categories into larger categories and risk classes (Table 1). Four of the six risks identified in the first four clusters (by-kill of native spp., by-kill of wild spp., risks to dogs, 1080 is inhumane) were all in the same

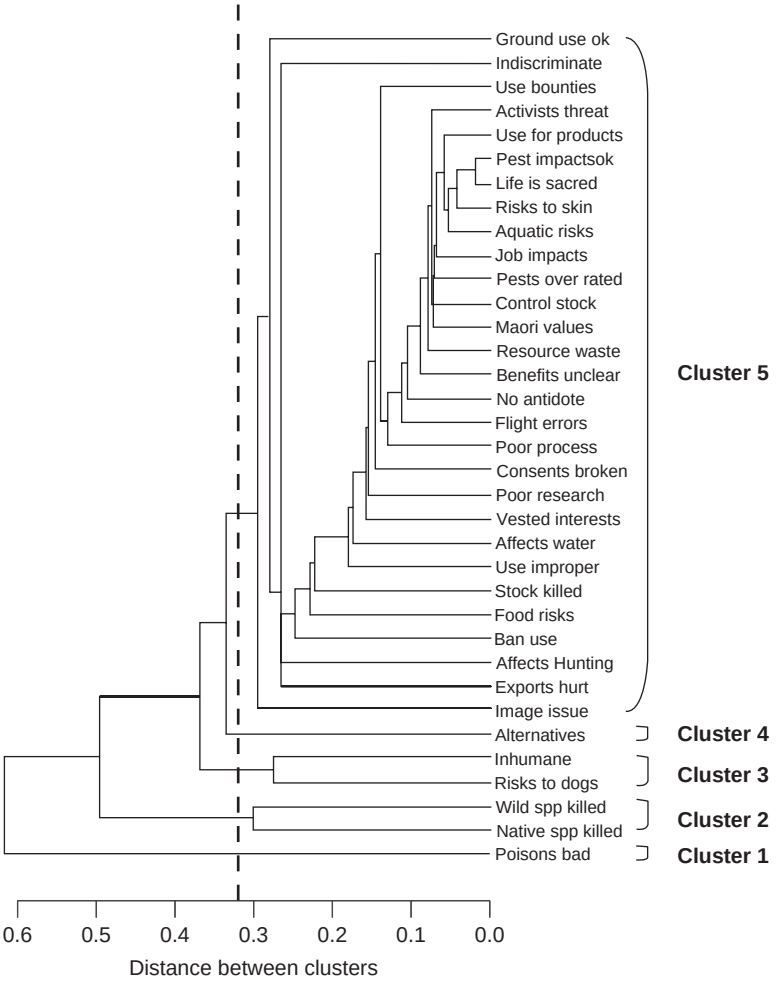

Figure 2 Hierarchical cluster analysis based on 35 risk factors identified from submissions opposing 1080 re-registration. The dashed line identifies the five major clusters.

'Risks to the environment' risk class. The other main risk, 'alternatives are better', was classified in the 'Economic and social risks' risk class. Amongst the large fifth cluster the adjacent clustering of 'indiscriminate' and 'ground use of 1080 is ok' should be noted. This showed a strong linkage between these two risks in submissions and reflected a discrimination by some submitters that accepts ground, but not aerial use of 1080 since the latter is seen as threatening by being 'indiscriminate'.

Comparison between perceived risks and agency responses

The extent to which material from pest management agencies, the National Possum Control Agencies and regional councils specifically addressed the perceived risks identified by submitters is summarized below. Risks mentioned in more than 10% of submissions are assessed, starting with the most commonly expressed risk. These results are qualitatively assessed in Table 3. There was considerable reliance on short (1–2 page) descriptors of most topics by agencies and councils although longer, more detailed publications have been produced and distributed, e.g. Green (2003, 2004), Department of Conservation (2004, 2009b), National Possum Control Agencies (2008). As a general comment, coverage by councils was extremely uneven and did not necessarily reflect the extent of aerial 1080 use within the region.

By-kill of native and introduced game species

This issue dominated submissions (77%) and therefore is arguably the most important one requiring a clear response from agencies. Yet although the AHB funds the majority of aerial 1080 operations its written material made very little reference to by-kill risks for native or introduced game species. Protecting biodiversity values is not within the stated mission of the AHB and much of their material was predictably focused on the role of 1080 in reducing Tb rates. However, given the high use of aerial 1080 by the AHB, addressing the concerns relating to 1080 by-kill is relevant to its communications approach.

The DOC covered by-kill in a variety of ways but could make more effective use of the research results and operational material at its disposal. Submissions often indicated a poor understanding of ecological processes, particularly food chain risks, but the reasons for the absence of food chain effects from 1080 were rarely explained specifically. Likewise, the major benefits for birds of direct poisoning of rodents and related by-kill of mustelids were mostly hinted at rather than directly stated. These topics were more thoroughly explained in comprehensive publications (Department of Conservation 2004), but not in the more widely available material.

By-kill information was only briefly summarized in the National Possum Control Agencies material including impacts on aquatic and invertebrate species. Coverage by regional councils was very uneven, ranging from none to good detail as well as providing links to other sites. Some councils actively used material produced by DOC or AHB in mailouts to inform people on by-kill risks. Risks to introduced game species and use of deer repellent baits were not widely covered.

