JULY 2004

The use of 1080 for pest control

A discussion document

Department of Conservation
Te Papa Atawhai

ANIMAL HEALTH BOARD

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Abbreviations

Acronyms

ACVM Agricultural Compounds and Veterinary Medicines Act 1997

AEE Assessment of environmental effects

AHB Animal Health Board
The members of the AHB are:
Federated Farmers of New Zealand (Meat & Fibre Producers);
Federated Farmers of New Zealand (Dairy Farmers NZ);
New Zealand Deer Farmers Association;
Meat New Zealand;
New Zealand Dairy Board;
New Zealand Game Industry Board;
Local Government New Zealand

BEI Biological Exposure Index

BSE Bovine spongiform encephalopathy

DOC Department of Conservation

HSNO Hazardous Substances and New Organisms Act 1996

MAF Ministry of Agriculture and Forestry

NOEL No Observable Effect Level

NZFSA New Zealand Food Safety Authority (a semi-autonomous body attached to MAF)

OECD Organisation for Economic Co-operation and Development

OSH Occupational Safety and Health Service

PCE Parliamentary Commissioner for the Environment

PMAV Provisional maximum acceptable value (New Zealand Drinking Water Standards)

Tb Tuberculosis (refers here to bovine Tb)

US EPA Environmental Protection Agency, United States

VPC Vertebrate Pest Control

WHO World Health Organisation

SPCA Society for the Prevention of Cruelty to Animals

Units

gm gram

ha hectare

kg kilogram

mg milligram (0.001 grams)

mg/kg milligram per kilogram (a unit of concentration)

mg/kgbw milligram per kilogram of body weight (a unit used to express dose)

mg/kg-day milligram per kilogram of body weight per day for repeated daily doses

mg/L milligram per litre (a unit of concentration)
1 mg/L = 1 part per million (ppm)

ppb parts per billion
(one billion = one thousand million)

ug/L microgram per litre (a unit of concentration)
1 ug/L = 1 part per billion (ppb)

Foreword

The introduction of mammal pests such as rabbits, stoats, ferrets and possums to New Zealand has resulted in a unique and complex set of ecological and animal disease control problems that we struggle to manage.

For more than 50 years the main response to these problems has been the use of a mixture of population control methods. These have mainly targeted the brush-tailed possum, first introduced from Australia in 1858, which has flourished in its new environment, rich in food and free of natural predators. More recent pest control efforts on the mainland have targeted stoats and ferrets, originally introduced in a misguided attempt to control yet another pest, the rabbit. Integrated, multiple-pest control programmes are being developed as we learn more about the extreme risks which many native species face from the mixed impacts of introduced mammals.

In recent years these pest control programmes have delivered real successes. The North Island kokako has been brought back from a rapid slide towards extinction. The collapse of forest canopies due to possum browse has been arrested or reversed in some of our finest native forests. The incidence of bovine Tb in cattle and deer herds has fallen dramatically.

Our ability to maintain effective control of mammal pests over large areas remains limited by the control tools at our disposal. Despite extensive and promising research into biological control, traditional trap and poison technology will remain the mainstay of animal pest control in New Zealand for the foreseeable future.

The toxin sodium monofluoroacetate (1080) is used mainly for possum control and is the only toxin able to be applied aerially. The ability to apply 1080 from the air makes it a key tool for possum control. It also makes it a controversial one. Concerns have long been raised about potential adverse impacts on native birds and insects, contamination of the environment and water supplies, and possible human health risks. The use of 1080 can and does kill deer that are valued for recreational hunting, and there have been incidents of accidental poisoning of livestock and domestic animals.

There is no doubt that as well as conferring major possum control benefits, the aerial application of 1080 carries risks that must be carefully managed, and which must be weighed against the benefits.

It is for this reason that the Animal Health Board and the Department of Conservation - the major users of 1080 in New Zealand - are preparing an application for a formal reassessment of 1080. This will be carried out by the Environmental Risk Management Authority (ERMA) under the Hazardous Substances and New Organisms Act (HSNO) 1996.

It is timely to reassess 1080. Recent increases in funding for both Tb control and conservation programmes are seeing an increase in possum control, which has in turn prompted an increase in concern over possible adverse effects. Monitoring and research work over the last decade has given us a more precise understanding of the benefits and risks of using 1080. The HSNO Act provides for a balanced consideration of these issues by an independent statutory body in the form of ERMA.

As part of preparing the reassessment application, the Animal Health Board and the Department of Conservation are seeking the views of iwi, the public, and interested organisations on the benefits and risks of the use of 1080 for pest control in New Zealand. This discussion paper has been prepared to provide background information on the use of 1080, the associated benefits and risks, and the reassessment process itself in order to help those who wish to make submissions.

John Dalziell
Chairman, Animal Health Board

Hugh Logan
Director-General, Department of Conservation

Written Submissions

Written submissions are now invited on this discussion paper and should be sent to:

1080 Reassessment,
PO Box 3412,
Wellington

or by email to: 1080@doc.govt.nz

The Response Form is on pages 59 and 60.

Online submissions can be made at:
http://www.1080reassessment.govt.nz

Submissions will close on 30 September 2004.

The views of iwi will be sought at hui to be arranged. The Animal Health Board and the Department of Conservation welcome your participation in this very important process.

1. Introduction

Since the Australian brush-tailed possum (*Trichosurus vulpecula*) was officially recognised as a major pest in New Zealand in 1947 (when the Government legalised the use of poisons for possum control), several control methods have been developed. Traps and poisons are the main methods of control for possums, which now occupy all of mainland New Zealand except for parts of Fiordland. For over 50 years, one of the most effective control methods in a range of environments has been the use of 1080. Because of its cost-effectiveness it is widely used by the two major agencies that control possums: the Animal Health Board (AHB) and the Department of Conservation (DOC). These two agencies use 1080 for different reasons. This reflects their different responsibilities and priorities with respect to possum control.

This discussion document has been prepared by AHB and DOC to provide information on the use of 1080 and how it 'behaves' when released into our environment.

The Animal Health Board

AHB is the agency responsible for New Zealand's programme to eradicate bovine tuberculosis (Tb) from farmed cattle and deer herds, and wild animals. The programme operates under the auspices of the National Pest Management Strategy developed in accordance with the Biosecurity Act 1993. AHB is a Management Agency, as defined by the Biosecurity Act. AHB is a non-profit making, incorporated society whose membership reflects the major stakeholders and funding interests in the Tb pest management strategy. The control and eradication of bovine Tb in New Zealand largely depends on controlling the wildlife sources of the disease. These are mainly possums. Possum and other wildlife control programmes under the Tb strategy have expanded in recent years. In the year to 30 June 2003, AHB spent over $55 million carrying out possum control and some ferret control, on 7.8 million hectares. AHB contracts the management of possum control programmes to regional councils in most regions, but also has management contracts with private companies in the Otago region and Tasman District.

The Department of Conservation

DOC is responsible for managing the 30% of New Zealand's land area that has protected status, such as national parks, reserves and conservation land. It also plays a major role in implementing the New Zealand Biodiversity Strategy, launched by the Government in 2000.

The third goal of this Strategy is to "*Halt the decline in New Zealand's indigenous biodiversity.*" This goal is linked to New Zealand's international obligations under the Convention on Biological Diversity to conserve our indigenous (native) ecosystems and species.

Field staff and research scientists within DOC work towards this goal in a number of ways. Many are focused on managing plant and animal pests to improve the condition and health of native ecosystems and the survival prospects of threatened species. As a major part of this effort, DOC currently spends about $14 million of its pest management budget on possum control. Significant amounts are also spent controlling stoats, rats, goats, deer and other pest species. Despite increasing the amount spent on possum control, the area currently under sustained management for possums is 15-18% of conservation lands, for the 2003/2004 period.

The use of 1080 toxin to control possums for conservation purposes is not preventing the decline in the overall condition of our indigenous forests. The introduction of pest species, the clearances and fragmentation of the natural vegetation led to inevitable declines in numbers of native species as pests invaded the remnant forests. The silence of our native forests is a legacy of the introductions and the increasing silence will continue unless we reverse the onslaught of pests on a massive scale.

1080 is one of the most effective tools we currently have to restrict the deterioration in biodiversity condition but only on a relatively small scale. We cannot prevent the ongoing deterioration on a landscape scale. Further loss of indigenous species is inevitable as habitats continue to shrink and pressure from pest species continues to affect the ability of native species to maintain their numbers, let alone expand.

Outline of the Document

Chapter 2	outlines why 1080 is being reassessed at this time and the steps that are required to be followed in the reassessment process.
Chapter 3	describes the damage that pests, and possums in particular, cause to agriculture and the environment, and hence the need for control.
Chapter 4	contains basic information on 1080, its life cycle, and the various ways it is used in pest control.
Chapter 5	summarises findings on how forests and animals respond after 1080 use, the fate of 1080 in the environment, and the health issues for people.
Chapter 6	describes alternative control methods for possums.
Chapter 7	is a summary section.
Response Form	is a form which you are invited to complete and submit with your views on the future use of 1080.

2. The reassessment process

2.1 Why 1080 is being reassessed

The Hazardous Substances and New Organisms (HSNO) Act was passed in 1996. However, the part of the Act covering Hazardous Substances* did not come into effect until July 2001.

Hazardous substances that were already approved for use in New Zealand at that time are referred to as "existing substances". Over the next 2 to 4 years there will be a transition period when these "existing substances" will be progressively transferred from the previous regulatory system (such as the Toxic Substances Regulations) to the HSNO framework.

"New substances" (that is, anything not imported or manufactured here prior to July 2001) require approval under the HSNO Act.

The Environmental Risk Management Authority (ERMA) was set up under the HSNO Act and has responsibility for approving applications for "new substances" and for transferring "existing substances".

For the majority of existing substances, the transfer process will be fairly straightforward, with the substance being given a HSNO classification and assigned controls to manage the risks. These controls will generally be similar to those already in place. ERMA is currently in the process of transferring controlled vertebrate poisons, presently managed by MAF under the Pesticides Regulations, over to the HSNO system. This process includes pesticides containing 1080.

While ERMA has responsibility for managing the risks to public health and the environment from these pesticides, the risks to trade, animal welfare and agricultural security are managed by the Ministry of Agriculture and Forestry (MAF). So as part of the transfer process, 1080 will also be controlled under the Agricultural Compounds and Veterinary Medicines Act 1997 (ACVM).

However, the HSNO Act also allows for a much more rigorous re-evaluation of existing substances (a process referred to as "reassessment"), which is essentially the same process required for approval of any new substance. The first step in this process is for ERMA to decide if there are grounds for reassessment, when it must take into account whether there is:

- Significant new information about the effects of a substance;
- Alternative substances that may have become available which have similar or improved beneficial effects and have reduced adverse effects;
- Significant changes in how it is used or how much is used.

Reassessment provides a mechanism to re-examine the risks, costs and benefits of a hazardous substance as well as to review the controls that regulate the use of the substance. In effect, it is a review that starts from scratch.

In the current situation regarding 1080, the first step was for ERMA to decide if there were grounds for its reassessment. In 2001, the Animal Health Board and Department of Conservation decided to apply to ERMA for a reassessment of 1080 for the following reasons:

- Since its registration in 1964 there is new information on 1080 that should be formally assessed;
- Given the strong public interest and concern over 1080, particularly its aerial application, the reassessment process provides an opportunity for public discussion and scrutiny; and
- Both agencies are seeking increased use of 1080 to meet targets for reducing the levels of Tb in cattle and deer herds and in support of government strategies on sustaining biodiversity.

A decision in favour of reassessment was made by ERMA on 12 March 2002.

* The HSNO Act defines a hazardous substance with one or more of the following intrinsic hazardous properties: explosiveness, flammability, oxidising capacity, corrosiveness, toxicity and ecotoxicity. The Act defines "ecotoxic" as capable of causing ill health, injury or death to any living organism.

2.2 Steps in the reassessment process

The following four steps are now under action by the applicants:

1. *Lifecycle assessment and hazard classification.* This will identify the lifecycle of 1080, from its manufacture to its application and how it is disposed of. It will also identify the hazards 1080 poses to people and the environment throughout its life. Pesticides containing 1080, as well as the raw material itself, will be classified according to the new HSNO scheme.
2. *Consultation.* For any substance that is used throughout the country and is of national interest, the HSNO Act requires the applicant(s) to undertake nationwide consultation. Given that 1080 meets both of these criteria, this requires a nationwide consultation to be carried out. In addition, it is necessary under the Act to assess any particular risks, costs and benefits that arise from the relationship of Maori and their culture and traditions with their taonga, as outlined in the next section.

   This discussion document is an important part of the national consultation process. You are invited to read it and respond to the matters it raises (see Response Form at the end).
3. *Risk assessment.* The consultations will be an important source of information to supplement the comprehensive assessment of the risks, costs and benefits of 1080, which will then be compiled by the applicants. The applicants will also be providing information on how 1080 will be managed, including the management of any adverse effects and the risks associated with its use.
4. *Overall evaluation and submission.* Finally, the applicants will prepare an overall evaluation by pulling together all the information that has been gathered on risks, costs and benefits. This will form the basis of the application to be submitted to ERMA.

Once ERMA receives the application, a new phase of the process begins under a timetable and process that will be set by ERMA. This will include an invitation for written submissions and the holding of a hearing. The decision-making process of ERMA involves weighing up all the scientific and non-scientific information in the application, including information in the public submissions. ERMA will then make a judgement on whether 1080 should continue to be approved for use in New Zealand and if so, what controls or conditions should apply to that use.

In the meantime, the use of 1080 will continue to be controlled by the statutes, regulations and operating procedures already in place. The transfer process is proceeding in parallel with the reassessment but is a completely separate exercise. Where there are requirements under the Resource Management Act to obtain resource consents for 1080 control operations, these requirements will also continue.

2.3 Additional ERMA requirements for Maori consultation

The Environment Risk Management Authority (ERMA) has protocols and guidelines for applicants which outline how ERMA takes into account the principles of the Treaty of Waitangi and the relationship of Maori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, valued flora and fauna and other taonga (valued resources, prized possessions) (ERMA 1999). The Authority has a duty to make informed decisions on applications in relation to Maori interests. Accordingly, in relation to this reassessment of 1080, it requires that the applicants conduct nationwide consultation with Maori. The ERMA protocol states that it will generally be sufficient for nationwide consultation to be at iwi rather than hapu level.

In the course of these consultations the applicants will need to find out the views of Maori on how 1080 may impact on their taonga and other concerns they may have. The ERMA protocol outlines matters which are likely to be of potential significance to Maori and which may require consultation. While iwi and hapu will decide which matters are of significance to them, the following list of topics extracted from Annex 1 of the ERMA protocol indicates some of the potential matters for comment. Maori may wish to raise other matters in addition to the following.

1. Potential issues of significance in relation to Treaty outcomes;

2. Potential issues of significance in relation to environmental outcomes:

- the continued and improved availability, quantity and quality of traditional food resources (mahinga kai)
- the continued availability, quantity and quality of traditional Maori natural resources
- the retention of New Zealand's diverse range of indigenous flora and fauna
- the protection of indigenous flora and fauna valued by Maori
- the purity of water and the need to retain and extend its productive and life-sustaining capacity
- the purity of the land and the need to retain and extend its productive and life-sustaining capacity
- the purity of human health and well-being
- the restoration and retention of natural habitats;

3. Potential issues of significance in relation to cultural outcomes:

- the recognition and protection of Maori cultural, spiritual, ethical or socio-economic values
- the protection of the mauri of peoples
- the preservation and maintenance of traditional Maori knowledge by Maori
- the maintenance, expression and control by Maori of their traditional practices, e.g. kaitiakitanga, tapu and rahui
- the protection of the mauri of valued flora and fauna
- the protection of the mauri of land and waterways; and

4. Potential issues of significance in relation to health and well-being outcomes:

- the protection of taha wairua: spirituality, balance with nature, protection of mauri
- the protection of taha whananunga: responsibility to the collective, the capacity to belong, to care and to share
- the protection of taha hinengaro: mental health and well-being, the capacity to communicate, to think and to feel
- the protection of taha tinana: physical growth and development.

From their consultations with Maori, the applicants will prepare an assessment of the risks, costs and benefits of 1080 that are significant to Maori. This assessment will then form part of the total application that will be duly submitted to ERMA for its consideration.

ERMA may treat as confidential any information that has been classified as being culturally sensitive by those Maori who have provided such information.

3. Why we use 1080 for pest control

3.1 Possums as reservoirs of bovine tuberculosis

Bovine tuberculosis (Tb) arrived in New Zealand with the cattle of the first European settlers. It was a serious problem by the 1940s, reducing productivity and putting many people's lives at risk. Today it remains the most important disease for both cattle and deer farming in New Zealand. It is a wasting disease in both cattle and deer, leading to weight loss and death. In cattle, milk production may decline. Bovine Tb is similar to human Tb and can move from livestock to humans with potentially fatal consequences. Owing largely to the pasteurisation of milk and the compulsory Tb control programme for cattle, bovine Tb is now a minor cause (1% to 5%) of Tb in humans in New Zealand. The current issue is how it affects our livestock industries and exports.

The trading threat

International animal health standards have risen since the 1960s and are now a major factor governing and threatening access to our overseas markets. The dairy industry is one of New Zealand's most valuable livestock industries, with an export value of $4.7 billion in the year to 30 June 2003, about 20% of all foreign trade. In 1990, the European Union proposed to introduce regulations (but didn't do so at the time) requiring milk and milk products to be free of all pathogens, including Tb. This indicates the direction some importing countries are heading and the obvious risks to our trade. It is imperative that New Zealand clears Tb infection from its remaining infected dairy herds. The perceived safety of meat products (with an export value of $4.2 billion in the year to 30 June 2003) is also a matter of international concern, especially since the emergence of "mad cow" disease (BSE). Effective control of Tb is critical to protect our trade in dairy, beef and venison products.

If the Tb eradication programme were to stop, then the potential cost to New Zealand, if major markets were lost, has been estimated at $5 billion over ten years. The levels of Tb in our cattle and deer currently prevent any exports of live animals to Australia and North America, and limit live export trade to other countries.

Eradication of bovine Tb

In most countries eradication of Tb from cattle herds is straightforward. All cattle are tested and those that are "test-positive" are either re-tested or slaughtered. Normally this rapidly reduces the level of Tb and can eliminate it entirely. The vast majority of our trading partners and competitors (Australia, North America, most Western European and South-East Asian countries) are classified as free from Tb. New Zealand has had a compulsory, national Tb eradication campaign operating in cattle herds since 1970, and in deer herds since 1990. However, 0.4% of the national cattle herds and 1.4% of deer herds are still infected with Tb. In the 12 months to July 2003, 767 cattle and 517 farmed deer were confirmed with Tb.

So why does New Zealand still have a significant Tb problem, despite a long-running national eradication campaign?

Pests as Tb reservoirs and vectors

In the late 1960s, veterinarians in the Westport area were puzzled by chronic infection in cattle herds that could not be cleared by standard test and slaughter methods. Researchers linked the problem to high levels of Tb infection in the possum populations adjacent to these herds. Bovine Tb had "jumped" to a new host. Since then, possums with Tb have been identified in widely separated areas of New Zealand, co-existing with tuberculous cattle. While several wild animal species can be infected with Tb, research suggests that possums, and perhaps ferrets, are likely to be the only self-sustaining reservoirs of Tb. Feral red and fallow deer have also been identified as important vectors of Tb.

