Australian Government
Australian Pesticides and
Veterinary Medicines Authority

REVIEW FINDINGS
SODIUM FLUOROACETATE

TECHNICAL REPORT

The reconsideration of registrations of products containing sodium fluoroacetate and approvals of their associated labels.

Environmental Assessment

January 2008

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FOREWORD

The APVMA is an independent statutory authority with responsibility for the regulation of agricultural and veterinary chemicals in Australia. Its statutory powers are provided in the Agvet Code scheduled to the *Agricultural and Veterinary Chemicals Code Act, 1994*.

The APVMA can reconsider the approval of an active constituent, the registration of a chemical product or the approval of a label for a container for a chemical product at any time. This is outlined in Part 2, Division 4 of the Agvet Code.

The basis for the reconsideration is whether the APVMA is satisfied that continued use of products containing sodium fluoroacetate (1080) in accordance with the instructions for their use "would not be likely have an unintended effect that is harmful to animals, plants or things or to the environment" (s34 (1)(a)iii).

The requirements for continued approval of a label for containers for a chemical product are that the label contains adequate instructions (s34(1)c). Such instructions include:

- the circumstances in which the product should be used
- how the product should be used
- times when the product should be used
- frequency of the use of the product
- the withholding period after the use of the product
- disposal of the product and its container
- safe handling of the product.

A reconsideration may be initiated when new research or evidence has raised concerns about the use or safety of a particular chemical, a product or its label.

The process for reconsideration includes a call for information from a variety of sources, a review of that information and, following public consultation, a decision about the future use of the chemical or product.

In undertaking reviews, the APVMA works in close cooperation with advisory agencies including the Office of Chemical Safety (OCS) within the Department of Health and Ageing, the Department of the Environment and Heritage (DEH), and State Departments of Agriculture as well as other expert advisors, as appropriate. In this case, the APVMA obtained expert advice from the DEH who assessed the information submitted to the review and provided advice on measures to avoid or minimise harmful environmental effects.

The APVMA has a policy of encouraging openness and transparency in its activities and community involvement in decision-making. The publication of review reports is a part of that process.

The APVMA also makes these reports available to the regulatory agencies of other countries as part of bilateral agreements. Under this program it is proposed that countries receiving these reports will not utilise them for registration purposes unless they are also provided with the raw data from the relevant applicant.

This document is Part 2 of *'The Reconsideration of Registrations of Products Containing Sodium Fluoroacetate (1080) and Their Associated Labels – Preliminary Review Findings, Technical Report'* and relates to all products containing 1080 that have been nominated for review by the APVMA. The review's findings and recommendations are based on information collected from a variety of sources.

The *Preliminary Review Findings* report containing the APVMA's preliminary assessments (*The Reconsideration of Registrations of Products Containing Sodium Fluoroacetate (1080) and Their Associated Labels*, Volume I) and the technical reports (Volume II) for all registrations and approvals relating to 1080 are available from the APVMA website: http://www.apvma.gov.au/chemrev/chemrev.html.

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1 INTRODUCTION

The National Registration Authority (NRA, now known as the APVMA – Australian Pesticides and Veterinary Medicines Authority) announced in the NRA Gazette of 4 December 2001 that a reconsideration of sodium fluoroacetate would be initiated in early 2002 due to environmental concerns. Sodium fluoroacetate, commonly known as compound 1080, is widely used in Australia for vertebrate pest control. It was selected for reconsideration because of concerns regarding the poisoning of non-target animals, either through the direct taking of baits or the consumption of poisoned animals.

The Gazette notice invited submissions in relation to any issue concerning sodium fluoroacetate, but in particular on how it is used in practice, the measures taken to decrease non-target animal exposure, poisoning incident reports, and information on the persistence of the chemical in baits under different conditions and its toxicity to native species. An associated media release highlighted the use of sodium fluoroacetate for fox control.

Information provided in response to the Gazette notice was taken into consideration during the drafting of a background and scope document, which was released by the NRA in July 2002. The scope of the review was defined as environmental aspects, animal welfare considerations, and assessment of product labels and associated extension material. The environmental aspects identified in the document include the persistence of 1080 in baits and poisoned animals, effects on non-target animal populations (particularly mammals, with a focus on native carnivores such as quolls and phascogales), consideration of incident reports, and the effectiveness of 1080 as a vertebrate pest control agent and its role in biodiversity conservation.

The APVMA's Preliminary Review Findings and associated Technical Report were released for public comment in May 2005. This Technical Report has been updated to correct errors that were identified in the draft, including in the draft conclusions. New research and argument that have occurred since the report was first drafted are presented in section 9 of this report. Many of the changes to the report's conclusions and recommendations are based on the information presented therein.

Sodium fluoroacetate is mainly used in Australia and New Zealand. The United States Environmental Protection Agency (US EPA) issued a reregistration eligibility decision (RED) document in September 1995, but the currently registered uses in that country are limited to livestock protection collars as a predacide in those States that have registrations and US EPA approved certification and training programs. The RED document records that the US EPA held hearings in 1981 and 1982 to revisit the 1972 predacide cancellation decision. The decisions of these hearings permitted the US EPA to consider registration applications for toxic collars and single-use baits, but not for carcass baits or smear posts. A toxic collar product was registered in 1985, but no single-use baits have been registered although field trials were authorised in the 1980s for single-use tallow baits containing 5 mg 1080. Use of 1080 also occurs in Mexico and Israel.

2 CONTEXT

The environmental behaviour and toxic properties of sodium fluoroacetate have been extensively studied in Australia and New Zealand. A very large volume of data is available for review. Although there are relatively few formal regulatory ecotoxicological studies for 1080 compared with modern crop protection chemicals, the availability of a large number of non-guideline studies and open literature publications, complemented by a considerable volume of practical experience with the use of 1080, provides a solid basis for review. Sodium fluoroacetate is a very well studied vertebrate pesticide, reflecting its importance in both jurisdictions for agricultural and environmental protection. New information on 1080 continues to be generated in Australia because of its importance to animal pest control. The use of 1080 in Australia and New Zealand has recently been reviewed by the Vertebrate Pests Committee (VPC) and a further review of use in New Zealand is also current, as outlined below.

This environmental assessment report will focus on the issue of non-target impact, including fauna recovery. Key issues for consideration are the sensitivity of non-target animals to 1080, the likelihood that they will be exposed to 1080 in baits or carcasses, and the outcomes of baiting campaigns (such as carcass discovery and changes in abundance of non-target populations). Issues relating to human sensitivities are covered by the VPC review, which has made recommendations on standardising practices and procedures. General safety matters such as notification of neighbours, distance restrictions around sensitive areas, display of warning signs and transport and storage of baits are amenable to standardisation, but more flexibility is needed with baiting practices because of the differing pest densities, fauna distributions, environmental conditions and sensitivities across Australia.

2.1 Vertebrate Pests Committee

A Working Group of the VPC has reviewed the current information, policies, practices and procedures for the use of 1080 within Australia and New Zealand, as well as evaluating the role and importance of 1080 in vertebrate pest management in Australia and New Zealand, with a view to ensuring its future availability and effectiveness in these jurisdictions (Eason *et al*, 2002). The VPC is a sub-committee under the Land and Water Biodiversity Committee, which advises the Natural Resources Management Standing Committee of the National Resources Management Ministerial Council, chaired jointly by Commonwealth Ministers for Agriculture, Fisheries and Forestry, and Environment and Heritage.

The VPC review identified two major issues beyond its terms of reference that needed to be addressed, being the unpromoted value of 1080 in protecting the environment as well as agriculture in Australia and New Zealand, and the need for greater public understanding of 1080 and its importance in Australia and New Zealand.

State-based conditions and restrictions are attached to the use of 1080 to address safety concerns. These relate to notification of neighbours, distance restrictions around sensitive areas, display of warning signs, bait preparation and placement, transport and storage of baits and in some jurisdictions, minimum property size. Distance restrictions mainly address human sensitivities such as property boundaries, homes, public roads and domestic water supplies, but in WA include a 20 m buffer for bush refuges for non-target species, and for dams and water courses. Tasmania, Victoria and WA also require a 20 m buffer around any waterway or other body of water, increasing to 50 m in Victoria for aerial baiting of rabbits.

While acknowledging that legislative differences between the States and Territories and New Zealand make the feasibility of national standards difficult, the VPC review made recommendations regarding neighbour notification, distance restrictions, signage, transport and storage, bait access and technical issues such as bait loadings and baiting practices. The review noted the ongoing need to control native species in some circumstances, recommending that current practices need to continue, but that alternative control techniques to 1080 need to be developed for this use pattern as a matter of priority. As general recommendations, each State and Territory should adopt and resource a Quality Assurance approach to 1080 usage, a 1080 information kit should be developed that outlines the facts concerning 1080 with a consistent message across agencies and States and Territories, dose rates should be reviewed and certain research requirements should be considered as high priority.

The specific dose rates recommended in the VPC report are 4.5-6 mg for wild dogs, 2.5-3.2 mg for foxes, and for rabbits 140-200 mg/kg in carrots or 400 mg/kg in oats (500 mg/kg in One-shot oats). The rates currently used for pigs (see table below) were considered acceptable. Dose rates for other species should be as labelled or specified by permit. Rates should be calculated to ensure effective control with the minimisation of sublethal doses and overdosing.

The VPC review also made specific recommendations regarding bait material, bait size, bait quality and bait preparation techniques.

The research priorities identified in the VPC review are alternatives to 1080 for vertebrate pest control, environmental impact (distribution of fluoroacetate tolerant species, identification of key species and habitats for more rigorous assessment, toxicity testing and residue analysis for key species as necessary, generation of risk assessment tables, biomarker studies and expanding the limited information on residue levels in the tissues of target and non-target species poisoned with 1080), ensuring an adequate regulatory database, resistance mechanisms, worker exposure, antidotes, veterinary treatment, improved public awareness and animal welfare issues.

2.2 Environmental Risk Management Authority

All aspects of the use of 1080 in New Zealand have been reviewed by the New Zealand Environmental Risk Management Authority (ERMA). The reassessment of 1080 was sought by the two largest users, the Animal Health Board (AHB) and the Department of Conservation (DOC). The DOC website states that "DOC and the AHB applied for the reassessment due to new information on 1080, and changes in its use since it was first registered under the *Pesticides Act* in 1964. The two organisations welcomed ERMA's decision to agree to the reassessment of 1080. The process will also provide an opportunity for objective and open discussion and scrutiny of 1080 use which continues to attract public interest. DOC and AHB believe the most effective way of addressing public issues is through official reassessment".

The New Zealand reassessment was postponed in May 2003 pending amendments to the New Zealand *Hazardous Substances and New Organisms Act*, which are expected some time in 2004. The amendments are intended to give ERMA wider legal powers to apply specific controls on the use of 1080, so that public confidence in the reassessment process can be fully maintained.

An update (10 November 2006) on the ERMA website extends the submission period for the reassessment of 1080 until 31 January 2007. The joint application from DOC and AHB was received by ERMA in October and publicly notified for submissions on 2 November 2006.

ERMA announced on 13 August 2007 that it had imposed a new management regime on the use of 1080 in New Zealand, following a full-scale reassessment that took over 6 months and involved public submissions as well as two weeks of public hearings. Tighter mandatory controls had been placed on the pesticide, with all aerial operations to be actively monitored by ERMA from 1 January 2008. ERMA also recommended that the government undertake more research into some areas of continuing concern to the public. It was emphasised that the decision was not intended to be for all time, with further reassessment likely at some point in the future. The timing for any reassessment would depend on how well the new management regime is implemented, and on the response to the recommendations from the reassessment.

3 CHEMICAL IDENTITY AND PROPERTIES

Sodium fluoroacetate ($CH_2FCOONa$) is a colourless hygroscopic powder which decomposes at about 200^{o}C. It has properties typical of carboxylate salts, being non-volatile, highly soluble in water and poorly soluble in organic solvents such as ethanol, acetone and petroleum oils.

4 FORMULATION

In January 2003, APVMA registrations were current for 21 products containing sodium fluoroacetate. Current registrants are Animal Control Technologies (Aust) Pty Ltd (ACTA), the Agriculture Protection Board of Western Australia (APB), the South Australian Animal and Plant Control Commission (APCC), the Tasmanian Department of Primary Industries, Water and Environment (DPIWE), the Victorian Department of Natural Resources and Environment (DNRE, which became the Department of Primary Industries and the Department of Sustainability and Environment in December 2002), the NSW National Parks and Wildlife Service (NPWS, known since September 2003 as the Parks and Wildlife Division of the Department of Environment and Conservation) and the State of Western Australia, acting through the Department of Conservation and Land Management (CALM). The APVMA website should be consulted for information on the current registration status of 1080 products.

The Queensland DPI Board Approval (70057) for the control of dingoes, wild dogs, foxes, rabbits and feral pigs authorises preparation and use of 125 g meat baits containing 6-10 mg 1080 for foxes, wild dogs and dingoes, carrot and grain baits containing 180-360 mg/kg 1080 for rabbits, and 500 g meat or 250 g grain baits containing 72 mg 1080 for feral pigs.

In NSW, preparation of baits by authorised control officers and their use are authorised by Pesticide Control Orders for foxes, wild dogs, rabbits and feral pigs. Baits for foxes contain 3 mg 1080 in fowl heads, fowl eggs, chicken wingettes, boneless red meat, manufactured baits which are dyed blue or green, or pieces of offal such as tongue, kidney or liver. Wild dog baits contain 6 mg 1080 but exclude the use of fowl heads, fowl eggs or chicken wingettes. Only boneless red meat baits may be aerially deployed. Rabbit baits contain 180-460 mg/kg 1080 in oats, carrot or pellets. Pig baits contain 310-460 mg/kg 1080 in pellets, grain, apples, quinces, cucurbits or root vegetables.

Twenty-five registered products containing 1080 were originally subject to review, as tabulated below. Registrations for five of these (33890, 42384, 42497, 42534 and 42624, as struck out in the table) have since lapsed, and four new products (53187, 57743, 57825 and 57956) have been registered. Registration has lapsed for the Rentokil product, which was a concentrate that is used for bait formulation only.

Dried meat or shelf-stable meat meal-based preparations are the bait materials usually used for foxes and wild dogs (note that the APB impregnated oat baits for canids are intended for insertion into meat baits by landholders) with fresh meat baits commonly used in some States. The commercial Foxoff and Doggone products respectively contain 3 and 6 mg sodium fluoroacetate in each 60 g bait. Foxoff Econobaits contain 3 mg in each 35 g bait. Baits for herbivores are generally oats and carrots, the latter containing approximately half the toxicant concentration as more is eaten by the target pests. Some herbivore baits are formulated as pellets (bran and pollard mixture). Two concentrates are registered, which may be used to prepare a variety of baits from these or other carriers, such as fresh meat or liver, tongues, eggs or (in NSW) chicken heads. The toxicant is added by injection or tumble mixing, as appropriate. Fresh meat baits are prepared just before a campaign because of their short shelf lives.

Product No.	Nominated Product Name	Content	Registrant
~~33890~~	~~*Rentokil AF Sodium Monofluoroacetate Tenate (1080) Brand Vermin Destroyer*~~	~~920 g/kg~~	~~Rentokil Initial PL~~
40573	*Foxoff Fox Bait*	52 mg/kg	ACTA
~~42384~~	~~*Agile Wallaby Bait*~~	~~500 mg/kg~~	~~APB~~
~~42497~~	~~*Feral Cat Baits*~~	~~6 mg/bait~~	~~APB~~
42450	*1080 Bait for the Control of Rabbits*	200 mg/kg	APCC
42458	*1080 Baits*	400 mg/kg	DPIWE
42498	*1080 Concentrate (Red)*	30 g/L	APB
42499	*1080 Concentrate (Black)*	40 g/L	APB
42500	*1080 Impregnated Oats (Wild Dog Control)*	6 mg/oat	APB
42501	*"One Shot" 1080 Impregnated Oats*	80 g/kg	APB
~~42534~~	~~*Dried Meat 1080 Fox Baits*~~	~~4.5 mg/bait~~	~~APB~~
42538	*1080 Impregnated Oats (Fox Control)*	3 mg/oat	APB
~~42624~~	~~*Special Fox Baits*~~	~~2.5 mg/bait~~	~~APB~~
42720	*1080 Baits for the Control of Foxes*	3 mg/bait	APCC
46434	*Foxoff Econobait*	85 mg/kg	ACTA
49350	*1080 Oats Rabbit Bait*	400 mg/kg	DNRE
49351	*1080 Carrots Rabbit Bait*	200 mg/kg	DNRE
49352	*1080 Pellets Rabbit and Feral Pig Bait*	480 mg/kg	DNRE
49354	*1080 Predator Bait*	4.5 mg/bait	DNRE
49355	*1080 Fox Bait*	3 mg/bait	DNRE
49384	*Doggone Wild Dog Bait*	100 mg/kg	ACTA
50304	*Rabbait 1080 Oat Bait*	400 mg/kg	ACTA
50911	*Yathong Fox Bait*	30 mg/kg	NPWS
52954	*1080 Ready-to-Lay Rabbit Oat Bait*	400 mg/kg	APB
54616	*1080 Dried Meat Fox Baits*	3 mg/bait	APB
53187	*Pro-bait 1080 fox bait*	3 mg/bait	CALM WA
57743	*1080 Dried meat wild dog baits*	6 mg/bait	APB WA
57825	*1080 Bait for the control of wild dogs*		APCC SA
57956	*ACTA 1080 concentrate*	30 g/L	ACTA

Details for some of the baits in the above table differ from current specifications. For example, the DPIWE has used a concentration of 140 mg/kg on carrots for at least the last 20 years, much lower than the concentration stipulated (400 mg/kg) on the approved label of the registered product (42458). There appears to be no need to retain registrations for redundant products, particularly those containing higher poison loadings.

5 ENVIRONMENTAL EXPOSURE

5.1 Environmental Release

5.1.1 Volume

Information received from State authorities at the commencement of the review indicated that 25-50 kg 1080 was used annually in Queensland, 25-30 kg in NSW, 10-12 kg in SA, 13-15 kg in Tasmania, and an average 38 kg over the last three years in WA. Other States are understood to use similar amounts. Annual distribution across Australia was about 200 kg. Current usage in Tasmania was mainly against native browsing and grazing animals (albeit with incidental rabbit control) and was on a declining trend, with a decrease over the past 3 financial years from 9 kg to just over 6 kg in 2003-2004. Most of the 1080 used in WA was for rabbit control, but with important uses for foxes and wild dogs and relatively minor use against pigs. Across Australia, rabbit control consumed the most 1080, followed by wild dog control. The amounts of 1080 used will vary from year to year in total and distribution depending on pest pressure.

In its response to the preliminary review findings, Tasmania noted the decline from 15.15 kg in 1999-2000 to 6.15 kg in 2003-04, followed by an increase in 2004-05 to 8.14 kg. The increase is attributed to seasonal conditions, an increase in plantation establishment and browsing damage on King Island. The declining trend resumed in 2005-06, to 4.7 kg. Western Australia advised in its response to the preliminary review findings that the average use over the previous 3 years had been 17 kg. Current annual use in SA is 5-6 kg.

5.1.2 Application and use pattern

Products containing 1080 are restricted chemical products, as declared by the Regulations to the Agvet Codes. As such, availability and use of 1080 are carefully regulated by State and Territory governments. Landholders can only obtain 1080 products (not the powder or concentrated solutions) through government agencies as authorised officers must approve supply and use.

Bait materials, toxicant loading and application methods for vertebrate pest control are briefly summarised in the table below. Further detail of control methods for the various target pests follows.

Target	Bait	Weight	Loading	Method
Rabbit	Carrot, pellets, oats		140-670 mg/kg	Aerial, trail, broadcast
Marsupial	Carrot		140 mg/kg	Surface
Fox	Meat, offal, commercial	40-250 g	2.7-4.4 mg/bait	Aerial, surface, mound
Wild dog		30-250 g	4.2-10 mg/bait	
Pig	Meat, grain, fruit, pellets, oats	500 g meat (Qld only)	144-670 mg/kg	Trail, surface, station, aerial (meat)

Note that approved labels for 1080 products do not generally specify an application rate, but require that usage be strictly in accordance with instructions from relevant government authorities, which can vary between jurisdictions. Details of application rate and other directions for use are commonly provided in separate documents which may form part of the label. General environmental exposure to 1080 is low as overall application rates are low, although use in baits leads to higher exposure in small areas where toxic doses are applied. The DNRE requires that users of pellet, oat and carrot baits for rabbits must ensure that broadcast or aerial methods do not exceed 15 kg/ha (3 g/ha 1080 for carrots, 6 g/ha for oats and 7.2 g/ha for pellets, although directions for use for the pellet baits refer specifically, but probably mistakenly, to carrots in defining the maximum rate). Predator baits tend to be laid along transects where they are most likely to be encountered, usually on a spacing of 200-500 m. Application rates for these baits equate to a few milligrams 1080 per hectare. Pig baits also appear to be laid at relatively low density, although very little specific information is available. A simulated aerial baiting exercise used rates of 18 baits/km^2 but concluded that higher rates would likely be needed to optimise efficacy (Mitchell, 1998). An application rate of 100 baits/km^2 equates to 72 mg/ha for baits containing 72 mg 1080.

Further information on specific pests and the baiting practices used to control them is outlined below. This information is not limited to that which might be implied by approved labels and is intended to describe how 1080 is currently used in its major applications. Users of 1080 should follow best management practices as outlined on labels and in associated extension material, but improved ecological knowledge and changes in social expectations and land use practices mean that use patterns are continually being reevaluated, updated and refined. For example, Victoria is about to embark on a large scale biodiversity conservation program (Southern Ark) under which the effects of different baiting intensities on fox control and fauna recovery will be investigated.

The Bureau of Rural Sciences has published comprehensive reviews of the history, biology and management of rabbits (Williams *et al*, 1995), foxes (Saunders *et al*, 1995), wild dogs (Fleming *et al*, 2001), and feral pigs (Choquenot *et al*, 1996). These are regarded as national best practice guidelines for the management of vertebrate pests in Australia.

Note that the word feral refers to animals that have reverted to the wild from their domesticated state, as opposed to its alternative meaning of wild animals in general. Thus pigs and cats are described as feral, but not foxes (i.e. the European red fox) as they were never domesticated.

Rabbits

Competition and land degradation by feral rabbits is listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999*. There is abundant evidence that the impacts of rabbits threaten the continued survival of a wide range of native species and ecological communities. The Commonwealth Threat Abatement Plan for this species notes that 1080 is the main toxin used in Australia for the control of a range of vertebrate pest species including rabbits. Very effective methods of use have been developed and these are generally target specific when properly applied. All of these factors combined have made 1080 the most widely accepted and suitable poison for rabbits.

Carrots are the usual bait material for rabbits in Queensland. Pre-feeding, which normally consists of two exposures, precedes baiting. Baits are laid in furrows at a maximum of 10 kg/km aiming to provide just enough for feeding rabbits based on pre-feed consumption. Application rates can be much less than this as they vary with terrain, rabbit numbers and proximity to warren areas. Aerial application of grain baits has been made to extensive warren systems in southwest Queensland, but only once.

Oats are the preferred bait in WA for reasons of cost and practicality (carrot baits tend to dry out under the arid conditions prevailing during the usual baiting season of late summer to early autumn). Baits are usually prepared in WA by mixing impregnated oats (4.5 mg 1080, or more than twice the lethal dose for a large rabbit) with filler oats to achieve a bait mix of 0.5 or 1% (i.e. one poisoned grain in 100-200 oats). Assuming an average weight of 40 mg for individual oats, these bait mixes contain 560 or 1120 mg/kg 1080. Small amounts of uniformly poisoned oats (400 mg/kg 1080, or 0.016 mg in each 40 mg oat) are also prepared from concentrate in WA. Pre-feeding with 1080-free oats is only required with the latter.

Operators in WA target areas of rabbit feeding and should avoid non-target exposure when laying bait trails. For example, baits are laid within paddocks but not in adjacent bushland or within 10-20 m of rabbit shelter areas in WA. All dead animals found on baited and adjacent properties during baiting and for 14 days after bait has been removed or eaten must be disposed of by burial or burning.

The WA Forest Products Commission applies oat baits (mixed from impregnated oats) in trails and bait stations for rabbit control within newly established pine and eucalypt plantations. Baiting only occurs when rain is not expected within 5 days. Trails are laid in the same way as for agricultural situations. Bait trails may be laid in furrows, in ribbons directly on the soil surface, or scattered along a trail about 5 m in width. Furrow or ribbon methods apply about 6 kg/km, increasing to 10 kg/km for scatter baiting. Bait stations are loaded with around 2 kg bait. Baits and rabbits are left undisturbed for at least 10 days.

Oats (375 mg/kg 1080) are also preferred in SA because they are easier to handle and store and are less attractive than carrots to stock and some native animals. In addition, the husking of oats by cockatoos, parrots and other birds helps reduce the risk of non-target effects as much of the 1080 is discarded with the husk rather than ingested. Advice from SA is that less than 2% of the toxin penetrates to the kernel when baits are prepared without vacuum impregnation.

Victoria uses pellet, carrot and oat baits, which may be laid in trails or broadcast from the ground or from aircraft (up to 15 kg/ha for carrot baits) according to DNRE directions. Rabbit control programs use 1080 to substantially reduce large populations, or where other methods are considered unsuitable. Untaken baits and rabbit carcasses should be collected within 4 days of baiting and incinerated or buried, with carcass collection and disposal to continue for 14 days after baiting. Baits should be placed in locations inaccessible to animals other than rabbits.

In Tasmania, carrot is the only bait material used with 1080 for rabbit control. It is recommended that a furrow less than 25 mm deep be ploughed across all feeding areas and around cover. At least three free feeds are used to attract rabbits, with the first being at a rate of approximately 7.5 kg/km. The rate used in later feeds and the poison feed depends on the amount of the previous feed eaten and may increase to 12 kg/km or more. Carcasses and uneaten bait must be collected and destroyed within 7 days of the poison operation.

The commercial product Rabbait is registered in NSW, SA, Vic, Tas and WA and must be used in accordance with its label directions and relevant legislation. Baits should be placed in locations inaccessible to animals other than target animals, and recovered for destruction after 4 days.

Wallabies and possums

Wallabies (Tasmanian pademelon and Bennett's wallaby) and other browsing and grazing native mammals (brushtail possums) are controlled in Tasmania. Poisoning is the least desirable but most cost effective method for reducing large populations of most browsing mammals. 1080 is the only poison registered for this purpose. Roughly equivalent amounts are used for forest and agricultural protection in Tasmania. Permits must be obtained before wallabies and possums can be controlled, and will not be issued unless Wildlife Officers of the Parks and Wildlife Service of DPIWE are satisfied that control is necessary, that alternative methods such as fencing or shooting are not feasible, and that use of 1080 will not pose an unacceptable risk to other wildlife populations. 1080 is only used as a last resort.

The target species have benefited from the resources provided by agricultural development, such that they often occur at higher densities than in their natural habitat. Baiting is intended to achieve a "knock-down" effect, allowing crops or trees to become established or pasture to grow. Populations may return to pre-poisoning levels after 6 months. Agricultural crops are normally treated once, but recently planted forestry coupes may receive further intermittent control where subsequent field inspections (every 2-3 months) show unacceptable levels of browse.

The carrot bait product (42458 containing 140 mg/kg 1080) is laid by hand, with no application within 20 m of the edge of a stream containing permanent running water. The optimum bait size is a 1 cm cube, with small fragments avoided as they are more easily eaten by birds. Baits are prepared on-site by mixing a dyed stock solution with the carrot pieces in a cement mixer or tub until even coverage is achieved. Trail baiting uses 10-20 kg/km. This probably equates to around a gram per hectare 1080, although conversion to an area rate is not straightforward. Baits may also be laid at intervals in piles, ideally of handful size. To minimise exposure to birds, baits should be laid in the late afternoon. Baits should not be laid until consumption of free feed reaches at least 50%, which may require 2-8 baitings. Frequent repeated 1080 baitings in one area are generally not supported.

A conservation group has expressed particular concern regarding aerial baiting for herbivore control in Tasmania. The DPIWE has affirmed that only the ground level laying of 1080 poisoned bait is practised in Tasmania.

Foxes

Predation by the European red fox is listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999*. The Commonwealth Threat Abatement Plan for this species recognises that, in most situations, poison baiting is the most effective method of reducing fox numbers and impact, although a major drawback is that it may affect some native carnivores and scavengers, and also domestic dogs. The benefits of this control method are confined to the baited area and, unless some barrier prevents reinvasion, last only for as long as baiting is regularly applied.

Tradition and convenience have usually determined the selection of bait materials: injected eggs, dried meat baits, fresh meat, and commercial products (Foxoff baits) have all been used. The effectiveness of the different baits and the factors that influence their acceptability to foxes need to be determined to ensure that the most cost-effective delivery systems are used. It is possible that some baits which work well in one environment may not be as effective in other environments.

The Plan notes that concern about the humaneness of 1080 has been expressed by animal welfare groups, but that it is possible that these concerns could be satisfactorily addressed by the inclusion of an analgesic with the poison bait. It also notes that alternative, more humane poisons for the control of foxes should be investigated. Research in these areas is continuing, as outlined later in this report.

Vertebrate pest control programs need to avoid non-target impacts while maintaining effectiveness against pest populations. In many situations, the twin goals of efficacy and target specificity are not fully compatible. For example, the NPWS (2001) reports that refinements to baiting practices that increase the time and costs of baiting, such as use of buried (sand pad) bait stations with free feeding and daily monitoring, may preclude the conduct of baiting at sufficient frequency and over sufficient area to counteract immigration by foxes. Such limitations on baiting programs would make them of no benefit to threatened prey species. Under the NSW threat abatement plan for predation by the fox (NPWS, 2001) free feeding and daily monitoring of bait stations will be used only where a non-target risk is identified (i.e. where spotted-tailed quolls are likely to be present).

A variety of factors impinge on the likelihood that pest and non-target animals may succumb to baiting operations. These factors include frequency, scale, timing and intensity of baiting, materials used for baiting, methods of deployment, bait placement, the environment where baiting occurs, and the sensitivity of the species present.

Although WA has an advantage when using 1080 as many native fauna have developed tolerance, target specificity can also be achieved in other States because of the sensitivity of the target pests, but a more cautious approach may be needed.

The above factors are exemplified by the different methods used for fox control in Western Australia and the eastern States. Large areas of Western Australia are aerially baited with 1080 up to six times a year for fox control under the Western Shield program that was introduced in 1996. Coordinated treatment of large areas in this way retards the immigration of new foxes into baited areas and allows recovery of native animal populations. There is relatively little conflict between efficacy and target specificity under this program because of the tolerance to 1080 that has developed in many Western Australian fauna. Similar large scale aerial fox control programs do not operate in the eastern States (although some aerial baiting with Yathong Fox Bait occurs in western NSW at sites where additional environmental impact assessment has been conducted, large scale ground baiting has commenced in eastern Victoria under the Southern Ark program, and large areas are baited in SA under Operation Bounceback) because of the greater sensitivity of resident native fauna to 1080 poisoning. Fauna recovery or threat abatement operations tend to be of much smaller scale and prioritised to those areas where foxes are threatening vulnerable populations. Baits are often placed by hand, which in sensitive areas entails burial beneath a sand pad, thus allowing insights into the animals which visit each bait site. Poison baits are only laid after a period of free feeding, and only at those bait sites with no evidence of visitation by non-target animals. The need to lay baits by hand and check baiting sites periodically greatly increases the expense of deployment and reduces the areas that can be covered. Smaller baited areas are more susceptible to reinvasion by foxes.

1080 meat baits are widely used for fox control in WA, both in agricultural landscapes and in large scale aerial operations over conservation estate. Trained landholders can purchase baits after obtaining baiting approval from an authorised officer of the Department of Agriculture. Most fox baits are prepared from kangaroo meat, which is dried as for the wild dog baits. Baits contain 3 mg 1080. CALM has recently developed a shelf stable salami-type bait (53187 containing 3 mg 1080 in each 35 g bait) but this is not subject to the current review. There is also some use of commercial Foxoff products and treated oats for insertion into meat baits. Hens' eggs are sometimes used, but must always be buried.

Research has confirmed that application rates of 5 baits/km^2 are effective in controlling foxes and that bait uptake does not increase when this rate is doubled (Thomson and Algar, 2000). Baits can be buried or tethered where potential non-target risks are identified, although burial appears to increase the time required for foxes to take baits. Most baits are taken within a few days, but normal practice is to allow 10 days to 2 weeks for a baiting campaign. Scent trails, prepared by dragging a carcass over the ground, are sometimes used to attract foxes to baits in some States, but care must be taken to avoid laying baits along a continuous scent trail as this may encourage multiple bait takes and possibly bait caching by a single fox. Bait locations should be marked, and untaken baits recovered at the end of a campaign.

As for wild dogs, fox baits must be buried to a depth of 8-10 cm in Victoria. Placement along fence lines, ridges and tracks, with a bait spacing of 500-1000 m, is recommended in broadscale agricultural areas. Free feeding with monitoring of bait stations should precede baiting. The exercise should be repeated at weekly intervals if foxes are still being detected. Carcasses should be incinerated or buried. According to the directions for use of fox baits that are posted on the DNRE website, any deaths of stock, wildlife or companion animals that are suspected to have been caused by baiting must be reported within 24 hours to DNRE (this requirement may not be enforceable as it does not appear in the directions for use that form part of the approved label for the DNRE registered 1080 Fox Bait). DNRE promotes group control programs over several farms and adjoining public land to reduce the rates of reinvasion.

A fox bounty trial was introduced in Victoria in July 2002 but after a scientific evaluation found the bounty to be relatively ineffective in reducing fox populations has been replaced by a new package of fox control measures, based predominantly on coordinated baiting programs in areas where they are most needed and effective. The evaluation examined mounting evidence from long term fox control programs both in Victoria and interstate that broad-scale, coordinated, baiting programs, where baits are deployed strategically throughout the year, can achieve high sustained levels of fox population reduction and contribute to the recovery of a range of threatened prey species. It was concluded that the key elements of successful programs are that they are intensive (baiting several times a year), well coordinated and cover large areas (VIAS, 2003).

Wild dogs

A range of methods can be used for laying wild dog baits, as described in a recent species impact statement (McIlroy, 1999) that evaluates the likelihood of adverse environmental impact from aerial baiting with 1080 poison for wild dog control in specified areas of five national parks in southern and northern tableland areas of NSW. Note that his findings may be less applicable to other parts of Australia. Simple ground baiting entails distribution of baits along access tracks from the back of a vehicle, and differs little in reality from aerial baiting. Strategic ground baiting involves placement at sites selected to maximise their uptake by dogs and minimise non-target disturbance. McIlroy notes that neither method is highly specific for dogs, and that questions remain regarding their efficacy with research results indicating 20-50% reduction in dog numbers or signs. These methods are common on private land.

Replacement baiting involves monitoring of bait stations used in strategic ground baiting and replacement of taken baits. The need to revisit bait stations increases costs, particularly in rugged terrain.

Specificity can be further improved by burying baits as many non-target species, particularly birds, are less likely to remove buried baits. However, the method is not tested and does not offer the same margin of safety as mound baiting in respect of animals such as the spotted-tailed quoll.

Mound baiting offers further improvements and was believed to be the most target-specific method, but again increases costs because of the need to revisit bait stations periodically. Baits are covered with a mound of sand or raked soil to facilitate the identification of animals which visit the baits. Nontoxic baits are used initially, and followed up with toxic baits only at those locations where dog activity has been recorded. Although dogs that visit bait stations can be specifically targetted in this way, McIlroy notes that the effectiveness of this method in reducing indices of wild dog abundance and their impact on livestock on adjacent properties has not been scientifically assessed.

In contrast to the above, aerial baiting is generally regarded as an efficient and cost-effective wild dog control technique, although success depends largely on the type of bait used and the age and social status of the dogs. The level of control may also depend on timing of baiting in relation to breeding season and seasonal changes in water distribution, leaching of toxin from baits by rain, availability of food, and the number and distribution of baits dropped. Thomson (1986) found that aerial baiting killed all of 18 radiocollared dingoes in one trial, and 62 and 63% in two others. Baits were dropped at high density (up to 50 baits/km) along major watercourses, roads and animal pads.

Whichever method is used, baiting for wild dogs is often followed up by trapping or shooting to remove individual animals. Effective wild dog control requires an integrated approach, as exemplified in NE Victoria where wild dogs have been effectively controlled in some areas but continue to cause significant stock losses in others. To achieve success, wild dog control programs need to be planned in advance and implemented year round using a strategic mix of control options such as trapping, baiting and fencing (North East Wild Dog Management Group, 2003).

Similarly, a recent evaluation of wild dog control in WA (WA, 2003) concluded that landholder complacency, a scaling down in the amount of ground control work carried out, and a gradual over-reliance on aerial baiting, have all contributed significantly to the progressive build-up of wild dog numbers in that jurisdiction. The evaluation concluded that medium to long term management of wild dog numbers in WA will require a move away from the present over-reliance on aerial baiting, with a return to the sustained and widespread deployment of all available control techniques in combination (ground baiting, aerial baiting, trapping and shooting). It is important to note that this evaluation continued to support aerial baiting: research advice confirmed to the Panel conducting the WA reevaluation that aerial baiting does work as long as it is properly implemented. Its effectiveness can be difficult to reliably monitor and measure because of the general lack of good information on dog numbers, movements and stock impacts.

It is noted that wild dog control in WA has relied on a single bait type, suggesting that an increase in the range of bait types available may help improve wild dog control.