Use of preferred alternatives

The argument that alternatives to 1080 should be used was addressed by AHB, DOC and the NPCA information, but not by regional councils. Since choice of method is a key issue of contention, information putting 1080 use into a wider context of 'How we manage possums' rather than 'Why we use 1080' would provide a more balanced perspective. The DOC website had an informative article on the bounty option (Department of Conservation 2010a). The related economic risk of losing potential employment opportunities by not exploiting possum fur and meat markets was also stressed. Agencies had adjusted local control

Table 3 Ranking of the effectiveness of agency responses to the major perceived risks
The percentage column is derived from the percentages in Table 1. Some sub-categories were not combined where the difference between topics justified separation. Discrete sub-category topics with small percentage values (less than 10%) were omitted where lumping was not appropriate. Key to rankings: 0 = no relevant material sighted; 1 = not well addressed; 2 = risk is addressed; 3 = risk is well described.

		Agency responses			
Perceived risk	%	Animal Health Board	Dept. of Conservation	National Possum Control Agencies	Regional Councils
By-kill or secondary poisoning – native and game animals	77	1	3	2	0–3
Preferable alternatives exist, including bounty system	31	3	3	3	0–1
Risks to hunting, farm or pet dogs	25	2	2	3	0–3
Inhumane suffering, including sub-lethal effects	25	1	0	0	0
Operational shortcomings by agencies	23	2	2	2	0
Inconsistent with clean green image of NZ	23	0	0	0	0
Potential impact on NZ exports	19	0	0	0	0
Criticisms of research justifying 1080 use	19	0	0	0	0
Aerial 1080 use means kills are indiscriminate	18	1	1	1	0–1
Just oppose aerial use, not ground use	18	2	2	2	0
Adverse impacts on recreational hunting	17	0	0	2	0
Eating poisoned animal products	15	0	0	0	0
Risks to farmed or domestic animals (excl. dogs)	14	3	2	2	0–2
Drinking contaminated water	11	3	3	3	0–2
Employment opportunities foregone	11	0	0	0	0
Agencies have vested interest in 1080 use	10	1	0	0	0

programmes to create local work opportunities, but these were not described. Only the AHB material commented that the fur industry can help reduce possum numbers in some places.

Risk to dogs and inhumaneness

Concerns over risks to dogs and alleged inhumaneness of 1080 occurred with equal frequency in submissions (25%), but were covered unequally in the agencies' material. Only the risk to dogs was covered well; agencies and most regional councils provided good technical information on how to minimize this risk and respond to accidental poisoning. In contrast, the ethical issue of humaneness and animal welfare aspects of 1080 were essentially ignored although there is relevant material in the literature (refer to Discussion).

Operational shortcomings and risks to 'clean green' image

The three major agencies all noted that stringent operational requirements need to be met. While these are explained, some additional details around controls would help to address specific concerns. This could include contrasting earlier and current practices, improved technologies and the emphasis on continual operational improvements.

While 23% asserted that using 1080 threatens New Zealand's 'clean and green' image, 19% of submissions cited a potential impact on food exports if they were found to have traces of 1080. These risks were not addressed and the conservative precautions imposed by the Food Safety Authority would make the latter a highly unlikely event. The AHB material noted that exports could be negatively affected if the incidence of Tb were to increase significantly. A related concern, also not addressed in any material, was the risk of eating animal products that had 1080 traces in them. Agencies all advised that 1080 does not bio-accumulate and is excreted within a week from living animals.

Criticisms of 1080-related research

The criticisms of the research into effects following 1080 use were not directly addressed by the two agencies that fund research, the AHB and DOC. Both agencies are well placed to report on research aimed at improving operational practice, monitoring of pest impacts and outcomes for Tb reduction and for biodiversity. The AHB published 'advertorial' material in West Coast newspapers in 2009 including several informative stories on the benefits from research for Tb testing procedures and improving pest control methods. The AHB publishes comprehensive annual reports detailing its research programmes (e.g. Animal Health Board 2009). It refers to research in regional newsletters for farming readers, but rarely in material that targets the general public.

Animal deaths are indiscriminate

Submissions referring to aerial 1080 baits as 'indiscriminate' raised two different concerns: toxic pellets allegedly dropped indiscriminately along operational boundaries, and that aerial use puts other species at risk of being killed indiscriminately. Information on the use of global positioning systems to accurately guide pilots was only in material from the AHB and DOC. The second issue was only addressed in the NPCA publication (National Possum Control Agencies 2008) in a section that noted the very different sensitivities of species to 1080, but not by the pest control agencies. This was surprising, as the concern over indiscriminate deaths is directly linked to by-kill risks. The different sensitivities and susceptibilities of species to 1080 are extensively covered in scientific literature (Chenoweth 1949; Robinson 1970; Atzert 1971; McIlroy 1981, 1983, 1984; Eason & Frampton 1991; Fagerstone et al.1994) while the link between sensitivity and target specificity was considered by Twigg and Parker (2010).

Distinguishing between aerial and ground applications

Another 18% of submissions opposed aerial application, but accepted ground-laid products that incorporate 1080. The AHB, DOC and NPCA material made reference to the fact that the majority of areas being controlled are treated from the ground. More frequent and quantitative reference to the areas under ground control (use of maps) should reduce the inaccurate perception that aerial distribution of 1080 baits predominates. Regional councils did not address this concern.

Risks to recreational hunting

Several species of deer have been successfully liberated in New Zealand (King 1990), and while most species, especially red deer (*Cervus elaphus*), have had markedly negative impacts on indigenous habitats, they are also valued for the hunting opportunities they provide (Nugent & Fraser 1993). Deer can be killed in aerial 1080 operations. This is a contentious issue for some hunters and may well fuel their opposition to 1080, but was only acknowledged in the NPCA material in a brief paragraph. The DOC has used deer-repellent poisoned baits in some aerial 1080 operations within recreational hunting areas, but only briefly mentioned this on its website (Department of Conservation 2010b).