In the 1960s and 1970s, infected possum populations were mostly confined to high rainfall areas of the West Coast, and the lower and central North Island. Since then, infected possum populations have continued to spread and now occur in the areas shown on Figure 1. Scientists now regard possums as the most important vector of Tb, for most infected herds in New Zealand, over the last 25 years.

In total, Tb-infected possum populations now occupy about 38% or 10 million hectares of New Zealand. By 2003, approximately three-quarters of this area (7.8 million hectares) was under sustained Tb vector control.

Figure 1 **Areas occupied by Tb-infected possums (in dark grey) (2002) Source: AHB**

How much control for Tb?

"No control" for bovine Tb purposes is not an option, given the trade, social and political risks. "How much" control is the issue.

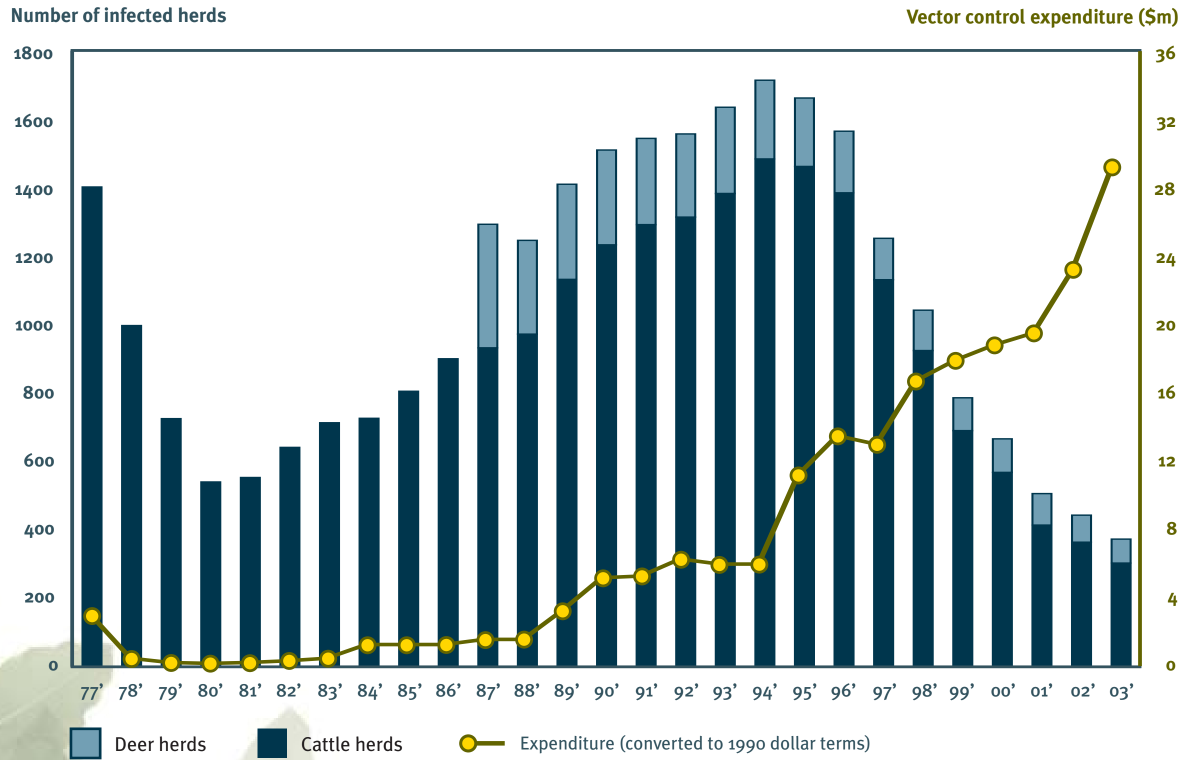
The initial control operations that focused on Tb possums between 1974 and 1978 were very successful at first, and the number of infected cattle herds dropped rapidly. Unfortunately, as a consequence of this early success, funding, and therefore the number of control operations, was reduced over the next 11 years. Over those 11 years, the number of areas where wild animals had bovine Tb increased from eight to fifteen, and the number of infected herds rose to pre-control levels. Clearly, this "do little" option was not enough to contain, let alone reverse the Tb problem. Funding for Tb vector control rose in 1989 as other species, particularly ferrets, were identified as Tb vectors. Funding now exceeds $50 million a year. Currently, the National Bovine Tb Strategy has set higher objectives to reduce the number of infected herds, and prevent new Tb areas from establishing. Obviously this means a greater effort, particularly in the control and eradication of Tb vector populations.

The downward trends are now very encouraging, thanks to the high investment in vector control since 1994. However, the areas with Tb infection are continuing to spread. Figure 2 shows the level of investment that has been required to control Tb vectors to achieve a decline in the number of infected herds.

Management of bovine Tb

Current management of possum populations for Tb involves two distinct phases[1]. First, the population has to be heavily reduced over a large area, to cut down the likelihood of infected possums interacting with cattle or deer herds. Sometimes in this initial stage it is necessary to target other wild animal vectors, such as red deer and ferrets, as well. Large

Figure 2 Number of Tb-infected cattle and deer herds and expenditure on Tb vector control (Source: AHB)



areas have to be treated, otherwise new possums moving in from the edges of the controlled area quickly increase the population again. Making these initial reductions often involves spreading 1080 baits by air, over large (>1000 hectares) or difficult areas of forest and scrub. Aerial operations provide rapid control over a large area, something that ground control rarely provides. Aerial operations are complemented with ground control of possums, often using a variety of techniques, on adjoining pasture and forest/pasture margins.

The second phase, or "maintenance phase", requires that the initial control is followed by regular re-treatment to hold the possums within a pre-determined density range. Low density levels are required to reduce the likelihood that possums continue to act as reservoirs or vectors for Tb. Maintenance operations are usually more frequent in the areas that were initially ground treated, such as farm-forest margins, as these are the areas where possums and cattle most commonly interact. Large bush and scrub blocks are re-treated by aerial 1080 operations at about four to six yearly intervals.

These control operations, coupled with herd testing, culling of "test-positive" animals, and controls on stock movement, usually achieve an immediate reduction in the level of Tb in herds close to infected possum populations. However, if the possum population and other vectors are not kept down through maintenance control, then Tb levels in the herds usually rise to the pre-control levels within five to eight years. On the other hand, if control operations are able to keep possum populations low enough for long enough, Tb can be completely eradicated from the population. This is the long term aim of AHB's operations, and has been achieved so far in six small areas.

3.2 Other impacts of possums on primary production

The major impact of the possum on primary production is as a Tb vector. The possum's impacts on pastoral farming, horticulture and forestry are of less significance, and the extent of these impacts has not been well quantified in economic terms, at a national level. Eight possums are about equivalent to one stock unit in terms of the pasture feed they consume. Hence, two to three possums per hectare on farmland can represent a significant loss of potential production. In Taranaki, this annual loss is estimated to be about $3,000 for each 100 hectares on dairy farms.

Possums caused significant damage to the new plantations of *Pinus radiata* in the central North Island, established in the 1960s and early 1970s. At some sites, up to 90% of young pine trees were browsed, and up to 50% may have died following possum damage to the terminal shoots (leaders) of young seedlings. Possums also bend and break terminal shoots and lateral branches in the upper part of young pines. Economic losses certainly exceeded control costs per hectare, and possums were controlled using 1080 and other methods in a number of plantations. Once *Pinus radiata* reaches 14 years old, possums have little effect on the trees. Areas with new plantings are likely to experience possum damage where possum densities are high. The value of a 5% loss at planting in a *Pinus radiata* plantation could represent losses at harvesting of between NZ$282 and $840 per hectare, at current prices[2].

The effects of possums on horticultural production are widespread, but poorly documented. Damage, which is often seasonal and patchy, has been reported to at least 46 varieties of fruit and vegetables. This damage is most common in areas close to trees and native forests.

The other significant damage can be to poplar and willow poles used for catchment protection and erosion control purposes. Young plantings can be protected from broken branches and possum browsing by using protective sleeves.

3.3 Possum damage to native forests

Over the past 50 years, possums have emerged as one of the major threats to the health and wellbeing of forests throughout New Zealand. Many of these impacts are subtle and indirectly affect native birds and insects. Possums cause damage to native forests from the ground level to the canopy where, by concentrating on individual plants of their preferred species, they can kill trees by defoliation over several years. Possums preferentially feed on some of the tall canopy species – such as tawa, northern rata, kohekohe, southern rata, kamahi, pohutukawa and

Hall's totara – while ignoring others. They also prefer some of the smaller trees, such as tree fuchsia and wineberry, along with mistletoe, forest herbs, some ferns, and a number of endangered shrubs.

It is difficult to imagine that possums, which are about the size of a large cat, can kill individual trees that have dominated forest landscapes for centuries before possums were released here. But when the number of possums is combined with the total amount each one eats, their impact on their preferred species is easier to appreciate. The amount of food consumed by an adult possum each night is about 160 gm of digestible dry matter. There are probably tens of millions of possums living in native forests. In total, possums are consuming thousands of tonnes of vegetation *each night*.

Possum populations have now modified many New Zealand forests[3]. The rate and extent of these changes vary widely between different types of forests. Beech forests are the least affected, but in the vulnerable southern rata-kamahi forests of Westland many valleys have lost between 20% to 50% or more, of their canopy trees. In severe situations, possums have caused the complete collapse of the canopy within 15–20 years of their arrival. Tall forest is then replaced by shrublands.

While the impact of possums is most visible and dramatic when it involves canopy trees, their most pervasive impacts are often less visible. Possums have recently been described as "reluctant folivores"[4]. This means that possums prefer to eat other forest foods than the leaves of trees. Flowers, fruit, leaf buds, fungi and insects are all highly favoured. The consumption of these foods has the largest impact on the healthy functioning of forests and the animals that rely on them (see Figure 3). The consequences of possums concentrating on these foods are:

Loss of flowers:

- preventing the formation of seeds
- removing nectar sources for birds and bats
- reducing the food supply for many invertebrates
- nectar loss reducing food supplies for chicks, e.g. kaka, tui.

Loss of fruits:

- reducing food supplies for birds and invertebrates
- affecting bird breeding condition and nesting success, e.g. kakapo, kereru
- reducing or eliminating seed dispersal
- reducing the regenerative capacity of native plants.

Loss of new shoots:

- reducing the ability of plants to overcome leaf loss from weather and seasonal patterns
- reducing numbers of new leaves, jeopardising plant health.

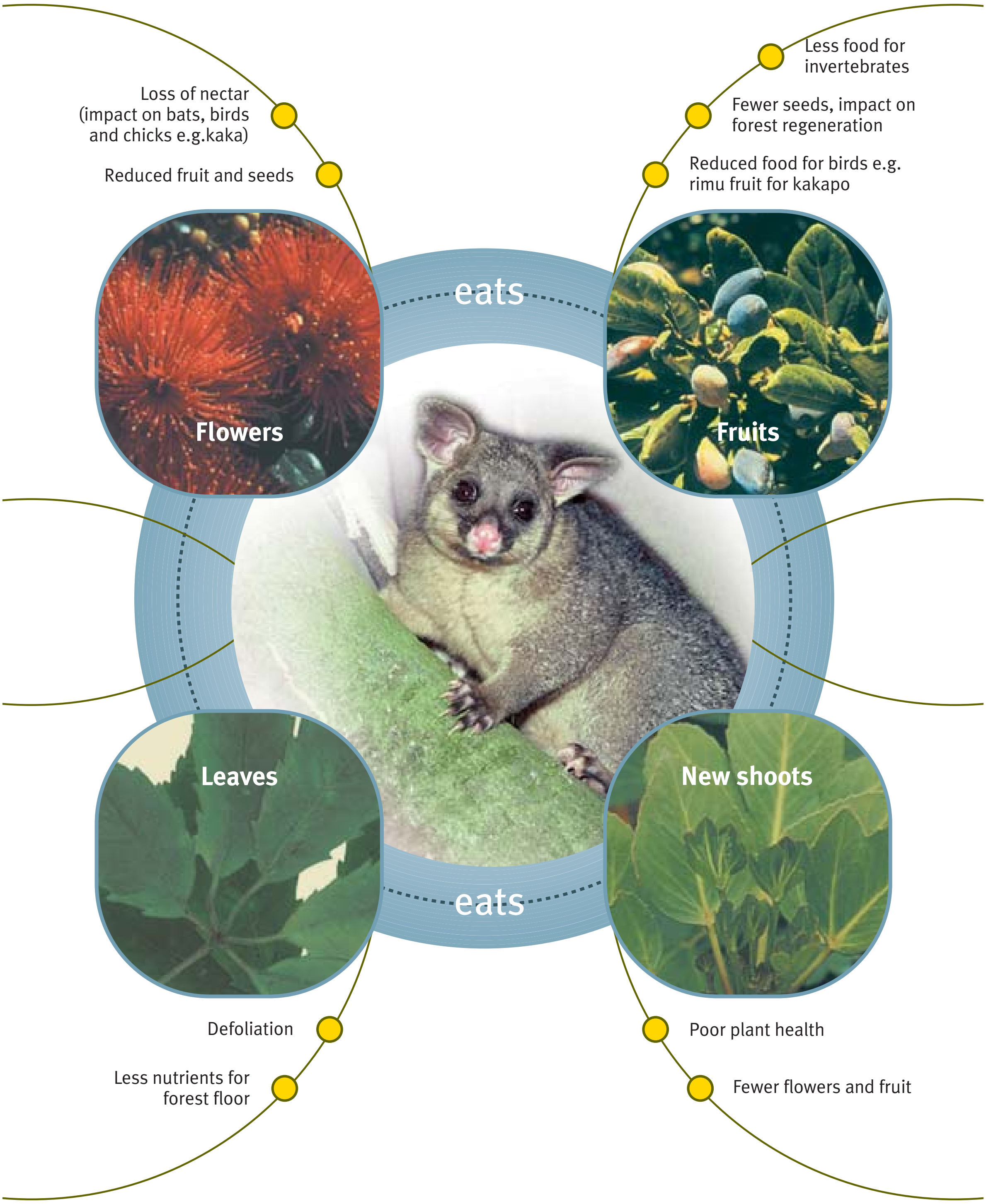
3.4 Possum impacts on native animals

Predation on birds

Effects on birds range from competition for vital foods at critical times of the year (described in Chapter 3.3) to direct predation. It is only in the last decade that researchers have confirmed that possums are significant predators of the eggs, nestlings, and even adults, of many native birds[5]. Their diet also includes a wide range of invertebrates. As a consequence, researchers have changed from thinking of the possum as primarily a folivore, to recognising that possums are generalist and opportunistic feeders on foods that may be high-energy, high protein or contain high levels of other nutrients, whenever such foods are available. These foods include flowers, leaf buds, fruit, eggs, birds and insects. As described above, one group of researchers coined the description of possums as "reluctant folivores", who will eat leaves to survive, but prefer other food. Use of these high-energy foods is seasonal, depending on availability. Obtaining direct evidence of possum predation is difficult, but time-lapse video cameras have shown possums eating adult birds, chicks and eggs, all in the nest.

The implications of possums as predators of native birds are very serious, given the large number of possums in native forests. Even if less than half of the possums in these forests were to eat one egg or chick during the year, their combined impact would be enormous. Research already shows that possums, along with ship rats, are major predators of kukupa/kereru (native pigeon) and the endangered kokako. As a result, very few eggs and fledglings survive to adulthood without active control of these predators. What role possums play in the 5% per year decline in

Figure 3 **Possum impacts on native forest ecosystems**



kiwi numbers is unknown, but in one study 14 adult kiwi were radio-tagged, and one of them was killed by a possum. Similarly, in another study, possums were identified as the culprits when kiwi eggs were destroyed before hatching. Chapter 5 documents the benefits for native bird populations of controlling predators with 1080.

Predation on bats

New Zealand's two species of bats, the short-tailed and the long-tailed, are both classified as nationally endangered, meaning they face extinction if conservation management is not successful at reversing their declines. The major threats to their populations are introduced pests – rats, stoats, cats and possums as well. In South Canterbury, where the bat population is declining by 5-9% per year, possums seek out young bats for prey at the roosts. Video cameras have recorded possums reaching into the roost cavities on half of the nights that the roosts were monitored.

Predation on invertebrates

Possums have seriously reduced the numbers of at least six species of the unique land snails (*Powelliphanta* species) of the southern North Island and Nelson/north Westland regions. Originating over 235 million years ago, these large and beautiful snails can live up to 20 years when undisturbed by predators such as possums, rodents and pigs. Possum and rodent control has led to increases in snail numbers at a number of sites[6].

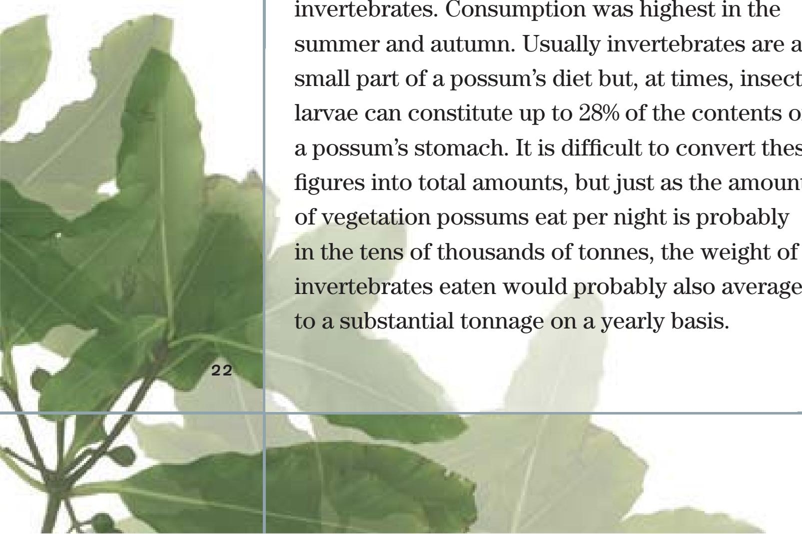
Large, sluggish, nocturnal species such as giant weta, large stag beetles and large weevils, may be the insects most at risk from possums. One study of a forest near Wellington showed that over half of the possum faecal pellets analysed contained invertebrates. Consumption was highest in the summer and autumn. Usually invertebrates are a small part of a possum's diet but, at times, insect larvae can constitute up to 28% of the contents of a possum's stomach. It is difficult to convert these figures into total amounts, but just as the amount of vegetation possums eat per night is probably in the tens of thousands of tonnes, the weight of invertebrates eaten would probably also average out to a substantial tonnage on a yearly basis.

In addition to direct predation on invertebrates, there are the indirect effects on invertebrates from possums eating the flowers, fruits and leaves that are an important part of invertebrate diets.

Possums, Kapiti Island and bird numbers

Once the stronghold of Ngati Toa chief, Te Rauparaha, Kapiti Island is one of New Zealand's most important sanctuaries for rare and endangered bird species such as the kokako, little spotted kiwi, stitchbird, saddleback (tieke) and others.