The question of bait shyness is discussed in a recent review paper from WA, which concludes that talk of extensive bait shyness is unsupported speculation. It is argued that the effectiveness of 1080 baiting would have deteriorated much more rapidly if consumption of sub-lethal baits had been a regular occurrence over the last 20 years. There is no evidence of bait shyness in foxes. Given the long latent period before animals become symptomatic, it is argued that a sublethally dosed animal would be unlikely to associate feeling sick with consumption of a bait many hours earlier, particularly if other foods have been eaten. Wild dogs are less likely to take baits when abundant food is available. Apart from this, the key to baiting success is bait placement, which can more readily be achieved from the ground. Aerial baiting may require five times as many baits as placement cannot be as well controlled, and baits may be trampled by cattle or fall into water. Although bait shyness is not considered to be a major issue with wild dogs, the review acknowledges that there is some merit in having alternative bait materials, and that the salami type bait developed for foxes may augment the current dried meat baits if testing against wild dogs proves effective (Thomson, 2003).

The need for an integrated approach to wild dog management is also recognised in NSW. An integrated approach is considered essential by NPWS as reliance on 1080 increases the propensity to select for bait shy animals (NPWS, 2003).

Specific detail on baiting with 1080 for wild dog control in NSW is contained in the report (NSW, 2002) of the recent Inquiry into Feral Animals. Aerial baiting is restricted to the northern and southern tablelands areas where rugged terrain makes ground baiting very difficult to undertake.

Regional aerial baiting programs occur once a year (May to early July) on a cooperative basis involving RLPBs, wild dog control associations and government agencies, with coordination by NSW Agriculture.

Representatives of the Barnard River Wild Dog Association (inland from Taree) informed the inquiry that, in northern areas, large scale aerial baiting has occurred since about 1962 and has developed into a perimeter baiting operation between sheep country to the west and the wild dog population in gorge country to the east. Baiting occurs along a narrow strip (10-20 km wide) between Singleton (upper Hunter) and Tenterfield (Queensland border) fringing sheep country on the edge of the tablelands. Baits were initially broadcast from fixed-wing aircraft but this has now been replaced by GPS guided helicopters that allow more precise and strategic placement of baits, with an overall reduction in the amounts used. Specific dog movement paths, particularly long saddles, bridle trails and crossing points, and areas known locally to be best for trapping wild dogs, are targetted. However, access to some movement paths has been restricted in recent years and predation is starting to increase again.

The NPWS suspended the use of aerial baiting in Kosciuszko National Park based on the recommendations of a species impact statement (McIlroy, 1999) that raised serious issues about non-target species impact. Aerial baiting was approved by NSW in August 2004 for the Adaminaby and Yaouk areas in the north of Kosciuszko National Park. State Forests has also discontinued aerial baiting as a general policy although some still occurs in the northern tablelands where it is integrated with RLPB operations.

The South Coast RLPB is different from other areas of NSW in that helicopter baiting and simple ground baiting from vehicles are opposed, because it is not feasible to monitor which animals are taking the baits. In addition, toxic baits are only present on the ground for a short time after aerial delivery, while with mound baiting they can be present for up to 150 days per year. Aerial baiting was discontinued in the early 1990s when the replacement mound baiting program, which continues to be updated, was found to be effective. However, this program may not be equally effective in other jurisdictions. For example, other RLPBs have noted that mound baiting can be compromised when pigs rapidly take baits from mounds, and that some areas are too rugged to allow regular access for mound baiting.

Lambs tongues are a preferred baiting material for some Rural Lands Protection Boards. They are said to be less likely to be taken by non-target animals because they are large, decay rapidly, and are easy to tether.

Baiting in the NT uses fresh meat baits (200-500 g) injected on-site with 6 mg of 1080 in solution and laid by hand under vegetation close to watering points or along fence lines. Untaken baits are seldom recovered, unless placed in areas frequented by the public. Aerial baiting is permitted but rarely used. Baiting is mainly restricted to large pastoral properties and conservation areas.

In Victoria, wild dogs occur on public land in the alpine areas of Gippsland and the North East and have recently been reported in the western Mallee. While wild dogs are not recognised as a threat to native fauna they can affect agricultural enterprises. The Victorian Landcare Note (LC0317 dated July 2000) notes that there is a strong community belief that the majority of the damage is caused by wild dogs moving from public land onto adjoining private land to attack livestock, particularly sheep. 1080 Predator Baits (49354) each contain 4.5 mg 1080, and must be buried to a minimum depth of 8 cm. Wild dog or fox carcasses must be destroyed by incineration or buried, and reasonable steps should be taken to ensure destruction within 14 days of placement for untaken baits. 1080 baits cannot be used in urban and residential areas.

Meat baits used for wild dog and fox control in Queensland are of two sizes, 125 g (containing 6 or 10 mg 1080) and 250 g (containing 6 mg 1080). Bait selection depends on location (higher loadings in western and far northern areas because of a perception that the lower dose is not effective), pest density and non-target risks (larger bait sizes where risks are identified). Baits are laid along transects on a 200-500 m spacing. The NRME Fact Sheet on wild dog control (PA10) notes that coordination of baiting programs across adjoining properties is essential to increase baiting effectiveness. Recolonising animals tend to be more likely to attack livestock than uncontrolled populations. Many graziers bait twice a year, to target adults during peaks in activity associated with breeding (April/May) and then again in August/September to target pups and juveniles.

Further detail on wild dog baiting in Queensland is contained in a recent referral (2003/966 received 21 February 2003) from the Queensland Parks and Wildlife Service (QPWS) under the *Environment Protection and Biodiversity Conservation Act 1999*. Standard dried red meat baits were to be laid at 500 m intervals in the Conondale Range complex (south of Gympie in SE Queensland) with aerial delivery in some remote locations where prior surveys had not detected the presence of quolls. Ground baiting would be used within 4 km of any locations where quolls had been detected since 1980, with baits buried and pre-feeding conducted, except in areas of unsuitable habitat such as pine plantations. Where found to be present, quolls would be monitored by trapping and radiotracking during and after baiting. These methods would be used to investigate whether baiting may be beneficial to quoll populations in areas where continued wild dog activity necessitates further baiting. The QPWS notes that other large scale State government 1080 baiting operations generally occur outside the range where quolls have been found, and that habitat has been assessed as being of low suitability for quolls where baiting has occurred within the former range of these animals.

In WA, most baits for wild dog control are prepared from kangaroo meat. Bait pieces (110 g fresh weight) are injected with a solution of 1080 (6 mg/bait) and sun-dried on racks to lose around 60% of their weight. Dried meat baits are more durable than fresh meat, and more difficult to eat for small native carnivores and other animals. Ground baiting is used in more accessible areas. Baits may be concealed, for example amongst leaves, to reduce potential non-target exposure. Aerial application aims to lay baits at watering points and along identifiable routes such as vehicle tracks, major pads, watercourses and gorges. Application rates are not specified but determined by local experience. Research is planned to examine baiting rates for wild dogs in WA. Baiting has traditionally occurred in autumn (breeding season) and spring (when pups begin to move about) but is now mainly restricted to spring and often deferred until later in the season when water becomes less available.

The recent review of wild dog control in WA (WA, 2003) noted that landholders may prepare their own baits by inserting treated oats into pieces of meat, but that individual landholders may be discouraged from doing this by the time and effort involved. The review notes that the Department of Agriculture has applied for approval to register a ready-to-lay meat bait that could be used by landholders. Thomson (2003) also notes that the current dried meat bait will be available in the future as a registered product, and may be augmented by a salami type bait if testing proves it to be effective.

The commercial product (Doggone) is registered in NSW, Qld, Vic and SA. The usual rate of application, based on a dog density of up to 4/km^2, is about 1 bait per 10 ha. Baits should be buried at a depth of 8-10 cm at minimum 200 m intervals, after free-feeding, and replaced as needed. Neighbours are encouraged to participate in coordinated campaigns. Doggone baits should not be used where native marsupial carnivores are active, unless authorised by the relevant government authority.

Feral pigs

Feral pigs are found on Flinders Island in Bass Strait and the wetter parts of the Australian mainland, from western Victoria, through New South Wales into Queensland, and across northern Australia, from Cape York in the east to the Kimberley region in the west, particularly in association with wetlands and riparian ecosystems. In SA feral pigs occur on Kangaroo Island and in the Coopers Creek and Diamantina River areas of the far north. They appear to be increasing in number and range throughout the better watered parts of WA, including forested areas in the south-west. The principal factors affecting feral pig distribution are reliable supplies of food, water and shelter. As feral pigs need to drink daily in hot weather, they are not found in dry inland areas of Australia where there is no permanent surface water. However, they may be found in arid rangeland environments, such as those of Queensland and northern NSW, anywhere that stock watering points are provided.

Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs was listed on 6 July 2001 as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999*. The draft Threat Abatement Plan notes that poisoning is a common control technique, with 1080 the most widely used poison, but that successful management of the environmental threat due to feral pigs requires an integrated approach that also addresses a range of threatening processes and other sustainability issues associated with land management practices.

Feral pigs consume bird chicks, reptiles, reptile and bird eggs, frogs, soil organisms, earthworms and other invertebrates, carrion, fruit, seeds, roots, tubers, bulbs and plant foliage. Habitat changes due to feral pigs include: destruction of plants; changed floristic composition; reduced regeneration of plants; alteration of soil structure; increased invasion and spread of weeds; increased access for other predator species; reduced amount and quality of water available; spread of exotic earthworms; and creation of habitat suitable for disease vectors. They provide reservoirs for endemic diseases, can be vectors of exotic diseases, spread the root-rot fungus *Phytophthora cinnamomi*, and physically damage plants, providing entry points for infection. Horticultural crops also suffer significant economic damage from pig activity. Feral pigs are seen as a valuable resource by the game meat industry and by hunters.

Parker *et al* (2003) described current and proposed methods of pig control at a recent workshop. Five control methods for feral pigs are currently utilised: poisoning, trapping, shooting, hunting and exclusion fencing. Of these, poisoning is the most practical and effective control method for large areas and is widely employed in rural areas. Five different toxins have previously been used, either legally or illegally, for feral pig control: sodium monofluoroacetate (1080), anticoagulants (warfarin), yellow phosphorus (CSSP), strychnine, and organophosphates (Luci-jet and Phosdrin). Of these, 1080 is the most widely recommended and employed, with the latter three either illegal or not recommended due to lack of humaneness and target-specificity issues. However, these authors suggest that the use of 1080 for feral pig control carries a high risk of non-target poisoning due to the large doses required, the incidence of vomiting, the risk of secondary poisoning, and the fact that it has no antidote (more recent evidence to ease some of these concerns is presented in section 9 of this report). Furthermore, feral pigs are known to develop bait-shyness towards 1080-laced bait and also survive apparent lethal doses. Research is underway to develop pig specific delivery systems (baits and feeders) and alternative poisons (warfarin, zinc phosphide and cyanide).

Fact Sheets on feral pig control issued by the NRME note that pigs are the major pest animal in the wet tropics, but that poison baiting is not the primary means of pig control because of the lack of a pig specific bait material. Dogging is the traditional and most common method of pig control in the wet tropics. However, advances in trap design and trapping techniques have proven trapping to be the most effective method of catching large numbers of pigs in the region. Through the wise selection and presentation of bait material, landholders can be species selective in their poisoning program. Examples include use of bait material such as fermented grains (very attractive to pigs but not to other animals), burial of baits (feral pigs are one of the few animals that will dig up bait) and establishment of a free feeding routine so that pigs are the only animals feeding (they keep other animals away from the feeding site).

In Queensland, bait application for feral pigs normally uses bait stations, although baits may sometimes be laid along transects. Pre-feeding with nontoxic bait is used to improve bait uptake. Baits are tailored for local circumstances, with grain baits used where pigs are eating grain and meat baits where they are eating carrion or preying on livestock such as lambs. Grain is soaked for at least 24 hours before bait preparation, and vegetable and fruit baits must be cut up. Baits contain high loadings (144 mg/kg in meat and 288 mg/kg in grain/vegetable/fruit).

Baiting for pigs in Qld is predominantly conducted on an individual property basis, although there are occasional exceptions such as a regional coordinated program at Cunnamulla, organised by the local Land Protection Officer. All baiting is carried out under the guidance of an accredited and approved State or local government officer.

Meat baiting using 500 g baits injected with 72 mg 1080 remains one of the most efficient means of pig control in the more sparsely populated grazing areas of Qld, but is not used in other States. It is conducted on properties greater than 40 ha in size. Prefeeding does not occur, but baits are laid in areas where pigs have been feeding on carcasses or carrion. Baiting occurs towards evening to minimise interference by birds, and only in amounts that the pigs will consume overnight.

Grain baiting is conducted after approval on properties larger than 5 ha by the relevant government officer. Prior soaking of the grain makes it softer and more palatable to pigs, and prevents bait storage by landholders. Baits are laid in trails or bait stations, after prefeeding for

2-3 nights. The use of partially fermented sorghum, with addition of creosote to improve target selectivity by deterring non-target uptake, has been shown to increase bait attractiveness in the grain growing areas of the Darling Downs. Baiting with fruit and vegetables is conducted in similar fashion, but requires up to 5 nights prefeeding. Grain, fruit and vegetable baits are dyed green to deter interference by birds.

Ground baiting may be conducted using transects or bait stations. Meat baits are placed irregularly at bait points along tracks where there are signs of pig activity. When aerial baiting is needed, as in seasonally inaccessible areas on Cape York Peninsula, placement occurs along areas of recent pig activity. Several bait piles are placed at each bait station in order to allow feeding by several pigs rather than monopolisation by dominant animals.

In some cases where non-target bait-take needs to be reduced, bait stations may be used. These may be of several designs, but have the common purpose of excluding non-target animals such as livestock, macropods and birds while allowing access by feral pigs. Feeders are only opened at night. Once pigs enter the bait stations, they will chase off or exclude non-target animals.

Thus target selectivity is optimised by prefeeding, bait placement where pigs are active, selection of bait substrates to match local pig preferences, dying of baits to deter birds, and partial fermentation of grains so that they are unattractive to non-target herbivores. All baiting requires prior approval and is subject to record keeping in relation to locations and timing of baiting and the types and amounts of bait used. Queensland government officers refuse to allow baiting in areas of environmental or public concern unless stringent risk management measures are in place, and certain sensitive locations may not be baited for feral pigs.

A catchment care group from coastal Queensland reports that feral pig populations increased greatly during 2001, with attendant damage to cane crops and semi-aquatic natural areas, but were successfully reduced to a few individuals by 1080 grain baiting. No non-target kills were seen. Poison baiting was preceded by a free-feeding campaign in which increasing amounts of grain were placed late in the evening at locations frequented by pigs. Once regular free-feeding was established, green-dyed poisoned grain was laid in the same way, with left over grain cleaned up and destroyed.

A 1080 bait (49352) is registered for feral pig baiting in Victoria, but its use is very limited and occurs only on public land.

NSW Agriculture determined that feral pigs occurred in 60% of NSW in early 2002, up by 20% from the previous survey in 1996. The increase probably reflects a run of good seasons, and would not have been sustained through recent severe drought conditions. The most commonly used control techniques are trapping (29%), recreational hunting (22%), poison baiting with 1080 (18%), and ground shooting (14%). Current control techniques are adequate for strategic control of feral pigs when numbers are low and pigs congregate at feed and water but are limited where feral pigs are dispersed during good seasons (Saunders *et al*, 2003).

The NSW NPWS considers baiting using grain laced with 1080 to be the most effective feral pig control option in habitats with dense canopy cover located away from urban areas, and has conducted many successful vehicle based baiting campaigns. In remote and rugged parts of the Blue Mountains area, free feeding is carried out aerially and NPWS staff are then transported by helicopter or horseback to bait locations in remote areas (Banffy, 2003).

A Rural Lands Protection Board from central-western NSW reports that pigs can be selectively targetted by ensuring that they are regularly free-feeding before poison baits are laid. Laying of baits in the late afternoon and removal of any uneaten baits before sunrise minimises avian exposure.

Pigs appear to be increasing in number and range in WA, and are known to damage production and conservation areas from the SW jarrah forests to the northern river systems. Feral pig control in WA is expected to remain heavily reliant on 1080 baiting in the medium to long term, but the specificity of baiting practices needs to be improved (Twigg, 2003).

As noted above, current methods of pig control require improvement. Baiting with 1080 presents risks to non-target wildlife, and needs to be ongoing because pigs have a very high reproductive capacity. Phosphorus based poisons are available but not recommended as they are inhumane, less effective than 1080, and can result in secondary poisoning of non-target species. Trapping is labour intensive, and shooting unsuitable for forest areas. The Pest Animal Cooperative Research Centre has conducted preliminary research into a sterilisation virus which would be transmitted to pigs through bait. Such options would likely take years to develop, particularly given the need to resolve target specificity issues and overcome the high fecundity of pigs. Peacock (2003) has summarised the issues involved and concluded that virally induced immunocontraception is not a viable option for feral pig control.

Feral cats

Predation by feral cats is listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999*. It is thought to have contributed to the extinction of small to medium-sized ground-dwelling mammals and ground-nesting birds in Australia's arid zone, and to threaten the continued survival of native species that currently persist in low numbers. The Commonwealth Threat Abatement Plan developed for this species notes that baiting feral cats is difficult as they are often found in low densities, can have large home ranges, are disinclined to feed on non-live baits or carrion except during drought or during food shortages, and are naturally wary. Cats take baits much less readily than do foxes, for example, and have less predictable movement patterns. A successful feral cat bait must be able to be detected by, and be attractive to, feral cats particularly where they occur at low densities. The timing of a baiting program is a critical element in the successful baiting of feral cats.

The Plan notes that recent studies funded under the National Feral Animal Control Program (formerly a joint program between the Department of the Environment and Heritage and the Bureau of Rural Sciences, but now exclusive to the BRS) have identified a potentially cat-specific toxin which appears to be a humane method of control. Further detailed studies are needed to confirm that the toxin causes a humane death and can be effectively applied in the wild, and to provide the information necessary for the new compound to be nationally registered as an approved method of control for feral cats. In the interim, it is expected that 1080 will remain the most common poison used for feral cat control. The alternative toxin mentioned in the Plan is PAPP (para-aminopropiophenone). It is selectively toxic to felids and canids, and is also being investigated for wild dog control.

As noted above, the single cat bait product captured by this review has not had its registration renewed. Permits have recently been issued to allow use of a specially developed sausage bait containing a proprietary attractant for feral cat control in parts of WA and SA. The sausage bait is regarded as less hazardous for non-targets than the formerly registered APB feral cat bait (a 4 g soft crackle bait based on fish and meat meal, containing 6 mg 1080) as it is larger (30 g), harder and contains less 1080 (4.5 mg). As there are no 1080 products registered for cat control, this use pattern will not be evaluated in the current review. However, current activities regarding the use of 1080 for feral cat control can be described.

CALM issued a media release on 12 May 2003 highlighting its new research program that aims to refine recently developed control techniques for feral predators. The release indicated that feral cat baits were about to be laid on Lorna Glen station, a recently acquired pastoral lease in the east Gascoyne region, following promising trials in the Gibson desert during 2002. In its response to the preliminary review findings, Western Australia advised that the efficacy of cat baiting campaigns was poor at bait densities of 10 baits/km^2 or less, but that successful control was achieved at 50 and 100 baits/km^2. Further trials are to be conducted to determine the optimum bait density for cat control.

In Qld, feral cats are now a declared species under new legislation, and a NRME fact sheet (PA26 dated June 2003) has been issued. The fact sheet indicates that registration of 1080 is currently being sought for the control of feral cats where conditions for its use are suitable.

Rodents

Sweet potato baits containing 1080 are used as part of an integrated management system for control of rats, particularly the pale field rat, in hoop pine plantations. This use is authorised by APVMA permit. Habitat manipulation occurs before winter to reduce the potential for rat colonisation. This mainly takes the form of vegetation management. Rat and non-target fauna populations are monitored, by trapping and observation respectively, followed by baiting in July where rat density indices exceed concern thresholds. Baiting does not occur every year, and not all compartments are baited. Some compartments are baited once during the initial 5 years of growth, and possibly twice if seasonal conditions favour abnormally high rat populations.

The baits are freshly diced cubes of sweet potato containing 500 mg/kg 1080, linseed oil (as attractant) and malachite green. These baits are said to be exceptionally attractive to the pale field rat. Baits are manually distributed, under cover with avoidance of bare ground, on a pre-determined grid pattern within affected compartments at 6 kg/ha within 30 hours (preferably 12 hours) of dicing. No baiting occurs within 50 m of wildlife corridors or native forest areas. Monitoring is conducted to confirm that any non-target impacts are minimal. Baited and adjacent areas are intensively surveyed for fresh non-target carcasses 2-4 days and 7-10 days post-baiting. Any casualties are examined and sampled by a veterinarian, with baiting suspended immediately if significant numbers are found.

The most recent monitoring results are for 2001. Pale field rats were the only identified casualties of baiting. The number killed is unknown, as rats were believed to have died underground in their burrows where detection is almost impossible. However, baiting was successful in reducing rat density indices to acceptable levels. Baiting did not occur in 2002 because of the success of the integrated damage mitigation strategy and was not expected to be needed in 2003 when application was last made to renew the APVMA permit.

5.2 Environmental Chemistry and Fate

As a water soluble compound, sodium fluoroacetate can be expected to be mobile in the environment with a tendency to leach to deeper soil layers and groundwater. Only limited sorption to soil of fluoroacetate, a large monovalent anion, may be expected. Given its simple carboxylic acid structure and the presence of only a single fluorine substituent, sodium fluoroacetate may be expected to be easily degradable, which would limit its leaching potential in soil. Low application rates and rapid bait uptake will also limit the extent of any leaching through soil that may occur.

The US EPA RED document notes that environmental data for sodium fluoroacetate are limited, but allow the following tentative conclusions. Leaching and metabolism are expected to be the major routes of dissipation from soils. Degradation appears to occur primarily by biologically mediated processes, with unvalidated data suggesting stability through 27 days in sterilised soil. The potential for leaching may be reduced in some soils by adsorption to organic matter and clay particles and absorption by plants.

Results from numerous studies conducted in Australia and New Zealand, described below, are in general agreement with the tentative conclusions of the US EPA.

5.2.1 Natural occurrence

About 40 species of endemic Australian plants produce fluoroacetate as a chemically mediated, anti-herbivore defence strategy. Most are *Gastrolobium* spp in south-western Australia, which contain up to 2600 mg/kg dry weight (up to 6500 mg/kg in seeds). Such plants (two species of *Gastrolobium* and *Acacia georginae*) also occur in northern Australia but are less abundant, patchily distributed and only contain up to 180 mg/kg fluoroacetate (Twigg and King, 1991).

Gas chromatography has confirmed that fluoroacetate is present at relatively high concentrations (0.1-3875 mg/kg) in plants of the genus *Gastrolobium* (Leguminosae) which are common in the southwest corner of Western Australia. Highest concentrations were found in flowers and young leaves. Only one of nine soil samples taken from directly beneath the toxic plants was found to contain fluoroacetate (3.9 µg/kg). No measurable amounts (limit of detection 0.1 µg/L) were found in water samples, although several were collected within 2 m of vegetation containing fluoroacetate. The absence of fluoroacetate in water samples suggests that fluoroacetate does not persist in the environment (Twigg *et al*, 1996).

SA has advised that other highly toxic fluorinated compounds exist in the seeds of these plants.

5.2.2 Persistence in baits

The VPC provided a submission to the review including a summary of the likely persistence of 1080 in different bait materials. Meat-based baits are likely to remain lethally toxic to target predators for 2-8 weeks in temperate Australia depending on rainfall and soil temperature, and possibly for 8-12 months under arid conditions. In reality, bait takes of 60% can be expected in the first 10-12 days, increasing to 80% in the first 3 weeks, depending on the availability of alternative food. Recovery and destruction of untaken baits are widely recommended. Oat baits used for herbivores can be detoxified by relatively small amounts of rain (6 mm) but carrot baits leach the toxin into underlying soil only slowly. Elimination of 1080 and nontoxic metabolites from living animals is fairly rapid, but the toxin can persist in carcasses for many months under cold and dry conditions. Published findings on these aspects are summarised below.

The VPC has also advised that burial shortens the effective life of meat baits. Fresh meat baits buried at 10 cm lost at least 85% of their toxin content after 7 days in the ground in cool conditions. Dried meat baits from WA lost 72% of their fluoroacetate content in the same time.

Fresh meat baits

Baits prepared by injecting 1080 solution (6.7 mg/bait) into pieces of fresh lean beef (190-239 g) began to lose their toxicity from the moment of preparation onwards. Rainfall and particularly blowfly larvae (in summer) were effective in detoxifying baits placed on pieces of lawn turf in Canberra. The rate of detoxification was much slower in winter when maggots were absent. Maggots probably detoxified the baits by physically removing bait material and increasing the rate of leaching, rather than by degrading the 1080. Microbial defluorination and leakage after injection were also identified as potential factors, with increased levels of fluoride providing evidence for the former. Surface laid baits were calculated to retain the LD50 for a 2.8 kg tiger quoll (*Dasyurus maculatus*) for 2-4 days in summer and 4-15 days in winter (McIlroy *et al*, 1988).

Similar experiments conducted near Kalgoorlie between October 1985 and January 1986 found that kangaroo meat baits (fresh or sun-dried for 48 hours) were attacked by ants, which fed on the undersurface of baits and gradually hollowed them out, removing 70-100% within 5 days at one location in mixed eucalypt woodland and bluebush (Merks and Calver, 1989).

SA has advised that ants are rarely seen feeding on fresh meat baits in its jurisdiction, and that baits are not seen to become flyblown or supporting maggots.

Twigg *et al* (2000) found that meat baits placed on soil in predator-proof enclosures to the west of Alice Springs remained toxic to dingoes, foxes and feral cats for at least 8 months, but that bait take from monitored bait stations reached 85% within 4 days. Untaken baits rapidly dessicated in this arid environment, such that they resembled very dry jerky within 2-3 days. Baiting near water points was effective (50-70% reduction in dingo numbers) on two stations but not on a third, apparently because of the presence of ephemeral water bodies. Dingoes that visit watering points are more likely to interact with cattle.

Manufactured meat meal baits

Foxoff baits are designed to be stable in storage and during transport, but not to remain lethal for long periods once placed in the soil. Shelf-stability has been confirmed experimentally, with at least 97% recovery of 1080 after storage for 6 months at 30°C and 22% relative humidity. Lethal efficacy against foxes was confirmed after storage at room temperature (10-39°C) for up to 11 months. Content of 1080 declined during 2 weeks in soil, by around 25% in dry soil (mean 13.7% moisture) and around 80% in wet soil (20.3% moisture) that received 56.4 mm rain over the test period. Baits from wet soil became visibly mouldy (Staples *et al*, 1995).

Degradation of 1080 in Foxoff baits buried under 5 cm of soil was investigated over a 12 week period (spring to early summer) under simulated field conditions in the central tablelands of NSW. Toxicant levels remained stable in shelf-stored baits. Buried baits began to physically degrade, mainly through fungal activity, after 3 weeks. Concentrations of 1080 were highly variable in buried baits protected from rain, and remained high enough to kill a fox or dog after 11 weeks. When buried baits were exposed to rain (natural and artificial, the latter applied once a week at average and twice average rainfall) concentrations of 1080 underwent exponential decay, reaching the LD50s for dog (15 kg kelpie) and fox (5 kg) after 1.7 and 2.4 weeks, respectively, and becoming nontoxic after 2.2 and 2.8 weeks (Saunders *et al*, 2000).

Twigg (2001) has reported that manufactured meat meal-based baits are more prone than dried meat baits to insect attack, which reduces the number of baits available to target and non-target species.

A number of Rural Lands Protection Boards testified that they mainly use commercially manufactured baits for fox control and find them effective. However, there were also criticisms that the shelf stability of the commercial baits facilitated their storage and subsequent uncoordinated use by landholders, although labels require that all baits be used or destroyed within one month of purchase.

Egg baits

Twigg *et al* (2001) studied the loss of 1080 from egg baits in 1999/2000 at Corackerup Nature Reserve in southern WA. Regular fox control for malleefowl protection had occurred at this site for at least 5 years. Eggs injected with 4.5 mg 1080 were placed in predator-proof enclosures in mallee heath country. Three different treatments were used, with eggs left unsealed (standard practice for baiting by the Malleefowl Protection Group) or sealed with candle wax. One set of sealed eggs was prepared aseptically. The level of 1080 in the eggs was determined at intervals to 63 days by a bacterial inhibition bioassay, with gas chromatographic confirmation of the dichloroanilide derivative for selected samples. Bait take in the 12 days after baiting (eggs buried at 1-3 cm depth at 200 m intervals according to standard fox baiting practices) was determined by visual examination of tracks at bait stations.

Most of the baits (94%) remained toxic to foxes (contained at least the estimated LD100 of 0.143 mg/kg for a 8.9 kg fox) for at least 42 days, and 72% retained this level of toxicity after 63 days. The longevity of egg baits appears to be greater than that of other predator baits, as might be expected given that freshly injected eggs contain few detoxifying microorganisms. The unsealed eggs declined in potency most rapidly during spring, while the sealed eggs lost toxicity most rapidly in summer. Sealing with candle wax probably had little effect in restricting microbial access as even unsealed eggs tended to be sealed by albumin that was withdrawn with the needle. Stability of 1080 in aseptically prepared eggs did not appear to be significantly enhanced. One egg bioassayed at 163 days was found to retain 0.96 mg 1080 (an approximate LD50 for a fox).

Goannas, rabbits and kangaroos were the most frequent visitors to bait stations, but patterns of visitation changed with season consistent with known activity patterns. Goanna activity increased in summer but visits by bob-tail skinks and cats decreased at this time. Goannas took 37% of baits laid (59% of bait takes) during spring, increasing to 61% (90% of bait takes) in summer. Fox takes were much lower, at 5% (8%) in spring and 17% (25%) in summer. Birds (probably crows) and bob-tail skinks took a few baits, mainly in spring.

Oat baits

Oliver *et al* (1982) exposed 5 g samples of vacuum impregnated “One-shot” oats (4-5 mg 1080) to sprinkler irrigation (0, 3, 6, 13, 25, 51 or 76 mm) or to natural rainfall (up to 21 days) or dewfall, or to wet soil. Loss of 1080 was determined by aqueous extraction and measurement of conductivity.

Oats lost more than half their 1080 content after 6 mm sprinkler irrigation, and were completely detoxified by 51 mm. Under natural rainfall, baits lost 34% of their 1080 content in the initial 2 days, when no rain fell, and the remainder over the next 2 days, when 4.8 mm rain fell. Dewfall also had significant effects, with 28% loss during the first 24 hours. Major losses (69% within 24 hours) also occurred when baits were placed on wet sand (Wheeler and Oliver, 1978).

Field evaluation of this kind of bait under Mediterranean conditions (south-western Australia) has shown that performance is reliable during summer but erratic during winter, perhaps because of rapid detoxification by rain but possibly reflecting better food availability.

Carrot baits

Carrot baits prepared by tumbling with 1080 stock solution and placed on turf were highly water resistant and showed no decline in 1080 concentration after being subjected to 200 mm of sprinkler irrigation. The authors conclude that such baits are best suited to wetter forest environments where prolonged retention of the toxicant is desired. In drier environments, carrot baits tend to rapidly dehydrate and become unpalatable (Bowen et al, 1995).

The lack of leaching from carrot baits presumably reflects diffusion of 1080 into the interior of the wet carrot baits, from where it is not easily removed by rain.

5.2.3 Uptake and movement of meat baits

Careful placement of baits can help improve target selectivity, but this objective may be compromised if baits are moved by animals. For example, there are unsubstantiated anecdotal reports of dogs being poisoned by 1080 baits, even though they were restrained in kennels, because baits were dropped by birds. The success of baiting operations can be compromised when baits are taken by non-target animals. Goannas can be a problem in some areas, but corvids and foxes are considered to move most baits. Baiting during winter when goannas are less active can improve the cost-effectiveness of canid control. Movement and caching of meat baits by foxes is a well documented problem, as outlined below, that can similarly compromise baiting operations.

Fox bait palatability and caching

Bait preferences have been studied in Victorian pen and field trials. Foxes preferred deep fried liver to commercial Foxoff baits in pen trials. Uptake rates in the field were the same for the two baits, but deep fried liver was most often eaten and Foxoff most often cached. Use of a more palatable bait should improve cost-effectiveness of fox baiting and limit the potential for non-target impacts following movement of baits (van Polanen Petel *et al*, 2001).

Foxes have been shown to remove and cache Foxoff baits after they were buried at 400-500 m intervals in agricultural land (5-10 cm depth) at various sites throughout the central and southern tablelands of NSW. Prefeeding was conducted with nontoxic baits over four consecutive nights, and baits containing radiotransmitters were then laid three days later. Uptake of nontoxic baits approached 40% (65/176) with a similar proportion (24/65) of taken baits being cached in the first season of the study. Most of these were cached in single locations, but some were subsequently moved. When toxic baits were used at different study sites the following season, uptake and caching rates were similar (78/230 and 23/78) but all the cached baits were moved to single locations where they remained undisturbed for the rest of the 10 day trial. The mean distance from bait station to cache was 156 m, but some baits were moved 800 m. As well as the non-target implications, the authors note that foxes reinvading baited areas may encounter cached or untaken baits and develop bait shyness if toxin levels have declined to sub-lethal levels when baits are taken (Saunders *et al*, 1999).

Recent baiting operations in SA have confirmed that foxes may refuse less palatable baits, but that a change in bait can overcome such aversion. Baiting over about 2500 ha in autumn 2003 required up to nine Foxoff bait replacements at each of 34 bait stations, but spotlight counts indicated little if any impact on the fox population. Baits were then changed to liver at 12 bait stations. All baits were taken, spotlight counts were halved, and six fox carcasses were recovered (Anderson, pers comm).

The NPWS has suggested that bait shyness may develop rapidly in some foxes where baiting campaigns are continuous, and that shallow caching of uneaten baits by foxes places non-target species at greater risk. Switching to fresh meat has been conducted during campaigns in the Warrumbungles to encourage bait take by foxes unwilling to eat Foxoff. The NPWS notes that such options must remain an integral part of future baiting programs and that further options such as egg baits should be considered, particularly under rainy conditions when 1080 is readily leached from some other bait types (NPWS, 2002a).

Similar observations have been made in WA, where foxes are reported to prefer dried meat baits over manufactured meat-based baits (Twigg, 2001). However, Thomson (2003) notes that there is no evidence for the development of bait shyness in foxes in WA, even though repeated campaigns have been carried out in wetter areas where baits would rapidly lose potency.

Bait presentation and target selectivity

Thomson and Kok (2002) studied the effects of three different kinds of bait presentation (buried 2 cm beneath the surface, tethered by wire trace to a hidden peg, or simply laid on the surface) on uptake of nontoxic dried meat baits (45 g) containing small radiotransmitters by foxes. Baits were laid in the late afternoon on sandplots along transects adjacent to rail lines in agricultural areas of the southwest corner of WA for one night only, with new transects established each day. Foxes visited 23% of 1521 baits, taking baits from 64% of the plots visited. Visitation rates tended to be higher for untethered baits, with similar trends for uptake (79% for all unburied baits in the spring, compared with 54% for buried baits). Some 25% of the baits taken were cached, but 59% of these were later consumed, mostly within 3 days. Buried baits were more likely to be cached.

Non-target species, mainly birds, took 3% of the baits, with a particular preference for the untethered baits. Bird signs in most cases were consistent with ravens (*Corvus coronoides*). Baits were less commonly visited by cats (20% of non-target visits), reptiles (13%) and domestic dogs (4%). More than half of the baits taken by birds were dropped within 400 m (mean distance 84±20 m) and around 20% of these were subsequently eaten by foxes.

5.2.4 Metabolism

Sodium fluoroacetate does not persist in biologically active systems such as soil, water and living organisms. Substantial amounts are excreted from living organisms, either as parent material or metabolites. Sodium fluoroacetate can be persistent in carcass because of the cessation of metabolic activity after death. However, residues in carcasses will generally not persist as carcasses tend to decompose rapidly. Decomposition may be slow under arid conditions, but dessication is likely to make carcasses inedible or less attractive to secondary consumers.

Soil

Biodegradation has been studied in a silt loam collected from native forest in New Zealand after heavy rain and a sandy loam from a semi-arid region (central Otago). The silt loam (14 g, containing 16 mL water) was inoculated with a solution of 1080 (6.1 mg) in 1 mL water and incubated at 5, 10 or 23°C. The sandy loam was similarly treated after adjusting the gravimetric water content to 9, 20 or 36%. Samples were centrifuged, and residual 1080 was analysed in the soil solution so obtained using anion chromatography, with gas chromatographic confirmation for selected samples. The initial half-lives in silt loam were 80, 30 and 10 days, respectively, with only traces detectable after 27 days at 23°C. No degradation occurred in sterilised soil, where the microbes that facilitate breakdown would have been deactivated. Degradation was slower in the sandy loam, particularly under low moisture (wilting-point) conditions where 1080 was persistent. Initial half-lives were around 2 weeks at 36% moisture and 5 weeks at 20% (Parfitt *et al*, 1994).

Soil samples from central Australia (Finke Gorge National Park, 150 km west of Alice Springs) were also found to have defluorinating activity, particularly when collected after rain. Twenty-four species of microorganism (13 bacteria and 11 fungi) capable of defluorinating 1080 were isolated (Twigg and Socha, 2001).