Drinking contaminated water

Although it was not widely mentioned in the submissions, potential risks to drinking water have long featured in public discussions about 1080 and are a concern for Māori (Ogilvie et al. 2010). This risk was well covered by all of the agencies and by several regional councils. Details were given of the dilution and breakdown rates as well as results of tests on water samples.

Risks to farmed or domestic animals (not dogs)

In addition to risks to dogs, accidental poisoning of other farm or domestic animals was a perceived risk identified in submissions. These risks were adequately covered in AHB material and did receive brief mention by other agencies and councils, primarily in reference to farm stock and the need to take precautions.

Agencies have vested interests in 1080 use

Ten per cent of submissions argued that agencies had a vested interest in using 1080, reflecting a distrust that is not likely to be resolved through written material. A point stressed by agencies is that 1080 is very cost-effective, especially in remote and difficult country. However, cost of control is not the motivator or key consideration for the public that it is for control agencies (Fitzgerald 2009). Hence repeatedly stressing that 1080 is the cheapest option does not necessarily have much impact in discussions with opponents of 1080. Highlighting other critical reasons for using 1080 is likely to be more effective.

Discussion

Main risks concerning 1080

The perceived risks raised in submissions opposing the continued use of 1080 in New Zealand covered a wide range of issues. The categories in the five broad risk classes were developed solely from the submissions, but closely matched the categories used by ERMA for its re-assessment, namely: environment; society and communities; market economy; human health and safety; Māori relationships to the environment (Environmental Risk Management Authority 2007c).

Despite the long list of perceived risks (Table 1) two stood out: a non-specific, negative reaction to the use of poisons for pest control and concerns over environmental risks. The perceived risks to non-target native animals dominated environmental risks along with by-kill of wild animals (introduced deer, pigs and game birds). The cluster analysis showed that these two concerns were closely linked (Fig. 2) and reflected a strong national attachment to the uniqueness and wellbeing of New Zealand's biota (Young 2004). Cluster analysis also showed that risks to dogs and an ethical concern that death from 1080 is inhumane, or that animals may suffer after consuming a sub-lethal dose, were closely linked, as reflecting issues of moral values. Negative comments about government agencies, particularly allegations that agencies included 'vested interests in wanting to use 1080' (10%) indicated a lack of trust in institutions. This sub-set of submitters is less likely to accept information that agencies may provide, regardless of its scientific accuracy.

Framing of agencies' responses

We found that the extent to which the pest management agencies addressed the major perceived risks in their written material was patchy (Table 3). The risks that were most effectively addressed in written material and website information related to scientific and technical issues. In contrast, ethical concerns, criticisms of agencies (research quality and motivations) and risks of possible impacts on the country's overseas image were mostly ignored. This particular mismatch was not surprising. Threats or risks are strongly influenced by framing, or the 'lens' through which they are viewed, and an extensive body of research has studied perceptions of environmental threats (Clayton & Myers 2009). As management agencies with a high degree of technical expertise, the AHB and DOC viewed 1080 risks through a lens of reducing bovine Tb and protecting biodiversity. This was consistent with the poor coverage of wildlife risks in AHB material (perceived as a biodiversity concern and therefore a DOC 'issue') even though the AHB covered a larger area each year via aerial operations than the DOC.

The technical focus of agencies may explain why they did not engage with the ethical or value judgement considerations. Omission of information on inhumaneness does not reflect an absence of research on the admittedly difficult topic of assessing whether specific toxins cause animals pain. Whether 1080 causes pain prior to death has been considered (Department of Agriculture 2002). O'Connor et al. (2003) assessed the relative humaneness of poisons used in New Zealand. Aspects of humaneness of poisons were described in a technical publication (Eason & Wickstrom 2001) and from an ethical and animal welfare perspective by Littin et al. (2004). Sherley (2007) reviewed the 1080 literature with respect to its humaneness. Research is ongoing in Australia to improve the welfare outcomes in fox control with the use of 1080 baits (Marks et al. 2009). Twigg and Parker (2010) critically reviewed the research concerning the humaneness of 1080 and argued that assessing humaneness '... must be commensurate with its mode of action, metabolism, target specificity, and operational use.' They concluded that use of 1080 is ethical when used appropriately, especially given the detrimental impacts of pest species.

There is also information available that could be used to answer the other perceived risks listed in Table 3 such as possible impacts on exports (19%) and risks from eating potentially poisoned animal products (15%). Since 1080 is not cumulative (Rammell 1993), sublethal doses are metabolized and excreted within 1–4 days (Eason 2002), and the Food Safety Authority sets very conservative times before animal products can be taken after 1080 operations, these concerns would appear unfounded. However, they were not comprehensively addressed in the information materials.

Information silos

Even allowing for the different framing that agencies bring to their respective rationales for using 1080, there was wide variability in the quality and quantity of information provided, particularly by regional councils. Information was 'siloed' within agencies rather than commonly shared. This was in spite of the interconnected nature of the pest control industry in New Zealand and the coordination functions of the National Possum Control Agencies. The extent to which NPCA material was used by councils and agencies was difficult to determine accurately. If web site references were indicative, however, then the answer was 'inconsistently'. The information provided on 1080 by council websites was only partially linked to their degree of involvement in aerial 1080 operations. For example, Greater Wellington and Environment Waikato have a history of extensive aerial 1080 operations and their websites (www.gw.govt.nz, www.ew.govt.nz) provide relatively more information about 1080 than other councils. By contrast, despite

a long history of frequent 1080 operations since the 1970s, the West Coast Regional Council (www.wcrc.govt.nz) has nothing on its website about 1080, or on the impacts of possum and other pests on forests and wildlife. Whether that absence of information contributed to the view held by 44% of West Coasters (survey done by the AHB in 2009) that 1080 is more dangerous to the environment than possums is an interesting research question. The same survey found that 19% of residents thought that the use of 1080 was the main environmental problem facing the West Coast.