Possums were eradicated from Kapiti Island after a sustained campaign between 1980 and 1986. In this 6-year period a total of 19,612 possums were killed; eradication of the last 48 possums took almost 2 years of intense effort. Most possums were killed using traps, but 1080 baits were dropped by air on the western cliffs prior to trapping. The impact of possums on bird numbers can be estimated from a study that counted birds between 1982 and 1988. In those six years the density of birds on Kapiti Island doubled in abundance, from about 15 birds per hectare to approximately 30 birds per hectare[6]. Significantly, these increases occurred with rats still present, so the gains for bird populations were clearly due to the removal of possums. Kaka numbers also increased on Kapiti after the possum removal. This result is consistent with a South Westland study, which showed that where possums had been present in forests for over 10 years, there was a significant decline in kaka numbers[6].



3.5 Use of 1080 to control other pests

While 1080 is used primarily against possums, it is increasingly used to target other pest species, sometimes as part of possum operations. Carefully selecting the time of aerial operations can reduce predators such as rats and stoats, just before birds start nesting. This can have significant benefits, and leads to improved survival rates as described in Chapter 5[7]. Stoats are killed through secondary poisoning, by eating poisoned rat carcasses, but can re-invade within 2-4 months of an operation. Aerial operations can often, but not always, achieve good rat control for about 3 months or longer. The consequence of failing to control predators is often a steady decline in bird numbers.

Possums and other predators controlled using 1080 are not the only threat to native forests. In many places, selective feeding by possums on forest trees is made worse by the browsing of deer and goats on ground vegetation, seedlings and shrubs. Research over many decades has clearly shown that introduced deer species and goats have a major impact, by stopping the normal regeneration cycles in forests. Under the combined assault of deer and goats from below, and possums from above, many palatable plants gradually or rapidly disappear from forests. These other pests can be killed as a consequence of aerial operations, and in some places, where they are causing significant damage, other control methods are used. For example, high densities of goats, deer, wallabies or other browsers can be targeted by using 1080 in a paste form applied to leaves.

Rabbit control

Although the focus on 1080 use is usually on possums, it has long been an important toxin in the battle to reduce rabbit numbers. As noted in the next section, its first use in Australia was in rabbit control operations. In New Zealand, 1080 paste baits are used for rabbit control, particularly on and around farms. Various baits and cereal pellets are also used for larger scale control operations on rabbits.

The susceptibility of New Zealand's native forests to introduced pests

Why are our forests so susceptible to possums and browsing mammals that have little impact in their native countries? The answer lies in our unique natural history. As they drifted away from the nearest landmasses, these islands continued evolving for over 60 million years without the browsing pressure of mammals. *No other large landmass on Earth has had such a history.* Hence, before the arrival of the first voyaging Polynesians about a thousand years ago, the only land mammals in New Zealand were three species of small bats, one of which is now extinct. Our native plants have co-evolved with browsing and grazing birds, and developed defences and strategies to overcome that impact, or to benefit from the birds, by pollination, seed dispersal or habitat maintenance. Our native plants have few of the defences against browsers, such as thorns, tough leaves and plant poisons (such as fluoroacetate), which evolved in countries with mammalian browsers and grazers. Nor have they developed pollination or seed dispersal mechanisms that could exploit mammalian behaviours. They are, therefore, particularly defenceless against the onslaught from introduced browsing and grazing mammals. To make the problems worse, many of the introduced animals found themselves in an environment without the controls that normally limited their populations (droughts, extreme winters, fires, predators, competitors, diseases and parasites).

4. Information about 1080

4.1 Key facts

Sodium monofluoroacetate, commonly known as 1080, is a fine white powder. It has a slight odour and taste, is stable under normal storage conditions, and is highly soluble in water. While manufactured 1080 is a highly lethal poison to many species, the active ingredient, fluoroacetate, is chemically identical to the fluoroacetate that occurs naturally in many poisonous plants. These poisonous plants occur in Brazil, South and West Africa, and Australia, especially Western Australia, where some 40 plant species produce it. Plants with high concentrations are potentially hazardous if eaten.

History and extent of use

1080 has been used in New Zealand for pest control since the mid-1950s and is the only poison registered for aerial application. 1080 was first registered as a pesticide for control of vertebrate pests in 1964, under the now repealed Pesticides Act. Its toxicity was well recognised at that time and hence it was classified as a "controlled pesticide", which means that 1080 is available only to licensed operators.

In addition to New Zealand, 1080 is used in Australia, USA, Mexico and Israel. In the USA, 1080 use is restricted to a livestock collar to protect livestock such as sheep and goats from coyotes. (Coyotes attack livestock around the throat and bite on a lethal dose of 1080 contained in the collar.)

In Australia, 1080 was first used in rabbit control programmes in the early 1950s, where it is regarded as having "a long history of proven effectiveness and safety"[8]. It is seen as a critical component of the integrated pest control programmes for rabbits, foxes, wild dogs and feral pigs. Since 1994, broad-scale fox control using 1080 meat baits in Western Australia has significantly improved the population numbers of several native species and led, for the first time, to three species of mammals being taken off the state's endangered species list. In Australia, minor direct mortality of native animal populations from 1080 baits is regarded as acceptable, compared to the predatory and competitive effects of those introduced species being managed using 1080.

Mode of action

Although animals vary widely in their sensitivity to 1080 (discussed in the following sections), the basic mode of action of the poison is the same in all animals. 1080 acts by disrupting the "Krebs cycle", the complex metabolic pathway that breaks down food providing energy for cells to function. Once the energy reserves are depleted, death occurs fairly quickly from heart or respiratory failure. Possums become lethargic and usually die within 6-18 hours from cardiac failure. This is the most common cause

Why does New Zealand use more 1080 than other countries?

New Zealand uses approximately 80% of the world's production of manufactured 1080. In the period 1 July 2002 to 30 June 2003, this amounted to 2.3 tonnes of raw powder.

This is because New Zealand, uniquely, does not have large populations of native land mammals, nor does it have any native mammalian land carnivores. Nearly all other countries involved in controlling mammalian pests have many native mammals including carnivores. An aerial drop of 1080 in the USA, for example, would put at risk many other mammals in addition to the target pest. Often a pest species uses the same sort of food and behaves in a similar way to the native mammalian species, which means pest control must be specifically targeted. This imposes limitations on how and where pesticides such as 1080 can be used.

In New Zealand, the wild mammals in the forests and around Tb control areas are not native (except for bats), and are also usually regarded as pest species. Losses from these populations are, therefore, usually either desirable or inconsequential. This means New Zealand has a unique ability to use 1080 in aerial applications without adversely affecting native species populations.

of death in herbivores poisoned by 1080. Carnivores experience central nervous system disturbances and convulsions as their energy supplies are exhausted, and then die of respiratory failure. Animals that eat sub-lethal doses may show mild signs of poisoning, but the 1080 is metabolised and excreted within one to four days and the animal recovers. All traces of 1080 are, therefore, likely to be eliminated within one week[9].

Toxicology

Laboratory-based regulatory toxicology studies are required to characterise the toxicity of a chemical to target organs, as well as a chemical's potential to cause genetic or foetal abnormalities. Such tests define No Observable Effect Levels (NOELs) that form the basis for setting limits on acceptable exposure levels for the chemical, for example, in drinking water or other media. Evaluation and interpretation of toxicology data in New Zealand is generally in accordance with internationally accepted methods specified by the OECD, US EPA or WHO. A series of regulatory toxicology studies on 1080 were conducted in the USA in the early 1990s and are summarised in the proceedings of a 1993 science workshop[10]. This workshop, convened by The Royal Society of New Zealand, brought together scientists from New Zealand, Australia, the United States and South Africa to review national and international research on 1080 and identity further research needs.

In addition to these studies, a demand for more information on the potential risk from regular, low-level exposure to 1080, and on the potential of 1080 to cause cancer or birth defects, led to further studies being commissioned and directed by New Zealand scientists.

As described above, 1080 acts by disrupting the Krebs cycle, and animals receiving a lethal dose die from respiratory or heart failure. Studies on rats and sheep indicate that the target organs for sub-lethal 1080 poisoning are the heart and the testes, which are both tissues with high metabolic needs. In other words, the heart and testes need lots of energy to function normally.

When rats were given doses of 1080 (0.25 mg/kg-day), which are close to levels that can cause rat mortality (see Table 1), and over a long period of time (90 days), there was damage to the male gonadal tissue and sperm were significantly affected. Sperm showed reduced concentration and less motility, and a higher percentage were abnormal. There were no 1080-related effects on the same measures of sperm condition (concentration, motility, abnormality) at two lower dosage levels of 0.025 mg/kg-day and 0.075 mg/kg-day after 90 days.[11] The 0.075 mg/kg-day dosage level is the NOEL for repeat exposures in rats given 1080 orally, over a 90-day period. These physical effects occurred as the result of relatively high and prolonged sublethal exposure to 1080.

As a quite separate question, tests have recently been carried out to see whether 1080 could interfere with specific mechanisms of the endocrine system. Some long-lived chemicals that can accumulate in the body, unlike 1080, have been found to act as endocrine disruptors in humans and wildlife. Endocrine disrupting chemicals can be described as external chemicals that interfere in various ways with natural hormones that are responsible for maintaining homeostasis, as well as reproduction, development and some behaviours. Recently, laboratory tests were carried out to assess the ability of 1080 or fluorocitrate to mimic or interfere with the normal action of the female sex steroid 17ß-oestradiol, using an *in vitro* assay.[12] The results indicated that 1080 and fluorocitrate are unlikely to act as endocrine-disrupting chemicals through this particular mechanism. Additional testing is underway to find out whether 1080 can interfere with the actions of the male hormone, androgen.

Three different, complementary genetic toxicity tests were commissioned to determine whether 1080 alters genetic material, and therefore has the potential to cause cancer. The results of all three studies indicate that 1080 is not genotoxic, and provide strong evidence that it is not carcinogenic[13].

Tests have also been undertaken to determine the developmental toxicity of 1080, that is, the effect on embryo development during pregnancy. In studies conducted on rats, mild skeletal defects were observed in 20% of the litters of female rats exposed to relatively high doses of 1080[13]. However, no effects were observed at doses below 0.1 mg/kg-day[13], a dose rate similar to the NOEL for organ toxicity in rats (of 0.075 mg/kg-day, described above).

Comparison of species sensitivity

In general, 1080 is extremely toxic to animals. However species vary widely in their sensitivity to 1080. Comparisons can be made using a measure of the lethal dose called the LD_{50}. The LD_{50} is defined as the dose of 1080, expressed in milligrams of 1080 per kilogram of body weight (mg/kgbw), which will theoretically kill 50% of the test subjects of a specific population, under specified conditions. The lower the LD_{50} value, the more sensitive the species is to 1080.

The following table shows that dogs are particularly sensitive to 1080 poisoning, as are most other carnivores. Herbivores and birds are less sensitive, and reptiles and amphibians are less sensitive again. There is little LD_{50} data on New Zealand's native insectivorous birds, but data for Australian insectivorous birds indicate the LD_{50} ranges from 3.4 to over 18 milligrams per kilogram of body weight[14].

Fish and other aquatic fauna (including invertebrates) generally have very low sensitivity to 1080. Toxicity tests have been conducted in the USA on bluegill sunfish, rainbow trout and the freshwater invertebrate *Daphnia magna*[10]. Tests at different 1080 concentrations on sunfish (for four days) and *Daphnia* (two days) showed that 1080 is "practically non-toxic" (a US EPA classification) to both these species[10]. Rainbow trout were also tested over four days at four concentrations ranging from 39 to 170 mg 1080 per litre. From these results an LC_{50} can be calculated, which is the concentration of 1080 per litre of water which theoretically kills 50% of the test fish. The LC_{50} for rainbow trout was calculated to be 54 mg 1080/litre, making 1080 "slightly toxic" to rainbow trout according to the US EPA classification system[10].

Table 1. Oral toxicity of 1080

Species	LD_{50} (mg/kgbw)	Reference
Dog	0.06	15
Cat	0.3 - 0.35	16
Rabbit	0.35	17
Sheep	0.25 - 0.64	18
Cattle	0.4	19
Deer	0.5	20
Goat	0.3 - 0.7	18
Pig – feral pig	0.4 - 1.0	18, 21
Norway Rat	0.2 - 3.0	15
Possum	0.8	22
Ferret	1.4	23
Mallard duck	7.1	14
Weka	8.0	24
Silvereye/waxeye	9.25	14
Australian magpie	9.93	14
Tree weta	91	25
South African clawed toad	500+	18

How does this compare with the highest levels of 1080 found in water samples following 1080 aerial operations? Chapter 5.5 notes that only five water samples out of almost 1650 samples tested so far have reported 1080 levels of greater than 0.002 mg/litre or 2 parts per billion (ppb). This concentration is 27,000 times *lower* than the LC_{50} for rainbow trout. It is also 6,500 times *lower* than the concentration of 13 mg 1080/litre at which no mortality or sub-lethal effects were observed in trout after four days[10]. It is, therefore, reasonable to conclude that 1080 is most unlikely to cause mortality in freshwater species.

Estimates have been made of 1080 toxicity to humans, in the absence of formal toxicity testing. Indications are that an equivalent LD_{50} for humans is in the range of 2.0-10.0 mg 1080/kgbw[15], indicating that 1080 is as toxic to humans as to many other species.

The susceptibility of (or risk to) different animals during 1080 poisoning operations depends on how much 1080 they eat. Susceptibility is also affected by body size (see box, next page). The likelihood of a particular individual or species encountering 1080 poison will depend on the amount and type of bait used, its pattern of distribution, and the population densities and movements of the animals in and around the baited area[26]. Actual susceptibility to 1080 can only be accurately measured in field studies, which can be difficult to carry out due to the large number of variables involved. Field studies on the impact of 1080 poisoning operations indicate that estimates of potential susceptibility may over-emphasise the actual risk faced by many non-target species[26]. Nonetheless, these estimates are useful for

Susceptibility to 1080

Other factors beside sensitivity to 1080 can determine the effect of 1080 poisoning operations on animal populations. Body size is particularly important. For example, Table 1 shows that silvereye and Australian magpie have similar sensitivities to 1080. However, a magpie (at 320 g average weight) is about 23 times heavier than a silvereye (of average weight 14 g) and, therefore, would need to eat about 23 times as much 1080 as a silvereye to receive the equivalent of an LD_{50}. The silvereye is, therefore, much more *susceptible* to 1080 poisoning than the magpie. Similarly, although a possum is much more sensitive to 1080 than a silvereye, its much larger size means it would need to eat at least 16 times more 1080 than a silvereye to receive the equivalent of an LD_{50}. Hence, the ranking list in Table 1 is not the same as a ranking list of susceptibility when body weight is considered. This means the very small insectivorous birds tend to be the most susceptible, or "at risk" species.

assessing risks for rare and endangered species and can be used in designing operations to minimise the estimated risks. The outcomes of 1080 operations for bird populations and other native animals are described in Chapters 5.1 and 5.2.

Breakdown of 1080 in animals

Over the past 50 years, studies in laboratory animals of how 1080 is absorbed, metabolised and excreted, show that sub-lethal amounts are excreted unchanged and as less toxic compounds. Studies of the rate of 1080 elimination in mammals such as mice, goats, sheep and rabbits indicate that sub-lethal doses of 1080 are likely to be metabolised and excreted, so that no 1080 is detectable in tissues within approximately seven days[27]. By contrast, anticoagulant rodent poisons, such as brodifacoum, are extremely persistent in animal tissues. This comparatively rapid metabolism and excretion of 1080 from animals means that 1080 does not bioaccumulate (build up) in the food chain through sub-lethal doses.

1080 degrades more slowly in carcasses, where it might persist for some months. In colder temperatures, 1080 degradation is slowed even further. In these circumstances, 1080 poses a risk to dogs if they feed on tainted carcasses. Most dog deaths occur as a result of the dog scavenging on poisoned possums, particularly if they eat the stomach of the carcass.

Degradation of 1080 in the environment

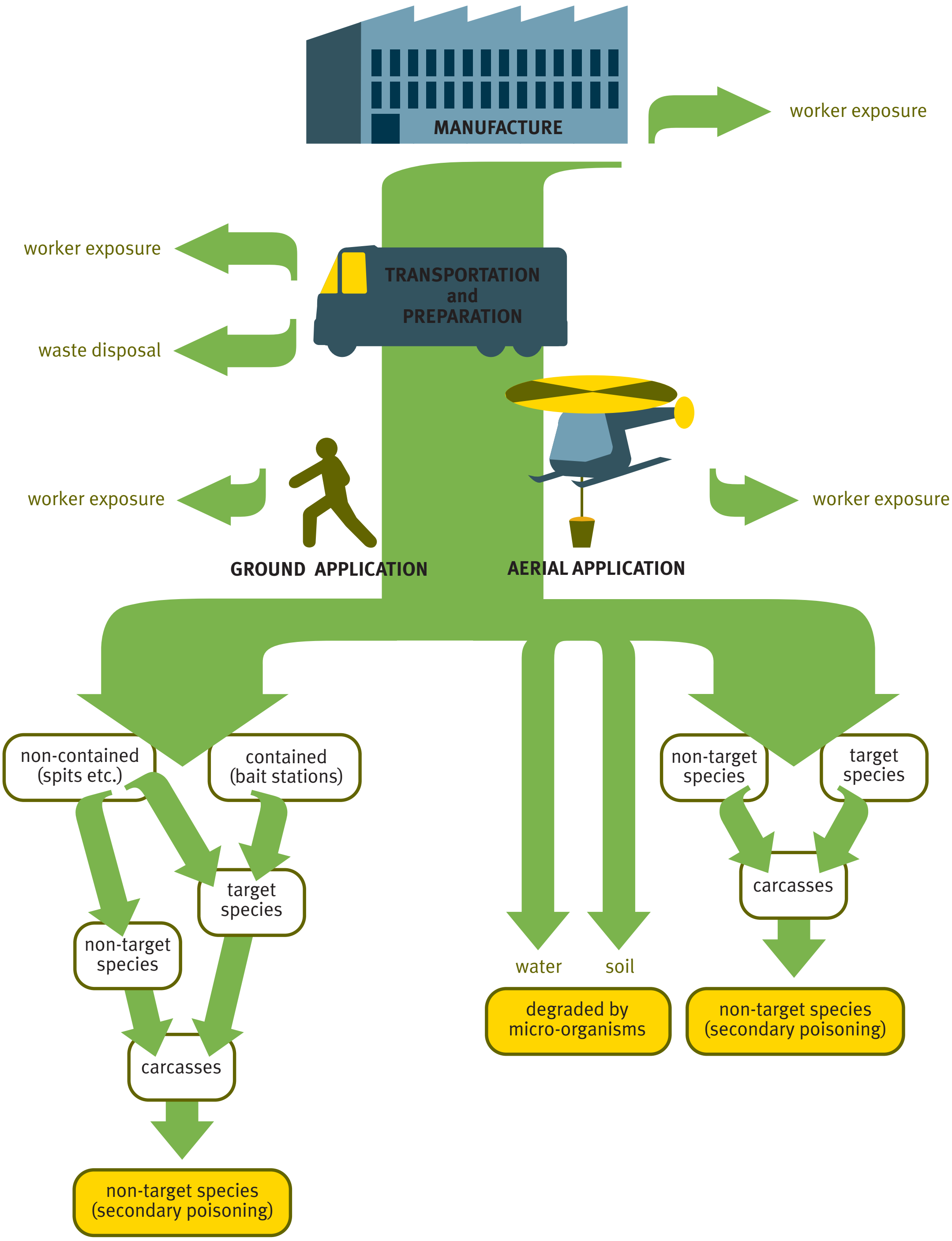
Studies show that micro-organisms in New Zealand soils will degrade 1080. The degradation occurs by enzymes defluorinating fluoroacetate (removing the fluorine atom). Ultimately, enzyme intermediates and non-toxic products are formed, such as glycolate[9]. Common soil fungi can also defluorinate 1080[28].