Water

Aquarium studies showed that 1080 (0.1 mg/L) was eliminated within 48-141 hours of its introduction into biologically active streamwater but remained stable in distilled water. Loss of 1080 was closely correlated with increased fluoride in the water. Monitoring of streamwater draining areas baited for rabbit control (< 15 g/ha 1080) found detectable levels at three of four sites. However, the majority of samples contained no detectable contamination (gas chromatographic analysis of the dichloroanilide derivative) and levels could only be quantified (0.3 µg/L and 0.6 µg/L) in two samples, both taken within 24 hours of baiting. These samples were thought to have been contaminated by carrot baits which fell directly into watercourses (Parfitt *et al*, 1994).

More recent aquarium studies have shown that fluorocitrate is produced when 1080 degrades in biologically active water. At low concentrations (0.12 and 2 mg/L) 1080 was completely degraded after 17 days at 21°C in stream water aquaria containing aquatic plants, while at higher concentrations (5 mg/L) the degradation was 85% complete after this time. Metabolism to fluorocitrate was efficient, with 0.6-0.9 moles produced for every 1 mole 1080 degraded when fluorocitrate concentrations were at their peak. Fluorocitrate was below the limit of detection (0.01 mg/L) at the lower concentrations after 17 days and near that limit at the high concentration. No degradation of 1080 occurred in deionised water. The authors conclude that it is more important to monitor 1080 than fluorocitrate, as the metabolite does not persist and has lower oral toxicity than the parent because its large molecular size limits absorption (Booth *et al*, 1999).

Living organisms

As a close analogue of sodium acetate, sodium fluoroacetate can take its place in biochemical pathways, the most notable being the citric acid cycle. Fluoroacetate is not itself toxic but is metabolised in the body to fluorocitrate, which disrupts this central metabolic pathway by inhibiting the mitochondrial enzyme aconitate hydratase, leading to citrate accumulation. An alternative metabolic pathway is defluorination, a detoxification mechanism long recognised to be probably shared by all animals to a greater or lesser degree (Atzert, 1971).

Early studies in rats administered radiolabelled 1080 found that about 2% was completely metabolised to carbon dioxide within 4 hours, irrespective of dose, but with little increase after this period. Metabolites detected in urine after administration of 5 mg/kg included unchanged fluoroacetate (13%), fluorocitrate (11%) and two metabolites (73% of urinary radioactivity) that were nontoxic based on incubation with aconitate hydratase. Around 32% of applied doses of 1.77 or 5 mg/kg was excreted in urine within 4 days, particularly in the first 24 hours (rats died within 2 days at the higher dose). Urinary excretion following dosing at 10.5 mg/kg was only 0.4%, but all rats died within 4 hours (Gal *et al*, 1961, as described in Atzert, 1971).

The biodistribution, elimination and metabolism of fluoroacetate has also been studied in mice dosed intravenously at 0.3-0.5 mg/kg, using a radiofluorine label (^{18}F, a short-lived, positron emitting radionucleide). Radiofluorine activity was readily detected in organs in the 4 hours after dosing, with little or no preferential organ accumulation, and declined exponentially with estimated half-lives of 1.7-2.0 hours. A progressive bone accumulation was thought to reflect fluoride uptake as this anion has a well known affinity for osseous tissue. Defluorination of fluoroacetate was confirmed by the detection of fluoride in plasma. Two hours after dosing, an estimated 38% of blood radiofluorine levels was in the form of fluoride. Separate studies with radiofluoride showed little soft tissue retention and a much quicker elimination from the blood pool (initial half-life of 11 minutes, compared with 1.6 hours for fluoroacetate) because of skeletal accumulation and considerable urinary excretion. Whole body retention of radiofluorine levels following fluoroacetate injection was 82% at 2 hours after dosing, decreasing to 57% at 4 hours. Because of the much more extensive urinary excretion, the authors suggest that almost all the ^{18}F activity excreted was in the form of fluoride, generated from the *in vivo* defluorination of fluoroacetate (Sykes *et al*, 1987).

The tripeptide glutathione, which participates in the detoxification of many substances, plays a key role in the metabolism of sodium fluoroacetate. *In vitro* studies with rat liver preparations found that glutathione is an acceptable substrate for the defluorination reaction, and that it also provides some protection against the inhibitory effects of fluoroacetate (fluorocitrate) on aconitate hydratase. The role of glutathione in protecting against the toxic effects of 1080 was also demonstrated *in vivo* by the more pronounced increase in plasma citrate levels following intraperitoneal administration of 1.5 mg/kg 1080 that occurred in rats with depleted (15% of control) liver glutathione levels. Defluorination *in vivo* was studied in a resistant species (brushtail possum from WA, LD50 > 100 mg/kg) to enable accurate fluoride detection. Plasma fluoride elevation after administration of 20 mg/kg 1080 was not significantly decreased in possums with depleted (33% of control) liver glutathione levels, indicating that only low levels are necessary to sustain the defluorination reaction. Fluoride concentrations in plasma increased to 20-25 µM (0.38-0.48 mg/L) at 4-6 hours after dosing. Other *in vitro* and *in vivo* studies in sensitive and resistant animals have found no direct relationship between sensitivity and defluorination rates. It appears that defluorination is an important detoxification mechanism, but not the major means for circumventing fluoroacetate toxicity in resistant mammals (Mead *et al*, 1985a).

Emus have been shown to possess much greater defluorination capacity than do possums. Plasma fluoride levels exceeded 150 μM 3 hours after intraperitoneal dosing at 20 mg/kg, and approached 600 μM after dosing at 50 mg/kg. The LD50 in this resistant species was determined to be 102 mg/kg using animals from south-west WA. At a higher dose (100 mg/kg) significant depletion of liver glutathione levels (to 42% of control levels) was observed 5.5 hours after dosing, with exceptionally high plasma fluoride elevation (1180 μM) and minimal accumulation (390 μM) of plasma citrate. By way of comparison, plasma citrate levels in Port Lincoln parrots (LD50 11.5 mg/kg) reached around 600 and 900 μM above baseline, following respective doses of 10 and 15 mg/kg. Plasma fluoride levels could not be determined in Port Lincoln parrots because of their small size, which precludes serial blood sampling, but wood ducks and black ducks, which have similar sensitivity, have substantially lower defluorination capacity compared with emus (Twigg *et al*, 1988).

A particularly rapid rate of defluorination, far in excess of that described for mammalian species, has been demonstrated in shinglebacks (*Tiliqua rugosa*). Plasma fluoroacetate levels increased sharply to 14 μM and fluoride to 221 μM in the 6 hours following administration of 500 mg/kg 1080, with a concomitant steep decline in liver glutathione levels. Fluoroacetate and fluoride levels in plasma gradually declined over the subsequent 90 hours (to around 3 and 30 μM, respectively) while plasma citrate increased, peaking at about 250 μM at 48 hours after dosing in this tolerant species. Laboratory rats, which are much more sensitive to 1080, suffered a much more rapid increase in plasma citrate levels, to more than 500 μM at 4 hours after dosing at 3 mg/kg (Twigg *et al*, 1986).

5.2.5 Residues

Residue data for sodium fluoroacetate need to be interpreted carefully as some of the older analytical methods lack specificity. Methods that use an initial alkaline digestion to convert fluorinated organic compounds to fluoride are particularly prone to error as there may be other sources of fluoride in the sample than fluoroacetate. In particular, metabolism of fluoroacetate to fluoride in living animals means that fluoroacetate residues determined by this method are exaggerated, unless comparative analyses of samples that have not undergone alkaline digestion are also conducted and the results adjusted accordingly. Residue data reported by McIlroy and coworkers, as outlined below, are likely to be exaggerated as no correction was made for such metabolism. Further errors are introduced as fluoroacetate may be converted in biochemical processes to other fluorinated organic compounds, which would subsequently be defluorinated during alkaline digestion of samples. More recent methods which rely on gas chromatographic analysis of derivatives of fluoroacetate are more specific and reliable.

The foregoing analytical concerns have been identified previously. As described below, Gooneratne *et al* (1995) found residues in orally dosed rabbits to be much lower than reported by McIlroy and Gifford (1992). Furthermore, the highest concentrations found by these researchers were in plasma, with much higher concentrations in muscle than in liver or kidneys. McIlroy and Gifford (1992) found that residues were highest in liver and kidney with lower concentrations in muscle. The lower concentrations in liver and kidney likely reflect breakdown of 1080 by glutathione-S-transferase or related enzymes that are predominantly found in these organs. Gooneratne *et al* (1995) believe that the fluoride ion estimation method used by McIlroy and Gifford (1992) grossly overestimates and may have little relevance to the true 1080 concentration.

Considerable variation in 1080 residue levels can exist between conspecifics, but some generalisations can be made. Residues in rabbits, sheep and dogs are amongst the lowest of any species examined. Rats contain higher residues than rabbits, for reasons that are unknown (Twigg *et al*, 2003a).

Orally dosed rabbits (laboratory studies)

Gooneratne *et al* (1994) found that sodium fluoroacetate was quickly absorbed in rabbits orally administered a sub-lethal dose (0.1 mg/kg) with rapid elevation of plasma 1080 concentration to 0.149 μg/mL after 50 minutes. The plasma half-life was a little over an hour, with very little 1080 remaining in plasma after 6 hours. Tissue concentrations were lower, with more in muscle (peak of about 0.02 mg/kg, as determined by gas chromatography of a dichloroaniline derivative) than in kidney or liver. Defluorination *in vivo* was confirmed by the rapid increase in plasma and tissue fluoride levels following dosing. All animals appeared clinically normal but ECG recordings were abnormal in five of the 36 rabbits dosed.

Complete mortality occurred following oral administration of 0.8 mg/kg (twice the LD50) to a group of 12 rabbits, with all except three dead within 3 hours. Mean plasma 1080 concentrations were about double those in the sublethally exposed group. Individual carcasses were stored at room temperature in the animal house and sampled at 1, 2 and 3 weeks after death to determine residues. Tissue concentrations over the ensuing 3 weeks were variable, possibly reflecting decomposition of tissues and or defluorination of 1080. The highest residue recorded in muscle was about 0.07 mg/kg immediately after death of one rabbit. One rabbit carcass contained about 0.06 mg/kg 1080 in muscle tissue at 1 week after death, and another assayed at the same level 2 weeks after death. Note that only a minor proportion (<10%) of the administered dose of 0.8 mg/kg 1080 was recovered as tissue residues, based on the maximum recorded residue of 0.07 mg/kg.

Results indicate limited risk to secondary consumers of sublethally poisoned rabbits, but significant risk to susceptible species such as dogs if they consume freshly dead rabbits. Simple calculations indicated a high risk to dogs for up to a week (extending to several weeks or even months if cold and/or dry conditions retard breakdown of residues) if they are hungry and consume a whole carcass.

Field poisoned rabbits (carrot baits)

McIlroy and Gifford (1992) determined residues on a dry weight basis in a random sample of ten rabbits taken from among those lying dead along or close to a carrot bait trail (nominal loading of 333 mg/kg 1080) near Cooma in February 1986, using the alkaline fusion-fluoride ion electrode method (accurate at 2 mg/kg) with allowance for a free fluoride level in the bait of 3% and correction for background fluoride levels in unpoisoned rabbits. Note that this method is likely to overestimate 1080 residues as it does not account for any defluorination of 1080 that occurs *in vivo*. The results from this study therefore need to be interpreted very carefully.

Highest residue concentrations were found in stomach contents (60-243, mean 171 mg/kg) and liver (57-363, mean 160 mg/kg), followed by stomach (26-136, mean 100 mg/kg), kidneys (27-263, mean 91 mg/kg), heart (4-151, mean 54 mg/kg) and muscle (7-40, mean 23 mg/kg). Muscle tissue contained the highest overall amount, followed by stomach contents (mainly masticated carrot bait, retaining around a third of total residues) and livers. Analysis of stomach contents indicated that the rabbits sampled consumed large amounts (39-73, mean 54 g, equivalent to 13-24 mg 1080) of carrot baits after being offered three free feeds rather than the customary two. Heavier feeders may have been selected as carcasses were collected from near the bait line, indicating that death followed soon after feeding as would occur with ingestion of a large dose. Total residues varied from 3.25 to 15.16 mg (mean 7.0 mg) with around a third residual in the stomach and its contents. This implies that around 30-50% of the 1080 ingested was recovered as tissue residues, compared with less than 10% using a more specific method, as outlined above. The discrepancy probably reflects metabolism of fluoroacetate to fluoride by living rabbits.

Similar analyses were conducted on carcasses (four wombats, a possum, two wallabies, a magpie and two rosellas) recovered from systematic searches of 368 ha of forest near Tumut in the five days following aerial baiting in May 1980 for rabbits using carrot bait containing 360 mg/kg 1080. In the absence of comparable data for native species, correction was made for background fluoride levels in unpoisoned rabbits. Residue concentrations in stomach contents were low (20-40 mg/kg) for the birds, and only one muscle sample tested positive, at 1 mg/kg. No organs were analysed. Highest residue concentrations for the mammals were found in stomach contents (74-348 mg/kg for wombats, 174 mg/kg for the possum, and 148-226 mg/kg for the wallabies) with only trace amounts (1-2 mg/kg) found occasionally in muscle. Kidneys (11-110 mg/kg), liver (13-60 mg/kg) and heart (26-31 mg/kg) contained higher residues, although lower than in the rabbits.

By way of comparison, laboratory dosed mammals (bush rats, antechinus, bandicoots, pademelon and sheep) which received doses of 0.3-10 mg/kg contained higher concentrations in muscle tissue

(0-60 mg/kg) but much lower concentrations in stomach and contents (0-53 mg/kg) indicating that 1080 is more rapidly absorbed when administered in solution by stomach tube rather than ingested in baits. Many of the samples of muscle, organs and stomach from animals killed in the laboratory contained no measurable amounts, or only minor traces of 1080.

Field poisoned rabbits (oat baits)

Rabbits can consume around 30 g of oats in a single feeding, or the equivalent of 12 mg 1080 (6 mg/kg for a 2 kg animal) assuming a content in oats of 400 mg/kg and consumption of the husk, although probably not more than 10 g within a short period (20 minutes). There is clearly a potential for rabbits to overdose, although rabbits would not consume this amount all at once, particularly as some reduction in appetite may be expected from consumption of this toxic material. Higher residues have been recorded in field operations compared with the above laboratory dosing procedure.

Twigg *et al* (2003a) have measured residues in radiocollared rabbits following a baiting campaign with "One-Shot" 1080 Impregnated Oats (42501) applied as a 1% mix (4.5 mg 1080 for each poisoned grain, mixed with 99 parts of unpoisoned grain) at 6 kg/km (followed up by a second treatment at 3-4 kg/km after shower activity) in remnant sandy heath in the southern agricultural area of WA in February 2002. Eighteen carcasses were recovered and prepared for analysis by skinning, removing head and feet, and dissection to remove a 5-7 g muscle sample, the liver, and the whole gut. The rest of the animal was then minced, slurried in water, decanted, extracted and derivatised with pentafluorobenzyl bromide before analysis by gas chromatography.

Muscle samples all proved negative for 1080 using a bacterial inhibition assay with a limit of detection of 6 mg/kg. The more sensitive gas chromatographic method returned positive results for most of 14 carcasses analysed, although four were below the limit of detection (0.02 mg/kg). The mean residue in the remaining 10 rabbits was 0.35 mg/kg (double that recorded in the laboratory following administration of 0.8 mg/kg) with a maximum of 0.78 mg/kg (equivalent to 1.34 mg in the animal). These results are more than an order of magnitude below those obtained following carrot baiting using a less specific method as described above. Rabbits in that study probably ingested 13-24 mg 1080, compared with a maximum 4.5 mg (or perhaps 9.0 mg where rabbits ingested two poisoned oats) in this more recent work. Actual consumption levels with the oat baits may have been considerably lower, as only 20% of the 1080 in One-shot oats is found in the kernel, and separate studies (Twigg *et al*, 2003b) found that rabbits in WA tend to dehusk oats and consume only the kernel. Note that rabbits in SA are not believed to dehusk oats in this way.

Fifteen of the carcasses recovered, within 6 days of bait laying, were of radiocollared animals. A further three untagged carcasses were also recovered. Six collared rabbits remained alive after the 6 day search period, and another was hand caught and euthanased. Only two of the recovered carcasses were found in the open, with twelve under thick scrub or in warrens, and four taken or scavenged by predators (three by foxes and one by a wedge-tailed eagle). Some carcasses were significantly decayed, particularly when recovered from warrens.

Residue analysis was also conducted on rabbits that had been poisoned by intraperitoneal administration of 1080 (0.46-1.63 mg/kg) in the laboratory. These rabbits originated from WA and appeared to have developed genetic resistance as their LD50s following intraperitoneal injection were in the 0.7-1.0 mg/kg range. Aqueous extracts were chromatographed over anion exchange resin and derivatised with dichloroaniline before analysis by gas chromatography with a limit of detection in muscle of 0.0005 mg/kg. The maximum recorded residue in muscle was 0.17 mg/kg, while levels were higher in blood, ranging up to 0.78 mg/kg. Residues were higher at higher dose levels. Respective mean values were 0.044 and 0.32 mg/kg. Only 2 of 31 livers were positive for fluoroacetate (0.013 and 0.036 mg/kg). Comparison with oral dosing found that intraperitoneal administration gave higher residues because of the lag phase associated with oral intake.

Residues were also determined by bioassay in 17 laboratory rats (*Rattus norvegicus*) poisoned with One-shot oats. The estimated intake of 1080 was 0.86-5.18 (mean 2.81) mg. An 18th rat which refused the poisoned grain was excluded from the analysis. Residues were higher than in rabbits, ranging from undetectable to 34 mg/kg. Liver contained higher concentrations (maximum 33.6, mean 14.3 mg/kg in 11 rats containing measurable residues) than the carcass (maximum 14.4, mean 5.3 mg/kg in 12 rats with measurable residues). This species is less sensitive than rabbits, with a cited LD50 of 1.68 mg/kg. Residues below the limit of detection (6 mg/kg) for the bioassay were obtained by evaporation of samples.

It is not known why rats contain higher residues than rabbits, although rabbits, sheep and dogs tend to retain lower residues than other species at comparable dose levels.

Carcasses of three rats, estimated to have consumed 1.7-3.5 mg 1080, were placed outside on the soil surface, with protection from scavenging vertebrates, to examine their decay during spring (early November). All had decomposed within 6 days, such that only poor quality muscle samples could be obtained for analysis. Negative bioassay results were obtained for all three, indicating that residues had declined below 6 mg/kg in the decomposing carcass.

Field poisoned possums

Possum carcasses in New Zealand were located and covered with wire cages after a baiting campaign conducted by the Wellington Regional Council in May and June 1994, using apple paste baits containing 800 mg/kg 1080. Residues were determined by gas chromatography in stomachs and contents at several intervals from 25 to 75 days after the estimated time of death. Carcasses remained relatively intact for 39 days but decomposition was advanced by the end of the sampling period. Residue decline was much slower in the carcass than in living possums, with an average 30 mg/kg at the earliest sampling, declining to 4.9 mg/kg at the latest sampling. There was considerable variation between carcasses, with residues in stomach and contents ranging from 4 to 70 mg/kg at the earliest sampling. Results indicate that dogs consuming offal would have been at risk of secondary poisoning throughout the sampling period (Meenken and Booth, 1997).

The residues found in stomach and contents are much lower than the residues of about 170 mg/kg in stomach and contents from rabbits and possums as reported by McIlroy and Gifford (1992) but were determined in older carcasses using a specific method. Residues in muscle were not determined but are likely to have been low based on the findings of McIlroy and Gifford (1992) that residues in possum muscle are an order of magnitude below those determined in rabbit muscle.

Sheep

Sheep dosed with 1080 at 0.1 mg/kg by gastric cannula and sacrificed at 2.5 and 96 hours after dosing contained very low residues, as determined by gas chromatographic analysis of the dichloroanilide. The highest residue was 0.098 mg/kg in plasma at 2.5 hours after dosing. Among the organs, kidneys contained the highest amount (0.057 mg/kg) while muscle contained 0.042 mg/kg. Residues were consistently low (0-0.003 mg/kg) at the later sampling. Plasma half-lives were short (6.6-13.3 hours) and substantial amounts were excreted in urine during the first 48 hours after dosing, coincident with a rapid decrease in plasma levels (Eason *et al*, 1993).

Canids

Residues in livers and kidneys of dogs suspected to have been poisoned by 1080 have been determined using a gas chromatographic method with a detection limit of 0.01 mg/kg. Residues were highly variable (0.045-5.45 mg/kg for liver and 0.055-0.297 mg/kg for kidney) with no clear differences between suspected primary and secondary poisoning cases (Casper *et al*, 1983).

A 27 kg black Labrador was administered a single large dose (25 mg) of 1080 and died within 2 hours. Residues in liver and kidney as determined by the same method were 0.22 and 0.44 mg/kg (Casper *et al*, 1984).

Coyote pups were poisoned in the laboratory by daily offerings of ground squirrels that had received 0.5 or 3 mg 1080 (0.8 or 4.8 mg/kg) as 0.05% oat bait. One of the low dose pups (11.8 kg) died after the last (fifth) feeding and the other (10.7 kg) was euthanased. The two high dose pups (16.2 and 17.2 kg) died after the first feeding, with one having consumed two squirrels. Residues determined by the same method in brain, kidney, liver, stomach and large intestine were below the detection limit (0.01 mg/kg) in the low dose pups and ranged from 0.025 to 0.14 mg/kg in the high dose animals. Kidney residues were higher than those in liver. Highest residues in the ground squirrels were found in stomach and contents (11.8 mg/kg in the low dose animals and 55.9 mg/kg in the high dose animals). Residues in muscle were 0.41 and 0.77 mg/kg, with similar amounts in liver (0.70 and 1.83 mg/kg) and kidney (0.28 and 1.14 mg/kg). It is not known why liver residues were higher than those in kidneys for squirrels but lower in coyotes (Casper *et al*, 1986).

Pigs

Individually penned pigs were dosed with small lumps of meat containing 1080 in the form of two small (5 mm diameter) enteric coated tablets, each containing 35 mg 1080. Doses varied from 1.91 to 3.13 mg/kg (mean 2.32 mg/kg). The tablets were intended to reduce losses through vomiting, but did not achieve this purpose because pigs tend to filter by size any material passing from the stomach to the small intestine. Furthermore, *in vitro* dissolution studies at pH 2 showed that most of the tablets began to leak 1080 after about 2 hours, even though the coatings appeared to remain intact. The author argues that this form of dosing is representative of oral dosing with injected meat baits as the toxin would become available fairly rapidly once the coating failed. Caution is warranted with this interpretation, as the *in vitro* studies indicated that some of the tablets retained more than half the dose at 2 hours after the coating began to fail.

Animals were observed continuously for 36 hours and at 8 hour intervals thereafter. Symptoms and time to death were recorded. Any vomitus was collected for analysis, and post mortem samples including stomach and contents, liver and kidneys were collected, from lethally poisoned animals and survivors sacrificed after 2 days. Analysis for 1080 used a HPLC method after esterification with bromophenacylbromide.

Only one of the five pigs tested died of poisoning. This was the only pig that did not vomit. Stomach contents retained 2.83 mg 1080. The high rate of survival may reflect premature capsule leakage, allowing the pigs to eject much of the dose by vomiting. If release of 1080 from the tablets was slow, pigs would have been better able to metabolise the toxin to fluoride. Premature culling may also have been a factor.

The surviving pigs vomited on numerous occasions (8-24). The total amount of 1080 in the vomitus ranged from 3.48 to 23.8 mg (Parker, 1990). The author has advised that individual samples contained up to 4 mg 1080.

O'Brien *et al* (1986) found that the concentration of 1080 in pig vomitus was highest when pigs vomited soon after taking baits and declined rapidly, as would be expected. The onset of vomiting occurred earlier following ingestion of higher doses (median latency 117 mins at the estimated LD50 of 1.1 mg/kg and 86 mins at the estimated LD99 of 2.1 mg/kg). This study used individually penned feral pigs (five for each dose level tested) captured in NSW (Cobar, Warren and Dubbo areas) and maintained in holding yards for 14 days and individual pens for a further 14 days before dosing with wheat containing 173 mg/kg (LD50) or 330 mg/kg (LD99) 1080.

Two pigs were randomly selected for vomitus collection at each dose tested. The first three samples of vomitus contained 2.62±2.21 mg 1080 at the lower dose and 4.30±2.70 mg/kg at the higher. Mean concentrations in the first three samples of vomitus were 26.4 mg/kg and 62.2 mg/kg, respectively, or slightly less than 20% of the ingested dose. Total ejection of the dose slightly exceeded 40% at each dose level. Only two of the forty animals tested attempted to eat their own vomitus.

Tissue residues have been determined in six feral pigs, lethally poisoned in captivity with poisoned wheat containing the estimated LD90 (O'Brien *et al*, 1987). The highest concentrations (1.60±0.55 mg/kg) were found in stomach contents. Mean residues in liver, kidney, muscle and small intestine were 0.48-0.72 mg/kg.

Secondary consumers

Residues of 0.4 mg/kg have been recorded in two New Zealand robin carcasses recovered 3-4 weeks after baiting with carrots containing 800 mg/kg 1080. A freshly dead robin contained 3.8 mg/kg. It is unclear whether the residues reflect direct consumption of carrot baits or secondary exposure via insects. Residues were determined by a gas chromatographic method with a detection limit of 0.1 mg/kg (Powlesland *et al*, 1999).

Also in New Zealand, residues of 0.68-1.80 mg/kg were recorded in ferrets (leg muscle samples) using a gas chromatographic method with a detection limit of 0.005 mg/kg. Residues were believed to reflect secondary consumption of rabbits that had been poisoned with carrot bait containing 200 mg/kg 1080 more than a month before death occurred in the ferrets. Similar analysis found 0.22 mg/kg in a dead cat recovered several months after baiting (Heyward and Norbury, 1999).

Invertebrates

Invertebrates will consume baits containing 1080. For example McIlroy *et al* (1988) demonstrated that blowfly maggots (mainly *Calliphora* spp) took up 1080 from meat baits (6 mg 1080 injected into 190-239 g pieces of lean beef, after air drying at 4ºC for 24 hours). Mean residues in individual maggots were 0.49 µg at 4 days after baits were exposed during a Canberra summer on pieces of turf, with protection from rain, declining to 0.30 µg at 6 days. Very few maggots were found on day 10, presumably because most had left the baits to pupate in the underlying soil. Metabolism of the ingested 1080 by the maggots remained unquantified as residues were determined by fluoride detection after alkali digestion, a method that does not distinguish between 1080 and its fluoride metabolite. Assuming a wet weight of 80 mg in mature maggots, these residues equate to around 400-600 mg/kg, but are exaggerated by the nonspecific analytical method.

Lloyd and McQueen (2000) collected invertebrates from cereal bait (0.15% 1080) and pitfall traps during an aerial possum baiting operation on the North Island of New Zealand. Baits were hand placed along transects at 3 m intervals (equivalent to 5 kg/ha) in the study area, which was located within a larger area that had been aerially baited at 5 kg/ha for possum control. Invertebrates were collected just after nightfall for four days, and on days 6 and 8. Pitfall traps were emptied daily for 10 days.

A total of 70 arthropods (20 taxa, mainly Insecta) were collected from baits, and 28 arthropods (9 taxa, mainly Malacostraca, terrestrial crustacea such as woodlice) from pitfall traps. The mean residue in the fomer group as determined by gas chromatography was 57 mg/kg (range 14-130 mg/kg) and remained constant through the sampling period. Residues in 26 arthropods from pitfall traps were much lower (mean 0.8 mg/kg). Four spiders (two from baits and two from traps) contained an average 14 mg/kg.

As noted later in this report, residues of 1.4 mg/kg as determined by a gas chromatographic method have also been recorded in a sample of dead ants collected from an anthill during ground squirrel baiting operations in the US using oat baits containing 750 mg/kg 1080 (Hegdal *et al*, 1986).

5.2.6 Mobility in soils

Column leaching studies in two acidic silt loam soils found that only very small amounts were adsorbed, and only in the soil with more hydrous iron/aluminium hydroxide. Mobility of fluoroacetate was comparable with chloride and nitrate anions, and slightly higher than for the divalent sulphate anion (Parfitt *et al*, 1994).

The mobility of sodium fluoroacetate has been confirmed by monitoring data at a New Zealand landfill (abandoned gravel pits) where 12 tonnes of cereal pellet and paste bait were disposed in August 1996. The substrate at this site consists of coarse gravels overlain by a veneer of alluvial soils, with the water table at 1-1.5 m below the surface. Groundwater samples were taken from two bores located 5 and 13 m south of the disposal pit, along the assumed direction of groundwater flow, at weekly intervals for the first 5 weeks and then monthly for a further 13 months. Five of 28 samples analysed contained sodium fluoroacetate, at higher levels in the shallower upstream bore (0.4, 7 and 24 µg/L) than downstream (0.1 and 0.6 µg/L) where the bore was deeper. The highest residue was found 5 weeks after burial, with the delay attributed to low permeability of the organic refuse pile. Downstream residues were not detected until 5 months after burial. Sampling of residual bait material at 10 weeks after burial found a reduction in 1080 concentration of about a third at the surface of the pile, but no degradation deeper in the pile. Considerably more degradation (further reduction to 20% in upper samples and 7% in deeper samples) was evident after a year, indicating that active anaerobic metabolism under landfill conditions is effective in degrading 1080 (Bowman, 1999).

5.3 Summary of environmental exposure

Annual use of sodium fluoroacetate (1080) across Australia amounts to around 200 kg. Rabbit control (oat and carrot baits) uses the greatest amount, followed by wild dog control (meat baits). Sodium fluoroacetate plays a key role in fox control and is also used against pigs and, in Tasmania, to control browsing native mammals.

General environmental exposure to 1080 is low as overall application rates are low (commonly much less than a gram per hectare) although use in baits leads to higher exposure in small areas where toxic doses are applied. While use of 1080 in this way does not lead to significant contamination of air, soil or water, its dispersal in bait form represents a potential hazard to some nontarget animals that may take the baits in some parts of Australia.

As a simple monovalent anion, fluoroacetate would be expected to be mobile in the environment and to be easily degraded. Various lines of evidence confirm these expectations.

Fluoroacetate occurs naturally in some plants, particularly in SW Western Australia, but has a limited presence in soils and surface waters where these plants occur. The absence of fluoroacetate contamination in areas where it occurs naturally in plants is consistent with its easy degradation.

Studies with baits have shown that fluoroacetate is easily leached from some materials such as oats by rain or even dewfall, while other materials such as carrots are more resistant to leaching but quickly dessicate and become unpalatable under dry conditions. Meat baits are also detoxified by rainfall, and more so by blowfly larvae. If not taken, surface laid meat baits are likely to remain lethally toxic to dogs and foxes for up to 8 weeks, depending on rainfall and temperature, and may retain toxicity for up to a year under arid conditions, although fresh meat would rapidly dessicate and become less palatable. Buried fresh meat baits lose toxicity more rapidly. Dried meat baits undergo little further dessication in the environment.

The usual fate of fluoroacetate in baits is to be consumed by the target pests in the days or weeks following baiting. Prefeeding, which allows users to lay just enough toxic baits to ensure their rapid consumption, is normally conducted for herbivore and pig control (except in WA where a mixture of poisoned and unpoisoned grain is preferred for rabbit control). Similarly, use of mound baiting where there are nontarget concerns in relation to meat baits allows users to only lay poison baits where target animals are feeding. Such precautions are not always practicable, particularly in remote or rugged terrain where access is difficult. Predator baits may be applied from aircraft in such situations, or in regions such as south-west Western Australia, far western NSW or the far north of SAwhere foxes need to be controlled over large areas and nontarget risks have been assessed as low.

Studies of the environmental fate of fluoroacetate have confirmed that it is easily degraded in biologically active systems, such as soils, surface waters and living organisms.

Most of the fluoroacetate absorbed by animals is rapidly metabolised and/or excreted, with only low levels retained in the carcass. Early reports of relatively high residues in rabbits, particularly in their livers and kidneys, are exaggerated as the analytical method made no allowance for the substantial defluorination of fluoroacetate that occurs in living animals. When analysed using a specific method, the highest residues in rabbits occur in blood, with very low residues in liver and kidney because of rapid enzymatic detoxification in these organs. Residues in rabbit carcasses remain below 1 mg/kg. Residues in pig carcasses, including liver and kidneys, also remain below this threshold. Some animals retain higher residues, with up to 9 mg/kg measured in rat carcasses. Stomach contents may also retain high residues, in excess of 50 mg/kg for possums and ground squirrels following use in New Zealand and the US. Pig vomitus can also contain significant levels (likely to be around 20% of the concentration in baits in early samples). High residues (up to 130 mg/kg) have been recorded in New Zealand invertebrates collected from high potency baits (0.15%).

Column leaching studies and groundwater monitoring downstream from a landfill confirm that sodium fluoroacetate is mobile in soil. However, use as baits presents minimal concerns with respect to leaching in soil because of the low application rates and ease of degradation in biologically active systems.

6 ENVIRONMENTAL EFFECTS

The toxicity of fluoroacetate has been reviewed by Twigg and King (1991) with a focus on native Australian fauna.

Fluoroacetate is converted in the body to fluorocitrate, which inhibits an important mitochondrial enzyme (aconitate hydratase) in the citric acid (Kreb) cycle, a metabolic pathway that breaks down carbohydrates. Inhibition of this enzyme blocks the Kreb cycle at the citrate stage, resulting in energy deprivation and accumulation of citrate in the tissues and plasma.

Symptoms usually begin to appear between 30 minutes and 3 hours after ingestion by endotherms, even when massive doses are used. This lag phase probably reflects translocation and cell penetration, conversion to fluorocitrate, and disruption of intracellular functions sufficient to induce gross symptoms. Herbivores generally die of cardiac failure, while carnivores experience central nervous system disturbances and convulsions before dying of respiratory failure. In omnivores, death tends to result from disorders of both the heart and central nervous system. Poisoned animals recover from sub-lethal doses as fluoroacetate is readily metabolised (for example by defluorination) and excreted.

The toxicity of 1080 has been studied in a broad range of species including birds, mammals and reptiles. Lethal doses in unadapted mammals are generally below 2 mg/kg. Dogs are extremely susceptible, and most other carnivores are highly sensitive to poisoning, although many native species show some resistance. Herbivores are also sensitive (with the exception of those from south-western Australia) but omnivores less so, and birds and reptiles increasingly resistant. Fish and aquatic invertebrates are relatively insensitive to 1080.

Native species, particularly those from the southwest corner of WA which have existed in close association with fluoroacetate-bearing vegetation, tend to have greater tolerance to 1080 than their overseas and eastern States counterparts. This developed tolerance is most pronounced in herbivores but is also present in omnivores and carnivores. Some unadapted Australian omnivores and carnivores (bandicoots and dasyurids) also appear to possess an innate tolerance to fluoroacetate when compared with their eutherian counterparts. This probably reflects the lower basal metabolic rate of the native species.

It appears from studies that administered high concentrations that sodium fluoroacetate has substantially the same oral toxicity whether the carrier is water, meat, grain, oil, gum acacia suspension or gelatine capsule. Furthermore, the toxicity is approximately the same whether the chemical is administered orally, subcutaneously, intramuscularly, intraperitoneally or intravenously (Atzert, 1971). In Australia, the response of western grey kangaroos (*Macropus fuliginosus*) to oral and peritoneal doses (the latter favoured because of reduced stress to the animals) have been compared, and the patterns of plasma citrate and fluoride elevation found to be very similar (King *et al*, 1978). Mean plasma citrate levels in rabbits 3 hours after dosing at 0.59 mg/kg were much higher following intraperitoneal injection (69 mg/L) compared with oral dosing (21 mg/L), probably reflecting an increased lag phase (slower absorption) after oral dosing (Twigg *et al*, 2002). At the lower concentrations typical of baits, toxicity may be modified by the bait substrate. For example, the LD50 for pigs is larger (a higher dose is needed) when grain baits are used, rather than an aqueous solution.

The US EPA describes chemicals as very highly toxic to birds and mammals when the LD50 falls below 10 mg/kg. This description does not necessarily reflect the environmental hazard of a chemical, and is mainly used for inter-chemical comparison. Compound 1080 is very highly toxic to many birds and mammals based on this broad comparative description. Given the very high toxicity of 1080 compared with most other toxic chemicals, a more discriminating descriptor is useful. This report will use the sensitivity definition adopted by McIlroy (1982b) for rodents. Highly sensitive organisms are defined as those with LD50s below 2 mg/kg. Moderately sensitive organisms have LD50s between 2 and 10 mg/kg, while relatively tolerant organisms have LD50s between 10 and 40 mg/kg. Organisms with LD50s above 40 mg/kg can be considered tolerant.

When categorised in this way, all target animals are highly sensitive to 1080, as are sheep and native herbivores (possums, macropods and wombats). LD50s in these animals are consistently below 1 mg/kg, with the exception of native animals from the south-west corner of WA which have developed a tolerance to the toxin. Some birds (red-browed firetail, crimson rosella and white-winged chough), rodents (plains mouse, bush rat, swamp rat and canefield rat) and dasyurids (stripe-faced dunnart, brown antechinus, spotted-tailed quoll and perhaps the eastern quoll) are also highly sensitive, although LD50s in these organisms are mostly above 1 mg/kg.

Most Australian birds are moderately sensitive to 1080, as are most dasyurids, bandicoots and some rodents.