However, council websites were not the only source of information regarding 1080 provided at a regional level by councils. Some council staff distributed publications produced by the AHB, NPCA and DOC, although it was difficult to gather accurate information on which of these publications were actively used. Few councils provided electronic links to other agencies, publications or references with more detailed information on 1080. The most detailed technical report on 1080 intended for a public audience (Eason 2002) was rarely referenced. The work of regional councils with local community groups and their support of biodiversity and biosecurity forums where pest management are discussed needs to be acknowledged. However, these initiatives do not have a focus on the larger lay public within the regions.

Notification of aerial pest control operations provided additional opportunities to inform people of 1080 issues and risks. Some councils relied on the pest control contractors to distribute their own information prior to control operations. The AHB and DOC, as well as councils, may directly address concerns about specific operations by consulting local communities over options for pest control. Good outcomes have been achieved, especially when a level of trust has been established over a period of years, which makes it easier to discuss and resolve differences that may emerge (e.g. Hawkes Bay Regional Council, Owen Harris, pers. comm. 2009).

Māori views on 1080

Aerial application of 1080 is controversial for many Māori, despite the small number of submissions (4%) that directly referred to negative impacts on Māori cultural values. Māori prefer other methods of communicating views and discussing issues that are more culturally appropriate (Tawhai 2010). As with the wider New Zealand public, there is a continuum within Maoridom ranging from support to strong opposition against 1080. An analysis of the 28 submissions to ERMA from individuals or groups identifying as Māori was undertaken by Ogilvie et al. (2010). These included submissions in favour of, as well as opposed to, 1080 use, and therefore percentages would be expected to differ from those in Table 1. The major issue for Māori submitters (57%) was 'a need for clear communication, consultation, or collaboration with iwi in areas where 1080 is used'. Three issues were all scored by a third of these submissions: continued research into 1080 effects on the environment, especially of taonga (treasured) species for Māori; general opposition to the use of poisons in the environment; ongoing research into suitable alternatives to 1080. There was also a desire for iwi to be involved in planning and implementing pest management plans (25%), concern over by-kill (21%), impacts on waterways (14%) and impacts on customary practices (14%).

Ogilvie et al. (2010) noted that although there was a call for more engagement with Māori there are examples of initiatives that have successfully addressed Māori concerns. In one case the pest control operator, regional council and Māori forestry trusts developed a working partnership which led to protocols for meaningful and timely consultation, changes to pest control activities and engagement in monitoring after 1080 operations. Horn and Kilvington (2002) reviewed communication processes that had been used where local iwi agreed to the use of 1080. They concluded that in these cases consultation had involved

empowering Māori communities and the negotiation of a mutually agreed course of action 'rather than working to persuade them to allow a predetermined course of action'. In its decision the ERMA Committee encouraged agencies to review the options for stronger Māori involvement in the development and decision making for pest and conservation management strategies (Environmental Risk Management Authority 2007b).

Possums, poisons and perceptions of risk

Notably, two risks did *not* appear in Table 1; that control of possums to reduce bovine Tb was not needed, or that extensive control of pest species was not justified. Submitters opposing 1080 did not challenge AHB's argument that vector control is a critical factor in reducing the incidence of bovine Tb. The policy decision to almost terminate expenditure for Tb vector control for a decade (1978–1988) provides compelling evidence that without vector control Tb levels rise inexorably (Green 2003) while annual AHB reports have demonstrated the ongoing success of its Tb reduction strategy (Animal Health Board Annual Report 2008). Also, there is little public debate over whether the possum is a pest in New Zealand that warrants control. Fraser (2001) found high public support for controlling possums: 72% favoured extermination, 21% control at low numbers and 6% wanted management of possums as a resource. This public view of the seriousness of the possum problem in New Zealand has remained fairly stable over the 1990–2005 period of interview studies (Fitzgerald et al. 2007). National surveys of public perceptions of the environment have also found that pests and weeds are the most highly ranked cause of damage to native plants and animals, native forests, national parks and wetlands (Hughey et al. 2008).

The findings of Fraser (2001) and from Fitzgerald's surveys (Fitzgerald et al. 2007) suggest that control agencies in New Zealand do not need to convince the public that possums are harmful pests needing control, although much of their public literature focuses on that point. New Zealanders also hold negative attitudes towards stoats and appreciate that their predatory habits are a major threat to New Zealand birds (Fitzgerald et al. 2005). But a warning is in order. A report by the Parliamentary Commissioner for the Environment (PCE 2000) found that, while people thought protecting biodiversity is the main reason for possum control, they were less certain about the extent and severity of the problems caused by possums. That report warned that an informed debate on future control options for possums would first require an ongoing recognition of, and consensus on, the risks caused by possums. Fitzgerald and his colleagues (Fitzgerald et al. 1996, 2000) also found that although participants in a study group thought that the possum had negative impacts on the environment, they were generally unaware of the scale and nature of the problem: 'the public seems more able to articulate the issues and risks associated with various forms of control than those associated with insufficient control. The ethical trade-off, in particular, is one experienced by few members of the public, and at present they lack information on possum impacts with which to make the trade-off' (Fitzgerald et al. 2000:195). In short, people identify more strongly with the risks of using toxins than with the ecological consequences of not controlling pests. The strongly negative reaction to 1080 by residents in the West Coast (above under 'Information silos') compared with damage by possums is consistent with this response. It is in this context that Innes and Barker (1999) argued the need to communicate the net outcomes of using toxins rather than specific aspects, such as non-target effects. They concluded: '[Communicating net outcomes] will demonstrate to the public that the inevitable ecological risks associated with disciplined use of toxins are much smaller that the equally inevitable risks to natural ecosystems due to the introduced pest mammals which toxins target.'