In laboratory experiments, the amount of 1080 remaining in soils was reduced to 50% after 10 days at 23°C, 30 days at 10°C and 80 days at 5°C[29]. Leaching experiments in soil showed that traces of 1080 might be leached through soil, particularly if heavy rainfall occurred shortly after 1080 was applied. These experiments indicate that 1080 does not persist long enough in the environment to have detrimental effects. The conclusion from a range of studies into the fate of 1080 in New Zealand soils is that "most New Zealand soils can be expected to contain micro-organisms with the ability to rapidly develop enzymes capable of degrading 1080"[28]. This means that any 1080 that leaches from baits or carcasses should have little persistence in our soils.

Bio-degradation of 1080 in the environment occurs even more rapidly in water. At 21°C, micro-organisms in water degrade 1080 in two to six days[29]. At lower temperatures, microbial action is slower and degradation might take one to two weeks, or longer, at temperatures below 7°C. Aquatic plants can also significantly affect 1080 degradation rates. In laboratory experiments, the presence of a native aquatic plant (*Myriophyllum triphyllum*) reduced concentrations of 1080 below detectable levels within one day (at 23°C) and within three days (at 7°C)[30].

The solubility of 1080 means that it is also rapidly diluted in water. This dilution effect, especially in flowing waterways, is more important in quickly reducing the level of 1080 to insignificant concentrations, than the rate of breakdown by micro-organisms.

Figure 4 **The life cycle of 1080**



In Western Australia the natural levels of fluoroacetate in plants may be several hundred times the concentration applied in 1080 aerial operations in New Zealand. No fluoroacetate has been found in water samples taken from the Perth water supply and catchment, despite the presence of some *Gastrolobium* species with higher concentrations of fluoroacetate in the leaves than in the 1080 baits used here.

4.2 The life cycle of 1080

The remaining sections in Chapter 4 cover the various uses of 1080, while Chapter 5 deals with the effects of its use on the environment. Figure 4 is a simple model of the 1080 life cycle.

The 1080 life cycle can be broken down into roughly four separate stages:

- Manufacture of 1080 products. Risks at this stage are to people involved in the manufacturing activities.
- Transportation and preparation for use of 1080 baits and products in the field. Associated risks are again mostly to people, although transport accidents could pose risks to the environment.
- Application - 1080 may be applied either aerially or using ground-based application methods. Both target and non-target species may be affected by the application of 1080, and secondary poisoning can occur if possum carcasses containing 1080 are eaten.
- Disposal of surplus or waste bait and containers.

Figure 4 shows the potential for 1080 to enter soil and water, primarily as a result of aerial operations. The fate of 1080 in the environment is discussed in Chapters 4.1 and 5.5.

4.3 How 1080 is used

1080 Products

1080 is manufactured in the USA and imported to New Zealand for formulation into 1080 products. Although most people think of 1080 in terms of the baits used for possum control, it is also used in a variety of different products, to control pest species ranging from wasps to goats. Table 2 lists 1080 products, the target species and the different situations in which they are used.

Cereal-based pellets are manufactured by compressing a mixture containing bran, kibbled grain and sugar, along with 1080, green dye and flavouring such as cinnamon. The green dye reduces the attractiveness of the baits to birds and the flavouring masks the odour of 1080 to possums, as well as deterring birds. Cereal baits are often preferred because they have a reasonably long shelf life, are easily handled, have a consistent amount of 1080, and degrade rapidly in the environment. Pellets are made in sizes ranging from 2 to 12 grams, and typically contain 1080 at a concentration of 0.15% (1.5 milligrams of 1080 per gram of bait).

Carrot baits are prepared just prior to use. Special cutting equipment cuts carrots into cubes weighing about 6 grams. This size makes them too big for most non-target species. The baits are sprayed with 1080 solution to give a concentration on baits of either 0.08% or 0.15%, the same concentration as used in pellets. Carrot baits are also dyed green and given an added flavour, both to deter birds and make the baits more palatable to possums.

Pastes and gels are also dyed green and masked with flavours such as cinnamon. Pastes are usually

Table 2 List of 1080 products and uses

1080 product	Target species	Use
Cereal pellets	possums, rodents, rabbits	Tb operations, conservation lands
Carrot baits (sprayed with 1080 solution)	possums, rodents, rabbits	Tb operations, conservation lands
Pastes	wallabies, possums, goats, rabbits, wasps	conservation lands
Gels	feral goats, deer, wallabies	conservation lands
Fish-based pellets	feral cats	conservation lands, island eradications

applied in bait stations or on raised earth “spits” (clods of earth). Any spits remaining after a certain period are overturned to bury the bait before stock are put back into the treated area. Soil microbes rapidly degrade the 1080 on the buried spits into harmless by-products. Some pastes are designed to be applied to leaves, so that pests such as goats can be targeted.

Research trials have shown that 1080 solution injected into hen eggs, which are then placed in special bait stations, can reduce stoat populations by about 90% within 22 days. Poisoned hen eggs have been used by DOC to control stoats in the Boundary Stream and Hurunui “mainland islands”[31].

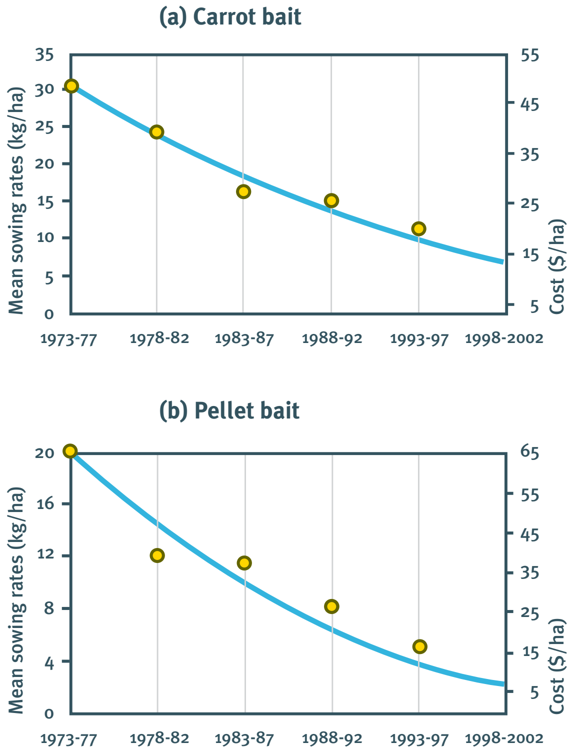
Aerial operations

During aerial application of 1080, bait is spread using custom-designed bait applicators incorporated into modified top dressing aircraft or suspended from helicopters. Over the past 25 years, there has been a significant reduction in the amount of bait distributed per hectare (sowing rates). Over this time, sowing rates have declined by a factor of over three for both carrot and pellet baits (see Figure 5). Pellet baits that used to be spread at a rate of 20 kilograms per hectare are now spread at 3-5 kilograms per hectare, and sometimes as low as 1-2 kilograms per hectare. Sowing rates of 3-5 kg/ha are now standard practice in aerial 1080 operations, for both carrot and cereal baits. For baits weighing about 6 grams, the range of sowing rates results in the distribution of about 830 baits per hectare (at 5 kg/ha) or 160 baits per hectare (at 1 kg/ha). In recent years there has been a move to larger baits of 12 grams, which further reduces the number of baits distributed per hectare. The reduced sowing rates have reduced the costs of operations and have lowered the risks to non-target species by exposing them to fewer baits and less poison.

Less bait

Why are fewer baits and less 1080 now used per hectare in aerial operations? A common reason for possums surviving aerial operations used to be due to poor bait coverage, meaning large areas within the treatment area might be missed entirely and receive no baits at all. Pilots now use global positioning systems equipment that allows them to track their

Figure 5 Trends in aerial application rates of carrot and pellet baits [Reproduced from: The Brushtail Possum, Page 146, Manaaki Whenua Press, Lincoln]



position very accurately while flying. This has led to a marked increase in the accuracy of the bait coverage. Improved bait quality has also meant fewer baits are needed per hectare. Further reductions are constantly being sought through improved bait-spreading machinery.

The application of baits containing 0.15% 1080, at the rate of 5 kg per hectare, means there will be 7.5 gm of 1080 (about 1.5 teaspoons), distributed per hectare. At 2 kg of bait per hectare, the amount of 1080 per hectare drops to only 3 gm. (less than a teaspoon). Nevertheless, there is always a need for a very high level of quality assurance in all phases of aerial control operations. Current procedures for using 1080 are described in Chapter 4.4.

Ground operations

In ground operations, 1080 is used in the form of pellets, paste or gel in bait stations, or as paste baits on the ground or in bait stations. Bait stations are commonly used where it is important to avoid exposing livestock, people, pets, or native animals to the toxin. Large bait stations can hold over a kilogram of pellets, which means that numerous possums or other pests can feed at each station over a period of days or weeks. When pellets are protected from rain they can last up to five weeks, compared with their deliberately short field-life when spread by air. Bait stations can be placed on trees out of the reach of many non-target species.

1080 paste is often used for ground control of possums. Paste made from apple pulp, invertase sugar and water, usually also contains cinnamon oil as an attractant or lure for possums, and a mandatory green dye to deter birds. Stock is usually taken off the control area. Paste bait is applied using an applicator gun onto upturned earth "spits", into small bait stations or onto retrievable cardboard squares or tin lids. Where possum numbers are high, as is often the case on farm/forest boundaries, baits may be replaced over several days before the spits are turned back to bury the residual paste, or bait stations emptied, and cardboard squares or lids retrieved.

Cereal 1080 pellets and carrot baits are occasionally spread by hand in small forest areas, where access by livestock and the public can be controlled. In all ground-based control it is important to prevent bait-shyness from developing in the possum population, by not using the same bait for too many poison cycles. This is achieved by changing the way the poison is presented (switching from pellets to gel) or by changing from one poison to another, (from 1080 pellets to cyanide, or vice versa, for example).

By air or by ground?

Management objectives, priorities, budget, risk management and cost-effectiveness all influence how control agencies use 1080.

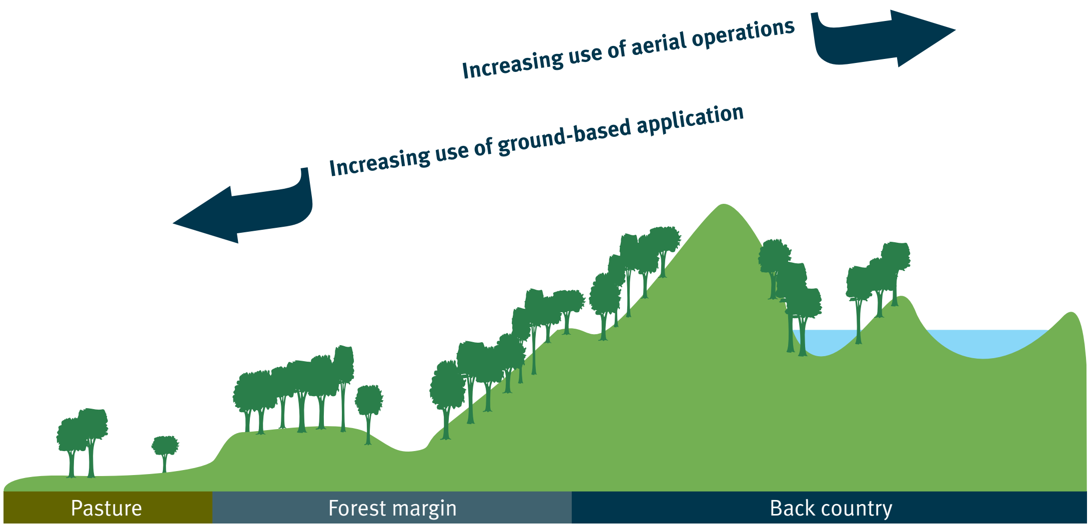
The major user of 1080 is the Animal Health Board, for the control of vectors of bovine Tb, usually possums, followed by Department of Conservation, for the protection of native plants and animals from a number of pests. Regional councils prepare regional pest management strategies under the Biosecurity Act 1993, and some regional councils use 1080 for pest control, although their use would be significantly less than either the AHB or DOC. (Some regional councils also undertake or manage control operations under contract to the AHB.) A much smaller amount of 1080 is used by other sectors, mainly the forestry sector, to control possums around areas with new pine plantings.

The different objectives of the AHB (controlling Tb vectors) and DOC (protecting conservation values) mean that they use different mixes of methods to achieve their objectives.

In Chapter 3, it was noted that AHB operations tend to comprise initial reductions (often involving large aerial operations as well as some ground control) followed by a second, maintenance phase, which tends to use more ground control. When DOC is controlling possums over large areas, it tends to favour aerial 1080 operations, particularly when the terrain is difficult and/or remote, and where there are other pests present. Even successful aerial operations need to be repeated at intervals of about eight to ten years to prevent the subsequent possum build-up from threatening conservation values. For some pests, however, DOC might rely on 1080 used in different products applied on the ground. This is the case for wasp control in beech forests, wallaby control, as well as possum and predator control in many accessible areas where bait stations are an effective and efficient technique.

Many possum management actions are designed to reduce possum densities to a 5% residual trap catch, that is, no more than five possums caught per 100 trap nights. In all cases, the choice of application method is influenced by the total area to be managed, terrain aspects, accessibility of the area, the initial density of possums and the cost, which is affected by all of these factors. The main contributor to the cost of an operation is the cost of labour. The longer it takes to get possum populations down to the desired density by hand, the more the labour costs will increase. Difficult terrain and access limit the area one person can work in a day, which drives up the costs. Sometimes areas can be close to farmland and

Figure 6 Trends in 1080 application methods



still be very difficult to work by hand. For example, dense undergrowth can be as problematic as cliffs. At the same time, aerial 1080 operations cannot be used in many farm areas because it is not possible to de-stock the area completely.

Figure 6 shows that, in general, the trend is to use aerial operations in more difficult country, well removed from human settlements and agricultural activities, and to use ground-based application in more accessible country.

While the actual proportions of ground versus aerial application vary from year to year as objectives change, 1080 remains the only vertebrate poison permitted to be applied by air in New Zealand. A 1978 report on 1080 use reported that 87% of 1080 used was applied aerially[32]. Although comparable data is not available on current operations, aerial application is still the major application method for 1080 use in New Zealand. As demonstrated by the application rates, however, the reduced density of application has resulted in more land area being able to be treated by an equivalent amount of 1080.

In summary, the aerial application of 1080 is often the only effective way to *simultaneously* achieve three major objectives:

- reduction of possum densities to below the 5% residual trap catch level
- reduction of pest populations of rats and other predators
- rapid achievement of low possum densities over large areas, which is particularly important to stop new outbreaks of Tb from spreading.

Aerial application, therefore, remains an important tool for all agencies. For all application methods, the need to optimise cost effectiveness and risk management continues to drive the search for better techniques.

4.4 Controls on the use of 1080

All aspects of the manufacture and use of 1080 in New Zealand are tightly controlled through legislation, regulations and operating procedures.

Controls over operators

The legislation governing the use of 1080 prior to July 2001 was the Pesticides Act 1979 and the Pesticides (Vertebrate Pest Control) Regulations 1983. The Pesticides Act has now been repealed by the HSNO Act 1996 but the Regulations will remain in force until the transfer of pesticides to HSNO management is complete. The functions of MAF with respect to pesticides are now the responsibility of the ACVM group of the New Zealand Food Safety Authority.

This has not changed the requirement that only people with a Vertebrate Pest Control (VPC) Operator's Licence are allowed to use 1080. Holding a 1080 licence allows the licence holder to apply, but not purchase, 1080. The licence is of use only if the holder is employed by a person or organisation that has been approved to be supplied with 1080. Applicants for a licence must be over 18 years of age, satisfy ACVM that they are a fit and proper person to use a controlled pesticide, and pass an examination.

As part of the transfer process, holders of 1080 licences will be required to obtain a HSNO Approved Handler Certificate (the HSNO equivalent of a VPC Operator's Licence) if they wish to continue to be 1080 applicators.

Controls over use

The VPC Regulations set out in detail the restrictions on places and methods of application of 1080. These define the circumstances when written permission is required from the appropriate authority for any use of 1080, the approvals required for aerial operations, and the requirements for public notification of 1080 operations. In particular, permission is required from the Medical Officer of Health for all aerial applications of 1080, for all operations on land to which the public has access, and for operations in proximity to water supply catchments. Regional or unitary authorities may also require a resource consent for 1080 operations, depending on how and where it is being applied.

Procedures and standards for use

Strict codes of practice require that appropriate protective clothing is worn by all those involved in the manufacture or handling of 1080. Standards for the safe handling, transport and disposal of pesticides, including 1080, have been developed to meet the requirements of relevant legislation and regulations.

DOC has a comprehensive set of procedures for "Safe Handling of Pesticides" as part of its Quality Conservation Management system. These procedures meet all the legal requirements, and any user of pesticides working on lands managed by DOC must follow the relevant standard operating procedures. The module details the procedures to be followed by staff, contractors or sub-contractors from the pre-operational phase, to transporting, applying 1080 to carrot bait, using pellet baits, bait stations, hand spread application, aerial operation, post-operational clean-up, disposal, accidents and first aid. Under these procedures, wearing protective equipment such as gloves and overalls is compulsory whenever handling 1080. Respirators and eye protection are also required when handling 1080 in large quantities, such as during aerial operations.

Separate standards and procedures detail the requirements for obtaining consents for all animal pest control operations run by the Department. DOC also requires an Assessment of Environmental Effects (AEE) to be prepared when pesticides are being used for pest control on land managed by DOC, or in DOC operations. These assessments require appropriate information about how potential risks and adverse effects will be managed, including those risks to the public.

For AHB operations, users of 1080 must have in place standard operating procedures that are approved by AHB's regional vector managers. Where AHB operations occur on land administered by DOC, they are subject to DOC's approval, and the processes required for an AEE.

5. Outcomes of 1080 use

5.1 Outcomes for bird populations

Over the past 30 years, there has been extensive and increasingly sophisticated monitoring of bird populations after aerial 1080 operations. Scientists conclude on the present evidence that "*the ecological costs of using toxins is much less than the damage if they are not used*"[7]. In fact, when aerial operations are timed to decimate rat and stoat populations as well, then birds benefit, especially endangered species, as significantly more adult birds and nestlings survive.

This section summarises results from bird counts, bird banding, radio tracking and nesting studies carried out to assess the impacts of possum control on non-target species[33].

Many operational improvements have occurred since 240 native birds, mostly insectivorous species, were found dead after four aerial 1080 operations in 1976 and 1977. Those operations had all used poor quality baits – undyed, raspberry-lured, unscreened carrot baits, with a very high percentage of "chaff". Some 40% by weight of the carrot was small fragments (chaff) of less than one gram, which were both extremely numerous and lethal to small birds. Screens now remove pieces of carrot weighing less than two grams. Raspberry lure is banned, carrot baits must be dyed green and the addition of cinnamon flavour deters birds while masking the 1080 odour to possums.