Some rodents (western chestnut mouse, sandy inland mouse, Mitchell's hopping mouse and Spinifex hopping mouse) are relatively tolerant of 1080. Native birds and mammals from the south-west corner of WA are relatively tolerant or tolerant of 1080. Ducks, raptors and doves from the eastern States are also relatively tolerant (but ducks from NW Australia are moderately sensitive). Emus, malleefowl, reptiles and frogs are relatively tolerant or tolerant of 1080.

Setting aside arbitrary classifications, the key toxicity issue in baiting programs is the relative sensitivity of target and non-target animals. Many native herbivores are of similar sensitivity to the target pests. A greater distinction is evident for native carnivores, with the spotted-tailed quoll (LD50 1.85 mg/kg) much less sensitive than the target canids (LD50 around 0.1 mg/kg).

6.1.1 Avian toxicity

The lethal dose of sodium fluoroacetate has been determined in acute oral studies with a wide range of species, including many tests conducted in Australia. Acute oral toxicity testing normally involves administration by oral gavage, but avian toxicity studies conducted in Australia have usually used subcutaneous (injection in the hind-neck region) or intraperitoneal administration (direct injection into the body cavity). This would normally represent a worst case exposure situation, in that ejection via regurgitation and the initial detoxification by the liver that may follow oral dosing would not occur, but as noted above the toxicity of sodium fluoroacetate does not appear to vary significantly with route of exposure.

A limited number of dietary studies, in which sodium fluoroacetate is mixed with the feed, have also been conducted. Dietary studies need to be interpreted carefully as toxic feed may often be rejected. Death may reflect starvation rather than poisoning, particularly when it occurs later in the exposure period. Despite these shortcomings, laboratory dietary studies can provide useful insights into the likely field response of birds to baits containing sodium fluoroacetate, particularly where concentrations in baits and laboratory diets are similar.

Northern hemisphere species

The US EPA RED document concluded that 1080 is highly to very highly toxic to birds via the acute oral route based on the following LD50 values: black-billed magpie, 1-2.3; widgeon, 3.0; chukar, 3.5; golden eagle, 5.0; ring-necked pheasant, 6.4; mallard duck, 9.1; and black vulture, 15.0 mg/kg. The US EPA describes chemicals as very highly toxic to birds when the LD50 falls below 10 mg/kg.

The document reached a similar conclusion regarding dietary toxicity, and reported LC50s of 231 and 486 ppm, respectively, for mallard ducks and bobwhite quail. The US EPA describes chemicals as highly toxic to birds when the LC50 falls in the 50-500 ppm range.

Dietary LC50s of 527 (373-3522) ppm in mallards and 385 (0-485) ppm in bobwhites are reported in the scientific literature (Kononen *et al*, 1991). The presence of sodium fluoroacetate in the feed had a marked effect on average food consumption in mallards, which dropped from 32.5 g/day in controls to 2.1-4.5 g/day in exposed birds. Mallards lost weight (19.6-28.3%, compared with an increase of 36% in controls) during the 5 day exposure period, but regained weight during the subsequent 3 day observation period when food consumption largely returned to normal. Similar responses were seen in bobwhite quail, although the reduction in food consumption was less marked (3.8 g/day in controls, 2.3 g/day at 95 ppm and 0.5 g/day at 720 ppm) and varied dose responsively.

The LD50 for the individual mallard ducklings tested (mean weight 114 g) would be around 1.1 mg, based on an LD50 of 10 mg/kg. As 1080 is an acute poison and is readily metabolised by living organisms, any deaths from poisoning would be expected to occur soon after the commencement of exposure. Food consumption data for individual days, and the times when birds died, are only reported for two concentrations (236 and 576 ppm). Mean food consumption on the first day was 7.1 g (1.7 mg 1080) at the lower concentration, and 3.7 g (2.1 mg 1080) at the higher. Food consumption then dropped markedly at both concentrations. During the exposure period, deaths occurred on days 4 and 5 (single birds) at the lower concentration and only on day 1 (3/12 birds) at the higher concentration (it appears that some mortality also occurred during the post-exposure period, but this is unclear). This suggests that birds were poisoned at the higher concentration but more affected by starvation at the lower, notwithstanding that mean daily consumption exceeded the LD50 at both concentrations. However, some fluoroacetate may have carried over from day to day at the lower concentration, perhaps contributing to the delayed death at lower exposures.

A similar pattern is evident for bobwhite quail, which consumed an average 2.7 g (0.38 mg 1080) at 142 ppm and 0.8 g (0.38 mg 1080) at 480 ppm on the initial day of exposure. Food consumption then dropped markedly at the higher concentration. First day mortality (2/10 birds) was only recorded at the higher concentration. The estimated LD50 for bobwhite quail (mean weight 17.5 g) is 0.35 mg 1080, based on data reported (Atzert, 1971) for Gambel's quail and Japanese quail.

It would appear that mallards and quail were only able to ingest a toxic dose within a short time when the feed was more highly contaminated, and that aversive effects reduced consumption to below toxic levels when levels in the food were lower.

Birds exhibited greater sensitivity to sodium fluoroacetate when it was present in the drinking water, reflecting their greater consumption of water compared with food. LC50s dropped to 18 ppm in mallards and 31 ppm in bobwhites. Comparison of the doses received in water and food indicated that a given quantity of sodium fluoroacetate was more likely to cause death when administered in water, suggesting a greater bioavailability via this route. A higher rate of consumption and more rapid absorption (greater bioavailability) may be expected when water is contaminated.

Food avoidance tests were also conducted. The discrimination threshold concentration in food, defined as the maximum concentration where birds do not discriminate between clean and contaminated feed, was less than 236 ppm in mallards and less than 95 ppm in bobwhites. Contaminated food represented 11 and 29% of total consumption at these lowest treatment concentrations. Mallards were able to discriminate on day 1 of exposure, while bobwhite quail did not discriminate between clean and contaminated food until day 2. When the water rather than food was treated, the discrimination threshold concentrations were 13-24 ppm in mallards and less than 9 ppm in bobwhites.

The results of this study indicate that birds may be able to detect the effects of 1080 and avoid poisoning when bait concentrations are low (less than 100-200 mg/kg) but that toxic amounts are likely to be consumed when bait concentrations are higher.

Unadapted Australian natives (eastern States)

McIlroy (1981a) found that Pacific black ducks (*Anas superciliosa*) were more sensitive as breeding females [LD50 10.01 (7.43-13.48) mg/kg] than as non-breeding females [LD50 23.80 (15.30-37.03) mg/kg]. No such differences were seen in galahs (LD50s 5.18-5.77 mg/kg from subcutaneous dosing). Birds were injected subcutaneously in the hind-neck region. The author notes that he found this easier than the usual methods of oral administration because of the presence of a crop in some species but not in others. Results obtained in galahs were not significantly different from that obtained [LD50 4.67 (3.10-7.04) mg/kg] after intraperitoneal injection.

McIlroy (1984) has determined acute oral LD50s for various Australian birds, (sampled from the eastern States except the wedge-tailed eagle and little crow from WA) as tabulated below. Results indicate that their sensitivity to 1080 (95.6% purity) is similar to that of overseas species (marked with an asterisk). Only three of the species tested (red-browed firetails, crimson rosellas and white-winged choughs) can be described as highly sensitive to 1080.

Groups of two to five wild-caught adult birds, males when possible, were dosed with aqueous solutions of 1080 by subcutaneous injection in the hind neck region, after acclimatisation to captivity for at least a week. Approximate LD50s in some species were calculated as the mean of the lowest dose level at which an individual died and the highest dose level survived by an individual. Results for galahs are expressed as a range, obtained from several studies with birds of different ages captured from different regions of NSW.

Species	Mean weight	LD50 (95% CI)
Emu	18.0-35.0 kg	278 mg/kg (approx)
Black duck (adult male)	0.82-1.13 kg	18.91 (16.33-21.89) mg/kg
Black duck (female non-breeding)	0.74-0.94 kg	23.80 (15.30-37.03) mg/kg
Black duck (female breeding)	0.69-1.04 kg	10.01 (7.43-13.48) mg/kg
Maned duck (wood duck)	0.61-0.86 kg	12.60 (10.14-15.67) mg/kg
Black kite	0.49-0.69 kg	18.51 (14.97-23.17) mg/kg
Wedge-tailed eagle	2.26-4.25 kg	9.49 (7.20-12.51) mg/kg
Bar-shouldered dove	0.11-0.15 kg	16.25 (14.51-18.20) mg/kg
Diamond dove	0.025-0.035 kg	35.5 (27.17-46.36) mg/kg
Galah	0.24-0.41 kg	4.67-6.36 mg/kg
Sulphur-crested cockatoo	0.76-0.91 kg	3.46 (2.90-4.14) mg/kg
Budgerigar	0.03-0.05 kg	2.13 mg/kg (approx)
Crimson rosella	0.13-0.17 kg	0.88 mg/kg (approx)
Eastern rosella	0.09-0.11 kg	3.45 mg/kg (approx)
Red-rumped parrot	0.05-0.06 kg	5.25 mg/kg (approx)
Fan-tailed cuckoo	0.04-0.05 kg	> 6 mg/kg (approx)
Laughing kookaburra	0.19-0.36 kg	> 6 mg/kg (approx)
White's thrush	0.08-0.12 kg	> 12 mg/kg (approx)
*Blackbird	0.07-0.10 kg	9.5 mg/kg (approx)
Eastern yellow robin	0.02-0.03 kg	11.65 mg/kg (approx)
Golden whistler	0.02-0.03 kg	> 18 mg/kg (approx)
Grey shrike-thrush	0.06-0.07 kg	> 12 mg/kg (approx)
Superb fairy wren	0.009-0.011 kg	3.38 mg/kg (approx)
White-browed scrubwren	0.011-0.012 kg	4.5 mg/kg (approx)
Little wattlebird	0.06-0.07 kg	7.75 mg/kg (approx)
New Holland honeyeater	0.019-0.023 kg	7.99 mg/kg (approx)
Yellow-faced honeyeater	0.014-0.019 kg	8.0 mg/kg (approx)
Yellow-tufted honeyeater	0.019-0.023 kg	< 7.5 mg/kg (approx)
Silvereye	0.012-0.017 kg	9.25 mg/kg (approx)
*European goldfinch	0.013-0.014 kg	3.5 mg/kg (approx)
Red-browed firetail	0.008-0.011 kg	0.63 (0.41-0.96) mg/kg
Zebra finch	0.010-0.013 kg	3.13 mg/kg (approx)
*Starling	0.06-0.08 kg	4.75 mg/kg (approx)
White-winged chough	0.22-0.39 kg	1.75 mg/kg (approx)
Australian magpie-lark	0.07-0.12 kg	8.83 (3.96-13.47) mg/kg
Australian magpie	0.25-0.38 kg	9.93 (7.59-12.92) mg/kg
Pied currawong	0.25-0.36 kg	13.09 (10.90-15.72) mg/kg
Australian raven	0.46-0.75 kg	5.1 mg/kg (approx)

Little raven	0.46-0.75 kg	3.10 (2.68-3.59) mg/kg
Little crow	0.32-0.46 kg	13.37 (11.73-15.24) mg/kg

Signs of poisoning appeared 1-60 hours after dosing with death occurring after 1.4-262 hours in around 70% of individuals showing symptoms. Birds initially became depressed, unsteady or quiet, with eyes partly or completely shut. Most birds had fluffed plumage and shivered or trembled occasionally. Rapid panting, squawking or other vocalisations and a brief period of activity preceded the onset of convulsions, generally progressing to death.

Results show that Australian birds in general are moderately sensitive to 1080, with some groups (ducks, raptors and doves) moderately tolerant and the emu tolerant. Birds are generally more tolerant of 1080 than are mammals. Native doves and waterfowl are more tolerant than their introduced counterparts (eg laughing dove LD50 5.5 mg/kg and mallard LD50 5.6-8.6 mg/kg). Parrots are moderately to highly sensitive, but probably less so in WA as the LD50 for the Port Lincoln ringneck exceeds 9.2 mg/kg. The little crow from WA is significantly more tolerant than eastern Australian corvids.

Malleefowl are also tolerant of 1080, with an approximate lethal dose (ALD, or the lowest dose that is lethal to 10% of the birds tested) of 100-125 mg/kg determined in birds from captive colonies in NSW and SA (King *et al*, 1996).

Unadapted Australian natives (Western Australia)

Further data have recently been reported for native animals from Kununurra in north-western Australia, using the increasing ALD dose procedure with individual animals dosed approximately 24 hours apart by intraperitoneal injection (Martin and Twigg, 2002). The dose-response curve for 1080 is quite steep, and the LD50 is generally greater than the ALD (approximate lethal dose, or the lowest dose causing death) by a factor of about 1.5. Animals from this area were tested in order to determine whether use of 1080 grain baits to control nuisance outbreaks of the long-haired rat would present risks to nontarget species.

Species	Weight range	ALD (100% purity)
Radjah shelduck	930-1004 g	1.24 mg/kg
Plumed whistling-duck	520-700 g	2.09 mg/kg
Brown falcon	390-490 g	20.04 mg/kg
Peaceful dove	33-59 g	9.50 mg/kg
Little corella	442-658 g	1.43 mg/kg
Chestnut-breasted mannikin	13.0-14.5 g	1.43 mg/kg

Results indicate that ducks from the area are moderately to highly sensitive, compared with their southern counterparts which are relatively tolerant. The brown falcon and peaceful dove are relatively tolerant. Captive bred barn and grass owls, from WA and eastern Australia respectively, returned ALDs of 14.54 and 6.46 mg/kg, respectively.

Note that there may have been some adaptation to 1080 in the birds tested as 1080-bearing plants also occur in northern Australia, although they are less abundant and more patchily distributed than such plants in south-west Western Australia. While adaptation appears unlikely in the ducks and corellas, given their sensitivity, the authors of this study suggest that the falcons have developed some tolerance to 1080.

The authors conclude that raptors face little risk of primary or secondary poisoning from 1080, except for pig campaigns. Many birds of prey, and other native carnivores, are potentially at risk of primary poisoning from the use of meat baits containing 72 mg/kg 1080 for pig control. Primary risks to granivores from grain baits appear significant in this part of Australia and in need of mitigation, for which a number of options are suggested. These are discussed in the hazard section of this report.

Adapted Australian natives (Western Australia)

As noted above, native animals from south-western Australia have developed a tolerance to 1080 because of its widespread presence in native flora. A recent compilation of toxicity data (WA, 2002) includes approximate LD50 values for 14 bird species whose current or former range includes areas with fluoroacetate-bearing plants. In general, birds from this part of Australia are relatively tolerant of 1080. The most sensitive is the wedge-tailed eagle (LD50 9.1 mg/kg). Port Lincoln parrots (LD50 10.8 mg/kg), regent parrots (LD50 11.8 mg/kg), wood ducks (LD50 11.8 mg/kg) and little crows (LD50 12.8 mg/kg) show similar tolerance.

Secondary poisoning

As noted above, raptors are relatively insensitive to 1080, although the high dose in pig baits raises some concerns. Evisceration and/or regurgitation of contaminated prey provide added protection against secondary poisoning. Incidents involving eagles have been reported in Australia but post mortem investigations have not shown 1080 to be implicated.

Radio-telemetry studies in the US (Hegdal *et al*, 1986) revealed no 1080-related mortalities from ground squirrel baiting with oats containing 750 mg/kg 1080, even though raptors were frequently observed feeding on the target species and other rodents. Hawks nesting around the baited area successfully fledged young. One American kestrel exhibited symptoms (convulsions). Similarly favourable outcomes have been reported in earlier rodent and rabbit baiting studies from the US, although occasional owl mortalities have been noted.

Although raptors do not appear to be susceptible to secondary poisoning by 1080, insectivorous birds may be more at risk because of their greater sensitivity, and possibly because of higher residues in insects. Hundreds of dead ants were seen on the surface of every anthill in an area baited for ground squirrels, and three bird species (acorn woodpecker, white-breasted nuthatch and ash-throated flycatcher) were found to be susceptible to 1080 poisoning. Residue analysis using a gas chromatographic procedure found 1.4 mg/kg 1080 in one sample of ants and none in another.

As described in the following section, North Island robins were found dead after laying of carrot baits, and the cause of death was confirmed by residue analysis of the carcass. It is unclear whether the residues reflect direct consumption of carrot baits or secondary exposure via insects. New Zealand robins live almost entirely on small insects and the worms and grubs that are to be found among decaying leaves and other vegetable matter. North Island robins are a sub-species that feed on the forest floor with a diet of invertebrates and summer fruits.

New Zealand field studies

Birds of 15 different species have been found dead following aerial 1080 operations in New Zealand, where bait loadings and rates of lay are higher than in Australia. The most commonly affected species were whiteheads, tomtits, robins, riflemen and moreporks. These birds are largely insectivorous, although the morepork also takes small vertebrate prey. Most losses occurred when carrot baits containing excessive small fragments were used, although it remains unclear whether poisonings were primary or secondary. The number of species reported dead after poisoning operations has declined since 1978, reflecting the screening of baits to remove small fragments, cessation of use of raspberry lure, introduction of cinnamon oil as an avian deterrent, reduced application rates, and increased use of cereal-based baits.

Monitoring of bird populations using techniques such as 5 minute counts and subjective assessments found no adverse effects in populations of common birds following aerial 1080 distribution. However, impacts on rare birds cannot be discounted because research is inadequate (Eason, 1997; Eason *et al*, 1998a).

Miller and Anderson (1992) monitored bird populations on Rangitoto Island during the course of an eradication operation using green-dyed cereal pellets to target possums and rock wallabies. Bird populations were monitored for a year at six-weekly intervals, starting just before poison was dropped in November 1990. Five minute bird counts were conducted along walking tracks. At 200 m intervals, all birds seen and heard within a 100 m radius were recorded. Searches were made for dead birds in the two days after the poison drop, and again two weeks later, but no results are reported.

There were no significant adverse effects apparent on bird populations that could be attributed to the baiting operation. Silvereyes, green finches and Australasian harrier hawks were significantly more conspicuous in the initial post-baiting count and again one year later. Chaffinches were more conspicuous after baiting, and tui a year after baiting. A number of non-significant fluctuations were also noted. Casual observation indicated an improvement in the quality of the vegetation with the removal of the introduced mammals, which would favour birds such as silvereyes and tui. The authors conclude that the poisoning operation had no detrimental impact on local bird populations.

Five minute bird counts record conspicuousness as well as number, and can give unreliable results if conspicuousness varies, as can happen with changes in weather or season. It can also be an unreliable method for assessing mortality except where this is substantial. More reliable studies have been conducted with North Island robins by capturing and marking them (Powlesland *et al*, 1999). These birds are territorial, and individuals have been found dead after aerial possum baiting operations.

The study was conducted in rolling forested country at an elevation of about 700 m near Pureora in the North Island of New Zealand. Carrot baits containing 800 mg/kg 1080 were aerially spread at 15 kg/ha over more than 16000 ha in September 1996. Disappearance of colour-banded birds over the subsequent 2 weeks reached 55% (12/22), and disappearance of banded and unbanded birds as determined by territory mapping reached 43% (12/28), with the majority of losses occurring in the first 3 days after baiting. No such losses were recorded in untreated areas. Carcasses of two banded birds were found in good condition 3-4 weeks later (weather had been cold and dry) and were found to contain 1080 residues (0.37-0.38 mg/kg in muscle). A freshly dead unbanded robin recovered the day after baiting contained 3.8 mg/kg 1080. It is unclear whether death occurred from direct consumption of carrots, or of invertebrates that had fed on them.

While baiting had a negative impact on adult mortality, effects on breeding success were positive with the removal of mammalian predators (possums and rats). Only 11% (4/35) of nests in the untreated area successfully fledged chicks, while 72% (13/18) were successful in the treated area. Populations remained stable as determined by territory mapping in the untreated area but increased by 29% in the treated area notwithstanding the adult mortality that had occurred.

A second operation across more than 8000 ha in August 1997 returned more favourable results, with adult disappearance in the treated area reduced to 9% (3/35) based on territory mapping and 10% (3/31) in colour-banded birds. Nest success was 67% (20/30) in the treated area and 30% (20/67) in the reference area, which was the area baited in September 1996. Population increase over the subsequent year as determined by territory mapping was 31% in the treatment area and 33% in the reference area.

The unexpectedly heavy adult mortality in 1996 is believed to reflect increased amounts of chaff or small fragments. The authors conclude that, provided carrot bait protocols are adhered to and large areas are treated so that mammalian predator populations remain low through the next breeding season, aerial baiting with carrots for possum control benefits robin populations.

Australian field studies

McIlroy and Gifford (1991) carried out diurnal bird counts along a fixed transect on three occasions (July, September and November 1974) before and three (February, May and July 1975) after laying of green-dyed cereal baits (500 mg/kg, 0.5 mg/bait) in trails for rabbit control on a semi-cleared property near Braidwood NSW. Carcass searches were also conducted along the bait lines.

Separate bait acceptance trials in the Brindabella Valley found that four species (galahs, pied and grey currawongs and magpies) fed on baits, but only infrequently.

A total of 103 species was observed, but many were vagrants, seasonal visitors or occasional sightings. Australian magpies, white-eared honeyeaters and grey fantails were most common. Some species increased in the treated area after the campaign and others decreased. These population changes did not always correlate with those seen in untreated areas. The greatest declines were in welcome swallows and tree martins, and crimson rosellas. Only one carcass (a fan-tailed cuckoo) was recovered after baiting, but was found to have no bait in its gizzard.

Welcome swallows and tree martins were considered unlikely 1080 casualties as they feed on aerial insects. A similar conclusion was reached for rosellas, notwithstanding their known sensitivity to 1080, as none were seen feeding on baits during this campaign or in separate trials, and no carcasses were recovered (although some crimson rosellas have reportedly been found dead after carrot baiting operations). It is thought that rosellas were attracted by ripe fruit on the property. Eastern yellow robins and fan-tailed cuckoos are also sensitive to 1080, but increased in number in the treated area while decreasing in the untreated control area.

The APCC has provided a report (Sinclair, 1988) of a rabbit baiting program on Torrens Island, a small island in the Port River adjacent to mangrove swamps at Port Adelaide. Approximately two-thirds of the island is owned by the Electricity Trust of South Australia (ETSA). After expressing concern regarding the possible impact of 1080 rabbit baiting on native birds, ETSA staff were invited to participate by helping search treated areas for dead animals.

Rabbit baiting entailed the laying of 1080 oat baits (375 mg/kg 1080) at 2.8 kg/km along 60 km of trail, after free-feeding at 2 day intervals on three occasions. Bird activity along the bait trail was observed, and the baited area was systematically searched on days 2, 3, 5 and 6 post-baiting.

Australian ravens, crested pigeons, bronze-wing pigeons, galahs, masked plovers, silver gulls, willy wag-tails, grey shrike thrushes, mud larks, singing honeyeaters, white-fronted chats, white-faced herons, European blackbirds, spotted turtleneck doves, sparrows and starlings were seen close to the bait trail. Spotted turtleneck doves were the only birds seen to feed on poison grain, and generally died within 1-2 m of the furrow after gorging. Crested pigeons fed along the furrow, apparently on vegetable matter rather than the grain bait. Silver gulls fed on untreated oats but were not seen to feed on the poisoned grain.

Carcass searches recovered 535 dead rabbits (420 in the first 2 days) and one feral cat. Fresh rabbit tracks almost disappeared after the campaign. Similarly, only introduced birds were affected by the bait. A total of 27 sparrows, 6 starlings, 11 spotted turtleneck doves, 1 feral pigeon and 1 silver gull were found dead after baiting. All had grain in their gut or crop, except for the pigeon and gull. The gull appeared from its state of decomposition to have died before poison baiting occurred. The lack of observed mortality in silver gulls or feeding on poison bait suggests that, like some native mammals, these birds can detect the presence of 1080.

An *ETSA Environment* article from autumn 1992 reported a marked increase in native plant growth and the return of associated bird life such as wrens, parrots and honeyeaters in the 2 years following the baiting campaign.

Incident reports

The Wedge-Tailed Eagle Recovery Plan (Bell and Mooney, 1999) notes anecdotal reports claiming that wedge-tailed eagles have died from eating carcasses of animals poisoned with 1080, but that no post mortem results have confirmed this, even though more than 20 have been carried out on eagles dying from unknown causes including several suspected 1080 kills.

The DNRE advised that it investigated 15 reports of 1080 misuse in the 3 years to August 2001. Most of these related to inadequate notification and/or domestic dog poisonings. Investigations into one incident where dead eagles were recovered at the roadside near Nagambie found mevinphos residues in the carcass.

In published studies, McIlroy (1982a) has provided a list, taken from unpublished Forestry Commission files, of nontarget birds found dead in NSW forest areas after 22 rabbit poisoning campaigns between 1971 and 1975, using carrot or pellet baits broadcast from the air or laid as trails on the ground. Carcasses of 12 magpies, 10 parrots, 3 kookaburras, 2 scrub wrens, a pigeon, hawk, lyrebird and crow were recorded by forestry personnel. These deaths cannot be confirmed as related to baiting as no confirmatory residue analyses were conducted.

Fluoroacetate poisoning is usually diagnosed based on local probability, and only rarely confirmed through residue analysis. The NRME has conducted residue analyses using the dichloraniline method for cases sourced from all States and Territories of Australia where fluoroacetate poisoning was a distinct possibility based on clinical signs or likely exposure. In the last three years, a duck and five black cockatoos have been tested. Only the duck returned a positive finding.

6.1.2 Aquatic toxicity

The US EPA RED document reported 96 hour LD50s of 54 (slightly toxic) and > 970 mg/L (practically nontoxic) to rainbow trout and bluegill sunfish, respectively. The 48 hour EC50 for *Daphnia magna* was 350 mg/L (practically nontoxic). No test results were reported for algae or aquatic plants, but the US EPA noted that 1080 is not a herbicide, and that there is no apparent basis for any phytotoxicity concerns.

In view of the low application rates, DEH considers that the toxicity of 1080 to fish, aquatic invertebrates and algae and aquatic plants is adequately addressed by the above findings.

The US EPA RED document does not discuss toxicity to amphibians. As sodium fluoroacetate is a water soluble compound that is not expected to be retained in tissues or organs, tadpoles may be expected to have similar sensitivity to fish. McIlroy *et al* (1985) have studied the effects of intraperitoneal injection of 1080 in spotted grass frogs (mean weight 4.6 g). Three frogs survived doses of 50-60 mg/kg and four died after receiving doses of 62.5-100 mg/kg, indicating an LD50 in the order of 60 mg/kg (moderately toxic, according to the US EPA's criteria for vertebrates). The authors note that this is similar to the reported LD50 in American bullfrogs of 51 (24-108) mg/kg but lower than earlier estimates for the North American leopard frog (150 mg/kg) and the African clawed toad (> 500 mg/kg).

6.1.3 Terrestrial invertebrates

The US EPA RED document does not address toxicity to these organisms because of the low exposure expected from the US use as a livestock protection collar only.

The insecticidal activity of 1080 was recognised in the 1920s when it was patented as a moth proofing agent. As for birds and mammals, insects that include fluoroacetate-bearing vegetation in their diet are much less sensitive to the toxin, as has been demonstrated with caterpillars hand collected from south-western Australia and injected with 1080. Thus the LD50s in saw flies (*Perga dorsalis*) and autumn gum moths (*Mnesamplea privata*), which feed exclusively on eucalypts, were 1.05 and 3.88 mg/kg, respectively. Tiger moths (*Spiolosoma* sp) which have a more cosmopolitan diet including herbaceous and woody plants were less sensitive, with an LD50 of 42.7 mg/kg. Bag moths (*Ochrogaster lunifer*) which feed on native legumes and some trees were less sensitive still, with an LD50 of around 150 mg/kg. This particular species was collected while feeding on the toxic plant *Gastrolobium microcarpum*. Further evidence that some insects have developed tolerance to 1080 is provided by the observations that seed-harvesting ants coexisting with toxic vegetation selected seed on the basis of size rather than 1080 content, and that some seed weevils consumed toxic seed in completing their development to pupae (Twigg, 1990, 1994).

Available LD50 data for invertebrates are sparse, as noted by Wright *et al* (2002) in a recent risk assessment. For example, an LD50 of 8 mg/kg has been reported for honeybees (*Apis mellifera*). This is equivalent to about 1 µg/bee, indicating that 1080 is toxic to bees according to the criteria of Mensink *et al* (1995).

Sherley *et al* (1999) conducted a detailed study in mixed podocarp and hardwood forest at Okahune in the central North Island of New Zealand. Two baits were studied, an extruded wheat chaff pellet (20 mm x 15 mm) containing green dye, cinnamon lure, and 0.153% 1080, and diced carrot of similar dimensions containing the same additives but no 1080.

The nontoxic pollard baits were more attractive to invertebrates than were the carrots, and appeared to be favoured by rats and possums as the carrot baits remained longer on the ground. Some 22.7% of the pollard baits and 11.6% of carrots were seen with at least one invertebrate on them. Numbers of three of the four most commonly seen species did not correlate with numbers caught in nearby pitfall traps. Results suggest that only a small proportion of baits have invertebrates on them at any time, and that these represent only a small proportion of the fauna present in leaf litter.

The proportion of baits with invertebrates on them and the numbers per bait were both significantly lower when the toxic bait was used. It is unclear whether this indicates poisoning or aversion. However, the effect was local as visits to nontoxic baits were comparable with controls, provided that the nontoxic baits were at least 20 cm from a toxic bait.

In a recent risk assessment, Wright *et al* (2002) review published and unpublished observations regarding impacts on invertebrates from 1080 cereal baits (toxic and nontoxic). No significant effects were generally found on invertebrate numbers following baiting, although unpublished data from one operation indicate significant differences in abundance, particularly for beetles, springtails and flies.

6.1.4 Mammals

McIlroy (1986) has analysed toxicity data for 171 terrestrial vertebrate species and reached the following general conclusions. Canids (LD50 around 0.1 mg/kg) are the most sensitive animals in Australia and shingle-backs the most tolerant. Overall, there is a general trend of decreasing sensitivity from the fairly strictly herbivorous mammals (excluding those from Western Australia) to herbivorous/granivorous animals such as rodents, carnivorous mammals, omnivorous mammals such as bandicoots, birds and finally amphibians and reptiles. Eutherian carnivores are more sensitive than marsupial carnivores.

North American species

The US EPA RED document reports that, consistent with its use as a vertebrate poison, 1080 is highly to very highly toxic to mammals based on the following LD50 values: coyote, cotton rat, 0.1; skunk, 1.0; racoon, 1.1; deer mouse, 4.0; and opossum, 41.6 mg/kg. The US EPA describes chemicals as very highly toxic to mammals when the LD50 falls below 10 mg/kg.

Target species in Australia

All the species targetted by 1080 in Australia are highly sensitive, as tabulated below, except for the pale field rat which is moderately sensitive. The animals listed below were given oral or intraperitoneal doses in aqueous solution. Although the two modes of administration should not be compared with each other, in this case the route of administration is unlikely to significantly affect the toxic response. Some attenuation of toxicity is likely, however, if 1080 is dosed orally as a relatively low concentration bait material.

Species	LD50 (mg/kg)	Reference
Dog	0.07	Tourtellotte and Coon, 1951
Dingo	0.11	McIlroy, 1981b
European red fox	0.13	McIlroy, 1986
Cat	0.4	McIlroy, 1981b
Rabbit	0.7	Meldrum *et al*, 1957
Pig	1.0	McIlroy, 1983a
Red-bellied pademelon	0.13	McIlroy, 1982a
Bennett's wallaby	< 0.21	McIlroy, 1982a
Common brushtail possum	0.47-0.86	McIlroy, 1982a
Pale field rat	2.3-3.4 mg/kg	Twigg *et al*, 2003c

The result for the dog is from testing of unspecified domestic breeds with a body weight of 6-15 kg. Based on unpublished data, McIlroy *et al* (1986) report an LD99 for captive dingoes and wild dog hybrids of 0.123 (0.110-0.137) mg/kg.

The result for the rabbit is for wild caught animals from Tasmania, with the authors suggesting that earlier studies indicating greater sensitivity may have used a domestic breed. Note that some field populations of rabbits in Australia may now be slightly less sensitive based on recent findings (LD50s in the order of 0.7-1.0 mg/kg after intraperitoneal injection) suggestive of the development of genetic resistance in wild caught animals from WA (Twigg *et al*, 2002). The tendency of rabbits in WA to dehusk oats is a possible explanation for sublethal dosing of rabbits, particularly with the One-shot product, and consequent development of resistance. Alternative bait materials, such as barley, have been identified as the best option for overcoming this shortcoming (Twigg *et al*, 2003b).

The result for the pig is also for wild caught animals. A subsequent study (O'Brien, 1986) found moderate sensitivity, with LD50s in the order of 4 mg/kg in wild caught animals acclimatised to test conditions for at least 28 days before dosing. Pigs tested by McIlroy (1983a) were only held for a few days after capture, and may have been more sensitive because of the stresses of captivity. In addition, McIlroy dosed restrained animals with an aqueous solution, while O'Brien fed treated grain to unrestrained pigs (with no evidence for aversion).

Carnivorous Australian natives

The toxicity of 1080 has been studied in a wide range of indigenous species. For example, McIlroy (1981b) obtained data on marsupial carnivores (tabulated below) during the 1970s. Test species are known to eat meat given the opportunity, although the dunnarts, antechinus, kowari and bandicoot are predominantly insectivorous or omnivorous. Animals (mostly adult males) were acclimatised to captivity for at least 2 weeks before dosing in groups of 3-5 with 1080, administered via syringe or oesophageal catheter, or as gelatin capsule within meat for the dingo.

Species	Mean weight	LD50 (95% CI)
Fat-tailed dunnart	13 g	2.06 (1.58-2.69) mg/kg
Stripe-faced dunnart	22 g	0.95 (0.57-1.60) mg/kg
Brown antechinus	36 g	1.85 (1.43-2.40) mg/kg
Dusky antechinus	62 g	3.21 (2.43-4.23) mg/kg
Kowari	135 g	2.85 mg/kg (approx)
Northern quoll	750 g	5.66 (3.91-8.20) mg/kg
Eastern quoll	1.45 kg	3.73 (3.18-4.38) mg/kg
Tiger quoll	2.79 kg	1.85 (1.28-2.68) mg/kg
Tasmanian devil	4.67 kg	4.24 (2.76-6.60) mg/kg
Long-nosed bandicoot	1.19 kg	7.70 (5.28-11.23) mg/kg
Dingo	16.23 kg	0.11 (0.09-0.15) mg/kg
Cat (introduced)	1.00 kg	0.40 (0.31-0.52) mg/kg

Symptoms of poisoning were preceded by a latent period, generally a few hours but occasionally longer. The most common response was for animals to suddenly become hyperexcited, with rapid breathing, bouts of trembling and sometimes periodic circling within their cages. Some animals recovered, while others progressed to vomiting and/or convulsions, with death following soon after. Other animals, particularly the small dasyurids, suddenly became unwell and rested quietly before progressing to hyperexcitability. The first symptom in quolls and the Tasmanian devil was usually the sudden onset of vomiting, even after intraperitoneal injection. Vomiting did not protect against lethal effects.

Results indicate that native carnivores are moderately to highly sensitive to 1080, while dogs and cats are highly sensitive. The higher tolerance of marsupial carnivores compared with their eutherian counterparts may reflect their lower basal metabolic rate. Among the quolls, the apparent high sensitivity of the spotted-tailed quoll (tiger quoll) may be an artefact of temperature as this species was tested under cooler conditions.

Herbivorous Australian natives

McIlroy (1982a) found that, unlike the carnivores, most marsupial and eutherian herbivores that have been tested according to the same procedure exhibit a similarly high sensitivity to 1080, with LD50s in the 0.1-1 mg/kg range as tabulated below. All Bennett's wallabies tested died at the doses selected. Results for bettongs, potoroos and eastern grey kangaroos are based on the range between survival and death of individual animals. The sensitivity of eastern greys was probably accentuated by the stress of captivity and handling. Where LD50s are cited as a range together with confidence intervals, data are taken from a series of trials. Results for introduced species (sheep and rabbits) are included for comparison.

Species	Weight range	LD50 (95% CI)
Brushtail possum (immature)	0.7-1.8 kg	0.86 (0.67-1.09) mg/kg
Brushtail possum (adult)	1.4-3.8 kg	0.47-0.79 (0.34-1.03) mg/kg
Tasmanian bettong	1.8-1.9 kg	1 mg/kg (approx)
Brush-tailed bettong (WA)	1.0-1.5	100-200 mg/kg (approx)
Tammar wallaby (pouch young)	0.3-2.0 kg	0.15 (0.12-0.20) mg/kg
Tammar wallaby (adult)	6.0-8.2 kg	0.27 (0.23-0.31) mg/kg
Western grey kangaroo	16.5-24.0 kg	20 mg/kg (approx)
Eastern grey kangaroo	21.8-60.0 kg	0.1-0.35 mg/kg (approx)
Bennett's wallaby	8.8-20.6 kg	< 0.21 mg/kg (approx)
Long-nosed potoroo	1.1 kg	0.15-0.20 mg/kg (approx)
Red-bellied pademelon	2.4-7.8 kg	0.13 (0.09-0.19) mg/kg
Common wombat (free-ranging)	20.2-20.8 kg	0.15 (0.12-0.19) mg/kg
Common wombat (captive)	18.0-26.5 kg	0.22 (0.18-0.27) mg/kg
Southern hairy-nosed wombat	20.5-28.2	0.21 (0.15-0.29) mg/kg
Sheep	32.9-42.8 kg	0.5 (0.42-0.64) mg/kg
European rabbit (immature)	0.6-1.0 kg	0.35-0.37 (0.30-0.42) mg/kg
European rabbit (adult)	0.8-1.9 kg	0.34-0.50 (0.26-0.58) mg/kg

The main exceptions are marsupials from Western Australia, such as the brush-tailed bettong, which have acquired a greater tolerance because of their exposure to indigenous food plants containing fluoroacetate. Thus King *et al* (1978) report that brushtail possums from WA can tolerate doses of 100 mg/kg 1080, compared with eastern and introduced New Zealand populations where the LD50 is less than 1 mg/kg.