While this is a sensible response using an ecological framing of the problem, it overlooks deeper social values that are more influential in shaping perceptions of risk. It also overlooks the challenge of translating an ecologist's understanding of complex ecological processes and ecosystem responses to 1080 into plain English and the possible implications of who the messenger is. Billington and Bibby (1991) quoted in Fraser (2006) found that New Zealanders generally have a negative attitude towards science. Hipkins et al. (2002) also found that New Zealanders are not inclined to take scientific claims on trust and are aware of past dishonesties in international science, such as the health effects of smoking. An important finding relevant to the 1080 debate was: 'Openness about uncertainty is seen as evidence of honesty on the part of scientists. Open acknowledgement of areas of uncertainty and new questions are preferable to bland assurances of safety or predictability.' Admission of uncertainties (and past mistakes) is not something that sits comfortably with the culture of most public or private organizations, despite the benefits that might accrue in building relationships and reducing distrust.

There is, however, a deeper and more important social response to poisons influencing the relationship between agencies and the public on the 1080 issue. Studies in the United States (Neil et al. 1994) and replicated in Canada (Slovic et al. 1995) explored the views of the public as 'intuitive toxicologists' and the views of experts (toxicologists) towards the dangers inherent in exposure to chemical products. Their concept of 'intuitive toxicologists' refers to the evolutionary necessity to rely on basic senses of sight, taste and smell to decide what's healthy or dangerous about potential food items. This research concluded (Neil et al. 1994) that as 'intuitive toxicologists' the public (a) have strong negative attitudes towards chemicals and their risks; (b) tend to view chemicals as either safe or dangerous; (c) 'Appear to equate even small exposures to toxic or carcinogenic chemicals with almost certain harm'. The 'either safe or dangerous' dichotomy meant that the public were much less discriminating than toxicologists over issues of dose and exposure. They also found that men and more highly educated people 'were somewhat less concerned about chemical risks'. New Zealand polling of the public on attitudes to 1080 has given similar results. A UMR Omnibus survey (April 2009) showed males were more supportive than females, support for 1080 use rose with personal income (those earning $50k or more) and fell for those earning less than $25k (H Broad, pers. comm. 2009).

This research provides part of the answer as to why some people view 1080 so negatively as a pest control tool, despite a widespread agreement that pest control is justified in New Zealand. It is consistent with the finding in Fitzgerald's review (2009) of Australasian and some international research that 'poisoning is one of the least publicly acceptable forms of pest control' and 'Even theoretical ''humane poisons'' do not rate particularly highly'. Fraser's review (2006) of the New Zealand literature had come to the same conclusion, stating that poisons 'fail to satisfy any of the three key criteria that influence acceptability', that is, they are not regarded as humane, specific and safe. Fitzgerald (2009) concluded that his research surveys between 1994 and 2005 had shown decreasing acceptance of poisons as control tools in western societies, with females consistently less accepting of poisons than males. This last point matches the gender difference noted by Neil et al. (1994) in North America. None of the information from pest control agencies specifically addresses this widely reported gender difference in attitudes towards poisons or to 1080 in particular.

Risk = hazard + outrage

Understanding the rationale behind the widespread antipathy towards the use of poisons is helpful. However, it does not explain the opprobrium towards aerial distribution of 1080 while less humane and more environmentally

persistent poisons, such as brodifacoum (Eason & Wickstrom 2001), are used without arousing similar levels of public concern. That difference is explicable in terms of risk perception research, itself an outcome of risk communication research. Since the 1980s, the science of risk communication has developed in response to a range of environmental issues to confront the dilemma that 'The risks that kill people and the risks that alarm them are often completely different' (Covello & Sandman 2001). Risk communicators identified the need to overcome obstacles of incompleteness and complexity of scientific data, distrust of information sources, selective media reporting, plus social and psychological factors affecting how information is processed. This last obstacle, the social and psychological factors, is particularly important in the 1080 context although we have also noted the complexity of the science data and distrust of information sources. Covello and Sandman (2001) identified seven factors that influence how people process information and risk, a very important one being how people assess the actual magnitude of the risk. They identified so-called 'outrage factors' and the formula: risk = hazard + outrage. 'Hazard' is defined as the product of the magnitude of the risk times its probability, while 'outrage' is a list of factors that have a direct bearing on how the public assesses risk.

It is simplistic and unhelpful to characterize and dismiss outrage factors as just 'emotional', which is implied in the unfortunately pejorative tone of the term. Outrage factors include wider social issues of power sharing, voluntary choice, alternatives, ethics, value choices, trust and fairness. Cvetkovich and Earle (1992) noted that there is a subtext to risk discussions that involves power, social control and values. Covello and Sandman (2001) pointed out that the longer-term value of the risk = hazard + outrage model has been in the recognition that risk should be treated as multidimensional. It is not simply the mathematical component of magnitude times probability which is the technical understanding of 'risk'. Therefore only providing more information covering the hazard components of 1080 (e.g. incidence of Tb, threat to exports, risk to wildlife) will not address the social component of 'risk'.