Since bait screening was introduced, there have been few dead birds found in ground searches after aerial operations. Between 1978 and 1993, extensive monitoring after 70 aerial 1080 operations, using screened carrots or cereal-based baits, found a total of 83 dead birds, of which 34 were native species. Blackbirds and tomtits were the species most commonly found dead. This was less than one detected native bird death per operation. Monitoring surveys indicate that few bird deaths occur from aerial 1080 operations as long as best practices are followed.

However, since not all birds that die from 1080 poisoning are found in searches, it is important to use other methods to assess 1080 effects. It is critical to determine whether the bird *populations* are more or less abundant after 1080 use, even though some *individuals* are killed. This is because the impacts on populations *as a whole* are more important for overall survival than the fate of a few individuals. One method for estimating population abundance is from 5-minute counts of birds seen or heard in areas before and after aerial operations. These results are compared with counts made at the same time in non-poisoned areas. This was done for 24 aerial 1080 operations, using carrot or cereal-based baits, between 1978 and 1993. The number of common bird species counted in poisoned areas did not change two to eight weeks after poisoning in relation to the numbers of birds counted in non-poisoned areas. This suggests there were no negative impacts on the populations from the 1080 operation.

Survival of kokako and fernbirds

One technique for more accurately tracking birds during 1080 operations is to band them with coloured leg-bands and check on their survival after the operation. During a number of aerial operations using 1080 cereal baits throughout New Zealand, 47 kokako were leg-banded. All 47 individuals of this endangered species survived. This result was particularly encouraging, as studies have shown that possums and ship rats are the major causes of poor nesting success for kokako. Seven fernbirds were also leg-banded, and all survived aerial operations using cereal baits.

Radio-tracking rare species

Another accurate way of examining the effects of aerial 1080 operations on rare or endangered species is by tagging them with radio transmitters. This has been done for about 230 birds, representing seven species, over the last decade. Birds are fitted with radio transmitters before the operation and then checked some weeks afterwards. The results, shown in Table 3, are very reassuring, indicating very low mortality from poisoned baits or secondary poisoning. Monitoring using radio-tracking is ongoing in various studies around the country.

The two dead birds (one weka and one morepork) both contained residues of 1080. Importantly, none of the endangered brown kiwi, great spotted kiwi, blue ducks or kaka died within a month of the operations. It is reasonable to conclude that aerial 1080 operations for possum control pose little risk to these

Table 3. **Survival of radio-tagged birds after aerial 1080 operations**

Bird species	Total with radio-tags	Bird deaths	Bait type used
Brown kiwi	61	0	Cereal
Great spotted kiwi	16	0	Cereal
Weka	32	1	Cereal
Morepork	7	0	Cereal
Kaka	57 – 62	0	Cereal
Morepork	6	1	Carrot
Blue duck	19	0	Carrot
Kaka	38	0	Carrot
Kereru (pigeon)	15	0	Carrot

Table 4. **Breeding success of robins after 1080 control**

	Nesting success	Fledglings/pair	Adult females eaten by predators
Before 1080 control	11%	0.4	28%
After 1080 control	72%	3.7	0%

species. On the contrary, bird populations benefit from the reduction of possums and other predators.

For example, the kaka population in part of Pureora Forest Park increased by 33% within six months of aerial control in 2001. All of the 20 females with radio transmitters in the treated area survived, whereas in the nearby Waimanoa Forest, stoats killed at least five of nine kaka females during the 2001 nesting season.

In 2001, before an aerial 1080 operation in Tongariro Forest, 32 kiwis were radio-tagged. All were still alive six months later and 40% of their chicks survived. Compare this to the usual survival rate of kiwi chicks which was less than 5% before the 1080 operation. The aerial operation, therefore, appears to have significantly improved chick survival and left the kiwi adults unharmed as well.

Effects on insectivorous birds

Insectivorous birds are probably the species most at risk from aerial 1080 operations (see Susceptibility to 1080, box in Chapter 4.1). These small birds are also very vulnerable to predators such as rats and stoats. Their small body size means that carrot chaff coated with 1080 can provide a lethal dose, while their diets can include invertebrates that may have eaten some 1080 from baits. Robin and tomtit populations, two common insectivorous species, have been monitored after carrot and cereal bait aerial operations.

Robin and tomtit females usually raise two broods each year. Two aerial 1080 operations at Pureora Forest Park, in 1996 and 1997, reduced possum and rat populations to very low densities. The benefits to the robin population the following year are shown in Table 4.

Robin populations increased by 28% after the 1996 operation, due to much better breeding success[34]. The proportion of females also rose significantly (from 35% to 44%). This positive outcome was despite a failure to adhere to the protocols for preparing carrot baits during the 1996 operation. As a consequence, there was a high proportion of chaff produced that caused about 50% mortality in the robin population. In 1997, when the correct bait protocols were followed, robin mortality was only 9%. This was not significantly different from robin mortality in a non-treatment area. This underscores not only the importance of good operational procedures being followed, but also the significant benefits to small birds when aerial operations are timed to reduce predators just before the breeding season.

The success of possum and predator control in Pureora Forest Park has meant that, in the past two years, 150 North Island robins have been able to be transferred from the Park to boost numbers in four other reserves.

The results of monitoring tomtit populations suggest that sowing rates and type of bait are important influences on tomtit survival[35]. Between 1994 and 1996, three aerial operations that used carrot baits, sown at 10–15 kg/ha, caused high losses of tomtits. One of these was the 1996 operation in Pureora Forest Park, referred to above, which had produced a lot of carrot chaff. By contrast, aerial operations in 1998 and 2001 that used larger 12 gram cereal baits, sown at the lower rate of 3–5 kg/ha, caused little or no mortality in the tomtit populations.

A recent study of five operations in the North Island tested the impacts of cereal and carrot baits on tomtits, using sowing rates of 3-5 kg/ha.[36] It confirmed that 12 gm cereal baits had little, if any, immediate impacts on tomtit populations at these sowing rates. After three aerial operations using carrot bait at 3-5 kg/ha, however, tomtit numbers initially declined by about 10-40%. The longer-term recovery rates of these populations were not monitored. The study authors stressed that these results may be specific to tomtits, since the 1997 carrot operation in Pureora Forest that had a substantial impact on tomtits had no apparent impact on North Island robins.

For this reason, in some operations, the use of cereal baits is preferred over carrot baits. Like robins, tomtit nesting success improved after a 1080 operation that poisoned most rats, possums and stoats[37].

Secondary poisoning effects

The small numbers of predatory and scavenging birds, such as harriers and moreporks, that have been found dead after 1080 operations have probably died from secondary poisoning after eating dead or sub-lethally poisoned possums, rodents, small birds or invertebrates. The low level of mortality observed is not regarded as a threat to the species involved. Secondary poisoning from eating invertebrates that have eaten some 1080, is theoretically possible for insectivorous birds. Monitoring results show that if such losses occur, they are quickly compensated for by the increased breeding success.

5.2 Outcomes for other native species

Bats

New Zealand has two species of bat: short-tailed and long-tailed. The short-tailed bat, which is primarily insectivorous but also eats fruit, nectar and pollen, did not eat carrot or cereal-based baits in feeding trials. The short-tailed bat feeds on ground-dwelling invertebrates, which are known to eat 1080 baits. Since bats may be vulnerable to secondary poisoning after aerial 1080 operations, it is important to determine the possible effects on short-tailed bat populations. One bat population was monitored in 1997, following an aerial operation using cereal-based baits, and showed no detectable impacts from poisoning[38]. More research is required to check for possible impacts, but monitoring bat populations is difficult. However, like native birds, short-tailed bats benefit from reduced possum numbers, as possums are competitors for the fruits and flowers that the bats feed on.

The long-tailed bat is entirely insectivorous, feeding in flight, mainly within or above the canopy, on flying invertebrates. This species is, therefore, only ever likely to suffer secondary 1080 poisoning, and the risk of this is considered minimal.

Frogs and lizards

Overseas studies indicate that both frogs and lizards are less sensitive to 1080 than most other groups of animals. They would need to eat large quantities of poisoned bait or poisoned insects to receive a lethal dose. New Zealand's three species of native frog have very restricted distributions and are rarely exposed to aerial 1080 operations. They are also not known to eat carrot or cereal-based baits. There was no evidence of any impact on populations of Hochstetter's frog or Archey's frog from two aerial 1080 operations that included frog habitat.

There are 17 species of native geckos and 22 species of native skinks in New Zealand, but there is little information about how many of them live in areas where aerial 1080 operations have been carried out. New Zealand lizards feed mostly on insects and theoretically might be at risk of secondary poisoning. Australian experiments strongly suggest that, given their high tolerance to 1080, lizards would not be able

"Mainland Islands" – Testing the arguments

Whether "silent forests are caused by pests" or "silent forests are caused by 1080" is an argument that needs to be evaluated, based on good evidence, in discussions on the use of 1080 in New Zealand. If aerial application of 1080 is responsible for our "silent forests", then places where it has been used intensively should be devoid of birdsong. "Mainland islands" can be used to test if this is true. These are areas of forest with endangered birds, which are largely isolated by farmland or other landscape features from close sources of predators. DOC initiated six mainland island restoration projects, totalling 11,500 hectares, during 1995 and 1996. The same type of intensive predator control is applied there as on offshore islands that have been used successfully as safe refuges for endangered species.

The evidence from mainland islands is very encouraging. The intensive control of predators, often using aerial 1080 operations and timed to kill rats and stoats as well, has resulted in higher breeding success and increases in the populations of endangered birds. Far from reducing bird numbers, these 1080 control operations have increased them. After four aerial 1080 operations in 11 years, Waipapa in Pureora Forest contains the only increasing population of kaka on the North Island. Some mainland islands now have such healthy populations that they are used as a source of birds to restock populations that have been decimated or extinguished by predators. Mainland island initiatives, although costly, represent an important tool to not only to protect rare species, but also to contribute to the wider goals of ecological restoration[39].

It is important to be clear about cause and effect relationships. Silent forests are silent because of decades of unrelenting predation on native species by introduced predators – rats, stoats, ferrets, cats and possums. Using 1080 in these forests has been successful in helping restore the birdsong that was diminished long before 1080 was first used.

to consume enough 1080 in poisoned insects or other animals to receive a lethal dose. Lizards have not been monitored after aerial 1080 operations, although this would be advisable.

Freshwater animals

Aerial operations avoid dropping baits near major waterways, with the result that monitored 1080 levels in waterways are zero or at trace levels only (see Chapter 5.5). The breakdown and solubility properties of 1080 also mean that any presence is transient, and the rare traces that do occur disappear in a few days. Given the low sensitivity of fish and freshwater invertebrates to 1080, the risk to freshwater species is probably negligible.

Freshwater eels

The long-finned eel, called "tuna" by Maori, is a taonga species for many iwi and is unique to New Zealand's streams and rivers. Recent preliminary research by Landcare Research (Manaaki Whenua) examined the possible effects of 1080 on long-finned eels, including the risks to humans if eels had eaten poisoned possum tissue, in the unlikely event dead possums got into waterways. There was no evidence that eels would eat 1080 cereal baits that are added to water, nor was any 1080 detected in eel tissue from water contaminated by baits.

Captive eels were presented with "sausages" filled with poisoned possum tissue of either minced muscle or gut tissue. The tissue in the "muscle sausage" contained about 1400 parts per billion (ppb) of 1080; the "gut sausage" contained about 8300 ppb of 1080. Eels ate both types of sausages, but none later died. The amount of 1080 in the eels dropped over time, but low levels were still detected 11 days after eels had fed on poisoned possum tissue. The highest 1080 concentration remaining in an eel from a "gut sausage" was measured at about 38 ppb after 3 days. A 60-kg person would need to eat about 5.5 tonnes of eel flesh at this concentration to risk death, based on an estimated LD_{50} for humans of 3.5 mg/kg body weight (see Chapter 3, "Comparison of species sensitivity" for explanation of LD_{50} values). These are all preliminary research findings only and are still subject to assessment by the Animal Health Board's peer review protocol.

Possum control in Egmont National Park

DOC has relied heavily on aerial application of 1080 to achieve control of possums in Egmont National Park, for the protection of the forests and wildlife of the park.

In 1993 and 1994, DOC began a concerted possum control programme. Aerial drops of 1080 achieved an average 70 – 80 % reduction in the possum population. Extensive monitoring of natural and reticulated water supplies was undertaken, and no measurable contamination of water by 1080 was found. Similarly, no decline in native bird populations was recorded. In contrast, there was a significant improvement in the condition of forest trees that were being monitored. Possum browse on mountain totara and mountain cedar was reduced to almost zero. Many people, including Park neighbours, commented on the forest improvement and subsequent increase in native bird populations.

The initial aerial knockdown operation was designed to reduce to a negligible level the impact possums had on the forest canopy. This operation was complemented by ongoing programmes in the area immediately surrounding the Park boundary, undertaken by the Taranaki Regional Council and local landowners, and smaller scale programmes undertaken by DOC. These programmes have kept the possum population below pre-treatment levels, but possum populations increased in the Park and re-treatment was necessary to protect forests and wildlife.

The aerial application of 1080 in Egmont National Park in 1994/95 was controversial and generated significant disquiet among a large number of people. Consequently, when re-treatment of the Park was planned for 2002, DOC placed considerable emphasis on consulting with and informing those people who might be affected by the operation, and informing the public in general. As part of a wider programme to talk about many of the Park/neighbour issues, all of the Park neighbours were visited in 2000 and their views and concerns, including those about possum control and 1080, were recorded.

Further consultation with Park neighbours and local iwi and hapu took place in 2001 to discuss the planned 1080 operation in particular, and to identify specific concerns and information requirements. All concerns were addressed by either modifying the operation, providing detailed information and/or by providing advice and assistance with issues such as managing the risk to dogs, water supplies and livestock.

Public interest and concerns were addressed by media coverage and the publication of two detailed newspaper supplements that went to every household in Taranaki. As well as providing information about possum control and 1080, they covered the detail and results of the Department's monitoring in the Park and reasons for planning further possum control.

A comprehensive Assessment of Environmental Effects (AEE) was prepared and this document provided the basis for consultation and consents from agencies such as the Medical Officer of Health and district councils.

The re-treatment of the Park, including a major aerial operation, was undertaken in the winter of 2002 and possum populations were successfully reduced to very low levels (< 1% residual trap catch). Although public interest in the operation was high, very few people expressed opposition and there was little protest. As in 1993/94, water and bird monitoring did not detect any adverse impact during or after the operation, and possum control and monitoring of the Park will continue.

Invertebrates

The seven most common groups of ground-dwelling invertebrates that have been seen feeding on carrot and cereal-based baits are ants, beetles, springtails, amphipods, harvestmen, mites and weta. The impact of aerial 1080 operations on invertebrate populations has been monitored by four pitfall trapping studies and two direct counting studies. Three of the four pitfall trap studies showed no effects on ground-dwelling invertebrates, up to 6 or 12 months after cereal-based and carrot bait aerial 1080 operations[40]. The fourth study showed short-term reductions in the numbers of ground-dwelling invertebrates. However, there were 10 times the normal number of baits within one metre of the pitfall traps in this study, which was highly likely to have affected the results. This study was eventually repeated with normal bait densities and no differences were detected in invertebrate levels between the treatment and control areas.

In one of the two studies that counted invertebrates feeding after aerial 1080 operations, numbers declined within 20cm of the baits, but recovered within three days after removing the baits. These studies suggest that it is only invertebrates living within a short distance (about 20cm) of a poison bait that are potentially at risk. As the number of baits dropped per hectare has decreased significantly, so too has the potential exposure of invertebrates to toxic baits. Neither of these studies suggested there would be long-term negative effects on ground-dwelling invertebrate populations, which is also the conclusion from the scientifically-robust pitfall trapping studies.

Possible impacts on tree weta and cave weta have also been studied by monitoring the occupancy of artificial nests before and after 1080 application. There was no change in nest occupancy following 1080 bait application around the nests[41].

Although invertebrates get less public attention than native birds, they play vital roles in all ecosystems. The scientific evidence to date is that insect populations are not adversely affected by aerial 1080 operations. On the contrary, possums, along with rodents, are major predators of native invertebrates (see Chapter 3.4) and low possum numbers benefit many insect and other invertebrate species.

In summary:

> *"Despite the loss of some individuals, there is no evidence of deleterious long-term impacts of 1080 poisoning for possum control on populations of any non-target species that have been adequately monitored. Mortality from poisoning either is occurring in place of mortality from other causes such as predation or winter starvation, or is compensated for by increased breeding success of survivors."*[33]

5.3 Outcomes for introduced animals

1080 has been used successfully to control pests other than possums. Combined possum and rodent pest control is often carried out using cereal-based baits, with 1080 fed from bait stations. Once low levels of possums and rodents have been achieved this way, levels can be maintained with anticoagulant baits in the bait stations. One such operation, at Trounson Kauri Park in Northland, was monitored for possum and rodent mortality and also for secondary poisoning effects on predators[42]. The initial poisoning reduced rats to negligible levels, and also killed feral cats, stoats and ferrets within three weeks, through secondary poisoning after eating poisoned prey. An aerial 1080 operation against possums in Pureora Forest (central North Island) also killed a large proportion of stoats in the same way[43].

The use of anticoagulants for possum and rodent control can have similar impacts on mammalian predators. Some managers suggest there is potential for secondary poisoning to be used as a predator eradication tool on off-shore islands where predator reinvasion is unlikely.

Possum operations using 1080 have killed red, fallow, sika and white-tailed deer, as well as goats, pigs, rats, mice, cats, ferrets and stoats. By far the most commonly killed non-target pests are rats. Ungulates and rodents die from eating poisoned baits. The impacts on populations of these species have been monitored on only a few occasions. Ship rat populations were reduced by 87–100% following six aerial 1080 operations for possum control, but the populations recovered within four to five months. One monitored stoat population was eliminated by an aerial 1080 operation, but recovered within nine months through immigration and breeding.

People acknowledge that killing the predators of our native species, such as rats, stoats and ferrets, helps conservation goals. However, some recreational hunters view the non-target deaths of deer and pigs as an unwelcome consequence of aerial 1080 operations. This is despite clear evidence that deer have serious adverse impacts on native forests and are officially regarded as pest species. In some communities, pigs and deer are considered to be an important resource, while in others they are widely regarded as significant pests.

The proportional loss of deer populations as a consequence of aerial 1080 operations has been highly variable. The loss of deer was greatest in those situations where deer were in poor condition (low body weights) and where their food supplies were limited. In situations where these conditions do not apply, minor losses of deer are usually replaced in one or two seasons. For this reason, aerial 1080 has rarely been used as a tool to manage pest populations of deer.

Trials in the winters of 2002 and 2003, conducted by Landcare Research, showed that carrot baits coated with a deer-repellent compound still successfully killed possums, while appearing to protect most, if not all, of the deer where it was used. Some work has also been done using this repellent on cereal 1080 baits. Again, the baits repelled captive red deer, but were eaten by captive possums. Testing the repellent in cereal baits on wild deer will be the next phase of the research.