Signs of poisoning were similar to those seen in other herbivores. Depending on the species, death mostly resulted from cardiac failure or ventricular fibrillation, or progressive depression of the central nervous system leading to cardiac or respiratory failure. This compares with the usual response in carnivores of respiratory arrest following central nervous system disruption and convulsions.

McIlroy (1981a) has studied the effects of variations in experimental factors, such as age, sex, nutritional status and population source, on the results obtained from acute oral testing in rabbits, brush-tailed possums, tammar wallabies and brown antechinus. He concluded that pouch young and possibly young-at-heel marsupials are more sensitive to 1080 than are older animals. More pouch young possums than adults died at each dose level, even though only the mothers were dosed with 1080. No other intraspecific differences were apparent between different populations in eastern Australia. The LD50 values obtained are very much a function of experimental procedure, particularly environmental temperatures. McIlroy cautioned against traditional laboratory trials with some species, such as wombats and certain macropods, because of problems with diseases and stress in captivity.

The effect of varying the route of administration was studied in adult possums. The LD50 was a little lower following intraperitoneal injection (0.57 mg/kg) than when the poison was administered orally (0.58-0.68 mg/kg) but the difference was not significant.

Omnivorous Australian natives

Testing in ten Australian rodent species according to the same procedure (McIlroy, 1982b) found that three (plains mouse, bush rat, swamp rat) were highly sensitive, three (long-tailed mouse, grassland melomys, water-rat) moderately sensitive and four (western chestnut mouse, sandy inland mouse, Mitchell's hopping mouse, spinifex hopping-mouse) relatively tolerant, as tabulated below. Canefield rats were also identified as highly sensitive (LD50 1.3 mg/kg) based on earlier testing by McDougall (1949). In general, species with the longest evolved history in Australia were most tolerant. The exception was the plains mouse, whose range does not overlap with those of 1080-bearing plants. The bush rats tested were from eastern Australia, from where this species is believed to have originated. Conspecifics from various parts of WA were known to be much more tolerant, with LD50s from 22 to 75 mg/kg.

Species	Weight range	LD50 (95% CI)
Spinifex hopping mouse	30-56 g	32.7 (27.4-39.3) mg/kg
Mitchell's hopping mouse	37-59 g	19.4 (15.8-23.9) mg/kg
Plains mouse	38-77 g	1.15 (1.07-1.43) mg/kg
Sandy inland mouse	11-20 g	39.3 (23.6-65.4) mg/kg
Long-tailed mouse	59-104 g	8.98 (6.16-13.1) mg/kg
Western chestnut mouse	23-72 g	14.7 (13.7-15.9) mg/kg
Grassland melomys	43-114 g	2.65 (2.23-3.15) mg/kg
Water rat	510-910 g	2.94 mg/kg approx
Bush rat	128-168 g	1.13 (0.85-1.51) mg/kg
Swamp rat	118-200 g	1.71 (1.39-2.11) mg/kg

The relative tolerance of many Australian species contrasts with the overseas situation, where nearly all LD50s are below 2 mg/kg. The notable exception is the house mouse, with an LD50 of 8.3 mg/kg determined in this study. Two other introduced species (white laboratory rats and black rats) were also tested and found to be highly sensitive (respective LD50s of 1.71 and 0.76 mg/kg). Considerable variation exists between LD50 data generated overseas for these three widely tested species (respective ranges of 5.0-19.3, 1.49-5.00 and 0.10-1.5 mg/kg).

The pale field rat (*Rattus tunneyi*) is a target species in Queensland hoop pine plantations. Testing of specimens from Wyndham WA, with limited possible exposure to fluoroacetate-bearing vegetation, returned an LD50 of 3.4 mg/kg, while specimens from nearby offshore islands where such plants do not occur were slightly more sensitive with an LD50 of 2.3 mg/kg (Twigg et al, 2003c).

Similar testing with three bandicoot species (McIlroy, 1983b) found all to be moderately sensitive, as tabulated below. The reasons for this are unclear, but evolutionary exposure to toxic plants appears unlikely as two species were collected from Tasmania and the third (long-nosed bandicoot) from the south coast of NSW

Species	Weight range	LD50 (95% CI)
Brown bandicoot (*Isoodon obesulus*)	0.86-1.40 kg	7.0 mg/kg approx
Gunn's bandicoot (*Perameles gunnii*)	0.73-0.83 kg	5.4 mg/kg approx
Long-nosed bandicoot (*P nasuta*)	1.00-1.48 kg	7.70 (5.28-11.23) mg/kg

Adapted Australian natives

As noted above, native animals from south-western Australia have developed a tolerance to 1080 because of its widespread presence in native flora. A recent compilation of toxicity data (WA, 2002) includes approximate LD50 values for 29 mammal species whose current or former range includes areas with fluoroacetate-bearing plants.

The most sensitive species listed is the carnivorous mulgara (LD50 4.8 mg/kg) which occurs in the north-west of the State where fluoroacetate-bearing plants are less abundant. Northern and western quolls (LD50 7.1 mg/kg) and brush tailed phascogales (LD50 9 mg/kg) are also moderately sensitive.

Omnivores are more tolerant, as indicated by LD50s of 8.4 mg/kg in golden bandicoots and 18.8 mg/kg in southern brown bandicoots.

Tolerance to 1080 is much more pronounced in the herbivores, particularly when compared with the sensitivity of macropods from the eastern States. Wallabies are moderately sensitive, with LD50s of 7.1 mg/kg in brush-tailed wallabies and 9.4 mg/kg in tammars, but other macropods are relatively tolerant or tolerant.

Sublethal toxicity

Studies with laboratory rats have shown that developmental effects can occur in offspring as a result of sublethal maternal exposures. Rats were dosed orally with 1080 in aqueous solution from days 6 to 17 of gestation. There was no mortality or maternal toxicity at the highest dose of 0.75 mg/kg/day, but decreases were observed in maternal body weight, gravid uterine weight and food consumption. Foetal body weight was similarly affected, and there were mild skeletal malformations and variations (bent scapulae, long forelimb bones, bent or wavy ribs, unossified sternebrae). The incidence of bent and wavy ribs was also increased at 0.33 mg/kg/day. No effects were seen in mothers or offspring at 0.1 mg/kg/day.

Significant maternal mortality (60%) occurred at 1 mg/kg/day in a pilot study, together with decreased litter size and increased resorption (Eason *et al*, 1998b, 1999).

Results of three complementary genetic toxicology studies provide strong support for the hypothesis that 1080 is not genotoxic (Eason *et al*, 1999). No mutagenicity was observed in two *in vitro* studies (Ames assay and mouse lymphoma assay) and an *in vivo* test (mouse micronucleus test).

Although 1080 is an acute poison that is readily metabolised, toxicity appears to increase with daily repeat dosing as the LD50 ranges from 1.49 to 5 mg/kg in acute studies with laboratory rats.

Studies in sheep indicate that repeated sublethal dosing gives rise to cumulative damage to the heart or other organs even though the toxin itself does not accumulate. Macroscopic lesions have been seen in the heart of sheep after doses as low as 0.11 mg/kg/day for 3-7 days (Eason, 1997).

Aversive effects

As noted above, there is evidence that the presence of 1080 in food material may limit its consumption by birds. There was a marked reduction in food consumption by mallards and bobwhites in dietary testing. Silver gulls at Torrens Island were seen to consume unpoisoned oats but not poisoned grain.

A similar response in mammals may be expected, given that preliminary free-feeding is often needed to ensure that target animals will take poison baits. Studies with penned feral pigs found that wheat intake declined significantly when grain was laced with 500 mg/kg 1080 and only 2 of 19 pigs died (Hone and Kleba, 1984). Dietary toxicity studies do not appear to have been conducted with mammals, but there are other sources of evidence for aversive effects of 1080.

Analysis of faecal pellets from western grey kangaroos (*Macropus fuliginosus*) in the lower south-west of WA indicates that these animals include up to 25% fluoroacetate-bearing vegetation in their diet but appear to be able to discriminate in favour of the less toxic forms, thus achieving a balance between adequate nutrition and avoidance of poisoning (Mead *et al*, 1985b).

Sinclair and Bird (1984) demonstrated aversive effects in the laboratory with the fat-tailed dunnart (*Sminthopsis crassicaudata*), a small dasyurid marsupial. Laboratory bred males (8-18 months old, weighing 12-19 g) were maintained under natural lighting conditions while their normal laboratory diet (mealworms and commercial pet food) was replaced by lean minced beef. Animals accepted this diet freely and consumed a third or more of their body weight in a night. Food was withheld the night before testing so that the animals would be hungry when offered meat laced with 1080.

One experiment compared the effects of an estimated LD90 (2.38 mg/kg) administered in aqueous solution directly into the stomach using a blunt-ended needle or offered as a mixture with 1.5 g meat. Mortality in 10 directly dosed animals reached 70%, preceded by retching but with no vomiting observed. All of 29 animals offered meat ate at least 5% of it but only six consumed the full amount, and only one of these died, along with one other animal that consumed 80% of the ration. All vomited after eating, even after doses as low as 2 µg 1080.

In a second experiment, ten animals were offered 5 g of poisoned meat (90 mg/kg 1080) either alone or with an equal amount of unpoisoned meat. As in the first experiment, some deaths occurred, but appeared unrelated to the amount consumed or retained with one animal having eaten only 0.2 g (18 µg 1080) of meat (the LD50 is 29 µg for a 12 g animal or 45 µg for a 19 g animal). There was no obvious first preference, with three eating the unpoisoned meat first, five the poisoned meat, and two not eating. Two of the first three subsequently ate poisoned meat. When only poisoned meat was offered, eight of ten animals consumed it, in similar amounts to the animals offered a choice. However, when unpoisoned meat only was offered to survivors 5 days later, after a normal laboratory diet in the interim, consumption more than doubled.

Close observation revealed that these small mammals consumed small amounts of unpoisoned meat through the night, but fed only once on poisoned meat, suggesting that the development of unpleasant symptoms deterred further feeding. In the second experiment four of twenty animals did not eat at all, and one ate only unpoisoned meat, suggesting that some individuals may react to odour. Regardless of the reasons, aversive effects appear to have reduced mortality by an order of magnitude from what might have been expected, based on the results of the first experiment.

Morgan (1990) found similar bait aversion in common brushtail possums, captured from the wild in New Zealand and acclimatised in individual pens for at least 6 weeks and in observation pens for at least 4 days before testing, which entailed presentation of twelve baits (6 g carrot chunks containing 0 or 9 mg 1080 and 0.02% Lissamine green, or 6.2 g extruded pollard/bran pellets containing 0 or 9 mg 1080 and 0.02% Lissamine green) of one type only. After preliminary trials on barley, some baits were also prepared with masking agents (0.1% cinnamon for both types, and 0.125% orange for pellets). The behavioural response of 261 possums (30-42 per treatment) to the baits was observed, with additional information on consumption obtained from a further 81 animals.

Only 7% of possums rejected nontoxic carrot (by smell or taste) but 27.5% rejected toxic carrots and survived. Similar responses (5 and 34% rejection) occurred with pellets. Rejection of toxic baits was overcome with the use of masking agents, to the extent that possums preferred toxic cinnamon pellets to the non-toxic variety.

Symptoms appeared around half an hour after first eating toxic carrot bait, and an hour after eating pellets. Possums typically stopped feeding and returned to the nest box or some other secure resting place. Very few possums survived the flavoured toxic baits.

Similar responses have been reported in brushtail possums from Western Australia offered bread and jam containing sublethal doses of 1080 (the equivalent of 0, 25 or 50 mg/kg 1080 daily for 4 days). Western Australian possums survive oral doses of 100 mg/kg 1080. All possums survived the experiment, but those offered the highest dose generally refused or ate only a small part of it (King *et al*, 1978).

Studies in wild caught New Zealand possums have shown that bait aversion is readily induced in the laboratory or in the field, and that aversion is likely to persist for at least 3 years. Possums appeared to develop a bait shyness rather than a toxin shyness, as there was no discrimination between baits containing 1080 toxin and non-toxic baits (O'Connor and Matthews, 1999).

Although evidence is limited and formal studies have not been undertaken, it is possible that other pest species would react to poison baiting in the same way as the possums described above. The NSW threat abatement plan (NPWS, 2001) notes that some proportion of the fox population can be expected to avoid baits, either through neophobia or as a learned response following sub-lethal exposure, and that these individuals are hard to detect. Bait rejection in foxes has also been observed during baiting operations in SA, but a change in bait overcame the aversion (Anderson, pers comm).

Secondary poisoning

Secondary poisoning of dogs was observed, albeit not recognised, during the early years of European settlement in south-western Australia. Settlers noted that dogs died after eating bronze-winged pigeons that had fed on toxic *Gastrolobium* seeds. SA has advised that these deaths were possibly due to some other fluorinated compound in the seeds.

Secondary poisoning of foxes during rabbit baiting campaigns was suspected to occur during the 1950s and 1960s because thriving marsupial populations in some nature reserves crashed when rabbit baiting was curtailed. An unplanned experiment in Watheroo National Park confirmed that incidental fox control attended rabbit baiting campaigns. Radiocollared foxes being monitored in the park underwent heavy mortality after consuming rabbits that had been baited with One-shot oats on an adjacent farming property (King and Kinnear, 1991; Algar and Kinnear, 1996). Secondary poisoning of foxes during rabbit baiting campaigns (83-333 mg/kg 1080 on carrots) has also been reported in the eastern States (Rathore, 1985).

Secondary poisoning following rabbit control operations using carrot bait (25 kg/ha containing 0.02% 1080) has also been demonstrated in New Zealand (Heyward and Norbury, 1999). Wild ferrets (LD50 1-1.4 mg/kg) and feral cats (LD50 0.4 mg/kg) were trapped and radiocollared at two sites in the South Island before baiting occurred.

Nine dead ferrets were recovered after baiting (5/28 at one site and 4/26 at the other) with two from each site containing high concentrations (0.68-1.80 mg/kg) of 1080 in leg muscle. Three others contained low levels (< 0.005 mg/kg) and the remaining two were uncontaminated. The four highly exposed ferrets are believed to have died from secondary poisoning as carrot was never detected in ferret scats. Their deaths occurred 33-47 days after baiting. The delayed death may reflect a preference for live and healthy prey, with carcasses only consumed when live rabbits became scarce. Although the ferrets appear to have died from secondary poisoning, this could not be confirmed as the estimated natural mortality, calculated over a longer period, reached 81% at the control site compared with 46-53% at the baited sites.

Two dead cats recovered after baiting were free of 1080 residues, but only limited numbers (5 at one site and 9 at the other) were radiocollared. One uncollared cat was discovered in a lethargic and disorientated state a month after baiting and found to contain low levels (< 0.005 mg/kg) of 1080 in muscle. Another radiocollared cat found dead in a nearby area several months after baiting, having left the study area several months before death, was found to contain 0.22 mg/kg 1080 in muscle. Reliable estimates of secondary mortality in cats could not be determined as insufficient numbers were monitored.

Secondary poisoning of cats following rabbit baiting (One-shot oats as a 1% mix) has also been studied at Shark Bay, Western Australia. Eight radiocollared cats survived the exercise, but a noncollared cat was found with symptoms (disorientation and limited muscular control) of 1080 poisoning. Rabbit consumption could not be confirmed as stomach and contents were empty (Risbey *et al*, 1997).

Secondary poisoning has also been reported from the US. Species affected (albeit without residue confirmation) were domestic dogs and cats, coyotes, bobcats, skunks and kit foxes. Secondary mortality was particularly evident during periods of food stress when animals ate poisoned ground squirrels or dug out dessicated carcasses (Hegdal *et al*, 1986).

Quolls

The sensitivities of three quoll species have been determined in the laboratory. Sensitivities were compared based on accumulation of citrate in the plasma following administration of 1080 (94%) by intraperitoneal injection. Approximate LD50s were determined based on mortality of individual adult animals. Wild caught western quolls or chuditch (*Dasyurus geoffroii*) survived doses of 3.5 and 5 mg/kg, and northern quolls (*D hallucatus*) survived a dose of 5 mg/kg, but signs of poisoning were apparent in one chuditch and three northern quolls at 5 mg/kg, and plasma citrate concentrations increased considerably. Three northern quolls died within 7 hours at 10 mg/kg, and a single chuditch died within 3 hours at this dose level. Captive bred eastern quolls (*D viverrinus*) were more sensitive, with marked increase of plasma citrate at 1 mg/kg and complete mortality of five individuals within 13 hours of dosing at 2 mg/kg. The approximate LD50s were estimated at 1.5 mg/kg (highly sensitive) for the eastern quoll and 7.5 mg/kg (moderately sensitive) for the chuditch and northern quoll (King *et al*, 1989).

Eastern quolls are not susceptible to secondary poisoning, according to material issued by the DPIWE. Agdex 657 No 35 (The Use of 1080 Poison) states that attempts have been made to induce toxicity in eastern quolls and Tasmanian devils by feeding them poisoned carcasses. No signs of toxicity were observed, even after 4 days. The original report (Statham, 1983) indicates that one quoll consumed a 120 g black rat within 24 hours without noticeable effect. Although no details are provided as to how this rat was poisoned, residue levels are likely to have been higher than would occur in field poisoned rabbits. Three other quolls were each offered a possum carcass (1.25-2.70 kg) but none consumed the whole carcass. Limited data as outlined in the fate section of this report indicate that residues retained in possums are likely to be lower than those in rabbits.

Particular concerns have been expressed for the spotted-tailed quoll, the most sensitive quoll species (LD50 1.85 mg/kg) based on data reported by McIlroy (1981b). King *et al* (1989) found eastern quolls (approximate LD50 1.5 mg/kg) to be more sensitive, but noted that stress associated with serial blood sampling may have contributed.

Phascogales

McIlroy (1999) has noted that no toxicity data are available for brush-tailed phascogales (*Phascogale tapoatafa*) but that their LD50 is likely to be in the 0.89-7.65 mg/kg range based on 95% confidence limits for nine marsupial carnivores. Brush-tailed phascogales were not considered to be at risk from aerial wild dog baiting in the tablelands areas of NSW because of a lack of records for their presence and a preference for arboreal feeding, mainly on invertebrates. However, an instant moratorium on wild dog baiting within 3-4 km should apply if any signs are found indicating the presence of these animals in areas where baiting is to occur.

Toxicity testing in red-tailed phascogales (*Phascogale calura*) returned an approximate LD50 of 17.5 mg/kg, indicating that these animals are relatively tolerant of 1080. This tolerance reflects their origins in south-west WA and is thought to have developed through consumption of insects that have fed on toxic plants (King *et al*, 1989). An approximate LD50 of 9 mg/kg (moderately sensitive) has been reported (WA, 2002) for brush-tailed phascogales. Martin *et al* (2002) note that brush-tailed phascogales from WA (now recognised as a new, undescribed species) are less tolerant of 1080 (approximate lethal dose 6 mg/kg) than might be expected, and that animals from the eastern States are likely to be more sensitive.

Field studies

McIlroy and Gifford (1991) studied the effects on non-target mammals of a rabbit trail-baiting campaign using pellet baits on a semi-cleared property near Braidwood NSW, consisting mainly of alluvial flats with some rocky hillsides. Spotlight counts were made each night after the diurnal bird counts (described above under avian toxicity) along a different fixed transect. Common wombats were estimated indirectly, by visual inspection of activity around burrows, and subsequently by mark-recapture methods. Small mammal trapping was abandoned because of very poor trap success. Carcass searches were also conducted along the bait line.

Populations of rabbits, eastern grey kangaroos and foxes in treated areas declined after baiting, while red-necked wallabies were most numerous immediately after baiting. The fluctuations in kangaroo numbers were probably correlated with flushes observed in their food supplies. Foxes appear to have been secondarily poisoned by eating poisoned rabbits. The number of wombats present declined by one or two after baiting, with two marked animals never retrapped. An adult male was believed to have been killed by baiting as it appeared to be a permanent resident and baits had been consumed near its main burrow, where it possibly died. Earlier bait acceptance trials in the treated area had shown that wombats consume baits left close to burrows, but not from open pasture. An immature female may have dispersed from the area.

Further field observations are included in the hazard section of this report.

Incident reports

The DNRE advised that it investigated 15 reports of 1080 misuse in the 3 years to August 2001. Most of these related to inadequate notification and/or domestic dog poisonings.

Dog poisonings also dominate the incidents that have been recorded in SA. Fifteen such incidents (ten confirmed) were reported between 1994 and 2000 in association with fox control, mainly for native fauna protection. Another incident in 1997 involved the deaths of two hand-raised kangaroos and a joey when oat baits were used to control rabbits living under a woolshed in the Flinders Ranges. The APCC has advised that the only reports of general nontarget damage to domestic livestock or native fauna date back to the early '70s and were associated with the now discontinued (in SA) "One-shot" product. Isolated anecdotal reports of nontarget poisoning of native fauna have since been received, but the APCC has never been able to confirm a direct link with 1080 use.

Dogs are also prominent among the incidents that have been investigated by the NSW Department of Environment and Conservation. Some of these incidents involved allegations of deliberate poisoning, with other substances such as strychnine, cyanide or organophosphates sometimes identified. Two incidents involving quolls (one of bait movement and one of apparent bait uptake) have been investigated, but no dead quolls were found.

NRME has conducted residue analyses on 190 dogs, livestock (9 cows and 2 horses), feral predators (8 foxes and 4 feral cats) and native wildlife (3 brushtail possums, 4 bandicoots and 4 spotted-tailed quolls) over the last three years. Numbers tested are too small to draw significant trends, except for the dogs where 44% of suspected cases returned positive results. Among the wildlife, two possums and two quolls tested positive for 1080.

Given the high bait loadings used, the use of meat baits for control of feral pigs raises particular concerns for nontarget poisoning. However, the NRME advises that it has not received reports of wildlife deaths associated with the use of meat baits for feral pigs in Qld. Post-baiting ground surveys have been conducted in relation to Exercise Wild Thing, a simulation of exotic disease incursion into the feral pig population in far north Qld that included extensive aerial and ground baiting using horse meat (NRME, 2002). Impacts on nontarget species were not expected to be great due to the specificity of 1080 and the size of the baits. The nontarget information recorded during post-baiting ground surveys was largely anecdotal, making notes of animals eating baits or nontargets killed by the baits. Three bird species were seen to eat meat baits, but no dead birds were seen. A cat and several dingoes were found dead, most likely from 1080 poisoning. In one instance, a professional fisherman reported that he had seen numerous kites and hawks dead at a waterhole where a pig carcass was located. A team was immediately sent to the area, but did not find any dead birds nor other nontarget species despite extensive searches of the area described.

As noted above, 1080 poisoning is normally diagnosed based on suspicion and is not confirmed by residue analysis. This needs to be borne in mind when considering the reliability of nontarget incident reports.

Nontarget poisoning incidents were also mentioned by a number of RLPBs, conservation groups and individuals. Domestic dogs were the usual casualty, with inadequate restraint frequently identified as a contributing factor. These reports need to be treated cautiously as the cause of death is rarely confirmed by analysis, and there are suggestions that unscrupulous individuals may take the opportunity presented by 1080 baiting campaigns to poison dogs or other nontarget organisms (such as the eagles at Nagambie that are referred to earlier in this report) with other substances.

A Tasmanian conservation group advised that a population of bettongs was completely wiped out by a single 1080 baiting operation by a forestry corporation, despite local protestations. The incident occurred in November 1995 when Forest Resources used 1080 in plantations near Weegena, following representations from the Deloraine Field Naturalists that an important regional population of bettongs lived adjacent to the site. There does not appear to be any evidence that the animals were affected by 1080, rather than by habitat disruption.

The same group also advised of an incident in which a number of rehabilitated animals were killed at a property on the outskirts of Hobart, after a 1080 baiting event on a neighbouring property. The owner of the property where this incident occurred was identified as wildlife photographer Dave Watts, but no other specific details were provided.

This group also provided a copy of an article by the Mercury's gardening writer Paul Healy concerning his impressions of 1080 use in the mid '90s for pine and eucalypt plantation establishment in the Huon Valley, where he has farmed for over 15 years. Mr Healy claims to have recovered dead or moribund quolls, potoroos, wombats, devils, wallabies and a young wedge-tailed eagle in the days after bait laying. Before baiting, bandicoots, quolls, devils, potoroos, wombats and other marsupials were abundant on Mr Healy's property, and around two dozen quolls and devils would be trapped and relocated each year. None were caught in the year following baiting, and populations are said to remain dangerously low. Roadkill suddenly became highly visible in the area with the removal of these predators, and rabbit populations increased to problem levels.

The same group also forwarded a copy of a handwritten testimonial from an anonymous "concerned bushman" based on his experience as a bait layer in Tasmania. This individual claims to have seen birds and many animals eating carrot baits, and to have seen many non-target animals affected by poison. Many of these are said to have left the poisoned area and to have been discovered in water storage dams on adjacent farming properties. This individual also states his belief that he was affected by 1080 because of poor working practices.

These observations are similar to those made by a former Tasmanian forestry worker identified as Steve, as published in the Australian Financial Review on 20 July 2002. According to Steve, a common response in poisoned animals was to try and get to water.

Similar claims from a former bait layer identified as Don Steers were aired in Channel Nine's Sunday program on 9 February 2003. Mr Steers recalled that ring-tailed possums were included among the species killed by 1080 baiting on forestry coupes.

Alternatively, Gunns Ltd advised that it recorded only two deaths of non-target animals over a period of just under four years, and that its employees involved in vertebrate pest control commented that this was the first time any of them had had such an experience. Data provided by the Browsing Damage Management Group (previously the Browsing Animal Research Council) indicate that carcasses of 1959 pademelons, 202 Bennett's wallabies, 527 brushtail possums, 108 rabbits, a hare and two bettongs were recovered after routine 1080 poisoning operations carried out by Gunns Ltd (including North Forest Products Ltd and Tamar Tree Farms) in eucalypt plantations between November 1998 and August 2002.

The DPIWE advised that more than 11500 carcasses of Tasmanian pademelons, Bennett's wallabies and brushtail possums were reported as being found after poisoning operations during 2001-02. It is a condition of the permit that users provide this information, but there was no obligation to report on nontarget species. Anecdotal information from DPIWE staff is that it is extremely rare to find nontarget carcasses. Nevertheless, over the past 15 years, there have been several instances of small numbers of Tasmanian bettongs being found dead following 1080 poison operations.

The Tasmanian Environment Minister announced in August 2004 that the estimated cull of Tasmanian pademelons, Bennett's wallabies and brushtail possums for the 2002-2003 season reached 97000 animals, almost twice the estimate of 49000 animals for the previous financial year. Commencing in 2003, users of 1080 in Tasmania are now required as a condition of permit to report any nontarget animals found after poisoning.

Recently, reports have been received of 1080 killing forester kangaroos in the Northeast of Tasmania. The killing of kangaroos as a side effect of rabbit control subsided after 1952, when 1080 was introduced to replace other poisons in Tasmania. Field observations have indicated that rabbit baits usually do not contain enough 1080 to kill forester kangaroos (Tanner and Hocking, 2001). The forester kangaroo has been nominated for listing as conservation dependent under the *Environment Protection and Biodiversity Conservation Act 1999*, but the nomination was rejected. Poisoning by 1080 was included among the factors that may threaten this species, but the Threatened Species Scientific Committee concluded that the strength of 1080 poison baits is usually not of sufficient dosage to kill forester kangaroos. The nomination noted reports that forester kangaroos are more likely to eat lethal quantities of 1080 when baits are laced with cinnamon to attract possums.

In published studies, McIlroy (1982a) noted that long-nosed potoroos readily eat carrot bait because their natural food is underground tubers and roots, and are killed during rabbit poisoning campaigns using this kind of bait. He also provided a list, taken from unpublished Forestry Commission files, of nontarget animals found dead in NSW forest areas after 22 rabbit poisoning campaigns between 1971 and 1975, using carrot or pellet baits broadcast from the air or laid as trails on the ground. Carcasses of 238 foxes, 218 wallabies, 82 possums, 56 grey kangaroos, 54 wombats, 24 swamp wallabies, 15 rats, 14 hares, 10 cats, 6 sheep, 5 dogs, 2 bandicoots and an echidna were recorded by forestry personnel, but no confirmatory analyses were conducted.

McIlroy (1982b) also reports that pellet baits laid for rabbits killed all adult residents in a marked population of the patchily distributed silky mouse (*Pseudomys apodemoides*) in the Big Desert region of Victoria, based on a personal communication from A Cockburn in 1979. However, the effect was temporary as juveniles quickly recolonised the area. McIlroy (1982b) also notes that his unpublished data indicate that a high proportion of *Rattus fuscipes* populations will take carrot baits and be poisoned.

Animal welfare

The symptoms of 1080 poisoning can be distressing to observe, but it is difficult to determine if poisoned animals are experiencing pain or whether the symptoms simply reflect central nervous system disturbances. The relative slowness of death as reported in laboratory studies raises animal welfare concerns as symptoms can be protracted, and animals may suffer injury while affected. However, the initial lag phase that follows ingestion is asymptomatic, with death tending to occur more rapidly in the field as dosing is heavier than in the laboratory where some of the doses administered are marginal with respect to lethality.

Gregory (1996) has attempted to elucidate the relationship between 1080 intoxication and pain by reviewing the relevant literature. In herbivores, poor cardiac performance and ventricular fibrillation induce cerebral anoxia and rapid loss of consciousness. The loss of electrical activity within the cortex leads rapidly to clonic muscular convulsions. Gregory argues that the convulsions seen in herbivores, and associated vocalisations, occur while the animal is unconscious and feeling no pain. In rabbits, Gregory cites evidence that the occurrence of these symptoms does not unduly disturb other rabbits.

Regarding central nervous system disturbances, which are the usual response to poisoning in carnivores, Gregory argues that the observed symptoms are similar to epileptic seizures as electroencephelographs of poisoned dogs display identical cerebral dysrythmias. Dogs are believed to become unaware of their predicament and surroundings, similar to the loss of awareness that occurs in humans suffering epileptiform seizures. Gregory notes that dogs normally respond to pain by becoming quiet, less alert, still or by adopting abnormal positions when pain is severe. Spontaneous barking is unlikely. This contrasts with the hyperexcitability, aimless movements and barking that typically occur during 1080 intoxication.

Gregory also compares fluoroacetate poisoning with hyperinsulinism, as both states reflect a depletion of energy in cells. Hyperinsulinism leads to mental disorientation, convulsions and loss of consciousness. Central nervous system stimulation in 1080 poisoned dogs has been shown to occur under anaesthesia. Gregory argues that the convulsions seen in 1080 poisoned dogs are therefore unlikely to be associated with pain.

Symptoms of 1080 poisoning in captive foxes have been described by Marks *et al* (2000). The average time for appearance of symptoms was a little over 4 hours, with an average time to death of 5.45 hours after dosing with a polyethylene glycol suspension of 1080 at 0.5 mg/kg by syringe to the back of the tongue. There appeared to be two distinct phases of activity, separated by a 10-40 minute period of minimal activity. The first period typically began with retching while the fox was ambulatory. This was frequently followed by collapse, paddling with the feet or sudden tetanic spasms. The initial symptoms of retching and running are probably not associated with central nervous system disturbances, and it is therefore possible that the animal suffers pain or distress during this early phase.

Although the measurement of pain in animals must always be a subjective exercise, some insight into the degree of suffering experienced by 1080 poisoned animals may be obtained from humans that have been poisoned in this way. Symptoms in humans involve central nervous system stimulation with clinical signs of anxiety, agitation, nausea and generalised tonic-clonic convulsions, but pain is usually not reported. This sort of evidence is understandably limited. In one example, a man (Williams, 1948) poisoned during mixing of 1080 powder reported tingling sensations around the mouth and nasal passages, extending to the arms and legs. However, there was no recollection of pain during the spasmodic contractions of voluntary muscles that occurred in the 2.5 hours before unconsciousness intervened.

Although the foregoing considerations indicate that pain during 1080 intoxication may not be severe, some pain or distress is always likely to occur in poisoned animals. Chi *et al* (1996) reported that the most common symptoms in cases of fluoroacetate poisoning presenting to hospital were nausea and vomiting, diarrhea, agitation, subjective respiratory distress and abdominal pain.

Sherley (2004) has presented detailed scientific argument to support the contention that 1080 is inhumane, including evidence from human exposures. These cases have identified symptoms of pain or distress, such as anxiety, irritability, agitation, hyperactivity, epigastric pain, headache, nausea and vomiting, faecal incontinence, respiratory distress, hyperaesthesia, muscular pain and tetanic spasms.

The RSPCA convened a scientific seminar entitled “Solutions for achieving humane vertebrate pest control” in Canberra in February 2003 where it gave a presentation entitled “Integrating animal welfare into vertebrate pest management”. The RSPCA believes that the available evidence indicates that, in general, the effect of 1080 on animals is not humane and is opposed to its continued use for the control of populations of introduced or native species. The APVMA gave a presentation, entitled “The NRA’s role in the regulation of vertebrate pest control agents”, where it was noted that the APVMA could be considered to have scope to consider animal welfare issues within efficacy evaluations, but that there is a lack of consensus on objective animal welfare standards and criteria.

The RSPCA issued a media release on 15 November 2007 to announce that a new report (Sherley, 2007) had found 1080 to be an inhumane poison, and to call for urgent research into improving the humaneness of vertebrate pest control methods in Australia.

The anticoagulant pindone is also used for rabbit control in Australia, but acts more slowly than 1080. Questions remain regarding the humaneness of anticoagulants as death occurs more slowly than with acute poisons such as 1080, and they cause bleeding into joints which can be very painful. Pindone is not suitable for predator control as multiple doses must be taken over several days. However, it is preferred for rabbit control in more closely settled areas because of the availability of an antidote. Pindone can be more hazardous to some native mammals than is 1080, particularly in WA as noted by the Conservation Council of Western Australia.

New Zealand uses a broader range of vertebrate poisons, including phosphorus, cyanide and cholecalciferol (vitamin D3). Cyanide is the most preferred from an animal welfare perspective and can be effective, although there are sometimes problems with bait shyness (Eason, 2000). Cyanide must be encapsulated before inclusion in baits because of its reactivity. The use of cyanide would also raise worker safety and target specificity concerns.

Research has been conducted into the use of analgesics and sedatives in 1080 baits, in the interest of animal welfare (Marks *et al*, 2000). If such methods are to be used, further research will be needed to ensure that the additives have no detrimental effect on nontarget animals. Baits containing an analgesic in combination with 1080 are currently being used at two Victorian field sites (Marks, 2003).

6.1.5 Reptiles

McIlroy *et al* (1985) studied the effects of 1080, administered orally with a hypodermic syringe and oesophageal catheter, in various Australian reptile species as tabulated below. The monitors, blue tongue and third group of shingle-backs were tested in outdoor enclosures and the remainder in the laboratory.

Species	Mean weight	LD50 (95% CI)
Bearded dragon	267 g	< 100 mg/kg
Gould’s monitor	732 g	43.6 (27.5-69.2) mg/kg
Lace monitor	3647 g	< 119 mg/kg
Blotched blue-tongue lizard	434 g	336.4 (232.4-487.1) mg/kg
Shingle-back lizard (SA)	468 g	205.9 (147.2-289.1) mg/kg
Shingle-back lizard (WA)	351 g	507.7 (447.0-577.1) mg/kg
Shingle-back lizard (WA)	349 g	543.2 (500.5-589.5) mg/kg

Affected animals slowly became lethargic (median time to onset 56 hours) and several of the blue-tongues were observed foaming at the mouth. The death rate in affected animals was 82%, but death was delayed in some individuals (22 days for one blue-tongue). Both lace monitors tested (at 119 and 150 mg/kg) died, as did all bearded dragons except that given the lowest dose of 50 mg/kg. Results show that reptiles are more tolerant of 1080 than all Australian birds except the emu and all mammals except some from WA. Note that the greater tolerance of animals taken from WA is confirmed in the omnivorous shingle-back.

6.1.6 Plants

Compound 1080 is not a herbicide, and there is no apparent basis for any phytotoxicity concerns. A number of native Australian plants contain 1080 at levels in excess of those used in baits.

6.1.7 Summary of environmental effects

Fluoroacetate is converted in the body to fluorocitrate, which inhibits an important mitochondrial enzyme (aconitate hydratase) in the citric acid (Kreb) cycle, a metabolic pathway that breaks down carbohydrates. Inhibition of this enzyme blocks the Kreb cycle at the citrate stage, resulting in energy deprivation and accumulation of citrate in the tissues and plasma.

Symptoms usually begin to appear between 30 minutes and 3 hours after ingestion by warm-blooded animals, even when massive doses are used. This lag phase probably reflects translocation and cell penetration, conversion to fluorocitrate, and disruption of intracellular functions sufficient to induce gross symptoms. Herbivores generally die of cardiac failure, while carnivores experience central nervous system disturbances and convulsions before dying of respiratory failure. In omnivores, death tends to result from disorders of both the heart and central nervous system. Poisoned animals recover from sub-lethal doses as fluoroacetate is readily metabolised (for example by defluorination) and excreted.