Good technical knowledge is necessary and informative, however, particularly to address the obstacle of incomplete and complex scientific data. In this context the dominant concern over by-kill of native and introduced wild species (Table 1, Figs. 1, 2) warrants a stronger response from agencies. The AHB should communicate by-kill risks for native and wild species more than it has done previously. Further research on non-target mortality is needed to better quantify risks and benefits as well as long-term monitoring of forest bird populations as advocated by Veltman and Westbrooke (2011). New research findings need to feed into communications material that is responsive to specific concerns. In addition, providing a local context for threats to conservation values and identifying risks associated with specific 1080 operations has more relevance than general information. People generally have a stronger affinity with local issues. The DOC provided specific information for an aerial 1080 operation in Taranaki that responded to public concerns and followed up with a post-poisoning report on specific gains for local wildlife (Department of Conservation 2010c).

However, better technical information alone is not sufficient as a response to public controversies. The view that controversies can be avoided, or resolved, by more effective communication of technical information is common among technical experts, but improving technical knowledge does not necessarily lead to more support for controversial technologies (Sandman & Miller 1993). The relevance of outrage factors to concerns over aerial 1080 is explored in Table 4. While there are different formulations, the outrage factors usually cited in literature are listed in Table 4, derived from Chess et al. (1989) as listed by Fitzgerald et al. (1996) with reference to

Table 4 Outrage factors and response options
Outrage factors are sourced from Fitzgerald et al. (1996); middle column comments are summarized from submissions with elaboration by the authors; the 'options' column is based on risk communications and dialogue literature.

Outrage factor	Relevance to 1080 concerns	Options for responding to the outrage factor
Exposure to the risk is involuntary rather than voluntary	Aerial spraying is perceived as a dominating control tool, available to few people compared to ground control	Communities are more effectively involved in planning. Management decisions are shared rather than imposed
Risk is controlled by an external body, not by individuals or community	Perception is that agencies determine and impose the 'rules' for aerial 1080 operations. Outcome is a sense of loss of social control	Partnerships with communities over pest management—control of risk is not one-way. The range of values is acknowledged and two-way learning is used to agree on outcomes and methods
Risks are seen as inequitable; there is an unequal sharing of benefits and costs	Certain groups seen to benefit at the expense of others (hunters) or locals are at risk of water contamination while others are not	As well as information on risks, benefits are well articulated and better understood in an overall risk-benefit framework. Operational improvements help to minimize mistakes. Groups are involved in monitoring with agencies
The risks are not balanced by benefits	Poison risks are perceived more strongly than the risks of inadequate control of pests. By-kill ranks as a major concern, despite impacts of predators on wildlife	Better information on benefits arising out of information, dialogue and local engagement rather than from 'outside' to increase trust. Information is more strongly tailored to local situations
Risk information is seen to come from untrustworthy sources or agencies are not trusted	Emphasis on science facts from agencies is not necessarily accepted or trusted. Potential for 'risk amplification' by opponents	Local leaders are better placed to act as reliable and trusted sources of information than agencies Information is adapted to respond to local situations
Risk is from human, not natural sources	Poisons are not natural, including 1080, despite its occurrence in plants including some in Australia, New Zealand and South Africa	Antagonism towards poisons is accepted as valid and their use is assessed in a wider framework of dialogue over alternatives—at the appropriate level
Risk is considered to be ethically objectionable	Belief that death from 1080 is inhumane, as evidenced by convulsive behaviour, etc.	Value of dialogue over ethics and getting community ownership of pest control to focus on solutions and the ethical choices that need to be faced in acting
Type of risk is novel rather than familiar	Operations are infrequent and therefore not 'normal' for many residents. Repeat operations can lower risk concerns	Importance of early discussions at community level to explore all the risks and increase understandings. Useful to involve trusted local leaders in these discussions

Table 4 (*Continued*)

Outrage factor	Relevance to 1080 concerns	Options for responding to the outrage factor
Risk can be associated with some memorable event (e.g. disaster or public problem)	Greater opposition to aerial spraying of toxins following painted apple moth spray programme in Auckland, 2002	Operational mistakes are admitted. Events external to 1080 use are relevant to public concerns and need to be recognized as such
Dread; activities evoking fear or anxiety, e.g. exposure to cancer-causing agents	Risk of drinking contaminated water or eating contaminated animal products	Independent analysis of water samples. Involve groups in water sampling and make results available to communities

Covello and Sandman (2001). Three points can be made from Table 4. First, a large number of the classic outrage factors are relevant to the opposition to aerial use of 1080. Second, all outrage factors featured in the submission statements. Third, the options proposed as responses to the outrage factors indicate that while technical information is important for some responses, more direct involvement with affected communities is required to address the remainder. Covello and Sandman (2001) note that the 'hazard + outrage' model implies that reducing the level of outrage will reduce the risk, even if there is no change to the level of the hazard. In fact, efforts to successfully reduce the '1080 aerial hazard' have been under way for some years (e.g. 10-fold reductions in baits/hectare, use of global positioning systems by pilots, improved sowing bucket technology, bait improvements). However, since hazard and outrage are almost independent variables, the presumption that improved operational effectiveness will automatically reduce opposition, i.e. outrage, does not hold, even if lowering the hazard does reduce risk. The model has another important implication for pest management agencies. It suggests that although agencies continue to invest research dollars into more specific or humane poisons (Animal Health Board, Annual Research Reports; Marks et al. 2009), this will not, ipso facto, reduce the public's antagonism towards poisons as pest control tools unless the independent outrage factors are specifically addressed as well.