Pig populations are rarely affected by aerial 1080 operations. While smaller pigs are occasionally killed, adult pigs usually survive. This is because pigs have a strong ability to vomit when they feel any ill-effects from the food they consume. In some areas, an increase in pig populations after 1080 operations, resulting from increased food supplies, is arousing concern.

The use of 1080 to specifically target pest populations of deer, goats and other large animals, generally requires the use of targeted ground-based techniques such as gel application to natural baits (leaves). Currently the use of such techniques is usually considered only in special circumstances, where techniques such as recreational and commercial hunting have been unable to achieve the required control.

5.4 Long-term effects on ecosystems

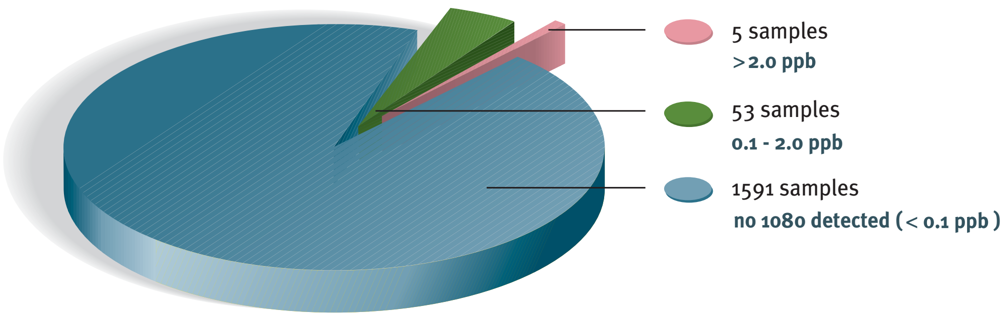
In 1998, the New Zealand Ecological Society held a special scientific meeting to examine the ecological consequences of using poisons in general, for the control of mammalian pests (see the New Zealand Journal of Ecology Vol. 23, No.2, 1999). The major review paper at that meeting concluded that the ecological benefits of using toxins for ecosystem management outweigh the costs[7], while noting that research on toxin use should continue.

Research, summarised in Chapter 4, also shows that 1080 degrades quickly in the environment, although degradation is significantly slower in cold dry weather. Accumulation in, or contamination of, soil or the environment does not occur because common bacteria and fungi degrade 1080 into harmless by-products. Likewise, research has shown that microbial degradation of 1080 in water is very fast. Animals that consume sub-lethal doses metabolise and excrete 1080 within one to three days, which means it does not persist or accumulate in the food chain. It can persist in carcasses long enough to cause secondary poisoning in predators such as rats, stoats, feral cats and dogs.

If 1080 does not persist in the environment, what are the long-term benefits of its use? There is evidence that significant reductions in possum numbers can benefit individual forest species as well as forest systems in general[44]. Possums reached the northern forests of Waipoua in the 1960s and were causing visible damage to the canopy by the late 1980s. In 1990, an aerial 1080 operation reduced possum numbers by about 87% and ground trapping has since kept them at low levels. Eight tree species were monitored between 1990 and 1994. All eight "indicator" species showed significantly more defoliation in a non-treatment area compared to the treatment area.

Several species of native mistletoe are favourite foods for possums, as well as providing nectar for birds such as tui and bellbirds. After being almost wiped out by possums in many forests, mistletoes

Figure 7 Results of water monitoring after aerial 1080 operations (1991-2003)



Ministry of Health recommended maximum concentration of 1080 in drinking water: 2.00 ppb

At this concentration of 1080 a 60 kg person would have to consume:

- 60,000 litres of water for a lethal dose of 1080
- 2,300 litres of water per day to suffer adverse sub-lethal effects.

do recover after 1080 operations, as long as possum densities are kept low. Preferred possum food species, such as northern rata, fuchsia, kohekohe and Hall's totara, have shown significant recovery after heavy reductions in possum numbers, while similar trees in non-controlled areas have not. A 30-year possum control programme using 1080 in the Otira Gorge of Westland has shown positive results. Giant southern rata, once threatened through defoliation, now flower regularly, and possum-vulnerable fuchsia trees, along with other native plants, are thriving.

Forest recovery can be complicated, however, by the impacts of other pest species on the forest ecosystem. Even if possums are kept at very low numbers, ongoing browsing of seedlings by deer or goats on the forest floor can prevent the re-establishment of many species, thus disrupting the normal patterns of forest dynamics[45]. In addition, birds are important for the dispersal of forest fruits and seeds. Predation on native birds by rodents, stoats and ferrets reduces bird numbers, which potentially reduces the dispersal of many forest species. The direct and secondary targeting of these predators by 1080 operations benefits forest regeneration as well as assisting bird recovery.

5.5 Monitoring waterways after 1080 operations

Because 1080 is water soluble, extensive water sampling programmes have been conducted following aerial operations, throughout the country. Over a 14 year period (1990-2003), Landcare Research has analysed 1649 water samples collected from streams on the days following application of 1080, and also after subsequent heavy rain, following 230 possum control operations[46]. The results are shown in Figure 7.

In 96.5% of the samples (1591 samples) there was no trace of 1080, that is, no 1080 could be detected above the level of detection of 0.1 parts per billion (ppb). 1080 was detected in 3.5% of samples (58 samples). Figure 7 shows the proportion of samples with no detectable 1080, those where less than 2 ppb were present, and the five samples where 1080 levels exceeded 2ppb. However, in 51 of those 58 samples the 1080 recorded was less than 1 ppb. Those samples where 1080 was found to be present were mostly taken from small streams, and 1080 baits were present in the water. Other samples from the same streams did not contain detectable concentrations of 1080, which showed that continuous contamination of the waterway did not occur.

Of the 1649 samples analysed, 107 were taken from reticulated town water supplies. All of these samples were free of detectable1080.

When 1080 was detected, it was present only for a matter of days. The solubility of 1080 and experiments demonstrating its degradation by micro-organisms indicate that, on the few occasions it is present in water after aerial operations, it has a transient presence only. It is also important to note that samples have been taken predominantly from within or adjacent to operational areas, where there would be the greatest chance of detecting 1080 in water.

While it is preferable to treat all possum habitat, including riverbanks, to ensure as few possums as possible survive the operation, the current practice by Medical Officers of Health requires that 1080 baits are not deposited within at least 20 metres of major waterways during aerial applications. This is achieved by using airborne navigation systems, and planning flight paths to avoid water supply reservoirs and feeder rivers. Where appropriate, contingency plans are made with urban and private water supply operators in case of accidents.

The potential risk posed by the occasional presence of 1080 in water is discussed in more detail in the following section. However, as a broad indication, the concentration of 1080 detected in all but three of the 1649 samples analysed was less than the provisional maximum acceptable value (PMAV) for 1080 in drinking water of 3.5 ppb, set by the Ministry of Health (Ministry of Health, 2000). The current standard was lowered from the previous PMAV, set in 1995, of 5 ppb. This new standard is a very protective value that incorporates a large safety factor. The Ministry has also set guidelines recommending that water taken from catchments in which 1080 has been applied should not be used for human supply until tests show that the concentration is below 2 ppb, approximately 50% of the PMAV. Only five of the 1649 samples analysed contained 1080 concentrations greater than 2 ppb.

There has been no evidence of 1080 presence in reticulated water to urban or rural water supplies in New Zealand. Clearly, however, it is most important to follow all specified safety procedures in any 1080 operation, and to use control methods that are appropriate to the risks needing to be managed.

5.6 Effects on people

Human exposure to 1080 may arise from drinking contaminated water, direct contact with baits or 1080 solution, or by consuming food, particularly meat from animals that may have consumed 1080. Each of these potential exposure routes is discussed in the following sections.

Exposure to contaminated water

The most significant potential exposure route for the general public is likely to be the contamination of surface water in water supply catchments[13]. As indicated in Chapter 5.5, 1080 has been detected in surface water only occasionally during an extensive sampling programme of water bodies within or adjacent to operation areas, where contamination is most likely to be found. Still, potential contamination of water supplies remains one of the most cited public concerns about 1080 operations, particularly aerial operations.

However, based on an LD_{50} of 2.0 mg/kgbw for humans, a 60 kg person would need to drink 60,000 litres of water containing 2 ppb of 1080, in one sitting, to absorb a fatal dose. Even allowing a significant safety margin (typically applied to allow for sensitivity in the general population and uncertainty in the toxicological studies), a safety factor of 1000 would still require a person to drink at least 60 litres of water containing 2 ppb of 1080 before being considered at risk. Given that the daily intake of water of an average person is typically estimated to be around two litres per day, it is clear that the risk of ingesting a lethal dose of 1080 at these concentrations is negligible.

The No Observable Effect Level (NOEL) for toxicity in rats (of 0.075 mg/kg-day[11], Chapter 4.1) however, does indicate that regular intake of 1080 contaminated water could cause sub-lethal effects. Based on this NOEL, a 60 kg person would need to drink 2,300 litres of water containing 2 ppb of 1080 per day, for an extended period of time, for sub-lethal effects to occur. Allowing a safety margin of 1000, a person would need to drink their entire daily intake of two litres per day of water from a contaminated source, for a period of weeks, to be considered potentially at risk. Similarly, a 60 kg pregnant woman would need to drink at least three litres per day, all of

An unlikely worst-case scenario

As a way of estimating the risk to human health, consider the concentration of 1080 that was detected in a water sample during the last 13 years of monitoring after 1080 aerial operations. That one sample, out of the 1649 taken during this period, had the highest recorded level of 1080 at four parts per billion. It was not taken from a water supply, but from a small, shallow stream just two hours after an aerial 1080 operation. A second sample from the same site 24 hours after the operation had only one part per billion. This rapid drop in concentration reflects the very high solubility of 1080 in water. Although it was a small stream, the dilution property of 1080 had quickly diminished the level of 1080 at this site.

What were the potential health risks? Imagine a 60kg person was camped next to the stream at the time of the operation and was relying only on this stream for water supplies. Assume the camper drank from the same place and at the same time that the first water sample was taken. The risk of acute lethal effects would require the person to drink, in one sitting, about 20,000 to 30,000 litres (if it was possible to do so - see Chapter 5.6 for exposure risks). (Daily average intake of water is about 2 litres.)

What about more realistic risks of sub-lethal health effects? These could possibly occur only if a person has access to water with a significant level of contamination for weeks at a time. Recall that the water at this site lost 75% of its 1080 concentration in just one day. The dilution of 1080 would have continued at a similar rate in the following days. Within a week any remaining 1080 would probably have been below the level of detection.

In the Drinking-Water Standards for New Zealand, issued in 2000 by the Ministry of Health, the Provisional Maximum Acceptable Value (PMAV) for 1080 in drinking water is 3.5 parts per billon. The PMAV is one that is not considered to cause any significant risk to health of the consumer over a lifetime consumption of the water. However, to be on the safe side, exposure to water that might be contaminated with 1080 should be avoided whenever possible, which is the aim of the public notification procedures, safety measures and water monitoring that takes place during and after aerial operations.

her daily intake, during the first 90 days of pregnancy, to receive a daily intake one thousand times less than the NOEL (of 0.1 mg/kg-day[13], Chapter 4.1) for developmental toxicity in rats.

It is for this reason that the Ministry of Health has specified a concentration of 2 ppb 1080 in water as the level above which water should not be used for human supply. The results of the extensive analysis carried out to date, and the solubility and biodegradability of 1080, which means that it does not persist in water, mean that it is highly unlikely that ingestion of contaminated water would pose a risk to the public.

Direct poisoning from baits

Direct contact with or ingestion of any poison baits obviously poses a risk to any person. 1080 operation planning includes public advertisements, notices, visits to schools, and other public awareness initiatives. Every attempt is made to ensure people who enter a treatment area are able to identify and avoid contact with 1080 baits.

Notwithstanding this, the amount of bait that an adult would need to ingest to receive a lethal dose is reasonably large. A person weighing 60 kg would need to eat about thirteen 6-gram baits or seven 12-gram baits (containing 0.15% 1080) to receive a fatal dose of 1080. Heavier people would need to eat more baits. A child weighing 20 kg would need to eat about four 6-gram baits or two 12-gram baits (containing 0.15% 1080) to receive a fatal dose. Sub-lethal effects could occur if significantly less bait was eaten, based on the toxicity studies on rats (Chapter 4.1), and for this reason all attempts are made to eliminate the potential for the public to accidentally come into contact with 1080 baits.

Exposure of workers in 1080 manufacture and application

The people with the greatest potential to be exposed to 1080 are the workers involved in manufacturing and distributing 1080 baits. Potential exposure routes for workers are ingestion, inhalation (of dust for example) and absorption through skin. Ingestion and inhalation are the most direct exposure routes that must be eliminated or minimised when handling 1080. Dermal (skin) absorption is a less significant exposure route, as studies conducted on rabbits in the USA showed that 1080 is poorly absorbed through the skin[10], but appropriate controls to minimise skin exposure are required.

Monitoring of worker exposure has been conducted to assess the level of exposure of workers in New Zealand. In January 2002, the Occupational Safety and Health Service (OSH) adopted a Biological Exposure Index (BEI) for the presence of 1080 in human urine. This is a more sensitive measure of exposure than using blood tests. The BEI was set at 15 ppb (0.015 mg/L). This level includes a large precautionary safety factor that ensures a conservative threshold level. As such it is more a measure of exposure to 1080, since health risks at this exposure level will be extremely low. Comparisons of worker BEI results can be used as a process to ensure worker exposure to 1080 is always minimised by appropriate handling practices and the use of protective equipment.

Workers were monitored between September 1998 and December 2000, in two factories making 1080 cereal pellet baits, during three aerial carrot operations, four aerial cereal pellet operations and one ground operation spreading 1080 paste bait[47]. None of the urine samples were above the BEI for the workers involved in the ground operation or in the aerial cereal pellet operation. Some of the workers monitored during the manufacture of 1080 baits and during the carrot bait operations were found to have some results above BEI exposure levels to 1080. Monitoring of workers involved with 1080 has now been expanded to ensure that 1080 handling practices and use of protective equipment minimise worker exposure levels to acceptable levels.

Meat from poisoned animals

Studies have shown that when animals such as sheep, goats and rabbits were given sub-lethal amounts of 1080, the 1080 levels in their blood peaked 2.5 hours after dosing, and were at negligible levels four days after dosing[27]. All traces of 1080 were eliminated within one week. DOC has set a precautionary period of four months following an aerial 1080 operation, during which time meat from feral animals should not be eaten. This is a conservative precautionary period, but it is set to ensure that animals that may have eaten baits some time after an aerial drop are no longer a hazard.

There may be occasions when domestic stock accidentally encounter baits and consume a sub-lethal amount of 1080. As a standard precaution, a withholding period is then followed. If none of the poisoned animals die, then a withholding period of five days should be applied before any meat is consumed. If some animals die after eating baits, it is standard practice to extend this period to 10 days and move the surviving stock to a 1080-free pasture.

Game packhouses that process game animals procured by hunters are required to operate systems to exclude animals from processing if there is risk of them having been exposed to 1080 baits in the field. Carcass samples from game packhouses are regularly tested for 1080 residues. Residue testing is carried out much less frequently for conventionally farmed red meats, due to the lower risk of exposure to 1080. Residue monitoring is the responsibility of the New Zealand Food Safety Authority.

Plants of cultural importance

The uptake and persistence of 1080 in two plants of cultural importance to Maori were recently examined in preliminary research by Landcare

Research and Lincoln University. The plants were the fern pikopiko (*Asplenium bulbiferum*) used for kai (food), and karamuramu (*Coprosma robusta*) used for rongoa (medicine). There was no evidence of pikopiko taking up 1080. Some 1080 was taken up by karamuramu, but at such low levels that there was negligible risk of people being poisoned by consuming the plant material. As for the recent research on eels (see section 5.2), these preliminary findings are subject to the Animal Health Board's peer review protocol. The full reports of both research projects will then be available. There is ongoing research, funded by the AHB, on the use, application and effects of 1080.

5.7 Effects on domestic animals

With a large number of Tb control operations occurring near farms, there are strict procedures that have been developed to minimise the likelihood of livestock being accidentally poisoned.

The most likely route for poisoning of livestock (sheep, cattle and deer) is from eating baits, given that they find both carrot and cereal baits attractive. Even baits that have started to break down should be regarded as hazardous to sheep and cattle. Livestock needs to be kept away from any areas where poisons have been laid, for a specified time. Landowners are advised of this at the time of the operation. Accidents have occurred when fences get breached, pilots miscalculate, farmers ignore safety procedures or communications between people break down. Occasionally livestock have been poisoned.

Dogs are very sensitive to 1080 (see Table 1) and must be kept away from baits and from possum carcasses. In cold weather, possum carcasses can potentially contain amounts of 1080 that could be lethal to dogs for at least 11 weeks after death[49]. 1080 applicators must warn dog owners of 1080 operations and may issue muzzles and emetics. Clearly, it requires diligence from owners to protect their dog(s) against poisoning, and for agencies to make dog owners aware of the risks and how to protect dogs against accidental poisoning.

Cats are also susceptible to secondary poisoning from eating carcasses, although they are about five times less sensitive than dogs to 1080, on a per weight basis.

An antidote for 1080?

At present there is no antidote for 1080 in the event of accidental poisoning of people, dogs or livestock. In April 2002, researchers at HortResearch said that after several years of working on a 1080 antidote they had made "good progress" and had achieved good survival rates testing the antidote on chickens, rats, rabbits and sheep. Before taking the next step and seeing if the antidote works on dogs, HortResearch wants to assess if there is a public or industry demand for an antidote to be developed, and to debate the ethics of such research. HortResearch is seeking guidance on whether to continue the research.

In the absence of an antidote for dogs, simple emetic treatment (using solutions of salt or washing soda) is available and effective if it is administered within an hour of baits being eaten.[48] The risk is that wandering dogs may not return within this time, which means that restraining dogs is the only sure protection.

5.8 Disposal of waste 1080

Occasionally, quantities of baits may need to be disposed of if they are damaged or unusable. In 1996/1997, 12,000 kilograms of 1080 cereal pellets and pastes were buried in a purpose-dug pit at the Winton landfill in Southland, after they had deteriorated in storage. Water samples were taken from two boreholes, 5 and 13 metres from the disposal pit, for 13 months. The 1080 concentrations in those samples were either below or close to the Ministry of Health PMAV for 1080 in drinking water. No 1080 was detected from the bore samples after 10 months.

The waste material was also sampled to find out how quickly it would break down. Sampling showed that 1080 concentrations decreased to less than 10% of their original level within 12 months. It appeared that the active bacterial processes operating in the landfill provided an ideal environment for the rapid natural breakdown of 1080. The conclusion was that, by following approved procedures and by not disturbing the site, the 1080 waste materials did not appear to pose any significant risk to public safety or the environment[50].

In a second example, 20 tonnes of cereal baits were buried in a West Coast landfill in March 2000. The baits were 8-20 years old and had lost some of their original toxicity during storage (manufacture strength was 0.15%, but a 1996 bait test was 0.11%). In the landfill, baits were mixed with a starter of organic material and buried about 2.5 metres deep. Water samples were taken one month after burial and every four months after that. Water samples were taken from surface water, 10 metres, 100 metres and 2 km from the dump site. No detectable levels of 1080 were discovered in any of the water samples. When concerns were raised about the safety of the landfill, the baits and surrounding soil were excavated in October 2000 (seven months after burial) and trucked to a Christchurch chemical waste disposal plant. Samples from the bait were taken in July 2000 and testing showed between 0.024% and 0.053% 1080. This was a 52-78% reduction in 1080 strength in seven months. After treatment at Christchurch, the bait was tested at 0.004%, and finally buried at a Canterbury landfill.