Native species, particularly those from the southwest corner of WA which have existed in close association with fluoroacetate-bearing vegetation, tend to have greater tolerance to 1080 than their overseas and eastern States counterparts. This developed tolerance is most pronounced in herbivores but is also present in omnivores and carnivores. Some unadapted Australian omnivores and carnivores (bandicoots and dasyurids) also appear to possess an innate tolerance to fluoroacetate when compared with their placental counterparts. This probably reflects the lower basal metabolic rate of the native species.

Extensive toxicity testing has been conducted in a broad range of native and introduced fauna, with much of this work reported in the published scientific literature. Many of these studies predate the development of modern regulatory test guidelines, but their results are generally consistent and considered reliable. The sensitivity of animals to 1080 poisoning can be divided into four broad categories. Highly sensitive organisms are defined as those with LD50s below 2 mg/kg. Moderately sensitive organisms have LD50s between 2 and 10 mg/kg, while relatively tolerant organisms have LD50s between 10 and 40 mg/kg. Organisms with LD50s above 40 mg/kg can be considered tolerant.

When categorised in this way, all target animals are highly sensitive to 1080, as are sheep and many native herbivores (possums, macropods and wombats). LD50s in these animals are consistently below 1 mg/kg, with the exception of native animals from the south-west corner of WA which have developed a tolerance to the toxin. Some birds (red-browed firetail, crimson rosella and white-winged chough), rodents (plains mouse, bush rat, swamp rat and canefield rat) and dasyurids (stripe-faced dunnart, brown antechinus, spotted-tailed quoll and perhaps the eastern quoll) are also highly sensitive, although LD50s in these organisms are mostly above 1 mg/kg.

Most Australian birds are moderately sensitive to 1080, as are most dasyurids, bandicoots and some rodents.

Some rodents (western chestnut mouse, sandy inland mouse, Mitchell's hopping mouse and Spinifex hopping mouse) are relatively tolerant of 1080. Native birds and mammals from the south-west corner of WA are relatively tolerant or tolerant of 1080. Ducks, raptors and doves from the eastern States are also relatively tolerant (but ducks from NW Australia are moderately sensitive). Emus, malleefowl, reptiles and frogs are relatively tolerant or tolerant of 1080.

Incident reports and field observations are consistent with the foregoing categorisation. Dogs are the most common casualties reported, as may be expected given their sensitivity and broad diet. They may be considered target or nontarget casualties, depending on whether they are predating livestock. Foxes are also common nontarget casualties of rabbit baiting, but this is not considered to be an adverse effect. Because of their sensitivity to 1080, dogs and foxes may be victims of primary or secondary poisoning. Poisoning among native animals (other than dingoes) appears to be restricted to primary exposures. Among native mammals, unadapted wombats, macropods, possums and some rodents can be killed by herbivore baits. Some birds may also be killed by 1080 baiting, although this is a very rare occurrence and not the usual situation. Scavenging species such as magpies and crows have been recorded as occasional casualties, together with some introduced species (sparrows, starlings, doves and pigeons). There are also anecdotal reports of crimson rosellas (a highly sensitive species) being killed by carrot baits laid for rabbits. Some insectivorous birds have been killed in New Zealand, although it is unclear whether small carrot bait fragments or insects that had fed on baits were the cause. Some insectivorous birds in North America are reported to have been killed when ground squirrels were baited with oat baits.

7 ENVIRONMENTAL HAZARD

The highest application rate for 1080 appears to be 7.2 g/ha as specified in the directions for use for aerial/broadcast rabbit and feral pig control with pellet baits in Victoria. Application rates for carnivorous vertebrate pests are consistently below 1 g/ha 1080. Application rates for feral pigs are not easily defined, but larger doses are needed and baiting may deliver around 10 g in a small area (for example, a 50 m transect). However, except for meat baits in Queensland, pig baits are laid by hand and are therefore unlikely to enter aquatic environments.

Application of 1080 at 7.2 g/ha to shallow water (15 cm) would leave residues of 4.8 µg/L, more than four orders of magnitude below available aquatic toxicity endpoints. Measured levels of 0.3 and 0.6 µg/L in New Zealand streams, recorded within 24 hours of baiting, appear to reflect the direct entry of carrot baits. The hazard posed by 1080 poisoning operations to aquatic fauna is predicted to be minimal, as expected with the use of baits for vertebrate pest control. Even for sensitive animals such as small dogs where a lethal dose of 1080 may be as low as 0.5 mg, the hazard from drinking water contaminated with 4.8 µg/L 1080 in this way is predicted to be minimal as the toxic dose would be diluted in more than 100 L of water.

Baits containing 1080 are targetted at vertebrate pests and can therefore be expected to be hazardous to a range of terrestrial vertebrates. Hazard assessment will focus on these organisms.

7.1 Hazard assessment based on laboratory data

Numerous laboratory toxicity data are available, indicating the levels of 1080 that are likely to be lethal based on the body weight of the animal. These data can be related to contamination levels in food consumed by considering food ingestion rates based on body weight of the animal. In the hypothetical situation where animals rely on a single source of food, acute oral and dietary endpoints can be related as follows:

$$LD50 = LC50 \times f$$

where f is the food consumption expressed as a fraction of body weight.

In reality, the relationship between oral and dietary endpoints is more complex as dietary consumption occurs over longer time periods than acute oral administration, and may be reduced by anorexic or aversive effects or regurgitation where the food contains toxic contaminants. It would be very unusual for animals to rely on a single source of food, but in a worst case situation where alternative foods are in short supply, for example through drought, bait may be an attractive food source that is rapidly consumed by hungry animals. Furthermore, the above relationship is conservative as it assumes that the bioavailability of 1080 in baits is the same as that administered (in aqueous solution) in LD50 bioassays. In reality, 1080 is likely to be less bioavailable when present in baits than in aqueous solution, as indicated by the different LD50s to pigs of the aqueous solution (1 mg/kg) and treated grain (4 mg/kg).

Food consumption as a proportion of body weight varies with the size of the animal. McIlroy (1986) notes that large animals such as sheep, wombats and dingoes consume around 2% of their body weight daily while small dasyurids such as dunnarts may consume 60%. For example, the fat-tailed dunnarts described earlier in this report consumed 30% of their body weight overnight. However, they only took small portions at any time and appeared to be able to discriminate between poisoned and unpoisoned meat.

7.1.1 Primary poisoning hazard

The risk presented to nontarget animals by baits depends fundamentally on whether an animal will eat the bait. It is therefore useful to distinguish between meat baits and those based on grain or vegetables.

Cereal and vegetable baits

Manufactured oat baits for rabbits contain around 400 mg/kg 1080. Animals that consume 10% of their body weight in a short period would ingest at least an LD50 where their LD50 is 40 mg/kg or less. This includes all birds tested except the emu, and all mammals except some from WA. Reptiles and amphibians have higher LD50s and would not appear to be at significant risk, particularly given the conservative nature of this simple analysis. The potential risk to birds and mammals needs to be interpreted cautiously, as bait consumption in the field is likely to be much lower than assumed in this hypothetical scenario. For example, wild rabbits have been recorded to eat 42 g carrot baits in the field, or less than 3% of body weight for a 1.5 kg adult rabbit (Rathore, 1985). Under laboratory conditions, wild rabbits consumed an average 71 g of carrot baits containing 200 mg/kg 1080 over a 17 minute period, falling to 56 g over 16 minutes at a bait loading of 500 mg/kg. Five times as much carrot as oats was consumed in a given time (Rowley, 1960).

Oat baits containing 1080 can therefore be expected to be lethal to a broad range of nontarget fauna if they are consumed at such levels., suggesting that some level of primary nontarget mortality is likely to occur if baits are eaten. How likely depends on the nontarget organisms present in baited areas, their sensitivity, and the attractiveness, potency and availability of the baits to those organisms. Prefeeding is important as it improves bait uptake by target animals. Husking of oat baits before consumption would limit exposure as only around 20% of the toxin penetrates to the kernel. Heavy pest populations will reduce the availability of baits for nontargets. Concealment of baits, including by burial, and deployment late in the day in locations where they are likely to be consumed rapidly by target animals, help improve target selectivity. Seasonal factors which influence the availability of alternative food help determine the attractiveness of baits to nontargets. A reduction in potency to the minimum level necessary for control of the target pest will help minimise potential nontarget risks.

Pig baits based on grain, fruit or vegetables are likely to be similarly or more hazardous. Toxin loadings may range from 288 mg/kg in Qld to 750 mg/kg in WA, and exposure can not be reduced by husking as may occur with oat baits. Baits tend to be heaped rather than scattered, increasing the likelihood that a toxic dose will be ingested when baits are encountered. The prefeeding phase is critical with pig baiting, as it is important that pigs consume toxic baits rapidly and exclude nontarget animals from access to the baits.

Carrot baits are only half as potent as oat baits, suggesting a reduced risk to nontarget organisms. However, these baits would still be lethal to those animals with LD50s below 20 mg/kg, which includes many birds and mammals. In addition, carrot baits are likely to be very attractive to potoroos, and exposure cannot be reduced by husking as may occur with oats.

McIlroy (1986) has evaluated the potential risks to nontarget animals from 1080 poisoning campaigns in Australia based on susceptibility to the poison. Unadapted macropods, especially the smaller ones, and wombats appear to be most at risk from the use of grain or carrot baits. This analysis is partly confirmed by the finding of poisoned common wombats after rabbit poisoning campaigns. Livestock appear the next most at risk, followed by brushtail possums, pigs, and various rodents and birds.

The main oat bait used for rabbit control in WA is the “One-shot” product in which only one in every hundred or two hundred oats is poisoned, but at a high loading (4.5 mg). This product would not be suitable in other States because of the greater sensitivity of unadapted animals. A single poisoned oat would deliver a lethal dose to many native mammals, including larger animals such as wombats. As reported by the APCC, use of this product in SA was associated with reports of general nontarget damage to native fauna. Even in WA where native animals have evolved a tolerance to 1080, a broad range of mammalian species (bandicoots, dasyurids and rodents) and some birds (parrots) whose current or former range includes areas with fluoroacetate-bearing plants would receive at least an LD50 from one poisoned grain (WA, 2002).

Risks to granivorous birds

Conventional 1080 oat baits (400 mg/kg) contain around 0.016 mg 1080 per oat (mean weight 40 mg). Approximate lethal doses for little corellas (550 g) and plumed whistling ducks (600 g) in northern WA are 0.8 and 1.3 mg 1080, respectively. These doses would be contained in 50 and 80 oats, respectively, indicating potential primary risk to sensitive granivorous birds from 1080 grain baiting operations if they feed extensively along bait trails. Corellas would need to eat 2 g oat baits, and ducks a little over 3 g. These amounts may readily be consumed, particularly if alternative food is in short supply, as they only represent around 0.5% of the birds' body weights.

The following suggestions have been offered for reducing this risk: baiting only within crops with avoidance of bare ground; careful selection of bait material (ducks are less inclined to eat oats than wheat or barley, and many parrots dehusk oats before consuming the kernel only); by using broadcast methods only with no trail baiting; by using covered bait stations; and by not baiting during times of known food shortage for granivorous birds. Monitoring of nontarget impact should be conducted, at least while baiting strategies are being developed (Martin and Twigg, 2002).

Note that the main product used for rabbit control in WA is the "One-shot" product in which only one in every 100-200 oats contains 1080, but at high levels (4.5 mg). Individual mortalities may be expected in a range of bird species if they are unfortunate enough to consume a poisoned oat, but depending on their level of consumption, most birds feeding in baited areas may not encounter any poisoned grain.

Meat baits

Primary poisoning risks to those native fauna capable of consuming meat baits are more easily assessed based on lethal dose in the animal rather than concentration in the bait. Marsupial carnivores are the main concern with canid baits because of their feeding habits and sensitivity. For example, the estimated LD50 for a 2.8 kg spotted-tailed quoll is a little over 5 mg, compared with 3 mg in fox baits and 6 mg in dog baits. Spotted-tailed quolls are therefore at significant risk of poisoning if they consume a single dog bait or two fox baits, which they are theoretically capable of doing. Brush-tailed phascogales may also be at risk of poisoning as they are likely to be moderately sensitive and are voracious if opportunistic feeders. Note that this assessment is based on the presumption that these marsupial carnivores will consume 1080 baits, which has not been substantiated in the field.

LD50s for predatory and scavenging birds include 24 mg for a 2.5 kg wedge-tailed eagle, 9 mg for a 0.5 kg black kite, 1.5 mg for a 0.5 kg little raven and 2.5 mg for a 0.5 kg Australian raven. ALDs include 8 mg for a 0.4 kg brown falcon, 6 mg for a 0.4 kg barn owl from WA and 3 mg for a 0.5 kg grass owl from the eastern States. Thus there is a potential for poisoning if these birds take fresh baits that have been laid for canid control, although significant quantities would need to be consumed (4 dog baits for the wedge-tailed eagle, and large fractions of body weight for the smaller birds). Dried meat baits are likely to be less hazardous than fresh meat because many animals find the dry product too hard to chew or eat. Captive brown falcons showed no obvious interest in nontoxic dried meat baits (Martin *et al*, 2002). Owls would not take baits as they only take live prey.

Meat baits for feral pigs are more hazardous than those for canids because of the high bait loadings (72 mg in each 500 g bait). A small wedge-tailed eagle would only have to consume 170 g of these baits (7% of body weight) to ingest the LD50 based on the assumption that the toxin is evenly distributed. In reality, the toxin will be unevenly distributed within the bait following injection, and animals that eat only a portion of a bait may or may not encounter a toxic dose of 1080.

McIlroy (1986) reached the general conclusion that carnivorous mammals, including the native marsupial carnivores, appear most at risk from the use of meat baits to control canids and feral pigs. Several rat species and a few birds that may take the baits appear next at risk. The smaller, more insectivorous dasyurids are probably less at risk because they are less likely to take baits in sufficient quantity.

A more detailed analysis of the potential nontarget risks from wild dog baiting has been conducted recently. The NSW NPWS has a legislative requirement to control wild dogs to the extent necessary to minimise their impact on adjoining lands, and also to ensure that its activities are environmentally sound. A Species Impact Statement (McIlroy, 1999) has been prepared because of concerns that aerial baiting with 1080 may have a significant effect on a threatened species, population or ecological community. Five National Parks were involved, four in the north of NSW and one (Kosciuszko) in the south.

A range of species may feed on meat baits intended for canid control, including reptiles such as varanid lizards, small and large passerine birds, raptors, many dasyurid mammals, bandicoots and rodents. Reptiles were considered unlikely to be affected because of their tolerance to 1080. Birds may be attracted to the baits or to insects that have fed on them, but population monitoring has not found any effects. Nontarget mammals are most likely to feed on wild dog baits. Some rodents such as bush rats are known to do so, but without significant effects on populations or sex or age ratios. Bandicoots will also consume baits, but are relatively tolerant and would need to consume more than one wild dog bait to receive an LD50. Small dasyurids such as brown antechinus will also consume baits, but tend to eat repeated small meals rather than isolated large ones and therefore are more likely to develop an aversion to baits. Fat-tailed dunnarts are reluctant to consume meat containing 1080. Monitoring of antechinus populations has found short term reductions, with populations rapidly restored through immigration.

Further consideration of known distribution patterns and feeding behaviour led the author to conclude that threatened bird, reptile, rodent, macropod and small dasyurid species are unlikely to be threatened by aerial baiting for wild dogs. The macropods (rufous bettongs, long-nosed potoroos and brush-tailed rock wallabies) are likely to benefit from reductions in wild dog populations.

The main concern was for larger dasyurids such as phascogales and quolls. Although these are more tolerant of 1080 than are the target canids, they are still at risk of poisoning if they feed on wild dog baits. Brush-tailed phascogales are predominantly arboreal feeders and considered unlikely to consume baits. Eastern quolls are no longer thought to exist in NSW and are therefore not a consideration for baiting unless rediscovered. Spotted-tailed quolls are threatened in NSW, with introduced predators, habitat alienation and primary/secondary poisoning by 1080 all identified as current threats in 1999. The risk of primary poisoning from wild dog baits was considered high. Locality records indicated comparatively high numbers in north-eastern NSW and low numbers in south-eastern NSW. Males are known to range over large areas in the breeding season (May-August) when baiting usually occurs, and a shortage of alternative food at this time of year may encourage feeding on baits. A quoll trapped in Tallaganda State Forest in July 1998 displayed symptoms of 1080 poisoning and was found to contain residues (33 ppb in stomach and 85 ppb in muscle) at post mortem.

Quolls remain relatively common in the northern parks, even though they have been subject to ongoing aerial baiting campaigns. In contrast the Byadbo Wilderness Area where baiting was proposed in southern NSW appeared to be marginal habitat for quolls, as it is a rain shadow area with shallow and highly eroded soils. Quolls had occasionally been recorded in the area, but not further north in Kosciuszko National Park. No comprehensive and systematic surveys had been carried out. Knowledge about distribution and abundance was inadequate, but it appeared possible that baiting could threaten an isolated remnant quoll population in the area.

The author noted that, apart from the question of nontarget impact, the need for aerial baiting in National Parks and its effectiveness in reducing stock damage on adjacent lands were simply accepted, particularly by landholders, and had never been rigorously tested or monitored. The presence and movement of wild dogs in target areas needed to be investigated, for example by fitting radiocollars or using bait markers such as rhodamine. Surveys were needed to determine where quolls occur, so that baiting can be targetted to minimise any impacts to them. Aerial baiting in Byadbo should be restricted in the interim. Effectiveness also needed to be surveyed, for example by monitoring stock losses. Mortality collars could provide considerable information on the actual degree of risk posed to quolls by aerial baiting with 1080 for wild dogs. Baiting earlier in the year (February-May) before the breeding season is likely to be less hazardous to quolls.

Note that further information is now available to clarify the concerns raised by McIlroy. In particular, recent live-trapping surveys have indicated that the Byadbo wilderness area supports a large population of spotted-tailed quolls, indicating that the ongoing buried baiting program for wild dogs in the area is unlikely to be exerting a detrimental impact on quoll populations (Murray, 2002). It can also be noted that radiocollared northern quolls survived aerial wild dog baiting in WA (Fortescue river) in October 1987, a time when male quolls were highly mobile and food was short. More recent research in eastern Australia has shown that the risk to spotted-tailed quolls appears to be lower than predicted by McIlroy, because only small quantities of bait were consumed. These studies are described in more detail later in this report.

Meat baits used to control pigs in Queensland are more hazardous because of the much higher bait loadings (72 mg in each 500 g bait). These baits are hazardous to a broad range of predatory or scavenging animals, including birds of prey and even reptiles. A single bait contains more than the LD50 of 40 mg for a large (4.25 kg) wedge-tailed eagle. Even goannas, which are tolerant of 1080 with a likely LD50 in the order of 50 mg/kg based on limited data, may be at risk of poisoning. A single bait would contain the LD50 for a 1.5 kg goanna, localised near the injection site, but it is unlikely that a 500 g bait would be completely consumed by an animal of this size. In order to minimise exposure of these diurnal predators, meat baits for pigs could be buried to minimise their uptake by birds of prey. Where goannas are likely or known to be active, meat baits could be laid late in the day and recovered the next morning as goannas will readily dig for baits. However, burial is impractical for aerial deployment, and in many cases for ground baiting given the numbers of baits that must be laid for effective pig control.

7.1.2 Secondary poisoning hazard

A similar analysis can be conducted for secondary poisoning risks. The data reported by Twigg *et al* (2003a) as described in the fate section of this report indicate that peak residues on a fresh weight basis in field poisoned rabbits are likely to be about 0.8 mg/kg. If consumption over a short period is again assumed to be 10% of body weight, rabbit carcasses may deliver an LD50 to sensitive predatory and scavenging species (those where the LD50 is 0.08 mg/kg or less, based on the maximum carcass residue of 0.8 mg/kg). This essentially excludes all animals other than canids. Scavenging and predatory birds, such as raptors and corvids, appear to face minimal risk of secondary poisoning. Secondary risks to native marsupial carnivores also appear minimal, as the most sensitive representatives (eastern and spotted-tailed quolls) have LD50s in excess of 1 mg/kg. Secondary poisoning of reptile scavengers appears to be inconceivable. Note that this analysis is conservative as it is based on maximum rather than mean residues in rabbit carcasses. Residues in other target pests are also likely to be relatively low, given their sensitivity, but rodents (mainly nontarget species) may contain higher residues.

The secondary hazard is likely to be higher for animals that consume the stomach contents of poisoned rabbits as these are likely to contain higher residues, particularly if rabbits have eaten a large dose. This would increase the risk to dogs, given their dietary habits.

Secondary poisoning hazards from pig baiting appear to be similar to those from rabbits, as mean residues remain below 1 mg/kg in pig carcasses (slightly higher residues have been determined recently in some individual pigs, as discussed in section 9 of this report). Only canids would appear to be at risk of secondary poisoning if they scavenge pig carcasses. The secondary poisoning hazards of pig vomitus may be more significant as peak concentrations in vomitus are likely to be around 20% (14-67 mg/kg) of bait loadings. However, pigs will be moving around, and vomitus will therefore be dispersed in small amounts across the landscape, frequently in inaccessible areas such as rubber vine thickets where poisoned pigs take cover. Pig vomitus is unlikely to be found in open areas near bait stations. Furthermore, as 1080 is hydrophilic, it can be expected to largely soak into the soil with the aqueous fraction, reducing risks to potential secondary consumers. No animals other than feral pigs are known to feed on pig vomit, although the possibility can not be excluded.

This simple analysis accords with the Australian field reality, in which secondary poisoning is often reported in dogs (and foxes during rabbit control campaigns) but where secondary poisoning suspicions in native species (except the dingo) remain largely unsubstantiated, although concerns have been expressed for quolls and phascogales.

Although secondary poisoning of native animals from eating poisoned rabbits appears unlikely, contaminated insects may be more hazardous. Many invertebrates are less sensitive than vertebrates (particularly the target pests) and may therefore consume more 1080, which is likely to lead to higher residues. New Zealand studies indicate a residue range of 14-130 mg/kg with a mean of 57 mg/kg in invertebrates collected from cereal baits containing 1500 ppm 1080 (much higher than used in Australia). Residues from meat baits are unclear as only limited data are available and they were determined using an unreliable method. Meat baits may contain comparatively high bait loadings (100 mg/kg for Doggone, or 144 mg/kg for pig baits in Queensland) with an uneven distribution in the bait. Residue levels may therefore be comparable with those determined in New Zealand, although it seems more likely that they would be at least an order of magnitude lower.

A worst case assessment with invertebrates containing 130 mg/kg 1080 indicates that insectivorous animals are likely to be at potential risk of secondary poisoning where their LD50s are below 13 mg/kg. This includes canids, cats, pigs, quolls, phascogales (voracious consumers of invertebrates), smaller dasyurids such as antechinus, bandicoots, some rodents, possums and gliders, Tasmanian devils, and most insectivorous birds. This assessment is conservative as it is based on maximum residues in invertebrates exposed to higher bait concentrations than would generally occur in Australia. In addition, these high residues occurred in invertebrates collected directly from baits, while residues in invertebrates from pitfall traps were much lower.

A more realistic assessment based on mean residues (57 mg/kg) in insects collected from baits in New Zealand indicates a potential risk to secondary consumers with LD50s below 5.7 mg/kg. Risks to bandicoots would appear relatively low based on this analysis. If it is assumed based on bait loadings that residues in Australian insects would be an order of magnitude lower, secondary poisoning risks from contaminated insects would appear to be confined to canids and cats which have LD50s less than 0.6 mg/kg.

The foregoing assessment indicates some potential for secondary poisoning by this route, although the risks are likely to be confined to canids and feral cats. One option for reducing this risk may be the inclusion of insect deterrents such as synthetic pyrethroids in the baits, although no such action would be warranted given that the risk, if any, appears to be confined to canids and feral cats.

Every effort should be made to maximise bait size and minimise the availability, potency and palatability of baits and carcasses to nontarget organisms. However, the key question to address is whether mortality affects populations, particularly as removal of target pests is likely to be of benefit to many nontarget populations.

7.2 Hazard assessment based on field data

Toxicity studies conducted in the laboratory provide information on the sensitivity of nontarget animals to 1080, but not the susceptibility. An animal may be highly sensitive to 1080 poisoning but at the same time have a low susceptibility because of limited exposure to baits. Aversive effects can limit bait consumption, as can other factors such as the availability of alternative food, the palatability of the bait matrix, the placement of baits in relation to areas where nontarget animals feed, and the rapid uptake of baits by target animals. Hazard assessments based solely on laboratory sensitivity tend to exaggerate the actual risk faced by native animals in the wild. Assessments based on field data are likely to be more reliable.

Several lines of evidence have been studied in the field with a view to determining the risk that 1080 baiting presents to nontarget fauna.

Numerous bait uptake studies have been undertaken. Visual observation of animal behaviour during baiting campaigns is an obvious way to determine whether nontarget animals feed on baits, but is labour intensive and potentially intrusive. The presence of human observers may alter animal behaviour, particularly for shy and cryptic species, although photography may overcome such difficulties. A less intrusive option is to examine animal tracks around bait stations, but these observations can be confounded if rain obscures the tracks or if a number of different species visit a bait station. In addition, the presence of tracks at a bait station does not constitute proof that an animal has taken and consumed a bait, and provides no information as to whether the animal was affected. The inclusion of biomarkers in baits provides less equivocal evidence that exposure has occurred, but provides limited evidence as to the level of exposure. Many such biomarker studies have been conducted with nontoxic baits in order to avoid any potential toxic impacts, but this approach is open to criticism as animals that feed on nontoxic baits may refuse the toxic variety because of aversive effects. Nontoxic bait studies do not offer a sound foundation for the development of guidelines on the use of toxic baits.

Carcass searches can provide evidence of nontarget mortality, but the slow onset of intoxication with 1080 allows poisoned animals to take cover, making carcasses hard to find. Discovery of a carcass does not necessarily indicate 1080 poisoning. Where nontarget mortality is detected through carcass discovery, investigations need to be conducted to determine whether 1080 was the cause of death and, if so, how future exposures can be minimised. It should be borne in mind, however, that isolated poisoning incidents only affect individual animals while poor control of feral animals can be a threat at the population level.

One way of overcoming the limitations of carcass searching is to trap nontarget animals and equip them with radiotransmitters. This facilitates the discovery of any animals that may be lethally poisoned, and also allows confirmation that animals have survived baiting, provided that they remain within tracking range.

The ultimate measure of the environmental impact of a baiting operation is the effect on populations, which will only be determined through well designed, detailed population monitoring. This can be a complex and expensive exercise, particularly for rare and cryptic species which are more likely to be of concern. Observed population declines may reflect movement out of an area, for example because of a loss of food resources following poisoning. Immigration may rapidly replace poisoned animals. Population studies tend to be most fruitful in the context of biodiversity conservation where significant population increases or the survival of reintroduced animals can be demonstrated.

A significant complicating factor with all field observations is that any given field trial can be assumed to be valid only for the type and toxicity of bait presented, and in the habitat and season of the study.

Notwithstanding these complications, useful insights into nontarget impact can be gained from field observations during actual and simulated baiting operations, including fauna recovery and biodiversity conservation programs. These programs are frequently ongoing and some, such as Western Shield and Operation Bounceback, involve regular treatment of large areas.

Most of the available information on the nontarget effects of 1080 baiting relates to the use of meat baits for canid control. Less information is available for herbivore control operations (rabbits and native animals) and pig control operations.

7.2.1 Bait uptake studies

As described in the avian toxicity section of this report, close observation of a rabbit baiting operation by staff of the Electricity Trust of South Australia identified only one species (turtleneck doves) that fed on poisoned oats. These introduced birds died close to the bait trail. Although not seen to feed on baits, some other introduced species (sparrows and starlings) were found dead after baiting, with grain in their gut or crop. Silver gulls were seen to feed on unpoisoned oats.

Similar observations were reported by McIlroy and Gifford (1991) from bait acceptance trials in the Brindabella Valley. Galahs, magpies and currawongs were seen to feed on cereal pellets or carrot baits, but only infrequently (less than 3% of the birds observed on the site). However, visual observations may have underestimated the level of consumption as many rabbits were observed in the area but none were actually seen feeding on the baits.

McIlroy (1983a) has made similar observations during pig baiting campaigns. As feral pigs are large and less sensitive than other vertebrate pests (LD50 1-4 mg/kg) it can be difficult to achieve target selectivity. McIlroy noted that poisoning risks are further increased as some pigs vomit after ingesting 1080, and the resulting vomitus may be toxic to secondary consumers. A broad range of animals and birds could easily consume enough pig bait to be poisoned (less than 10% of body weight) with only insensitive birds such as the emu at low risk of poisoning. Cats, foxes and various birds (mainly raptors) have been observed feeding on baits or pig carcasses, and some birds (two black kites, a magpie lark and several corvids) have been found dead after baiting. Risks of nontarget poisoning, particularly for birds, can be reduced by laying baits just before sunset and covering or recovering them early the next day, where such measures are practical.

Less direct forms of observation such as inspection for tracks, the use of biomarkers or photographic techniques have provided further insights into nontarget bait uptake, as outlined below.

Wild dog control in Kosciuszko National Park

Two sequential wild dog trail baiting operations in Kosciuszko National Park have been studied, using radiotransmitters to determine effects in the target population. Baits (fist sized pieces of beef, drained for 24 hours in a refrigerated room and injected with 5 mg 1080 in aqueous solution) were laid on sand pads or areas of raked soil to allow identification of which animals visited them based on inspection for tracks.

Foxes removed most of the baits during the first operation, followed by birds (currawongs, Australian ravens, Australian magpies and wedge-tailed eagles), dogs and feral pigs. Bait removal reached 92% after 4 days and 99% after 21 days. Initial bait removal in the second operation was much slower because of a reduced fox population, but reached 99% after 18 days. Birds removed most of the baits, followed by dogs, foxes, pigs and cats. Only two of nine dogs carrying transmitters were killed by the two campaigns, although dogs removed a total of 27 poisoned baits. Baits were analysed at around 60% of nominal poison loadings at the start of the campaign, and quickly declined to less than 40% after 5 days exposure (McIlroy *et al*, 1986).

Fox control in coastal NSW

Baiting at Beecroft Peninsula in southern NSW during March 1996 entailed a 13 day free-feed period followed by a 10 day baiting period using Foxoff baits buried in bait stations located along roads and tracks. Bait stations were visited daily and any removed baits were replaced. Six radiocollared foxes were monitored.

Bait takes increased from 3% to 54% during the free-feed period but dropped abruptly to 12% for the first day of poison baiting and declined further to 1.3% on the final day. Some baits were not removed even though foxes visited the bait stations, but these only represented a very small proportion (<4%) of the bait stations visited by foxes. Four of the six radiocollared foxes were dead within a day of poison baits being laid, and the other two after 3 and 10 days. Four other fox carcasses were located 5 days after the commencement of poison baiting. Tracks of rabbits, cats, kangaroos, lizards and snakes were found at the bait stations, but only rats (probably *Rattus rattus*), currawongs and, to a lesser extent, Australian ravens were recorded as taking baits. Rat and bird populations did not appear to be affected as there was no appreciable decline in bait takes by these organisms (Dexter and Meek, 1998).

The NSW threat abatement plan for predation by the European red fox (NPWS, 2001) notes that sightings of ringtail possums have more than doubled since fox control at this site, and that long-nosed bandicoots and bush rats have become abundant although they had not previously been seen.

Uptake of nontoxic meat meal-based baits in northern NSW

Removal of nontoxic buried Foxoff baits during simulated baiting campaigns along roadsides has been studied in forest areas of the central and northern tablelands of NSW by observation of tracks in sand plots and remote photography. Bait removal was recorded on 106 occasions (9.4%) from 1126 bait-nights. Animals which removed nontoxic baits included foxes, wild dogs, spotted-tailed quolls, Australian brush turkeys, superb lyrebirds and small mammals (probably bush rats, but these small animals did not trigger the camera). The study areas contained high quoll populations, and more baits (49/106) were taken by quolls than by any other animal. Remote photography was more informative than sand plot analysis, particularly during wet weather, but is comparatively labour intensive and unlikely to be suitable for routine monitoring of baiting operations.

Quolls were able to locate and excavate nontoxic baits buried at 7 cm, particularly when buried in mounds constructed above the ground surface. Individual quolls were recorded taking nontoxic baits from 3-4 stations (spacing 400 m) in a single night. Canids responded similarly, being more likely to take uncovered than buried baits, with limited evidence that uptake is higher when baits are buried in mounds constructed above the soil surface (Glen, 2001; Glen and Dickman, 2003a, b).

Because of the evidence that quolls can more readily access baits from mounds compared with with those that are simply buried beneath the ground, the NSW best practice guidelines for fox baiting do not recommend mound baiting in quoll areas.

Rat and bandicoot response to nontoxic fox baits in Victoria

Fairbridge *et al* (2001) opportunistically filmed the behaviours of free living southern brown bandicoots (*Isoodon obesulus*) and bush rats (*Rattus fuscipes*) at buried bait stations at a lowland forest site near Cann River (East Gippsland) and in the Royal Botanic Gardens at Cranbourne. Only nontoxic baits (Foxoff econobait, deep-fried beef liver and semi-dried horse meat) were used in this study.

Four of twenty bait stations at the Gippland sites were visited by bush rats at least once during two nights of observation. Rats burrowed to the baits and retrieved small pieces for consumption, with entire baits consumed on occasion. No definitive prints or scats were left.

One of six trial bait stations at Cranbourne was visited on both nights of observation by a bandicoot, suspected to be the same individual, which consumed 10 g (30%) of bait on the first night and a further 20 g on the second night.

In the absence of filmed evidence, it is likely that the disturbance by bandicoots at the bait stations could have been attributed to dog and fox activity, and conceivable that the rat diggings could be similarly misinterpreted by untrained observers, particularly if obscured by rain. Bush rats are highly sensitive to 1080, and bandicoots moderately sensitive.

Further work using manufactured baits containing the biomarker Rhodamine B found 6 marked bandicoots in a sample of 37 animals that were exposed to 82 baits over a 5 week period at Cranbourne. Although this level of exposure indicates a relatively low risk, baiting strategies have been changed to further reduce exposure (Robley and Fairbridge, 2001).

Antechinus and rat response to nontoxic fox baits in Victoria

Fairbridge and Fisher (2001) carried out bait uptake studies using the biomarker Rhodamine B in East Gippsland. These were a simulated aerial baiting campaign in February 2000 over 144 km^2 of lowland forest in Croajingalong National Park using dried meat baits from WA, and a simulated buried baiting campaign in February-March 2000 in Coopracambra National Park using Foxoff econobaits. Non-target and target populations were sampled from 2-3 weeks after the final availability of marker baits. Small mammals were collected by trapping near bait lines or stations, and canids by trapping on tracks. Whisker samples were screened for the presence of the biomarker.

The most common animals trapped at the two sites were agile antechinus and bush rats. Dusky antechinus, swamp rats, long-nosed bandicoots, southern brown bandicoots and brushtail possums were trapped in low numbers but their exposure to the biomarker is not reported. Marking rates for agile antechinus at the two sites were 4/199 and 11/112, respectively, and for bush rats 15/223 and 10/107. Four wild dogs and one fox trapped at Croajingalong were all marked, but four wild dogs from Coopracambra were unmarked while the single fox captured was marked.

Agile antechinus and bush rat populations have a high capacity to recover from poisoning and appear to be at minimal risk based on the marking rates obtained in these studies. However, bait disturbance is of concern as it reduces exposure of the target pests and may increase exposure of other nontarget fauna. The authors noted that community and animal welfare concerns (rather than ecological risks) are likely to drive the development of more target specific baiting techniques.

Robley and Fairbridge (2001) reported that no dusky antechinus (*Antechinus swainsonii*) or swamp rats (*Rattus lutreolus*) were marked following aerial baiting in East Gippsland. Twenty animals from each species were sampled.

Nontoxic bait uptake by captive and free-ranging quolls

Belcher (1998) presented non-poisoned Foxoff baits for 3 days to captive tiger quolls and eastern quolls at the Healesville Sanctuary near Melbourne. Baits were buried according to standard procedures. Bait holes that did not contain baits were investigated initially, but only baited or previously baited holes were investigated in subsequent trials, with baits rapidly consumed when found. Tiger quolls consumed 2-3 baits overnight.

Buried nontoxic bait trials were conducted along tracks near an active tiger quoll latrine at Suggan Buggan (NE Victoria) between May 1994 and January 1995, again using nontoxic baits. Wild tiger quolls were observed by remote photography to dig up and consume buried meat and Foxoff baits.

Spotted-tailed quoll response to meat baits in NSW

Nontoxic kangaroo meat baits (200-250 g) were loaded with the biomarker Rhodamine B (50 mg/bait), air-dried for 2 days and deployed by helicopter in July 1999 at the high rate of 40 baits/km on a 30 km transect through Tallaganda State Forest, 60 km SE of Canberra (Murray *et al*, 2000). This is the rate used by Rural Lands Protection Boards. The Braidwood RLPB conducted such campaigns in the forest until 1996 but has since restricted baiting to adjoining freehold land.

Trapping for quolls was conducted for 12 consecutive nights commencing 3 weeks after baiting, using 28 wire cage traps baited with raw chicken and located at 11 sites, mostly in gullies and creek lines but including one rocky outcrop. Captured quolls were microchipped and had eight whiskers removed for analysis before release at the point of capture.

Sixteen quolls were captured on 41 occasions. Four of the seven females had pouch young. Ten of the captured quolls, including three of the four reproductively active females, were identified as having fed upon at least one bait. If poison baits had been used, it would appear that significant quoll mortality would have resulted.