The stages of risk communication provide a useful framework of options for pest management agencies within which they can assess their response to the way people perceive risk. Drawing on a summary by Covello and Sandman (2001), the first stage, up until about 1985, was to ignore the public and is referred to as the pre-communication stage. Nuclear power utilities and chemical industries then learnt that ignoring the public meant controversies became larger. The second stage or first level of real risk communication was learning how to explain risk data better (the hazards). Techniques for doing so are improving and many organizations remain at this stage. However, when a hazard is low, but people are very outraged, then better explanations of the data are seldom helpful. As Covello and Sandman (2001) observed: 'You can never produce a video that will transform people who are trying to throw rocks at you into a pacified, well-informed audience.' Chess et al. (1989) noted earlier that 'merely hammering away at the scientific information will rarely help'. Consequently, risk communication evolved to the third stage, which is built around dialogue with the community. This stage recognized that a paradigm shift occurs when policy makers include in their decisions and actions all of the factors that the public includes in its definition of risk. To succeed meant that real dialogue was needed

among all the interested parties. Hence risk communication was also about reducing outrage, not just providing better explanations of risk. The Environmental Protection Agency's two-page publication 'Seven cardinal rules of risk communication' underlined the expectation of accepting and involving the public as a legitimate partner (EPA 1988).

The fourth and most difficult stage 'requires fundamental shifts in an organization's values and culture' (Covello & Sandman 2001). It involves treating the public as a full partner, which can happen more easily in some cultures than others. There are organizational and individual barriers including habit, inertia, internal scepticism (public are irrational), threats to power and self-esteem that limit progress. Covello and Sandman (2001) stressed that the various stages of risk communication build on, but do not replace, one another. Hence explaining pest impacts, research results and outcomes more effectively still matters, even as efforts to improve dialogue and partnerships are under way.

Is 1080 a 'wicked' problem?

Does the concept of 'wicked' problems have any relevance to how agencies might best respond to the 1080 issue? 'Wicked' problems were defined initially by Rittel and Webber (1973) in the context of social policy issues, centred on planning-type problems. The concept continued to gain currency and has been extended to include environmental problems such as forest losses, endangered species and, in particular, climate change (e.g. Ludwig et al. 2001). Ludwig and colleagues argued that when dealing with policy issues science cannot be separated from issues of values and equity, one consequence of which is a diminished role for specialists. They viewed this trend not with alarm, but as a reality to which scientists in a number of disciplines needed to adapt. Ludwig (2001) expanded on the view that the era of the disinterested expert is over, that experts dealing with wicked problems should be prepared to participate, on an equal footing, with interested parties with respect to advisory and decision-making roles. Rittel and Webber (1973) originally described 10 properties of wicked problems. This list was reduced to six by Rayner (2006). He listed these as:

- symptomatic of deeper problems
- unique opportunities that cannot be easily reversed
- unable to offer a clear set of alternative solutions
- characterized by contradictory certitudes
- contain redistributive implications for entrenched interests
- persistent and insoluble.

The extent to which these properties of wicked problems match the controversy over the aerial application of 1080 is considered in Table 5. This rating of 'match' is open to dispute; it is offered here only as an initial assessment of whether there is any relevance to the wicked problem framing and therefore to methodologies that have been proposed as effective responses to wicked problems.

From this initial assessment aerial use of 1080 may qualify as a 'partially wicked' problem. As such, it fits within a 'post-normal' approach to the way that science and policy-making are considered, recognizing the aspects of uncertainty and values that are more traditionally ignored in research (Frame & Brown 2007). Rayner (2006), like Ludwig (2001) and others (Allen & Horn 2009; Cronin 2008) emphasized the importance of dialogue between relevant players to make progress in solving complex problems. Rayner suggested that a minimum of three voices (perspectives) is needed for solutions to emerge to wicked problems. If there are only two, then the result is binary opposition. Fortunately, each of the voices is only partially right and hence each ends up contributing to the emerging solution. Rayner called this the law of minimum requisite variety—it takes at least three perspectives on a wicked problem before a complex solution

Table 5 Assessment of the match between wicked problems and 1080 use

Properties of wicked problems	Match to objections to 1080 use
Symptomatic of deeper problems	Yes; some public opposition to poisons will remain regardless of use benefits
Unique opportunities that cannot be easily reversed	Yes; with respect to Tb reduction when cost and practical issues are considered; yes, if species go extinct without pest control using 1080
Unable to offer a clear set of alternative solutions	Yes; 1080 needed to meet Tb vector control objectives in deep forest. No, for species where traps, ground baiting are alternatives, but only if cost is ignored
Characterized by contradictory certitudes	Yes; clear divisions exist between groups and communities with different values and interests
Contain redistributive implications for entrenched interests	No; financial investments in 1080 products are relatively minor. Pest control agencies could switch to using other methods
Persistent and insoluble	Yes or no. Pest problems will not go away. Future control technologies may effectively replace 1080, but not in the near future

starts to emerge. Rather than try to reduce the number of perspectives, pest control agencies would, in this approach, be encouraged to acknowledge the benefits of having around three to five voices to listen to, providing key interests are included.