5.9 Overall assessment

A review was completed in 2004 regarding the continued use of aerial 1080 poisoning for possum control.[51] It concluded that, if "good practice" is followed, the continued use of 1080 for aerial possum control is desirable and justified on scientific grounds. "Good practice" means following all the specified protocols to ensure high-quality baits are delivered over targeted areas accurately and completely at specified, low application rates. It also includes meeting all the statutory requirements as specified in various Acts.

The review concluded:

> *"If these procedures and statutory requirements are followed, aerial application of 1080 is highly cost-effective, time-efficient, environmentally beneficial, and entails few significant risks."*

The question of risks, such as to dogs, and debates over risks to game animals can, the review suggested, form part of the decision-making process in which public attitudes are recognised.

6. Other control options

6.1 Non-toxic control techniques

This section discusses the alternatives to 1080 for killing possums or reducing the effects of possum damage.

Traps

Commercial possum operators and some of the management agencies have used traps for many decades. Public pressure in the 1970s to ban leg-hold traps led to research on the capture efficiency and humaneness of the wide variety of traps commercially available. Research showed that the available kill traps were relatively ineffective at catching possums, compared to leg-hold traps. However, welfare aspects were improved by using a leg-hold trap called Victor No.1, which reduced injuries to possums while still being effective at catching them. The Victor No.1 is now the most widely-used trap. By legislation, all leg-hold traps must be checked within 12 hours of sunrise on the day after they are set.

Poorly set traps can kill or injure birds. Surveys of trappers in 1936 and 1946 showed that the native birds most commonly caught were harriers, moreporks and kiwis. A 1984 survey of only 66 trappers reported catching 141 kiwis. Catches of other native species were not reported. Currently DOC requires that traps used in areas of kiwi or weka habitat be set well above ground level, so that these birds are not placed at risk.

The Timms trap kills possums humanely and quickly, and is widely used in urban situations, but is not capture-efficient compared with leg-hold traps. It is too large and cumbersome for use in the back country. Other kill traps that are effective and small enough for use in large-scale control operations have recently been introduced. Four trap models have been developed specifically for possums over the past two years (Warrior, Sentinel, Master and Holden) and they are now commercially available.

Shooting

Shooting possums is labour-intensive and there is little evidence to suggest that shooting alone is an effective technique for controlling possums over large areas. Shooting can be effective in small areas such as orchards and stands of trees surrounded by pasture. Possum populations may become wary of spotlights if they are shot at over an extended period of time.

Repellents

Researchers have developed a number of repellents designed to deter possums and other herbivores from damaging young trees. Egg and paint formulations are used by forestry contractors because they are relatively cheap. These repellents can significantly reduce damage to young seedlings, but don't provide total protection. They are not practical to use for Tb control or in the protection of native forests.

Tree guards and bands

Tree guards are physical barriers used to keep possums from damaging seedlings. Tree bands or sheaths have proven to be highly successful at preventing possum browse to saplings and older trees, by presenting an impassable barrier to climbing possums. They have been used to protect isolated pohutukawa growing in coastal areas and individual rata trees. Pole guards are used routinely to prevent possums from climbing power poles and affecting electricity supplies.

Fence barriers

Predator-proof fences can be constructed to exclude possums and other pests, the most notable example to date being that at the Karori Wildlife Sanctuary. However the cost of such barriers can be prohibitive. A "floppy top" fence that rolls over to the outside causing climbing possums to fall off has been trialled, and an operational fence installed at Warrenheip, to exclude pests from an area to be used as a nursery for kiwi chicks. A local conservation trust also intends to install a predator-proof fence around Maungatautari, in the Waikato, and is currently fund-raising for the project.

Various designs of electric fence have been tested. Electric fences can exclude possums effectively, but maintaining them requires continual vigilance, especially in summer when vegetation is growing vigorously and may fall on the fence, shorting the electrical circuit.

6.2 Biotechnology for possum control

Research involving biotechnology is being used to develop new methods of possum control that will complement existing control methods. This research is accorded a high priority by the National Science Strategy Committee for the Control of Possums and Bovine Tb. Two approaches are being pursued at present.

Differences in physiology (life processes) between possums and other animals are being exploited in attempts to develop possum-specific toxins. These could ultimately reduce the use of non-specific toxins, and hence reduce risks to non-target species. For example, possums have a unique mechanism for maintaining their water and salt balance (an essential life process), so it may be possible to target this process to kill possums but not other species. Research on possum-specific toxins has only recently begun, and such compounds are unlikely to be available before 2007.

Methods of interfering with possum fertility are also being actively researched. Fertility control would suppress the recovery of possum numbers after conventional control, and offers potential advantages of humaneness, specificity and a reduction in the use of toxins. Two approaches are being investigated. One aims to block production of the hormones essential for breeding (and does not involve genetic modification). The other uses genetic modification technologies to stop breeding, by stimulating the possum's own immune system to interfere with reproduction during the stages of egg-to-embryo development. Research on delivery of fertility control is exploring both bait-delivered systems (which may not contain living, genetically modified material) and the use of a genetically modified possum-specific parasite, which would transmit naturally from possum to possum.

Significant technical problems and regulatory issues remain to be overcome in each approach. Bait-delivered products may be available by 2006-2008, with transmissible systems, if approved, available by 2010-2012.

The use of bio-controls is, understandably, the subject of considerable public debate. Surveys of public attitudes have clearly shown support for fertility control for possum management, but people are more cautious when delivery involves the use of genetic modification. A recent report by the PCE "*Caught in the Headlights: New Zealanders' Reflections on Possums, Control Options and Genetic Engineering*"[52] canvasses the range of views of New Zealanders on this issue.

6.3 Alternative poisons

There are six poisons currently registered in New Zealand for possum control: 1080 (sodium monofluoroacetate), cyanide, cholecalciferol (Vitamin D_3), phosphorus, pindone and brodifacoum. Some are also registered for the control of other pests. All six poisons are used in concentrations in baits that are deadly poisonous and should be treated as such. Of these, 1080 is the only poison registered for aerial application. There are advantages and disadvantages associated with each poison and these are summarised in Table 5 (overleaf).

Cyanide, phosphorus, cholecalciferol and 1080 are all used in pastes for ground control of possums. Cyanide kills possums in 10-20 minutes by disrupting oxygen metabolism, leading to respiratory failure and death. Cyanide is cheap and has been used in New Zealand for several decades, but, its instability is a potential risk, and it is considered too hazardous for use in pest control in a number of countries. A significant drawback of cyanide has been the aversion that some possums have to its smell, and the fact that some possums become cyanide-shy if they do not receive a fatal dose. One study showed that the proportion of cyanide-shy possums in four populations ranged from 12% to 54%. Advances in the formulation of cyanide paste may overcome some or most of the cyanide shyness. Cyanide is now also used as a pellet (Feratox®), developed as a safer alternative to paste, that is less likely to lead to bait shyness. There is little known about the non-target impacts of cyanide, although cyanide baits have been known to kill native birds including kiwi.

Phosphorus was first used for killing rabbits in the 1920s. Deregistration on the grounds of inhumaneness has been considered, although there is currently some debate about the basis for concluding that the mode of action of phosphorus is inhumane.

Table 5 Comparison of effectiveness and risks of different poisons

Poison	Advantages	Disadvantages
1080 • paste • cereal pellets • carrot baits • gel	• moderately rapid effects (4-12 hours) • very effective • low environmental persistence • only poison registered for aerial application • effective for multiple pest control • very cheap	• high risk to dogs • secondary poisoning risks • currently no antidote
Cyanide • paste • pellets (Feratox®)	• cheap • rapid action (possums die in 10-20 minutes) • low environmental persistence • low secondary poisoning risk • effective for fur recovery	• hazardous in paste form • risk to humans if ingested • cyanide aversion reduces effectiveness • antidote must be used immediately
Phosphorus • paste	• effective	• considered to be inhumane • causes secondary poisoning in birds and dogs • no antidote
Cholecalciferol • paste (Feracol®) • cereal bait (Campaign®)	• effective • low risk of secondary poisoning • no poison licence required	• expensive compared with 1080 or cyanide • long time to death • risk to dogs • secondary poisoning risks unknown
Brodifacoum • cereal pellets (Talon® or PESTOFF®)	• effective against low density numbers • effective against bait or poison-shy possums • antidote available • no poison licence required	• long time to death (1–2 weeks) • very persistent in the environment • high secondary poisoning risk • widespread contamination of other wildlife possible • expensive compared with 1080 or cyanide • risks not acceptable for DOC areas where feral pigs, deer or other animals, taken for human consumption, are present
Pindone • cereal bait	• low secondary poison risk • antidote available	• need large amount before death occurs • possums take 2-3 weeks to die • low effectiveness • moderate persistence in environment

The SPCA opposes its use. There is little research data on its effectiveness, fate in the environment, or its persistence in carcasses. Phosphorus can cause secondary poisoning in birds and dogs.

Possums are particularly sensitive to cholecalciferol (Campaign®), which causes heart failure. A relatively new poison, used only in bait stations since 1995, cholecalciferol is more expensive than 1080 or cyanide. Not enough is known yet about its potential to cause secondary poisoning. Early tests show that cholecalciferol is less toxic to birds than 1080 or brodifacoum, although its non-target and environmental risks are not yet known.

Brodifacoum and pindone are both anticoagulant poisons, registered in New Zealand in 1991 and 1992 respectively. They act by disrupting blood clotting factors, causing extensive internal haemorrhaging, with death following after two to six weeks for possums. They are incorporated in cereal baits, and are currently used only in bait stations on the mainland. Pindone use has declined because of the large amounts of bait (over two kilograms) that possums can eat without being killed, and is considered more effective at controlling rats and rabbits than possums. Brodifacoum and pindone are particularly useful in areas where possum populations are at low density, such as after aerial 1080 operations.

The major disadvantage of brodifacoum is the persistence of brodifacoum residues after both primary and secondary poisoning. Trials with captive pigs have shown that brodifacoum accumulates in the liver and, to a lesser extent, in muscle. Research has shown that possums retain brodifacoum in the liver and, to a lesser extent, the muscles, for eight months after treatment with near-lethal doses[53]. While large amounts of brodifacoum-contaminated meat would need to be eaten to cause death, it is important to remember that a much lower sub-lethal dose will produce significant clotting abnormalities and some haemorrhaging. Predatory and scavenging birds such as morepork, weka, southern black-backed gull and the Australasian harrier are at risk from secondary poisoning. DOC no longer uses brodifacoum widely on the mainland because of concerns about residues accumulating in non-target species.

Since the costs of developing a new poison could be as high as several million dollars, there is a considerable incentive for the smarter use of existing poison products to reduce risks to non-target species and to minimise unwanted environmental effects.

6.4 The bounty option

Many people think that introducing a bounty system would be an effective inducement to reduce possum numbers, as well as reducing the need for poisons. It is, therefore, relevant to summarise New Zealand's one and only experience with a possum bounty scheme. During the 10 years 1951-1961, a bounty payment equivalent to approximately $6.00 in 2002 dollars was paid for each possum "token" (the tail plus a bit more skin). During that decade, 12.4 million possums were accounted for, with 4.3 million skins exported and 8.2 million presented for payment of the bounty. The proportion of skins presented for bounty rose from 3% in 1951 to 90% in 1961. After a government payout of about $2 million on bounties (approximately $47 million in 2002 dollars) the scheme was stopped.

Why was the scheme stopped? When the places where the tokens had come from were analysed, it was found that over 75% were being taken from or near farms, picked off roads, or caught in other easily accessible places. During the time the bounty was operating, the harvest of possums from Egmont National Park exceeded one possum per hectare in only one year. This level of harvest was always less than the normal productivity rate of the population. Therefore, losses to the bounty scheme were almost immediately replaced and there was no net conservation benefit.

The fact is that possums living in roadside bushes cause little economic damage, compared with a tuberculous possum next to a cattle farm, or a possum eating kokako eggs. A simple bounty system equally rewards roadside kills and the possum killed on a deer farm or high value conservation area. If the costs and effort are low to kill possums at the roadside, but high in conservation areas where access is difficult, bounties will result in the wrong possums being targeted. When particular objectives are being sought (for Tb control or conservation reasons), the pest population needs to be reduced to the levels that provide that benefit. This is why the AHB and DOC specify the precise areas where they want to manage possum populations, and set desired density targets.

In summary, although bounty systems may benefit possum hunters and create employment, they will not effectively reduce possums to the low levels required for Tb control and forest recovery unless the fundamental problem of ineffective targeting can be overcome.

6.5 Possums as a resource

Commercial hunting

Because possums were originally introduced to New Zealand to establish a fur trade, it is worth examining the potential for using the possum as a resource, as a way of reducing possum numbers in critical areas. The pressure on possum populations for skins has always been driven by price and never by the benefits of reducing possum numbers because of the damage they cause. High prices mean lots of hunters and large numbers of possums killed, but when prices fall, so does hunter interest, and the number of possum skins. Export prices were good throughout the late 1970s, with sales peaking in 1981, when 3.2 million skins were exported. This hunting pressure reduced possum populations in many areas, especially in the easier “front edge” country. Hunting for commercial gain may not achieve the very low densities needed to meet Tb control targets or to restore forests and protect endangered species, but commercial hunting pressure, when prices are high, could provide useful ecological benefits in many areas where funds for possum control are unavailable.

Possum fur is less than 1% of the world fur market by value. It is best suited to the trimming business, where the fur trade supplies pre-made collars, cuffs and strips to textile or leather garment manufacturers. Prices and exports have been low since 1990, and many professional and part-time hunters have left the industry. The auction system for buying skins ceased in 1990, and large companies have abandoned the possum skin business.

Several attempts at farming possums were tried during the 1980s, from small hobby farms to large publicly listed companies. All attempts failed, because it took too long to get a saleable product and there was a high death rate of possums due to captivity stress.

Recent initiatives

Since 1993, there has been some interest in diversifying the range of possum-based products away from the traditional export of dried pelts. In 1996, the Possum Products Marketing Council was established, bringing together the previously disparate sectors of the possum industry. The Council aims to counteract the volatility of the fashion market by developing a broader range of possum products, and thereby creating a stable and sustained demand. It is hoped that this will lead to sustained control pressure on some possum populations and provide employment opportunities, especially in rural areas. There are now five major product groups derived from possums. They are pelts, leather, fibre, added-value products and meat. Various initiatives are showing promise, such as the use of possum leather for the manufacture of gloves, shoe uppers and innersoles. Fur fibre is now a commercial reality after extensive research.

By itself, commercial use of possums is unlikely to reduce possum numbers to the levels required to meet Tb control and biodiversity protection targets, particularly in the areas now controlled with 1080. However, hunting for profit is an additional mechanism that pest control agencies can use to put pressure on possum populations, especially in areas that do not justify official control measures. The harvest of possums for fur or meat could also act to slow the recovery of populations after initial control operations.

Employment schemes and contract hunters

The use of people on government employment schemes to carry out possum control, particularly during the late 1980s and early 1990s, was not a success. Kill levels and motivation were often poor, costs were high, stock and dogs were poisoned, and participants often returned to unemployment at the end of the scheme. One reason for the failure was the misconception that any able-bodied person can make a good hunter. In practice, successful hunters are highly skilled, motivated, self-employed professionals who do not fit the personal profile of many of the unemployed. Prospective hunters need high-quality training, and several training courses have now been established.

With the downturn in skin prices, and the increase in funds available for possum control work since 1989, there has been a significant transition by many professional hunters from being commercial hunters to possum control contractors. They have developed new commercial skills, have to tender for control operations, and have developed the ability to reduce possum numbers to the levels required by their clients. Contract hunters are increasingly used by DOC, private landowners and most regional councils, especially as more operations shift from initial reduction to maintenance control. Companies that employ contract hunters are currently reporting that there is a shortage of skilled and willing people in the industry.

7. Summary

New Zealand uses more 1080 each year than any other country. The major users of 1080 are the Animal Health Board, to control Tb vectors (mainly possums), and the Department of Conservation, to protect conservation values from mammalian pests (again, mostly possums). This situation is a consequence of our unique evolutionary history. We are trying to rectify the mistakes of the early European settlers who, in the absence of native land mammals, imported a great variety of "replacement mammals". Unfortunately, some of these have had disastrous impacts on our native plants and animals. As a vertebrate toxin, 1080 can be used here to control pest mammals without putting at risk a wide range of native mammals, as would be the case in most other countries.

As 1080 use has increased in New Zealand, it has been necessary to find out how 1080 behaves in the environment, what risks it poses to native and domestic species, and whether it affects human health. Over the past 30 years, the possible risks of 1080 in the New Zealand environment have been studied intensively. Researchers have also studied the benefits of using 1080 for the reduction of Tb in cattle and deer herds, and the benefits for the native animals (especially birds) and ecosystems that have proved to be so vulnerable to introduced species. A third line of related research has been into improving management techniques for pest control, seeking ways to increase effectiveness, lower costs and reduce risks to pest control workers, non-target species, and the environment in general.

For the major user of 1080, the AHB, the benefits of 1080 as the primary tool to reduce the incidence of Tb in cattle and deer herds are clear. There are currently no effective and affordable alternatives. The present approach of ground and aerial operations, and combining 1080 use with other poisons, is effectively reducing the incidence of Tb. While the trends are encouraging, the goal of Tb eradication is still some years away. The costly mistake, made during the 1980s, of relaxing the control effort cannot be repeated if Tb is to be eliminated.

Studies of native forests and birds have shown the widespread benefits of using 1080 to control mammal pests. Although only 15–18% of conservation lands are under sustained management for possums, DOC research and monitoring show significant gains are being achieved. These gains are essential if we are to achieve the goals of the New Zealand Biodiversity Strategy[54] which outlines the threats causing the decline in our indigenous biodiversity. Where no control occurs, predators (including possums) are annually killing about 95% of kiwi chicks, about 85% of kokako chicks, and similarly high numbers of chicks and nestlings of other endangered birds, including kaka and mohua (yellowhead). 1080, used in bait stations or in aerial drops, and in combination with other toxins, is helping to "stem the slide" to extinction faced by a number of our bird species.

Research on management techniques has led to steady reductions in the aerial sowing rates of 1080 bait, from a high of 20 kg per hectare in the 1970s, down to current rates of 2–5 kg per hectare. These current sowing rates represent the application of 3-7.5 grams of 1080 per hectare, about 1-2 teaspoonfuls, respectively. Monitoring shows that these low sowing rates appear to have little or no deleterious impact on the bird species most at risk, that is the small insectivorous species such as robins and tomtits. Instead, populations of these species benefit from fewer predator and possum numbers, despite the occasional deaths of some individuals. Similarly, many insect species benefit from low possum numbers as they make up an important part of possum diets.

Other studies summarised here have shown how plant species such as northern and southern rata, mistletoe, fuchsia, tawa, kohekohe and others have recovered after possum populations have been reduced to low densities and maintained through follow-up 1080 operations. The non-target deaths of deer in aerial operations also assist forest recovery, although deer numbers generally recover within a few years through annual breeding.