The authors note that it may appear contradictory that a relatively large and trappable quoll population remains in an area that had been systematically baited on an annual basis for at least 15 years (1982-1996, with control restricted to the eastern freehold boundary in 1997 and 1998) and suggest that dispersal from adjacent Deua and Wadbilliga National Parks where aerial baiting does not occur may have compensated for quoll mortality during baiting. Risks to quolls are likely to be most severe where populations are small and isolated, particularly where they occur in suboptimal habitat. Baiting along creek lines, gullies, saddles and drainage lines would also be expected to increase risks to quolls. The use of buried bait stations in quoll habitat is recommended, although aerial baiting remains an appropriate technique for canid control in large areas of remote and inaccessible parts of Australia where quolls do not occur.

Nontoxic bait uptake by phascogales in Victoria

Fairbridge *et al* (2003) used rhodamine B to determine the exposure of brush-tailed phascogales to nontoxic Foxoff baits buried at a depth of 10 cm beneath slightly mounded sand pads. The biomarker (20 mg in 0.5 mL water) was added to a small well drilled in each bait. Baits were laid at 12-16 per km^2 (higher than the usual operational rate) in box-ironbark woodland at Puckapunyal Military Area (central Victoria) in summer and autumn 1999/2000 and 2000/2001, with inspection every 3-7 days for about 3-5 weeks and replacement of any taken baits. Woodland areas are usually avoided when baiting at Puckapunyal. Small mammal trapping was conducted two weeks after each operation.

Total bait take varied from 40 to 85% with at least half being attributable to foxes, except for the January 2001 baiting when it fell to about 30%. This was the only occasion on which non-target bait takes (1 phascogale and 4 possums/gliders) were reported, based on tracks. Between 15 and 40% of bait takes could not be identified.

Rhodamine B marking was detected in six phascogales among forty captures (including two recaptures). Marking was also detected in yellow-footed antechinus (7 from 40 captures), sugar gliders (two captured animals) and brushtail possums (all three captured animals). Three common dunnarts were also captured, but none are reported to have been marked. Uptake by phascogales at individual sites was limited to one or three animals during each trial.

The authors note that unpublished monitoring data indicate an increase in the abundance and range of a number of fox prey or competitor species, including phascogales, antechinus and possums, since broad-scale fox control was implemented at Puckapunyal.

Studies in Victoria and Western Australia have shown brush-tailed phascogales to be essentially arboreal insectivores that supplement their diet with nectar when available. Phascogales do not appear to prey on vertebrates but will consume carrion, and it is believed that this may represent a small but important part of the phascogale diet (Scarff *et al*, 1998).

Baiting for pigs in NSW

Fleming *et al* (2000) studied bait uptake by pigs at four sites (one control) on the Paroo River in north-western NSW. Ground-placed kangaroo meat baits (mean weight 141.3 g) containing a biomarker but no 1080 were exposed at one hundred bait stations for a total of 251 baitnights in April 1995; most were removed by birds (57.8% of total baits) and foxes (30.3% of total baits). Only six baits (2.4%) were removed by pigs. One bait was removed by a cat and eight by unidentified animals. Some baits (4.0%) were visited but not removed and 2.0% were not removed or visited. During the first 24 hours' exposure, 94.8% of baits were removed by animals.

Pigs require a large 1080 dosage to kill them and so aerially-distributed 1080-meat baits for pigs may be hazardous to birds. However, it should be noted that the relatively small baits used in this study would be more easily scavenged by birds than the 500 g baits used in Qld.

The low bait uptake by pigs was thought to reflect seasonal factors that affected the foraging behaviour of pigs. The pigs in this trial were mainly utilising pasture resources and probably took meat baits opportunistically rather than actively searching for them.

7.2.2 Carcass searches and incident reports

The above bait uptake studies used nontoxic baits, and therefore provide limited information regarding the likelihood of poisoning. The discovery of carcasses provides clear evidence that mortality has occurred, although the cause of death often remains unconfirmed.

McIlroy (1982a) has listed a variety of species that have been found dead after rabbit baiting operations in NSW forest areas between 1971 and 1975, albeit without confirmatory residue analyses. Searching was confined to areas after baiting, with no control searches prior to baiting or in matching unbaited areas. Carcasses of 12 magpies, 10 parrots, 3 kookaburras, 2 scrub wrens, a pigeon, hawk, lyrebird and crow were recorded by forestry personnel. Carcasses of mammals were more often reported, with 238 foxes, 218 wallabies, 82 possums, 56 grey kangaroos, 54 wombats, 24 swamp wallabies, 15 rats, 14 hares, 10 cats, 6 sheep, 5 dogs, 2 bandicoots and an echidna recorded. Long-nosed potoroos and bush rats were specifically identified as being killed by carrot baits laid for rabbits, and widespread mortality was recorded in an isolated population of silky mice exposed to pellet baits (McIlroy, 1982a, b).

McIlroy (1983a) has reported that carcasses of two black kites, a magpie lark and several corvids were discovered after pig baiting.

Kangaroos have been identified as poison casualties in SA, although the animals in question were hand-raised. It is claimed that Forester kangaroos in Tasmania have also been killed by 1080 baiting, but these claims are unconfirmed and considered unlikely. Also in Tasmania, bettongs are occasional casualties of 1080 poisoning. Further information on Tasmanian bettongs is outlined below.

Tasmanian bettongs

Like most unadapted herbivorous marsupials, the Tasmanian bettong is highly sensitive to 1080 with an estimated LD50 in the order of 1 mg/kg. Information has been collected from Tasmanian Departmental officers as to whether poisoning operations had occurred within 2 km of known bettong sites. In most cases bettongs were present after poisoning operations, but there was a marked decline in the incidence of bettong diggings associated with the frequency of poisoning. These findings support earlier conclusions, based on the observation of a 50% population reduction in a study population, that repeated use of 1080 poison leads to a decline in bettong density which in isolated populations may result in local extinction. Accordingly, use of 1080 should be avoided in or near areas containing isolated bettong populations, and should not occur adjacent to any reserve known to contain bettongs (Driessen *et al*, 1990).

Frequent repeated 1080 poisoning in the one area is recognised generally as bad practice. It is risky to nontarget populations such as Tasmanian bettongs, and also unlikely to be effective because of the development of bait shyness in target animals (Coleman *et al*, 1997). The DPIWE submission to this review notes that frequent repeated 1080 poisons in one area are generally not supported because of the risk to nontarget animals such as bettongs. The laying of baits at a clear distance from bush edges is said to reduce risks to bettongs, which limit their activities to bush edges and prefer not to traverse open areas. The DPIWE has advised that there have been several instances of small numbers of bettongs being found dead after 1080 baiting operations over the last 15 years.

7.2.3 Radiotracking of nontarget animals

The use of radiotransmitters allows the survival of nontarget animals to be confirmed or carcasses to be discovered after baiting operations, although it does not allow confirmation that baits have been consumed unless combined with bait biomarkers and post-baiting sampling.

Radiotracking has been particularly useful for quolls, as outlined below.

Northern quolls in the Pilbara

The response of ten radiocollared northern quolls (*Dasyurus hallucatus*) to a standard aerial baiting campaign for dingoes on the Fortescue River (western Pilbara) has been described. Annual wild dog baiting had occurred in the area for the previous three years. Air dried meat baits containing 6 mg 1080 were aerially dropped along the dry river bed in October 1987, with around 1000 baits deployed over a flight path of 54 km. The quolls captured for this study had lost considerable weight since being trapped in July, having lost condition following mating, and were therefore considered more likely to consume baits than at other times of the year. It is not known whether any quolls actually took baits, but exposure was considered likely as the animals were highly mobile and captive quolls readily consumed dried meat baits in the laboratory. All quolls survived the two weeks following the operation, suggesting little risk to their populations from wild dog baiting (King, 1989; King and Kinnear, 1991).

Western quolls in the south-west forests

A similar study (Morris *et al*, 1995) has since been conducted in mixed jarrah/marri forest at Collie, 180 km south-east of Perth, where fox baiting was carried out every 3 months. Ten radiocollared chuditch were monitored by radiotracking and trapping through four baiting cycles. A 1 kg chuditch would ingest more than the LD50 of 7.5 mg if it consumed two fox baits (4.5 mg/bait) but these animals did not favour dried meat in previous captive feeding trials. All radiocollared chuditch survived the baiting, and trap success rates started to increase two years after baiting commenced, both in baited areas and adjacent unbaited forest. These observations indicate that fox baiting is unlikely to adversely affect chuditch, and that populations are likely to respond positively when competition with foxes, and possible predation particularly of young animals, is removed. Similar positive responses were seen with woylies (brush-tailed bettongs), brushtail possums and quenda (southern brown bandicoots).

Tiger quolls in northern NSW

More recent field studies (Körtner and Gresser, 2001) on the eastern escarpment of the New England Tablelands (two in Werrikimbe National Park and one in Cunnawarra National Park) have examined the question of whether spotted-tailed quolls will actually consume Foxoff baits, surface buried (no deep burial) beneath sand pads at 400 m intervals with no free feeding. Baits contained the biomarker Rhodamine B as well as 1080. Quolls were trapped before baiting and fitted with radio-collars, and again after baiting to retrieve the transmitters. Trapping also caught cats, northern brown bandicoots, a long-nosed potoroo, dusky antechinus, bush rats, water rats, currawongs, a catbird, a lace monitor, a cunningham skink, and bluetongues. Overall, 67 quolls were trapped (329 captures, or an average 3.8 per 100 trap nights) with a bias towards males.

Cumulative trap success approached a plateau before baiting, indicating that most of the trappable population had been caught, and this conclusion was generally supported by the results from trapping post-baiting. The exception was the second study at Werrikimbe, conducted in autumn/winter, when 11 new animals were caught post-baiting. A higher trap success rate in this study, and the presence of juveniles in the trapped population, was thought to reflect seasonal factors. The two other studies, conducted in winter/spring, caught only adult animals. Quoll populations are at their peak and young have become independent in autumn/winter. Natural mortality may also have influenced the trapping results as at least three quolls died before baiting following prolonged heavy rainfall in the second study.

Radiocollars were fitted to 18 quolls in the first study, 25 in the second, and 13 in the third. Signals were lost for one animal in each study, and one animal in each of the second and third studies could not be recaptured. Overall, fifteen quolls died, but only one of these deaths occurred during the baiting phase. This was not considered to be related to baiting as no baits had been taken near to this animal's home range and the carcass remains (after scavenging by a fox) contained no detectable 1080. Likely causes of mortality for these animals included predation and fighting, roadkill, hypothermia in the trap, and starvation during the pre-baiting period. Starvation was only identified as a cause of death in the second study, with juveniles particularly susceptible (three of the five deaths recorded). Two post mortems remained outstanding when the studies were reported.

Consistent with the trapping results, visits to bait stations by quolls as determined by track analysis were most frequent in the second study (24 visits and 7 bait takes, compared with 6 visits/1 take and 7 visits/5 takes in the first and third). Although baits were often excavated and removed by quolls, only one could possibly have been consumed based on its non-retrieval. This occurred during the first experiment, when removed baits were not initially searched for. Baits were retrieved on all subsequent occasions, although one had been moved a distance of 30 m and some had small pieces bitten off when recovered. Fox, dog and cat visits were also most frequent in the second study, as was the incidence of caching by foxes. Small native mammals also took baits, particularly at Werrikimbe, but these were predominantly bush rats and their populations were sufficiently dense to remain unaffected by baiting.

Vibrissae had been sampled and analysed for the first two studies when results were reported. The absence of the bait marker from all the trapped quolls was consistent with the observed lack of bait consumption, and indicates that use of the commercial product Foxoff in fox baiting campaigns in this area is unlikely to have any significant adverse effects on quoll populations. Rejection of the bait would appear to reflect the presence of 1080, as captive quolls had previously been reported to consume nontoxic Foxoff baits, and similar consumption in the field has been demonstrated with the biomarker Rhodamine B. The latter evidence is more persuasive as captive animals are more likely to eat a range of novel foods than their free-living counterparts in the wild. However, similar rejection of other types of 1080 meat bait, which may be more palatable, remains to be demonstrated.

An updated report of this work, including a further experiment in which half the bait stations contained nontoxic baits, has been presented to the Second NSW Pest Animal Control Conference (Körtner *et al*, 2002). A quoll carcass collected 2 months after this additional trial had finished was found to contain Rhodamine B residues, which had been ingested some 6 weeks after baiting based on the location of fluorescent bands in some vibrissae. The authors suggest that the 2.3 kg male quoll had ingested a bait that had been cached by foxes. As the fresh baits contained less than the estimated LD50 for this animal and had probably deteriorated before consumption, it appears unlikely that this animal was poisoned by 1080, although the possibility cannot be excluded.

Quolls took and discarded toxic and nontoxic baits during this later study, indicating that the low palatability of the Foxoff matrix to quolls relative to other available food sources at thius location is more likely to have deterred consumption than the presence of 1080.

This work has now been published (Körtner *et al*, 2003). The published paper concludes that predation and starvation during the pre-baiting period were the main causes of quoll mortality. Three animals died within a few weeks of the end of a baiting period, but two of these deaths were unconnected with baiting as the carcass were not marked with Rhodamine B and contained no 1080 residues (one showed injuries consistent with a collision with a vehicle, and the other died of hypothermia, possibly associated with infection). The marked quoll recovered dead in the final experiment must have survived for at least a few days after bait ingestion in order for the biomarker to appear in the papillae of five whiskers. No 1080 residues were detected in the carcass. Baiting with Foxoff in areas with no prior exposure to this product had at most a marginal impact on spotted-tailed quoll populations, leading the authors to suggest that bait stations frequented by quolls could be baited with Foxoff in order to avoid the demands of free-feeding and daily monitoring of bait stations. Baits should still be buried to reduce bait take by birds, small mammals and quolls.

Research in this part of Australia is currently addressing the effects of aerial baiting for wild dog control. Preliminary results are contained in a media release dated 24 August 2004 posted on the website (nationalparks.nsw.gov.au) for the NPWS (known since September 2003 as the Parks and Wildlife Division of the Department of Environment and Conservation). There was no significant impact on the quoll population in a trial conducted in an area where annual baiting with 1080 has occurred over a long period. Seven of 31 monitored quolls died during the trial, with five carcasses recovered. Only one of these contained 1080 residues. It appeared that injuries, predation and disease accounted for most of the deaths. The biomarker Rhodamine B was used in the baits and detected in some of the surviving quolls. These results were to be confirmed using an independent laboratory. Further research is planned for areas where quolls have not recently been aerially baited, as well as for southern NSW. These studies have now been completed and are discussed in more detail in section 9 of this report.

Tiger quolls in SE Queensland

The response of spotted-tailed quolls to 1080 meat baiting (for wild dog control) is also under investigation in SE Queensland. Fourteen tiger quolls (7 male and 7 female, 4 with young) were trapped and equipped with radiocollars before 63 baits were laid at 500 m intervals across four pastoral properties on the Queensland side of the border, between Temangum in the west and Cullendore Gate in the east. Ox heart pieces (250 g) containing 6 mg 1080 were used, buried beneath sand plots on two properties and laid on the surface of a sand plot on the other two, with bait recovery after 7 days. Most baits were taken within 1-2 days, with a more rapid take for surface laid baits (interference by birds was noted). Eleven of the collared quolls survived the exercise based on trapping and radiotracking, and eight uncollared quolls were also trapped. The remaining three collared quolls are assumed to have migrated away from the site. None of the tracks at bait stations resembled those of quolls and it is considered unlikely that any quolls took baits (Cremasco *et al*, 2003).

The VPC has advised that two of the remaining three collared quolls were known to still be alive several months after the study and that the other was presumed to have survived although its fate is unknown.

The recent QPWS referral under the *EPBC Act* notes that all quolls were found on the two properties where 1080 baiting for wild dogs had been carried out previously, suggesting possible benefits to quoll populations from wild dog control, although it is acknowledged that other factors such as vegetation type and extent of clearing may have affected this outcome. The QPWS believes that invasion of habitat by cane toads may be one of the greatest threats to quolls in this part of Australia.

Further detail is contained in a media release dated 7 April 2004 from the NRME. Radio-telemetry studies had been used to track the movements of 35 quolls over the previous two years. The properties where this research has been conducted had been baited every year (sometimes twice in a year) for the past 8-14 years. Only one of these quolls, from the older section of the population, died from ingesting bait.

Quoll monitoring has now been conducted for three baiting campaigns, in spring 2002, spring 2003 and autumn 2004 (Peter Cremasco, personal communication). During that time, 56 quolls have been radio-tracked, (55 throughout baiting), and their fates recorded. 161 baits were used for a total exposure time of 817 bait nights. Four baits may have been taken by quolls in the three years.

A total of 51 quolls were known to be still alive in the month following baiting. One of these quolls was later found dead 10 weeks after baits were removed from the field. Cause of death is unknown. One quoll is presumed to have died before baiting commenced (mortality signal detected but collar was unable to be retrieved, and animal has not been re-trapped). Two dead quolls have been recovered, within 7 days of baiting, with analysis showing traces of fluoroacetate in their stomach. The fate of two animals is unknown, as their radio signals have not been detected and they have not been re-trapped in the area.

Efforts are now directed towards finding other populations of spotted-tail quolls, and replicating these studies.

Tiger quolls in Kosciuszko National Park

The NSW National Parks and Wildlife Service predominantly uses the bait mound technique in its year-round baiting programs for wild dogs, but has recently come under strong pressure from many rural landholders in the Southern Tablelands to recommence aerial baiting, which formerly occurred on an annual basis but was discontinued because of concerns for quolls. Landholders in this area are concerned that wild dogs are breeding up within the park, although there is no evidence that changes to baiting practices are responsible for increased stock predation. Recent drought on the Monaro has weakened both stock and native animals and has provided a rich food source for wild dogs.

Similar problems near Charleville Qld have been attributed by woolgrowers to a reduced control effort on cattle properties. Coordinated baiting programs are needed in order to protect stock. Single property baiting programs are vulnerable to recolonisation, and it has been argued that the young and inexperienced dogs that disperse in this way are more likely to attack stock than wild animals such as kangaroos. A media release dated 16 August 2004 from the NRME encourages landholders to participate in coordinated wild dog baiting programs, noting that reactive approaches once problems become visible tend to result in constant or increasing feral populations. Control, whether by shooting, trapping, fencing, security animals or baiting, should be conducted on a coordinated basis between neighbouring/regional landholders. The NRME cites research that has shown that wild dog populations are more prone to attack livestock when they are recolonising an area.

A research program has been developed to evaluate the risks to quolls from canid baiting practices. The first stage, which could not commence until May 2002 when most adults in the population visit common (latrine) sites, would be to survey the distribution and habitat preferences of quolls within Kosciuszko National Park. Subject to approval from the Animal Ethics Committee, the second stage would involve fitting live-trapped quolls with radiotransmitters in order to determine whether baiting (bait mound technique initially, followed by aerial distribution if initial results are favourable) impacts on low-density populations. Levels of stock predation would also be surveyed.

The project has been disrupted by recent bushfires in the Kosciuszko region, and there are no current proposals to lay toxic baits from aircraft in the study area. Studies with nontoxic baits containing the biomarker Rhodamine B were scheduled during winter 2003. The quoll population in the study area has proved to be resilient, with at least half the tagged animals surviving the bushfires of January 2003 (Claridge, pers comm).

Recent live-trapping surveys have indicated that the Byadbo wilderness area within Kosciuszko National Park, where the above trials were to be conducted, supports a large population of spotted-tailed quolls. A capture rate in excess of 16% was achieved during two surveys in late May and June 2002, with 21 animals caught on a total of 99 occasions. The authors conclude that the ongoing buried baiting program for wild dogs in the area is unlikely to be exerting a detrimental impact on quoll populations, but that control of wild dogs and foxes may be beneficial. Scat analysis indicates that brushtail possums are a major prey item for quolls. The availability of possums is likely to be increased following fox removal (Murray *et al*, 2002).

A proposal by the NSW Department of Environment and Conservation to conduct an aerial baiting trial in the Byadbo and Pilot Wilderness Areas, Kosciuszko National Park and in the Styx River State Forest and Cunnawarra National Park in northern NSW, in late May 2005 was referred to DEH under the *EPBC Act* on 19 January 2005. The aim of this proposal was to determine the response of local spotted-tailed quoll populations to a single aerial baiting exercise, by monitoring radio-collared quolls. It was decided on 2 March 2005 that this proposed action is not a controlled action, with the understanding that the trials will be undertaken in a particular manner. The results of this trial are discussed in section 9 of this report.

Further evidence for the likely beneficial effects of fox baiting on spotted-tailed quoll populations is provided by recent sightings of these animals, or evidence of their presence, at or above the treeline near ski resorts in the Snowy Mountains following an intense fox baiting program. As spotted-tailed quolls occur in the snow country of Tasmania, it appears that they may have been out-competed by foxes on the mainland as the major mammalian top-order predator above the winter snowline (Green, 2003).

Radiotracking of target animals in Tasmania

The fate of poisoned animals following baiting of newly planted eucalypts has been studied by attaching radiocollars to ten Tasmanian pademelons, seven Bennett's wallabies and nine brushtail possums. Carrots laced with 1080 were deployed in bait stations situated at 10 m intervals along the coupe's central access road, boundary and nearby firebreaks, after five free feeds at 3-6 day intervals during April 1998. All bait was consumed within 24 hours. Eleven animals were located alive within 2 days of baiting and the remaining fifteen (eight pademelons, one wallaby and six possums) were killed. Separate investigations based on population density are said to have found that the poisoning was more successful than indicated by these figures.

Carcasses from twelve animals were recovered within 85 m of the bait line, with 84% within 40 m. The authors acknowledge that more study would be needed to confirm that wallabies die this close to the bait line, given the low kill rates in radiocollared individuals. Most carcasses were found inside windrows, under fallen vegetation or inside dens, and there was no indication that poisoned animals had sought water as is commonly believed. Two of the remaining three collars were recovered and showed signs of predation (chewed leather and teeth marks in the epoxy resin casing). Tasmanian devils and spotted-tailed quolls were known to inhabit the site. The difficulty of carcass recovery, with poisoned animals taking cover, suggests that routine carcass searches are unlikely to be effective (le Mar and McArthur, 2000).

7.2.4 Population monitoring

Although some nontarget animals are known to be poisoned during some 1080 baiting operations, and concerns have been raised that such impacts in rare species such as quolls and phascogales may threaten populations, 1080 baiting may also benefit nontarget species by reducing competition with and predation by introduced pests. The overall impact of 1080 baiting is therefore best determined by measuring the response of populations. A range of methods may be used to achieve this, as outlined below. Population monitoring integrates the potential negative consequences of nontarget poisoning with the potential positive consequences of pest removal. This is best illustrated by the success of fauna recovery programs, where ongoing predator control has allowed the return of various mammal species to areas where they no longer occurred. It is unlikely that such programs would be successful if 1080 baiting was poisoning significant numbers of nontarget animals.

In some cases, the evidence for population recovery tends towards the anecdotal rather than being scientifically rigorous, although even this evidence can be compelling where populations respond markedly. For example, an *ETSA Environment* article from autumn 1992 reports a marked increase in native plant growth and the return of associated bird life such as wrens, parrots and honeyeaters in the 2 years following the rabbit baiting campaign on Torrens Island.

Similarly, indirect and somewhat anecdotal evidence that eastern quoll populations are not adversely affected by 1080 baiting is reported by Jones and Rose (1996). The increased abundance of eastern quolls in some Tasmanian farming areas such as the southern Midlands compared with 50-100 years ago is attributed to the replacement of strychnine by 1080 as a poison bait for rabbits, macropods and possums. Apart from changes in the poison used, availability and frequency of baiting have declined with the introduction of strict controls on 1080.

Anecdotal reports of negative population responses are also available, and can be persuasive even though not supported by hard scientific data. Thus McIlroy (1982b) reported that pellet baits laid for rabbits killed all adult residents in a marked population of the patchily distributed silky mouse (*Pseudomys apodemoides*) in the Big Desert region of Victoria, based on a personal communication from A Cockburn in 1979. However, the effect was temporary as juveniles quickly recolonised the area.

In contrast, the results from more rigorous monitoring of rare and cryptic species such as phascogales can be more equivocal, with effects from baiting sometimes obscured by climatic variation and associated resource fluctuations.

As evident from the following examples, positive responses in populations of nontarget animals, including successful reintroductions, are most clearly seen in WA where fox control has been regularly carried out over large areas for more than ten years. Similar biodiversity conservation operations in the eastern States are more recent and cover smaller areas because of greater concerns regarding nontarget poisoning of unadapted animals. Smaller baited areas are more vulnerable to reinvasion by foxes. However, increases in medium sized native mammal populations are beginning to be seen in the eastern States, and further such success stories are anticipated in the future as baiting programs continue and are refined.

Red-tailed phascogales in the WA wheatbelt

Regular trapping to assess red-tailed phascogale population numbers has been carried out on nine reserves in the Great Southern district of WA, three of which have been baited for foxes over the previous five years. These animals persist in a scatter of isolated remnants of native vegetation in this area of the wheatbelt, but have largely disappeared in arid and semi-arid zones coincident with the introduction of foxes. Comparison of animals known to be alive in 1994 and 1995 showed stable or slightly increasing populations on five reserves and decreases on the remaining four, with two (one newly baited and one unbaited) very marked. The authors of this study note that low rainfall in 1994 is likely to have affected populations in the following year by reducing resources. Populations on the long-baited reserves appeared more stable, suggesting that fox control is likely to be beneficial to this species although the evidence available at the time did not allow firm conclusions (Friend and Scanlon, 1996).

Brush-tailed phascogales in the south-west forests

Brush-tailed phascogales have been studied in jarrah/marri forest near Manjimup (350 km south of Perth) between May 1992 and January 1997 by trapping and radio-telemetry (Rhind and Bradley, 2002). Some sites had been fox baited since about 1970 and appeared to support few cats or foxes, while regular fox baiting at other sites commenced in about 1993. Non-target animals were initially more abundant at the long baited sites, but woylies, brushtail possums and bandicoots increased dramatically at the other sites following the introduction of baiting. Phascogale population densities appeared from occupancy rates in nest boxes to fluctuate between seasons in response to conditions. In December 1994, following the worst winter drought on record in the study area, several nest boxes were found with abandoned young, apparently reflecting maternal mortality during late lactation under the stressful conditions. Population reductions were evident in the following seasons, with recovery not evident until early 1997.

The effects of fox control on phascogale population densities was not determined, but phascogale size, growth and orphaning were similar between sites with long or recently commenced baiting histories. It therefore appears that the removal of fox predation has little influence on brush-tailed phascogales, particularly as they were relatively abundant prior to fox baiting. Similarly, the laying of 1080 baits within their habitat does not appear to exert significant influence on brush-tailed phascogales in south-west WA as they remained relatively common in the face of baiting and no poison-related deaths were reported among those animals monitored by radio-telemetry.

Tiger quolls in south-eastern Australia

Population monitoring by trapping as described below has found indirect and some direct evidence that spotted-tailed quolls are affected by 1080 baiting, leading one researcher to suggest that 1080 poison baiting is likely to be one of the main causal factors in the continuing fragmentation and decline in abundance of this species (Belcher, 2002). Live cage trapping was undertaken at the same sites pre- and post-baiting at the same time each year during the breeding season (May to September). Individual animals were identified from photographs or by microchip transponders.

A population in eastern Victoria (Suggan Buggan) was monitored from 1993 to 1996. Six animals (one female) were recorded in the first two years, and four in the third (one male was shot in a poultry shed). Only two animals (the adult female from 1994 and a juvenile male) were recorded in 1996 after baiting in spring 1995. Fox baiting with Foxoff baits had commenced around a rock wallaby colony 6 km north of the study site, and rabbit baiting had commenced 7 km to the south.

A population at Badja (NE of Cooma, NSW) was monitored from 1996 to 2001. Ten animals were recorded in 1996, and nine in 1997. Hand baiting with air-dried meat baits occurred along the boundary of adjoining freehold land from late 1997. Only four animals were recorded in 1998 and 1999. Illegal hand baiting for wild dogs occurred in the State Forest in December 1999. No quolls were recorded in 2000 or 2001.

A population at White Ash Road (Tallaganda State Forest) was monitored between 1997 and 2001. Six animals were recorded in 1997, seven in 1998 and eight in 1999. Aerial baiting for wild dogs occurred in July 2000. A single animal was captured when the site was surveyed a month later. An adult male trapped in 1998 displayed symptoms of 1080 poisoning (vomiting and convulsions) several days after the freehold boundary was aerially baited for wild dogs (note that this is likely to have involved high application rates in the order of 40 baits/km). The animal died three days later, in good condition and with no obvious cause of death. Residue analysis found 1080 in muscle and stomach tissues.

Trapping was conducted at several sites along a transect through Tallaganda State Forest in 1999 and 2000. Twenty animals were recorded in 1999, but only six in 2000 after aerial baiting for wild dogs in July.

Note that population monitoring would ideally extend across several years at baited and unbaited sites in the same region. Short term studies with small sample sizes may be confounded by external factors such as random fluctuation, trappability and natural mortality. More recent studies in which quoll populations were monitored by radiotelemetry are considered more reliable. These are described in section 9 of this report.

Tasmanian spotlight surveys

Driessen and Hocking (1992) have conducted spotlight surveys across Tasmania since 1975 to monitor the abundance of various native species, including the three target species (Tasmanian pademelon, Bennett’s wallaby and brushtail possum). The precision of the method is sufficient to allow changes in population size of approximately 20% to be detected. The method is also useful for monitoring long-term trends of less frequently reported species such as eastern quolls.

Wallaby populations, but not possums, were found to be regulated by high levels of commercial hunting. Dry conditions increased population counts of herbivorous mammals in the short term by making them more visible, but tended to reduce populations in the longer term (6-12 months) through resource limitation. The abundance of wallabies was found to influence the amount of 1080 used by primary producers, but there was no evidence that 1080 use had any effect on wallaby abundance across Tasmania.

Populations of Tasmanian pademelon, brushtail possum, common wombat, eastern quoll and Tasmanian devil increased from 1975 to 1990. These species benefit from land clearing practices which produce a mosaic of pasture and forest. Bennett’s wallaby showed a small decline, apparently due to hunting pressure. Among infrequently recorded species, there was a small but significant increase in the number of routes on which Tasmanian bettongs were seen.

The DPIWE provided an update on spotlight data to the year 2000. These data are also contained in a recent report (FPB, 2002) on Tasmanian forestry. Populations of Tasmanian pademelon, Bennett's wallaby, brushtail possum, common wombat, eastern quoll and Tasmanian devil have remained generally stable since the early '90s, with a small peak in the mid '90s, although the devil population is currently in decline due to the effects of devil facial tumour disease. The target species have undergone major population fluctuations since European settlement as land uses have changed. Possum numbers have now started to decline towards levels seen in the early '80s, but only in those areas where there was a major increase in numbers during the 1980s.

Western Shield

It has been evident since the '80s that fox predation is very detrimental to medium size mammals, as rock wallaby populations in the Western Australian wheatbelt increased in abundance with fox control but declined to extinction without it. Similar responses were seen in woylies, brushtail possums, tammar wallabies and numbats. Benefits to chuditch in jarrah forest were demonstrated in the early '90s.

Under the Western Shield baiting program, fox baits are laid up to six times a year from aircraft across 3.5 million hectares of conservation estate, at a rate of one bait for every 20 ha. WA has an advantage in that many indigenous species have developed tolerance to 1080 through long association with plants that express the toxin. Since 1990, 15 species have been translocated to 49 sites with a success rate of 85%. Three species (woylie, quenda and tammar wallaby) have been removed from threatened fauna lists, and other species have shown good recovery in the wild (Morris, 2001).

Use of 1080 for biodiversity conservation in NSW

Although WA has an advantage when using 1080 as many native fauna have developed tolerance, target specificity can also be achieved in other States because of the sensitivity of the target pests.

In order to establish priority sites for fox control, the NSW NPWS has identified populations of high priority species based on the potential for fox impact at the site, the ability to achieve effective fox control at that site, and the importance of the population to the species overall. Species accorded high priority were black-striped wallaby, broad-toothed rat, brush-tailed rock-wallaby, long-footed potoroo, long-haired rat, long-nosed bandicoot, mountain pigmy possum, rufous bettong, smoky mouse, southern brown bandicoot, yellow-footed rock-wallaby, Australasian bittern, Australian bustard, beach stone-curlew, brolga, chestnut quail-thrush, flock bronzewing, hooded plover, little tern, malleefowl, pied oystercatcher, plains wanderer, southern scrub robin, squatter pigeon, Bellinger River emydura, central blue-tongued lizard, narrow-banded snake, south-eastern lined earless dragon, Stimson's python and western blue-tongued lizard (NPWS, 2001).

Fox control has already provided demonstrable benefits to biodiversity in NSW. The NSW NPWS has summarised these successes in a recent report (NPWS, 2002b). Populations of yellow-footed rock-wallabies in Mutawintji Nature Reserve have increased several fold since fox baiting with 1080 commenced in 1995. Fox control has contributed to high fledgling success in threatened shorebirds at many priority sites along the NSW coastline during 2001/02. Brush-tailed bettongs, which disappeared from NSW in the late nineteenth century, have been set free into Yathong Nature Reserve with none taken by foxes in the 6 months following release in October 2001. Recent reports (Priddel and Wheeler, 2004) indicate that foxes are no longer a threat to wildlife at Yathong, but that cats are now the major impediment to fauna restoration at this semi-arid (rainfall < 350 mm/year) location. Similar programs are being developed for brush-tailed rock wallabies, Alberts lyrebird, plains wanderers, brolgas and other wading birds, southern brown bandicoots, broad-toothed rats, black-striped wallabies and the Bellinger River emydura.

The NPWS follows an integrated approach to pest animal management. Baiting with 1080 is a key element, but an integrated approach is likely to result in the most effective long-term reduction in pest populations because it is less likely to select for bait shy foxes.

Malleefowl

An experimental program to re-introduce the endangered malleefowl is being undertaken on Yathong Nature Reserve. Yathong, Nombinnie and Round Hill Nature Reserves form a large, contiguous area in central NSW between Cobar and Griffith. They comprise plain and ridge country with a variety of woodland communities and the largest continuous stand of mallee remaining in NSW. The reserves support a rich array of wildlife communities and are a major area of habitat for a number of rare and endangered plant and animal species. Yathong Nature Reserve has been formally recognised as an International Biosphere Reserve.

The NPWS has developed a conservation strategy for malleefowl which involves captive breeding and release of chicks into Yathong Nature Reserve combined with supplementary feeding, fire, fox (*Vulpes vulpes*), goat (*Capra hircus*) and rabbit (*Oryctolagus cuniculus*) control and continued research. The malleefowl is extinct in the more arid areas of its former range and numbers are rapidly declining in the remaining areas to the extent that the species may be extinct in NSW in 10-20 years. Numbers in Round Hill Nature Reserve have dropped since the 1950s from possibly 200 to no more than a few pairs. Reduction in food resources and loss of cover as result of frequent fire, and heavy predation by foxes, appear to be the major threats to survival in the remaining areas of habitat.

Previous releases of young captive bred malleefowl into Yathong Nature Reserve were unsuccessful, with 50% mortality within a week of release and no survivors after 3 months. More than half were killed by foxes. Widespread fox baiting (buried fowl heads injected with 3 mg 1080) was conducted across the reserve and adjoining properties. Mallefowl released into baited areas survived longer than those released into nearby unbaited areas, and survival in both areas was higher than before fox control (29% after 3 months). Fox predation remained the primary cause of mallefowl mortality, as baited areas continued to support significant fox populations. More sustained baiting efforts would be needed to ensure mallefowl protection (Priddel and Wheeler, 1997).

The NSW NPWS provided an update of baiting at Yathong Nature Reserve in August 2002. Aerial baiting has been so effective that the reserve is now virtually free of foxes, and malleefowl survival has increased.

Use of 1080 for biodiversity conservation in Victoria

The progress of key projects that rely on the use of 1080 poison to reduce or remove the threat posed by introduced carnivores to native species has been briefly summarised in a document (Robley and Fairbridge, 2001) prepared to assist in the preparation of the VPC report.

Project Deliverance is a large-scale research project aimed at monitoring the response of critical weight range species in forested habitat to the control of foxes. Four paired treatment and non-treatment sites covering 7000 to 14000 ha have been established in various habitats from coastal heath to cool temperate rainforest. Mound baiting with Foxoff baits has been used, with replacement of untaken baits every 3-5 weeks. After 2 years of baiting, bait take by foxes has declined substantially with few baits now being taken, indicating that foxes that move into baited areas are being controlled and that nontarget animals are not removing the baits. Nontarget bait takes have remained below 1%, with rats responsible in most cases and goannas or bandicoots suspected in several others. Nearly 40% of baits were removed by canids in the initial 2 year period. Clear responses in native species as determined by cage trapping had yet to emerge when this summary interim report was prepared.

The mound baiting method was supported by earlier work (Murray, 1998) indicating that burying baits to a depth of at least 10 cm reduces the likelihood of spotted-tailed quolls taking bait.

The summary report also describes work with eastern barred bandicoots. The fate of released animals near Hamilton demonstrates the devastating impact of fox predation on such species. Nine of ten eastern barred bandicoots fitted with radiotransmitters and introduced to Cobra Killuc Nature Reserve in December 1998 were killed by foxes within a month (five within 4 days). Only three animals were recovered from a similar attempt in May 1999, with four killed by foxes within a week of release. Intensive fox control preceded a similar release at Woodlands Historic Park

(30 km NW of Melbourne) with 68 (46%) of 147 poison baits removed by foxes. None of the baits were removed by nontargets, although eastern barred bandicoots, brushtail possums, eastern grey kangaroos and birds visited the bait stations.