Listening to the voices

Over the years DOC and AHB have, of course, been doing much more than producing information pamphlets and publications to respond to concerns over the use of 1080. They have also been listening and responding in different ways to at least four distinctive voices about the 1080 problem. The ethical voice said 'Forget 1080 and use alternatives that are safe and humane, regardless of the cost'. Agencies responded with research into more targeted and humane poisons, improvements of existing ones (such as cyanide encapsulation), and more humane and innovative trap designs. In 2009, DOC-funded researchers developed a self-setting trap for rats and stoats, with modifications now under development for trapping possums (Department of Conservation 2010d). The conservation voice said '1080 is essential for Tb reduction and protection of wildlife. In the absence of effective alternatives, get better at using 1080 to minimize the risks and maximize the gains'. So there has been further research into pest dynamics, the impacts of 1080 on animals (Murphy et al. 1999; Sherley et al. 1999), pest impacts on ecosystems (Nugent et al. 2010), smarter baiting strategies using 1 kg/ha (Nugent et al. 2009) or as little as 0.25 kg/ha of toxic bait (Morriss & Nugent 2009), improved operational practices and closer integration between agencies. The resource voice said 'Stop treating possums and deer as pests and let the private sector manage them as recreational and economic resources'. The response was the development of deer repellents that substantially reduce deer deaths and some local initiatives combining employment opportunities with control operations. The local community voice said 'Why should we risk baits in our water supplies and being told what is good for us?' The response has been extensive monitoring of water after aerial 1080 operations, stricter operational controls, research into key factors behind good community consultation (Wilson & Cannon 2004; Horn & Kilvington 2002; Lyver et al. 2004) and establishment of good working partnerships with some communities and organizations.

Individually these voices have been contributing to parts of the emergent solution,

influencing the research agendas and agency responses. In the absence of an overall grand strategy the important thing is that the voices have been heard from time to time and have, in a meandering way, been usefully contributing to a complex solution to a 'partly wicked' problem. Science continues to be an important voice in this context. As Sarewitz has persuasively argued, science is one voice, not the voice (Sarewitz 2004). Sarewitz proposes that open discussion of the conflicts over values and interests should take place and goals should be identified before scientific resources are allocated to the controversy. Science would then be the tool to both support and assess the effectiveness of policies that have been widely agreed through relevant political processes.

Public views on 1080 can be strongly polarized. On the one hand, national organizations such as Federated Farmers of New Zealand and the Royal Forest and Bird Protection Society have jointly created a web site covering the importance of 1080 for Tb reduction and protection of wildlife (http://www.1080facts.co.nz). On the other hand, opposition to aerial use of 1080 can be entrenched, organized and vocal (e.g. www.kaka1080.co.nz). Wicked problem characteristics can be easily identified in these responses as well as the reality of social amplification of risk (Kasperson et al. 1988). The vocal opposition from these communities attracts media interest and can generate ripple effects that add to perceived risks by strengthening outrage responses. In such environments agencies will need to commit considerable time and expert resources if they are to find common ground, build trust, and collectively find acceptable ways to move forward (Hayes et al. 2008). This could be a risky process and is easier said than done. Morgan et al. (1992), quoted in Fitzgerald et al. (1996), noted 'one should no more release an untested communication than an untested product'. Greater recognition by agencies that collaboration with social sciences can help to resolve conservation problems would also be beneficial (Fox et al. 2006), but Rayner's (2003) warning that participatory techniques for decision-making can face political-cultural constraints that tend to frame ethical issues as scientific ones is also relevant.

Implications for pest management agencies

This research was stimulated by the ongoing public disquiet about the aerial broadcast of 1080 poison baits and the apparent inability of pest management agencies to reduce it. ERMA's call for users of 1080 to explain risks and to answer the public's specific concerns has not yet been fully addressed. The major implication of this research is that public disquiet is about much more than communicating technical information on the use, outcomes and science of 1080. The risk issues are multidimensional, social as well as scientific, and need to be recognized and addressed accordingly by agencies.

Risk factors that cause outrage need to be acknowledged and responded to accordingly if communications methods, written or otherwise, are to be more effective. Agencies need to appreciate that several perceived risks (e.g. ethical ones) are not mitigated by reducing hazards (e.g. the amount or specificity of a poison), nor by explaining the science better, particularly to 'intuitive toxicologists'. The analysis also suggests that aerial use of 1080 does display some characteristics of a 'wicked' problem. Working towards solutions to wicked problems is more likely to succeed if all the significant constituencies or voices, of which science is only one, are able to contribute to solutions

There is good evidence that agencies have been listening to several voices and thereby addressing some aspects of the controversy over the aerial use of 1080. However, in terms of risk communication theory, pest management agencies seem to alternate between stage two (explaining risk data better) and stage three (building dialogue and collaboration with communities). Therefore pest management agencies

might well achieve better outcomes by moving more deliberately and consistently into the third level of risk communication, one based on dialogue with affected, sometimes antagonistic, communities and focus on resolving the outrage factors. Successful dialogue with communities would reduce the outrage risks and thus lower the overall risks associated with 1080. The best practice in risk communication has been articulated in general (EPA 1988) and usefully contextualized for New Zealand communities (Wilson & Cannon 2004; Hayes et al. 2008), but seems to be difficult for agencies to implement consistently and strategically. The extent to which they are able to do so will depend on their ability to adapt and respond as learning organizations by building on past successes (Lyver et al. 2006; Wilson & Cannon 2004). Failure to do so could mean that pest management agencies face a further decline in public support for the use of a control method that currently has no equal in its efficacy in reducing Tb levels and protecting native flora and fauna.

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