The concerns people have held over possible contamination of water supplies have led to extensive water sampling after aerial 1080 operations since 1990. The results show that 96.5% of 1649 samples contained no traces of 1080. Only 0.3% of the samples had 1080 levels of between two and four parts per billion. An adult would need to drink an impossibly large amount of water from such a source, over a period of weeks, to suffer any health risk. Research has shown that common bacteria and fungi rapidly break down 1080 in both water and soil, but less quickly at low temperatures. The high solubility of 1080 in water and the breakdown action of common bacteria mean that 1080 has only a short-lived presence in water bodies if pellets do get into water systems.

1080 has never been detected in rural or city water supplies following 230 aerial 1080 operations between 1990 to 2003. Continuing strict adherence to all the specified operational features to protect human health should maintain this safety record.

Glossary

1080
sodium fluoroacetate or sodium monofluoroacetate (from Compound 1080, the original registration number given when it was tested as a rat poison in the USA in 1944). The chemical formula for 1080 is FCH_2COONa

biodiversity
the variability among living organisms; includes the genetic diversity within species, the variety of species on Earth and ecosystem diversity - such as forests, deserts, streams, estuaries, oceans - and their biological communities

bioaccumulation
the accumulation and concentration of stable substances as they move up the food chain. Perhaps the best known examples are organochlorine pesticides such as DDT, now banned in New Zealand

carcinogen
cancer-causing agent; carcinogens may be genotoxic (affect DNA directly) or non-genotoxic. Carcinogens produce cancerous tumours that may be benign or malignant

chaff
small fragments; refers to small or undersized pieces of carrot, or small pieces of other baits treated with 1080

controlled pesticide
pesticide listed in the First Schedule of the Pesticides Act 1979, including 1080, phosphorus and cyanide. Use of controlled pesticides is restricted to approved and licensed operators

detection limit
the minimum concentration of an analyte (substance being analysed) that can be detected at a known confidence level. The term is generally applied to laboratory testing and may vary depending on the method of analysis

degradation
the breaking down of substances by physical or biological means; bio-degradation refers specifically to breaking down of substances by natural processes, including bacteria, action of sunlight etc

dose
the quantity of chemical or substance to which an organism is exposed, usually expressed as a mass per unit body weight (eg. mg/kgbw) either discretely or over time (eg. mg/kgbw–day)

endocrine disruptor
a chemical that interferes with endocrine system function (the glands that produce hormones that guide the development, growth and reproduction in people and animals); known endocrine disruptors include DDT and other chlorinated hydrocarbon compounds

existing substances
hazardous substances already approved for use in New Zealand prior to July 2001 (HSNO Act)

exposure
contact of a chemical with an organism, for example a person or animal; the way in which a chemical enters an organism after contact is usually described as the exposure route, e.g. by ingestion, inhalation or dermal absorption (through the skin)

feral
wild population of a species that is also domesticated (e.g. cats, deer, pigs, cattle)

folivores
an animal eating mostly leaves

genotoxic
an agent or substance that harms an organism by damaging its genetic material (DNA); in this document, the term refers specifically to carcinogens that are genotoxic

hazardous substance
any substance with one or more of the following intrinsic hazardous properties: explosiveness, flammability, oxidising capacity, corrosiveness, toxicity and ecotoxicity (HSNO Act)

insectivorous
feeding on insects

invertebrate
animal having no backbone (vertebral column)

LC_{50}
the concentration of a chemical that is estimated to be fatal to 50% of the population of a particular organism (usually based on laboratory tests under specified conditions), usually expressed as milligram per kilogram, milligram per litre etc

LD_{50}
the dose of a chemical that is estimated to be fatal to 50% of the population of a particular organism (usually based on laboratory tests under specified conditions), usually expressed as milligram per kilogram of body weight

mainland island
an area of forest, largely isolated from close sources of predators by farmland or other landscape features

metabolism
the chemical processes in organisms that convert food into living tissue or break down the contents of cells into simpler substances for specific functions

new substances
hazardous substances not imported or manufactured in New Zealand prior to July 2001 (HSNO Act)

pesticide
agent that kills pests. Pesticides may be chemical or biological agents; chemical agents may be naturally occurring or synthetically manufactured. Vertebrate pesticides specifically kill vertebrates

possum
Australian brush-tailed possum (*Trichosurus vulpecula)*, introduced to New Zealand from Australia from 1837 to 1922. In early New Zealand literature, possums were often referred to as opossums, although recent literature, including this document, has standardised on possum. The term opossum is used in North America and refers to the native American marsupial *Didelphis virginiana*

reservoir species
those species able to maintain a disease within populations of the same species (in this case bovine Tb) and also pass it on to other host species. See also vector species

toxic substance
as defined by the Toxic Substances Act 1979. 1080 and cyanide are classified as deadly poisons under the First Schedule Toxic Substances Regulations 1983

trace amount
in analytical terms, an amount that is detectable but not able to be quantified

trap-night
a measure of trapping effort, e.g. 100 trap nights represents 10 traps set for 10 nights, or 50 traps set for 2 nights

ungulates
hoofed mammals (e.g. pig, deer, cattle, goat)

vector species
those species able to spread disease (in this case bovine Tb), but not known to maintain the disease within its own populations

vertebrate
animal with backbone (vertebral column)

References

1. Coleman, J. and Livingstone, P., 2000: Fewer possums less bovine Tb. *The Brushtail Possum*, Montague, T.L. (Editor), Manaaki Whenua Press, Lincoln: 220–231.
2. Butcher, S., 2000: Impact of possums on primary production. *The Brushtail Possum*, Montague, T.L. (Editor), Manaaki Whenua Press, Lincoln: 105-110.
3. Payton, I., 2000: Damage to native forests. *The Brushtail Possum*, Montague, T.L. (Editor), Manaaki Whenua Press, Lincoln: 111–125.
4. Nugent, G., Sweetapple, P., Coleman J., Suisted, P., 2000: Possum feeding patterns: dietary tactics of a reluctant folivore. *The Brushtail Possum*, Montague, T.L. (Editor), Manaaki Whenua Press, Lincoln: 10–23.
5. Sadleir, R., 2000: Evidence of possums as predators of native animals. *The Brushtail Possum*, Montague, T.L. (Editor), Manaaki Whenua Press, Lincoln: 126-131.
6. Veltman, C., 2000: Do native wildlife benefit from possum control? *The Brushtail Possum*, Montague, T.L. (Editor), Manaaki Whenua Press, Lincoln: 241-250.
7. Innes, J. and Barker, G., 1999: Ecological consequences of toxin use for mammalian pest control in New Zealand – an overview. *New Zealand Journal of Ecology 23(2):* 111–127.
8. Department of Agriculture, Department of Conservation and Land Management, Department of Health, 2002: 1080 Summary information. Miscellaneous Publication No. 011/2002. Australia.
9. Eason, C.T., 2002: Technical Review of Sodium Monofluoroacetate (1080) Toxicology. Animal Health Board and Landcare Research New Zealand Limited.
10. Fagerstone, K.A., Savarie, P.J., Elias, D.J., Schafer, E.W. Jnr., 1994: Recent regulatory requirements for pesticide registration and the status of Compound 1080 studies conducted to meet EPA requirements. In Proceedings of the science workshop on 1080. Seawright, A.A., Eason, C.T. (Editors). *The Royal Society of New Zealand, Miscellaneous Series 28.*
11. Eason, C.T. and Turck, P., 2002: A 90-day toxicological evaluation of compound 1080 (sodium monofluoroacetate) in Sprague-Dawley rats. *Toxicological Sciences 69:* 439-447.
12. Tremblay, L.A., Fisher, P., Leusch, D.L., 2002. Evaluation of the potential of sodium monofluoroacetate (1080) and fluorocitrate to bind to mammalian oestrogen receptor. *Landcare Research Contract Report: LC0203/044.*
13. Eason, C.T., Wickstrom, M., Turck, P., Wright, G.R.G., 1999: A review of recent regulatory and environmental toxicology studies on 1080: Results and implications. *New Zealand Journal of Ecology 23(2):* 129–137.
14. McIlroy, J.C., 1984: The sensitivity of Australian animals to 1080 poison. VII. Native and introduced birds. *Australia Wildlife Research 11:* 373-385.
15. Chenoweth, M.B.,1949: Monofluoroacetic acid and related compounds. *Journal of Pharmacology and Experimental Therapeutics 97*: 383-424.
16. Eason, C.T., and Frampton, C.M., 1991: Acute toxicity of sodium monofluoroacetate (1080) baits to feral cats. *Wildlife Research 18*: 445–449.
17. McIlroy, J.C., 1981: The sensitivity of Australian animals to 1080 poison I. Intraspecific variation and factors affecting acute toxicity. *Wildlife Research 9*: 369-383.
18. Atzert, S.P., 1971: A review of sodium monofluoroacetate (Compound 1080), its properties, toxicology, and use in predator and rodent control. United States Department of the Interior Fish and Wildlife Services Special Scientific Report – *Wildlife No 146.*
19. Robinson, W.H., 1970: Acute toxicity of sodium monofluoroacetate to cattle. *Journal of Wildlife Management 34*: 647-648.
20. Rammell, C.G. and Fleming, P.A., 1978: Compound 1080 properties and use of sodium monofluoroacetate in New Zealand. Ministry of Agriculture and Fisheries, Wellington.
21. McIlroy, J.C., 1983: The sensitivity of Australian animals to 1080 poison. V. The sensitivity of feral pigs, *Sus Scrofa*, to 1080 and its implications for poisoning campaigns. *Australia Wildlife Research 10:* 139-148.
22. Bell, J., 1972: The acute toxicity of four common poisons to the opossum *Trichosurus vulpecula*. *New Zealand Veterinary Journal 20*: 213-214.
23. Tucker, R.K. and Crabtree, D.G., 1970: Handbook of toxicity of pesticides to wildlife. Resource Publication No. 84. Bureau of Sport Fisheries and Wildlife, Denver Wildlife Research Centre.
24. McIntosh, I.G., Bell, J., Poole, W.S.H., Staples, E.L.J., 1996: The toxicity of sodium monofluoroacetate (1080) to the North Island weka (*Gallirallus australis greyi). New Zealand Journal of Science 9*: 125-128.
25. Ogilvie (unpublished) cited in Booth, L.H., and Wickstrom, M.L., 1999: The Toxicity of sodium monofluoroacetate (1080) to *Huberia straiata*, a New Zealand native ant. *New Zealand Journal of Ecology 23:* 161-165.
26. McIlroy, J.C., 1994: Susceptibility of target and non-target animals to 1080. In Proceedings of the science workshop on 1080. Seawright, A.A., Eason, C.T. (Editors). *The Royal Society of New Zealand, Miscellaneous Series 28.*

27. Eason, C.T., Gooneratne, R., Rammell, C.G., 1994: Review of the toxicokinetics and toxicodynamics of sodium monofluoroacetate in animals. In Proceedings of the science workshop on 1080. Seawright, A.A., Eason, C.T. (Editors). *The Royal Society of New Zealand*, *Miscellaneous Series 28*.

28. Walker, J.R.L., 1994: Degradation of sodium monofluoroacetate by soil micro-organisms. In Proceedings of the science workshop on 1080. Seawright, A.A., Eason, C.T. (Editors). *The Royal Society of New Zealand*, *Miscellaneous Series 28*.

29. Parfitt, R.L., Eason, C.T., Morgan, A.J., Wright, G.R.T., Burke, C.M., 1994: The fate of sodium monofluoroacetate in soil and water. In Proceedings of the science workshop on 1080. Seawright, A.A., Eason, C.T. (Editors). *The Royal Society of New Zealand*, *Miscellaneous Series 28*.

30. Ogilvie, S.C., Bowen, L.H., Eason, C.T., 1995: The effect of the plant *Myriophyllum triphyllum* and temperature on the degradation of sodium monofluoroacetate (1080) in an aquatic ecosystem. *Proceedings of the New Zealand Plant Protection Conference 48*: 260-263.

31. Manaaki Whenua, 2001: Research report 2001. Manaaki Whenua, Landcare Research New Zealand Limited.

32. Batcheler, C.L., 1978: Compound 1080. Its properties, effectiveness, dangers and use. Report to Minister of Forests and Minister of Agriculture and Fisheries. New Zealand Forest Service, Wellington.

33. Spurr, E., 2000: Impacts of possum control on non-target species. *The Brushtail Possum*. Montague, T.L. (Editor). Manaaki Whenua Press, Lincoln: 175-186.

34. Powlesland, R.G., Knegtmans, J.W., Marshall, I.S.J., 1999: Costs and benefits of aerial 1080 possum control operations using carrot baits to North Island robins (*Petroica australis longipes*), Pureora Forest Park. *New Zealand Journal of Ecology 23(2)*: 149–159.

35. Westbrooke, I.M., Etheridge, N.D., Powlesland, R.G.,2003: Comparing methods for assessing mortality impacts of an aerial 1080 pest control operation on tomtits *(Petroica macrocephala toitoi)* in Tongariro Forest. *New Zealand Journal of Ecology* 27(2): 115-123.

36. Westbrooke, I.M., Powlesland, R.G., 2004: Comparison of impact between carrot and cereal 1080 baits on tomtits *(Petroica macrocephala toitoi)*. Submitted to *New Zealand Journal of Ecology.*

37. Knegtmans, J.W. and Powlesland, R.G., 1999: Breeding biology of the North Island tomtit (*Petroica macrocephala toitoi*) at Pureora Forest Park. *Notornis 46*: 446–456.

38. Lloyd, B.D. and McQueen, S.M., 2002: Measuring mortality in short-tailed bats (*Mystacina tuberculata*) as they return from foraging after an aerial 1080 possum control operation. *New Zealand Journal of Ecology 26(1):* 53–59.

39. Saunders, A., 2000: A review of Department of Conservation mainland restoration projects and recommendations for further action. *Department of Conservation*, Wellington.

40. Spurr, E.B., 1996: Impacts of 1080-poisoning for possum control on non-target invertebrates. *Science for Conservation 21*, Department of Conservation, Wellington.

41. Spurr, E.B., Berben, P.H., 2002: Study shows weta populations not significantly affected by 1080. *ConScience* 45: 1-3. Also refer to: "Spurr, E.B., Berben, P.H., 2004. Assessment of non-target impact of 1080-poisoning for vertebrate pest control on weta (Orthoptera: Anostostomatidae and Rhaphidophoridae) and other invertebrates in artificial refuges. *New Zealand Journal of Ecology* 28(1):

42. Gillies, C.A. and Pierce, R. J., 1999: Secondary poisoning of mammalian predators during possum and rodent control operations at Trounson Kauri Park, Northland, New Zealand. *New Zealand Journal of Ecology 23(2)*: 183–192.

43. Murphy, E.C., Robbins, L., Young, J.B., Dowding, J.E., 1999: Secondary poisoning of stoats after an aerial 1080 poison operation in Pureora Forest, New Zealand. *New Zealand Journal of Ecology 23(2):* 175–182.

44. Norton, D., 2000: Benefits of possum control for native vegetation. *The Brushtail Possum*. Montague, T.L. (Editor). Manaaki Whenua Press, Lincoln: 232-240.

45. Rogers, G.M. and Leathwick, J.R., 1997: Factors predisposing forests to canopy collapse in the southern Ruahine Range, New Zealand. *Biological Conservation 80:* 325–338.

46. Fisher, P. and Wright, G., 2003: Water monitoring for contamination after aerial 1080 pest control operations - an update. Unpublished report by Landcare Research. Additional 2003 data provided by G. Wright, Landcare Research.

47. Fisher, P., O'Connor, C.E., Eason, C.T., 2002: Monitoring workers in the pest control industry against a Biological Exposure Index (BEI) for 1080. *Landcare Research Contract Report: LC0102/087*.

48. Eason, C.T. and Wickstrom, M., 2001: Vertebrate pesticide toxicology manual. Department of Conservation Technical Series 23. Department of Conservation, Wellington.

49. Meenken, D. and Booth, L.H., 1997: The risk to dogs of poisoning from sodium monofluoroacetate (1080) residues in possum (*Trichosurus vulpecula).* *New Zealand Journal of Agricultural Research 40(*4): 573-576.

50. Bowman, R.G., 1999: Fate of sodium monofluoroacetate (1080) following disposal of pest bait to a landfill. *New Zealand Journal of Ecology 23(2):* 193–197.

51. Morgan, D.R., 2004: Maximising the effectiveness of aerial 1080 control of possums (*Trichosurus vulpecula*). Ph.D. thesis, Lincoln University.

52. Parliamentary Commissioner for the Environment, 2000: Caught in the Headlights: New Zealanders' Reflections on Possums, Control Options and Genetic Engineering. October 2000.

53. Eason, C.T., Wright, G.R., Meikle, L., Elder, P., 1996: The persistence and secondary poisoning risks of sodium monofluoroacetate (1080), brodifacoum, and cholecalciferol in possums. *Proceedings of the Vertebrate Pest Conference 17*: 54-58.

54. The New Zealand Biodiversity Strategy. Our chance to turn the tide. Whakakōhukihukitia Te Tai Roroku Ki Te Tai Oranga, 2000. Department of Conservation and Ministry for the Environment, Wellington.

Response form for submitters

This form is a guide for preparing submissions. Please write your answers in the spaces provided and send this form to the address at the bottom of the next page. If you need more room, please use other sheets and attach these to your response form.

Please complete all questions. The information you provide will be used by the applicants and a summary will be provided to ERMA along with the application.

First of all, we need some information about yourself. This information will be kept strictly confidential. Please tick the appropriate boxes.

Fill out this box only if you are making a submission on behalf of a group or organisation.

Please specify the name of the group or organisation:

____

Fill out this box only if you are making an individual submission.

What is your sex? ☐ Male ☐ Female

What is your ethnic group? ☐ NZ European ☐ NZ Maori ☐ Asian ☐ Pacific Islander ☐ Other (please specify) ________________

Do you live in a rural or urban area? ☐ rural ☐ urban (city or town)

If you are a member of a group with an interest in 1080 issues, please specify the name of that group:

____

continued overleaf

Please feel free to photocopy this response form.

Questions (Please complete all questions that apply to you)

1. Do you support the use of 1080 to control bovine tuberculosis?

   ☐ yes ☐ no ☐ maybe

   Please give reasons for your answer:

2. Do you support the use of 1080 to conserve New Zealand's native forests, plants and animals?

   ☐ yes ☐ no ☐ maybe

   Please give reasons for your answer:

3. If you do not support the use of 1080 (for either bovine TB control or conservation), how could its use be modified to make it more acceptable to you?

4. Do you have any other comments about the use of 1080? (We are especially interested to hear your comments about other environmental issues; health and wellbeing issues; cultural and spiritual issues; or Treaty of Waitangi issues.)

Please mail or email your response form to:

1080 Reassessment, P.O. Box 3412, Wellington

Email: 1080@doc.govt.nz

Online submissions can be made at: http://www.1080reassessment.govt.nz

Southern rata in flower

Front cover photo: Possum-ravaged rata on Mt Messenger, north Taranaki, photography © by Dave Hansford/Origin Natural History.
Close up of a possum face, photography by Chris Stewart, © Department of Conservation Te Papa Atawhai
Above: © Department of Conservation Te Papa Atawhai