The summary report also describes the response of rats, antechinus, bandicoots and phascogales to simulated (nontoxic) baiting in east Gippsland and at Cranbourne and Puckapunyal. These bait uptake studies are described in more detail earlier in this report.

Summary details are also provided of nontarget species monitoring at Puckapunyal military area, where baiting has been conducted since 1994/95, and have been confirmed in discussions with the researcher involved (Anderson, pers comm). Positive responses were first seen in the introduced brown hare, with populations increasing by an order of magnitude in the two years following commencement of baiting. The longer duration of baiting at this site has also allowed native species to recover. Bush stone curlew populations have increased in number and doubled in distribution, brushtail possums have increased markedly with juveniles now being trapped on the ground in relatively large numbers, common dunnarts have tripled in abundance and increased in distribution, and brush-tailed phascogales have shown a steady increase since 1997. Data on other mammals, birds, reptiles and amphibians remained to be collated and analysed when the summary report was prepared.

Recent successes with fox control in Victoria

A recent update (Robley and Murray, 2003) of the Deliverance research project confirms that fox activity has declined sharply at all treatment sites, while nontoxic Foxoff baits at nontreatment sites continue to be taken at consistently high rates.

Captures of medium-sized mammals have significantly increased on the treatment sites in the 4.5 years that the research has been conducted. The response is most pronounced at the Cape Conran site. Long-nosed potoroos have shown the most significant response at the Cape Conran and Stony Peak sites, and have been caught for the first time at the Nowa Nowa site in the most recent monitoring session (October 2002). Long-nosed bandicoots, southern brown bandicoots and brushtail possums have also been recorded but are showing mixed, more complex responses.

Another large scale project, Southern Ark, is due to commence in 2003/04 (Vic, 2002). Southern Ark is essentially an extension of the Deliverance project, moving from the research phase more to the operational level. An ongoing fox control program based on buried Foxoff baits will be established and maintained across State forests and protected areas. Baits will be buried to at least 10 cm at 1 km intervals across large areas of forest and checked at 4-6 week intervals, after a prefeeding period. The viability of placing baits on a 1.5 km spacing will also be investigated. Most baits will be placed along vehicle tracks, but some will be deployed in more inaccessible areas by staff on foot or quad-bike or rafts along the Snowy and Genoa rivers. A monitoring and evaluation program will demonstrate the success of the baiting program and its target specificity by measuring increases in the abundance of native species and declines in fox activity. Nontarget species visiting bait stations will be identified by tracks or by infrared photography in difficult cases, and the effects on population viability will be evaluated where non-target species are consistently identified as consuming buried baits.

The Southern Ark project was launched on 21 November 2003.

Parks Victoria initiated the fox adaptive experimental management project in July 2000 in conjunction with the Arthur Rylah Institute for Environmental Research, in order to investigate the effects of varying control intensity and timing on fox control and prey response (Robley, 2003). The project operates in five national parks (Coopracambra, Discovery Bay, Grampians, Hattah-Kulkyne and Little Desert). Initial results indicate that annual/continuous baiting programs are suppressing fox abundance, as measured through bait take and sand pad activity, but that sites that are running seasonal programs are having little long term effect on fox abundance. The prey response is unclear at this early stage, and it is envisaged that it will take several years for a coherent picture to emerge.

7.3 Summary of environmental hazard

The potential risks of 1080 to aquatic organisms or to terrestrial organisms drinking from contaminated water in and around baited areas are minimal because of the low application rates needed for effective pest control.

Nontarget birds and mammals are potentially at risk from 1080 baiting if they consume the baits (primary poisoning) or scavenge carcasses (secondary poisoning).

For primary poisoning, consideration of the sensitivities of nontarget birds and mammals to 1080 indicates a potential risk to most birds and mammals if oat or pellet baits are consumed. Potential risk is highest for macropods and wombats. Some granivorous birds may also be poisoned, based on their sensitivity. The one-shot product used in WA presents a potential risk to most small birds and mammals if they consume a poisoned oat because of the high toxin loading of 4.5 mg. The potential risk is lower for carrot baits because they generally contain a lower concentration of 1080, but some species such as potoroos may be at higher risk from carrot baits because of dietary preferences.

With meat baits for canid control, spotted-tailed quolls are the nontarget animal of principal concern because of their rarity, sensitivity and dietary preferences. Phascogales may also face a risk of poisoning from canid baits, but are probably less sensitive and are primarily arboreal feeders. Meat baits for pig control as used in Queensland are much more hazardous than canid baits because of the high toxin loading and represent a potential risk to many scavenging species, extending to raptors and probably goannas.

Secondary poisoning risks in general are relatively low because of the rapid metabolism of 1080 in living animals and the consequent low level of residues in tissues and organs. Secondary poisoning risks in Australia appear generally to be restricted to cats, dogs and foxes. Sensitive insectivorous birds also appear to be potentially susceptible to secondary poisoning if they consume insects that have fed on baits. Although earlier measurements of residues in rabbits indicated a potential secondary risk to some native animals, these findings are misleading because the analytical method used was nonspecific and exaggerated the residues present.

Sensitivity is one factor that influences the likelihood that nontarget animals will be poisoned during 1080 baiting operations. Other factors include frequency, scale, timing and intensity of baiting, materials used for baiting, methods of deployment, bait placement and the environment where baiting occurs. The actual degree of impact in the field can not be determined from the sensitivities of nontarget animals but is lower than would be predicted on this basis alone. Bait uptake studies, carcass searching and radiotracking provide greater insight into the likely nontarget impact of baiting. The ultimate measure is population monitoring, although interpretation of population changes can be difficult for highly mobile species, and population monitoring can be challenging for rare or cryptic species.

Observations of bait uptake indicate that a range of scavenging birds (currawongs, corvids, raptors) are likely to take meat baits under open field conditions, while some granivorous birds may feed on grain baits laid for herbivores. In forest situations, baits are more likely to be taken by mammals, such as bandicoots, rats, antechinus and quolls, with some interference by forest birds such as lyrebirds also recorded. Quolls have been shown to consume nontoxic meat baits in the laboratory and to interfere with meat baits at bait stations in the field, but the actual level of consumption of poison baits appears to be relatively low.

Very few nontarget carcasses have been recovered following 1080 baiting campaigns. Where radiotracking has been used to facilitate recovery, carcasses have been found in burrows or under cover rather than in open situations, and tend not to be found near water. Carcass recoveries indicate that a range of animals may be poisoned by 1080 baits under field conditions, although confirmatory residue analyses are usually not available. The most likely avian casualties based on carcass recovery appear to be introduced species such as sparrows, starlings and pigeons, scavengers such as currawongs, corvids and kookaburras, and occasional raptors in pig poisoning campaigns. Among mammals, dogs are the most common nontarget casualty, usually following consumption of meat baits or contaminated carcasses. Macropods, possums, wombats and rodents may be killed by grain or carrot baits.

Radiotracking has been particularly useful for measuring the response of quolls to baiting. Northern quolls and western quolls have been shown to be unaffected by baiting. Spotted-tailed quolls in NSW and Qld also appear to be unaffected by baiting for canids based on radiotracking, in contrast to earlier trapping studies that found significant population reductions following aerial wild dog baiting.

Population responses integrate the possible negative effects of poisoning with the benefits that accrue from removal of predatory and/or competitive species. A marked increase in native plant growth and return of associated bird life has been reported following rabbit baiting. In WA, the Western Shield fox baiting program has allowed the recovery of various species including quolls, wallabies, bettongs, possums and numbats. Phascogales in WA appear to be unharmed by fox baiting. In western NSW, populations of rock wallabies and malleefowl are increasing following successful fox control, while fox control in coastal regions has contributed to high fledging success in threatened shorebirds. Victorian baiting programs are beginning to return results, with favourable responses seen in bush-stone curlews, possums, dunnarts, phascogales, potoroos and bandicoots. Even for the target species in Tasmania, monitoring has shown no adverse effects on Tasmanian pademelon, Bennett's wallaby or brushtail possum populations. Wombats, eastern quolls and Tasmanian devils also maintain stable or increasing populations in the face of baiting, although the devil population is currently in decline due to the effects of devil facial tumour disease. Isolated populations of bettongs can be impacted if baiting is carried out inappropriately in their habitat, as demonstrated in one incident in the mid-'90s. Similarly, adult rodent populations have been wiped out locally by 1080 baiting for rabbits, although juveniles quickly recolonised the area. Note that these concerns relate to single incidents rather than populations in general.

7.4 Alternatives to 1080

Although the APVMA is not able to have regard to alternative options when reconsidering 1080 product registrations and label approvals, these are briefly discussed for information.

Alternative control options include fencing, shooting and trapping, tree guards in plantations, repellents, or other poisons. These have all been researched, and some options are included in vertebrate control programs, but none has been found to be cost-effective in isolation. The Vertebrate Pests Committee notes that research to expand the range of non-lethal and lethal pest animal management options is ongoing, but that much of the work is high-risk and long-term. In the medium term, effective management of pest animals will be dependent on conventional techniques, the most widely used of which is 1080.

Fencing is an expensive option as fences need to be of high quality if vertebrate pests are not to breach them, particularly in rugged and rocky country. Shooting is often used in conjunction with 1080, particularly for control of individual animals after baiting, but is generally ineffective in isolation, particularly where vegetation and/or terrain reduce visibility. Trapping is useful for some species such as dogs but generally needs to be combined with other methods. Shooting and trapping need to be repeated regularly to be effective, which raises costs. Tree guards have limited application as emerging foliage tends to be browsed. Repellents only seem to be effective when browsing pressure is low, and even then do not protect new foliage.

Guard dogs (and llamas) are used on some properties to protect sheep against attack by foxes and wild dogs.

Alternative poisons must match the performance and safety characteristics of 1080. While various poisons are used in New Zealand, 1080 remains by far the most widely used poison in that jurisdiction. Approaches based on controlling reproduction rather than lethality, such as cabergoline (see below) are also under investigation.

The anticoagulant pindone is used for rabbit control in more closely settled areas. The availability of an antidote makes this poison more suitable in situations where exposure of humans or domestic dogs is more likely. Fumigants such as phosphine and pindone may also be used against rabbits. Warren ripping is an important part of rabbit control.

Another anticoagulant, warfarin, is being investigated for feral pig control. It has the advantage of being relatively specific for pigs, but raises animal welfare concerns.

A number of respondents to the review noted that withdrawal or restriction of access to 1080 would be likely to encourage increased use of illegal alternatives by some landholders, and that this would be likely to increase the hazards of vertebrate pest control operations. Organophosphates tend to be the favoured illegal option, as illustrated by the detection by DNRE of mevinphos residues in wedge-tailed eagles found near Nagambie.

One option that has been explored for improving the target selectivity of 1080 baiting is the M44 ejector. The device is triggered when a predator pulls at the bait, and the poison is then ejected directly into the animal's mouth. Modifications have been made to allow burial and to ensure that the fox's mouth is in the optimum orientation when delivery occurs. Only a few species can trigger the device (Marks *et al*, 1999). Such devices would be ideal for discrete sites that require highly target-specific and intensive control, but it is acknowledged that they are not practical for programs that need to control foxes over larger areas.

Reproductive control methods for foxes are also being explored as potential adjuncts to conventional control methods. The potent dopamine agonist and inhibitor of prolactin, cabergoline, can cause abortions and postnatal cub mortality. Studies in a limited range of marsupials suggest that suppression of prolactin is unlikely to cause abortions in these organisms (Marks, 2001).

7.5 Environment Protection and Biodiversity Conservation Act 1999

One view expressed by some respondents to the review is that the use of 1080 may be a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*). Any person may nominate a threatening process for listing as a key threatening process. An opposing view from WA, where 1080 is widely used for fauna recovery, is that removal of 1080 may be in breach of the *EPBC Act*. No nominations for listing as a key threatening process have yet been received with respect to the use of 1080, although 1080 baiting in Tasmania has been cited as one of several factors threatening populations of the forester kangaroo, and is one of the factors identified as threatening spotted-tailed quolls on the mainland.

The EPBC Act provides for the protection of defined matters of national environmental significance (world heritage, national heritage, Ramsar wetlands, listed threatened species and communities, listed migratory species, nuclear actions and Commonwealth marine waters). New developments and activities with the potential for significant impacts on one or more of these matters need to be referred to the Australian Government Minister for the Environment and Heritage for a decision on whether assessment and approval under the Act is needed.

The NSW NPWS (Southern Directorate) referred a proposal to investigate the impact on tiger quolls of aerial 1080 baiting for wild dogs in Kosciuszko National park on 6 May 2002. This proposal involves exposure of a radio-collared quoll population to a one-off aerial baiting exercise. The then Minister for the Environment and Heritage, the Hon Dr David Kemp MP, decided on 31 May 2002 that the proposal was not a controlled action.

The Queensland Parks and Wildlife Service referred a proposal to control wild dog and fox populations in the Conondale Range complex, using aerial and ground baiting with 1080, on 21 February 2003. The proposal was made as a precautionary measure, due to public and scientific debate on the potential impacts of 1080 baiting on spotted-tailed quolls, although the applicant did not consider that this operation would constitute a controlled action. This position was endorsed on 31 March 2003 when the First Assistant Secretary of the Approvals and Wildlife Division within DEH decided that the proposed action was not a controlled action. The aerial baiting methodology was to be agreed with DEH, taking into account the results from pre-baiting surveys that had commenced a week earlier.

As noted earlier in this report, the forester kangaroo has been nominated for listing as conservation dependent, with 1080 baiting cited as one of the factors supporting the nomination. The Minister for the Environment and Heritage decided that this nomination did not meet the criteria for listing. In its listing advice to the Minister, the Threatened Species Scientific Committee noted that the strength of 1080 baits is not usually of sufficient dosage to kill forester kangaroos.

The SE mainland population of the spotted-tailed quoll has been similarly nominated, for uplisting from vulnerable to endangered. Primary poisoning from canid baits, particularly when deployed aerially for wild dog control, and secondary poisoning from rabbit control using 1080, were both cited as factors supporting the nomination. The Minister for the Environment and Heritage has agreed to the uplisting with effect from 14 May 2004, based on the advice of the Threatened Species Scientific Committee as outlined below. The Tasmanian population was considered as a separate species for the purposes of the *EPBC Act*, and was listed as vulnerable at the same time. In its listing advice to the Minister, the Threatened Species Scientific Committee identified habitat loss and degradation and competition with introduced predators as the the key threats to the SE mainland population, noting that inappropriate application of 1080 baits may also be contributing to declines.

The Department of the Environment and Heritage released guidelines on the use of 1080 in pest animal control programs to support the listing decision. The importance of 1080 to conservation programs is noted, with reference to the threat abatement plans for foxes and rabbits and the draft threat abatement plan for feral pigs. All of these plans note that the use of 1080 is an effective and appropriate measure for abatement until such time as feasible alternatives are found.

The guidelines note that much of the research to date on the impact of 1080 baiting programs on spotted-tailed quolls has been inconclusive, but that aerial baiting and extensive surface baiting programs have in some cases been suspected to result in the death of quolls. These programs typically rely on uncooked meat baits. A precautionary approach to baiting is therefore appropriate. The guidelines advise that activities that are likely to require referral under the *EPBC Act* include large scale 1080 baiting (aerial or broadscale surface baiting) as used for wild dog and dingo control in areas where the SE mainland population of the spotted-tailed quoll is known to, or potentially occurs.

One other referral related to the use of 1080 has been received. Wyndham City Council referred a proposal on 28 March 2002 to conduct weed and pest control operations in a coastal wetland near the mouth of the Werribee River, adjacent to the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Wetland site. Proposed pest control operations were rabbit baiting (with pindone as toxicant) and a possible fox control program with buried Foxoff baits. The Assistant Secretary of the Policy and Compliance Branch determined on 28 April 2002 that the proposed action was not a controlled action.

Numerous wild dog aerial baiting programs have been referred since the release of the preliminary review findings in May 2005. Details of these can be viewed on the DEH website.

8 LABELLING

As noted in the scope document, specific directions for use do not generally appear on product labels, but are contained in a variety of documents issued by individual States. These documents usually take the form of a combination of legislative initiatives (eg regulations) and Codes of Practice, manuals or standard operating procedures. Approved labels may refer to these documents. The scope document states that the APVMA will need to consider various matters including the assessment of product labels and associated extension material in order to satisfy its legislative requirements.

The environmental precautions contained on labels for the products registered by the APVMA are outlined below. Restrictions relating to human sensitivities (such as neighbour notification, erection of warning signs and dangers to domestic dogs) are also included on labels but will not be discussed in detail in this report as they are addressed in the VPC review.

8.1 Rabbit (and native herbivore) control

The following products are registered for rabbit control. In Tasmania, the registered product is also used for control of native browsing mammals.

8.1.1 Rabbait (50304)

Rabbait 1080 Oat Bait is registered in NSW, SA, Tas, Vic and WA. The Rabbait label warns users that the product is toxic to birds and wildlife, and that baits should be placed in locations inaccessible to animals other than target animals. Unused baits are to be destroyed by incineration or burial at the end of a control program. Baits that remain uneaten within 4 days of being laid are to be collected and destroyed in the same fashion, or covered with soil. Poisoned rabbits remaining on the surface at the end of a control program should be collected and buried. Apart from the standard container disposal instructions, there are no other specific environmental warnings on the label. Use must be in accordance with directions from the relevant authority and relevant legislative requirements.

8.1.2 Victoria

The DNRE product labels for rabbit control (oat, carrot and pellet baits) include detailed directions for use. The front pages direct users to lay baits in furrows to a maximum depth of 10 cm and a maximum width of 20 cm when trail baiting, and to place baits in locations inaccessible to animals other than target animals. The oat and carrot baits also include the option of broadcast or aerial application.

The directions for use exist in a number of different versions. For the oat (49350) and carrot (49351) baits, they are posted as Landcare Notes on the DNRE (now DPI/DSE – Department of Primary Industries/Department of Sustainability and Environment) website. These directions state that restrictions will apply to designated urban and wildlife areas. Within 4 days of bait laying, untaken baits must be collected and buried or incinerated, or covered with soil. Users must also take all reasonable steps to collect carcasses within 4 days of baiting and continue these efforts for 14 days after bait laying has ceased. Carcasses must be burned or buried, or otherwise disposed of as directed. Unless exempted, the provision of poison baits is subject to two free feeds having been carried out on the land intended for poisoning. Containers and application equipment shall not be washed within 20 m of water.

A different version of the directions for use can be downloaded via the APVMA website, and further alterations have recently been notified to the APVMA. The key difference from the environmental perspective is the removal of requirements for recovery of untaken baits and carcasses.

The directions for use of the pelleted product (49352) indicate that it may only be trail baited, but also contain instructions regarding broadcast and aerial baiting. This inconsistency should be removed.

8.1.3 South Australia

The label for the APCC product (42450: 1080 Bait for the Control of Rabbits) does not specify an application rate or contain detailed directions for use, but approval to use baits is only granted once the user has agreed that the APCC's directions for use, which include such details and form part of the label, have been read and are understood. The label warns that dogs and cats are highly sensitive and that stock should be removed before baiting, but is silent regarding risks to native animals as there is no evidence that such a risk exists in SA. Unused bait must be disposed of by incineration or deep burial.

8.1.4 Western Australia

Three products are registered, being a 40 g/L liquid concentrate (42499) and two oat baits (the One-shot product 42501 and a ready-to-lay formulation 52954).

The liquid concentrate must be mixed with oats immediately before use by authorised departmental officers or a person approved by the Commissioner for Health, to give a bait concentration of 750 mg/kg. This product requires a free-feed period before the laying of poison grain. The label includes a directions for use leaflet, which states that a formal assessment of risks to wildlife must be undertaken before baiting is considered. Animal carcasses found during baiting and for 14 days after all bait has been removed should be burned or buried.

The One-shot product label states that information on nontarget animal distribution, conservation status, habitat preference, diet, tolerance to 1080, body weight and size of home range can be used to reduce the risks of baiting, which should occur at times when nontarget species are not particularly active. Baiting must not occur when rain or heavy dew is expected over the next 5 days (preferably 10 days). Baits should be covered at the conclusion of baiting, and animal carcasses found during baiting or for 14 days after all bait has been removed should be burned or buried. Bait trails must not be laid in bush areas where there are adjacent areas in cleared paddocks. Bait stations may be used where trail baiting is impractical, but prefeeding is essential so that rabbits become accustomed to eating at bait stations.

The label for the ready-to-lay product, which is also registered outside WA, carries similar precautions regarding nontarget risks. It also states that baits should be laid at least 10 m from habitat areas, and not within 30 m of and a minimum 3 m above the high water level of catchments. There are no specific instructions regarding carcass recovery, but use must be in accordance with directions from the relevant authority and relevant legislative requirements.

8.1.5 Tasmania (42458)

The label needs updating as it states that the active constituent is 0.4 g/kg sodium fluoroacetate whereas the DPIWE has used a concentration of 140 mg/kg on carrots for at least the last 20 years. No specific pest is identified and there are no specific directions for use. The label states that the product is to be used only with the authority of and following the instructions of the Department of Primary Industry for the control of vertebrate pests.

The use of 1080 to control native browsing animals is governed by the Code of Practice for Use of 1080 Poison for Native Browsing Animal Control issued by DPIWE. A permit to lay 1080 poison will be issued only when an officer authorised under the *National Parks and Wildlife Act (1970)* is satisfied that there is an unacceptable risk to a crop or pasture, that the use of 1080 does not pose an unacceptable risk to non-target species and, following discussion with the permit applicant, that alternative control measures including shooting and fencing have been considered and are not practicable. Uneaten baits must be covered or collected and destroyed on the property within 7 days of mixing, or as instructed by the Competent Officer. The site must be visited within 24 hours of laying bait and all reasonable effort must be made to recover carcasses, which should be disposed of by either burial or incineration. The Code of Practice also stipulates distance restrictions around streams and other sensitive areas. It is currently being reviewed to better reflect community expectations and to ensure that 1080 is only used as a last resort.

8.2 Fox control

The Foxoff bait products are registered in all mainland States and Territories except the ACT, with further products registered in individual mainland States and Territories.

8.2.1 Foxoff

The labels for Foxoff Fox bait (40573) and Foxoff Econobait (46434) contain specific directions for use in NSW, alerting users that the *Environmental Planning and Assessment Act 1979* could be triggered where a baiting program is likely to have an environmental impact, and that a license may be required under the *Threatened Species Conservation Act 1995* where baiting programs are likely to have an impact on threatened species. Baits should be buried 8-10 cm deep at marked locations with an initial density of one bait per 10 ha, and replaced every 3 or 4 days until bait take is minimal. The minimum space between baits is 100 m. Mound baiting should not exceed 1 bait/ha. Unused baits need to be returned after a month to RLPBs.

The general directions for use in NT, Qld, SA, WA and Vic specify that baits should be buried 8-10 cm deep at intervals of 200-500 m at marked sites away from habitation, water courses and boundaries. Baits should be checked regularly and replaced at sites where there is evidence of fox take. Baits should be used or destroyed within a month of purchase. Untaken baits should be destroyed by burning or deep burial. Use is to be strictly in accordance with directions for use as issued by the relevant authority.

Directions for use of Foxoff in Victoria are contained in a DNRE Landcare Note (LC348). Any death of stock, wildlife, and/or companion animals that is suspected of having been caused by ingestion of Foxoff and/or from ingestion of carcasses poisoned with Foxoff® must be reported to the DNRE office that issued the Foxoff within 24 hours of any such death or suspicion of poisoning occurring.

8.2.2 Victoria

The label for 1080 Fox Bait (49355) instructs users to bury baits to a minimum depth of 8 cm at marked sites, and to check regularly and replace baits at sites with evidence of fox take. The directions for use require that all reasonable steps be taken to collect carcasses within 4 days of baiting and to burn or bury them. These efforts are to continue for 14 days after laying of baits has ceased. There is no explicit requirement to recover untaken baits, but stock must not be returned until untaken baits have been recovered or covered with sufficient soil to prevent access by stock. This requirement would appear redundant if baits are buried to at least 8 cm as stipulated.

Directions for use of 1080 fox baits in Victoria are contained in a DNRE Landcare Note (SC355). The Landcare Note differs from the directions for use that form part of the approved label and appears to be an earlier draft of those directions. For example, the requirement on the Landcare Note that any death of stock, wildlife, and/or companion animals that is suspected of having been caused by ingestion of baits and/or from ingestion of carcasses must be reported does not appear on the registered label.

8.2.3 South Australia

The APCC product (42720) requires that use be strictly in accordance with APCC directions. The “Directions for Use” specify application rates and detailed directions.

Unused or uneaten baits must be disposed of by incineration or deep burial.

8.2.4 Western Australia

The label for 1080 Dried Meat Fox Baits (54616) states that information on nontarget animal distribution, conservation status, habitat preference, diet, tolerance to 1080, body weight and size of home range can be used to reduce the risks of baiting, which should occur at times when nontarget species are not active. The directions for use require that a formal assessment of risks to humans, domestic animals and wildlife must be undertaken before baiting is considered. Baits should be laid at least 20 m from habitat areas and should be available to foxes for about 10 days, with checking and replacement of taken baits at least every 2 days. The most effective fox control is during late winter and spring, when foxes are less mobile and food demands are high as foxes are feeding young. The recommended bait density is five per 100 ha. Baits should be placed at least 200 m apart at strategic points, such as where fox tracks are seen, along water courses, tracks and fence lines where foxes regularly travel, at prominent points within paddocks, or under or near carcasses visited by foxes. The baits should not be stored for lengthy periods, and should be buried if not used in a campaign. Any animals captured or found dead on the baited or adjacent properties during the baiting period and for 14 days after the removal of uneaten baits are to be disposed of by burning or burial.

Labels for the concentrate (42498) contain the same advice regarding information that can be used to reduce the risks of baiting. A formal assessment of risks to humans, domestic animals and wildlife must be undertaken before baiting is considered. The concentrate is used to prepare dried meat or egg baits. The label for the concentrate states that dried meat baits containing 1080 are very effective in controlling foxes. It also states that, when used according to the label, baits are safe to use and offer little risk to nontarget animals and the environment. The label does not contain directions for use of the baits but refers the user to the instructions issued by the relevant State authority. These are contained in a Farmnote (Agdex 674) on fox baiting. Requirements are the same as those specified on the label for dried meat baits, except for the 20 m buffer around bush refuges.

The label for the impregnated oat product (42538) contains similar advice. The impregnated oats are issued to approved landholders to prepare dried meat or egg baits.

8.2.5 New South Wales

Yathong Fox Bait (50911) is registered for use on NPWS managed land with application at up to 5 baits/km^2 by either helicopter or fixed-wing aircraft. Use should be in accordance with the NSW Vertebrate Pest Control Manual. It is used only to control foxes on Yathong, Nombinnie and Round Hill nature reserves which are located south of Cobar in western NSW. Use is also covered by the Pesticide Control (1080 Fox Bait) Order 2002.

8.3 Wild dog control

Five products are registered for wild dog control, to ACTA, the DNRE and the APB.

8.3.1 Doggone (49384)

The general instructions on the label note that these manufactured meat baits will also be lethal to foxes but can only be used for destruction of wild dogs unless otherwise approved by relevant authorities. It is noted that the dose in each bait is generally below that necessary to kill most mammals, birds and reptiles, and that research has shown that very few animals other than dogs and foxes are likely to dig up and consume the baits. The label states that Doggone baits should not be used where native marsupial carnivores are active, unless authorised by the relevant authority (Doggone is registered in all States and Territories except Tasmania).

The label also includes advice on degradation of the poison 1080 in the bait, stating that it will be degraded when baits are placed in moist soil. It is recommended that all bait stations be marked to facilitate bait replacement and recovery, but there is no further advice on recovering baits at the end of a campaign (recovery would seem appropriate as warning signs must be removed when poisoning is completed). The label also notes that the poison is destroyed as the carcass putrefies, and that it is unlikely that any animal could be secondarily poisoned by scavenging dog or fox carcasses. There is no need to recover carcasses.

A baiting density of about 1 bait for every 10 ha is specified, subject to local advice. Baits should be separated by at least 200 m and placed along fence lines or vehicle tracks. Instructions are provided for free feeding in bait stations, but the label notes that this is not usually necessary in most farming areas. Taken baits should be replaced as other dogs may visit the bait station. The advantages of coordinated group campaigns are noted.

8.3.2 Victoria

The label for 1080 Predator Bait (49354) instructs users to bury baits to a minimum depth of 8 cm at marked sites, and to check regularly and replace baits at sites with evidence of wild dog activity. The directions for use require that all reasonable steps be taken to collect carcasses within 4 days of baiting and to burn or bury them. These efforts are to continue for 14 days after laying of baits has ceased. There is no explicit requirement to recover untaken baits, but stock must not be returned until untaken baits have been recovered or covered with sufficient soil to prevent access by stock. This requirement would appear redundant if baits are buried to at least 8 cm as stipulated.

A DNRE Landcare Note (LC301) states that an initial baiting campaign should ideally commence in March/April, about a month before lambing/kidding/birthing when maximum livestock predation is most likely to occur, and continue until bait take ceases. Alternatively, baiting may be timed to coincide with the wild dog reproductive phase, which would require baiting to be continued through autumn and winter. Preventative control including removal of stock and native animal carcasses is encouraged as reactive control once predation commences may be less effective as dogs taking live prey are less likely to take baits.

8.3.3 Western Australia

The label for the impregnated oat product (42500) states that information on nontarget animal distribution, conservation status, habitat preference, diet, tolerance to 1080, body weight and size of home range can be used to reduce the risks of baiting, which should occur at times when nontarget species are not active. The impregnated oats are issued to approved landholders to prepare dried meat baits.

The directions for use require that a formal assessment of risks to humans, domestic animals and wildlife must be undertaken before baiting is considered.

Baits should be laid separately without using bait stations, if possible at sites where wild dog activity has been identified but otherwise at watering points and along identifiable routes such as vehicle tracks, major pads or watercourses. Baits should be left undisturbed for at least 10 days, and should be retrieved for disposal by deep burial unless at least 50 mm of rain has fallen. Any animal carcass found after baiting should be burnt or buried.

The concentrate (42498) is used to prepare meat baits for wild dog control. Label instructions for foxes and wild dogs are similar, except that wild dog baits are dosed more heavily, and eggs are not to be used for bait preparation.

8.3.4 New South Wales

Complete instructions on how wild dog baits may be used and what precautions must be taken to minimise impacts on the environment, persons, livestock, wildlife and domestic dogs are contained in the Pesticide Control (1080 Wild Dog Bait) Order 2002.

8.4 Feral pig control

The only products registered for feral pig control are the DNRE pellet bait (49352) and the APB liquid concentrate (42499). These products are also registered for rabbit control.

8.4.1 Victoria

The pellet product (49352) finds little use in Victoria. It is also used for rabbit control, as described above, and does not contain specific directions for use for pig control.

8.4.2 Western Australia

The APB concentrate (42499) may be used to prepare baits (750 mg/kg 1080) from wheat, barley, lupins or pig pellets. The directions for use state that prefeeding is essential for successful control and should be conducted for at least 10 days. The free feed should initially be placed in heaps of about 1 kg on a 5-6 m spacing, using at least 7 kg of the selected feed. At the end of this period, any remaining free feed should be removed and replaced with heaps (1-2 kg) of poisoned bait. Seven 2 kg heaps of bait equates to 10.5 g 1080. The heaps should be checked daily and topped up until pigs stop feeding. The same environmental precautions as taken with rabbit control apply.

8.5 Variations to labels

As described above, current labels contain limited information on the precautions necessary to minimise nontarget poisoning of native fauna, although a considerable amount of extension material on best baiting strategies and precautions is available. Specific label precautions would reduce the risk that inappropriately laid baits impact adversely on wildlife.

8.5.1 Grain and vegetable baits

Rabbit baits are likely to be toxic to a range of nontarget native birds and mammals. Even in south-western WA, the main rabbit bait used is likely to be toxic to many birds and small to medium native mammals because of the high loading of 4.5 mg 1080 on individual poisoned oats. There is some recognition of this risk on current labels, which may advise users to place baits in locations that are inaccessible to nontarget animals or to time baiting for when nontarget species are not active. These warnings could be better expressed as the following specific instruction: "This product may be toxic to some birds and other native wildlife. Baits should not be laid at times when, or in locations where, birds or other nontarget wildlife are likely to be harmed by them". Similar restraints are appropriate for feral pig baits based on grain, fruit or vegetables.

The carrot baits used in Tasmania for control of native herbivores present similar hazards. Labels need to specify the target species, and include a similar restraint with particular reference to bettongs and potoroos.

The herbivore and feral pig baits may be dyed blue or green to minimise uptake by birds.

As the secondary poisoning risk to native species scavenging pig, rabbit (and native herbivore) carcasses appears relatively low, there is no need from the perspective of biodiversity conservation for a label requirement that carcasses be collected. However, such a label requirement would help reduce risks to domestic dogs and avoid attracting scavenging feral species.

8.5.2 Meat baits

Labels for many fox and wild dog products advise users to bury them to a depth of 8-10 cm, particularly if they are likely to be taken by nontarget animals, but burial does not appear to be a legal requirement. Although burial should generally be preferred, to make this a legal requirement would be impractical and counterproductive, given recent research indicating that some kinds of fox baits need not be buried in quoll habitat, and that to require this would reduce the efficiency of baiting. Fox and dog baits are often surface laid.

The meat baits used for canid control are likely to be toxic to native carnivores such as quolls if they consume the baits, particularly if more than one bait is taken. However, recent research as described in section 9 of this report has shown that consumption by and harm to the spotted-tailed quoll is relatively low. All labels should therefore contain the following instruction: "This product may be toxic to some marsupial carnivores. Where appropriate, potential risks can be reduced by careful bait placement, selection of the minimum effective rate, and avoidance of baiting during the main breeding season".

As baits lose toxicity in the field, baits that are not recovered at the end of a campaign may deliver a sublethal dose to foxes. Labels should therefore advise users where appropriate to mark bait stations to facilitate the recovery of baits and their destruction by burning or burial according to State requirements at the end of a campaign.

The meat baits for feral pig control contain higher loadings than the canid baits and are likely to be toxic to carnivorous native mammals, birds of prey and goannas. As for the canid baits, burial is impractical, particularly when baiting in inaccessible areas such as Cape York Peninsula where aerial deployment is the only option. The main concern is for birds of prey, as goannas are likely to be tolerant of 1080 while recent research on spotted-tailed quolls in the southern States (see section 9 of this report) indicates that these animals tend to consume only small quantities of 1080 meat baits laid for wild dogs. While quoll populations have declined markedly on Cape York, the main causal factor is believed to be invasion by cane toads. Label instructions that would minimise the risk to birds of prey of aerially deployed meat baits laid for pigs are not feasible.

9 PUBLIC SUBMISSIONS AND VIEWS

Public submissions were received on the scoping document and the preliminary review findings, as summarised below.

9.1 Initial submissions

Submissions to the scoping document were received from a wide range of interested parties. The majority were supportive of continued use, citing the following arguments.

1080 is a naturally occurring compound that does not persist in the environment nor accumulate in wildlife. Its availability and use are tightly controlled by State authorities. Differences in sensitivity (carnivores and especially canids most sensitive, native species more tolerant than introduced) and feeding preferences allow target selectivity, while greater tolerance in WA makes target selectivity easier to achieve. There are biodiversity conservation benefits from the use of 1080, such as successful fauna reintroductions in WA and elsewhere in Australia.

Use of 1080 to control browsing mammals in Tasmania exerts a temporary “knock-down” effect on target animals and sometimes kills a few non-target animals, but spotlight surveys indicate that baiting is not reducing populations of target or nontarget animals. 1080 is an essential tool for forestry plantation establishment in Tasmania, although not the complete answer.

More broadly, 1080 is a vital tool for agriculture that also protects flora and fauna; its removal or restriction would lead to increased use of illegal alternatives which are more damaging to the environment, and to increased predation and competition for native animal populations.

Coordinated area campaigns are most effective for canid control, but may be difficult to achieve in some areas due to opposition by some landholders, mainly because of concerns for dogs. 1080 is known to kill domestic dogs, but many respondents consider that dogs should be under closer supervision. Rare species such as quolls are also sensitive but continue to be seen in previously baited areas, sometimes after not being sighted for many years.

Agricultural interests expressed a view that the review should focus on labelling and related control of use aspects, and analysis of alternatives with a focus on efficacy.

A number of respondents, while recognising the benefits of 1080, considered that some aspects of its use needed to be further explored or refined.

The issue of bait uptake was a prominent theme. Further research is needed into bait movement, including caching of baits by foxes, as this may increase nontarget risks. The lower palatability and consequent increased rate of caching for commercial baits was identified as a potential shortcoming. There is a general need for specific data on bait uptake by target and nontarget species.

Evidence that 1080 impacts on quolls was presented, and the following issues were identified: bait specificity (whether dried meat baits are less attractive to quolls), mound baiting (optimal depth for bait burial and independent auditing) and possible secondary poisoning during rabbit baiting operations. It was argued that aerial baiting should not occur in quoll habitat as the impact is likely to be significant and could be a major factor in the ongoing decline of mainland species. It was noted that aerial baiting has ceased in Kosciuszko National Park because of these concerns, but that adjacent landholders don’t believe that the current ground baiting operation is as effective, even though this occurs throughout the year whereas the former aerial operations were conducted annually. Further research is underway to try and resolve this issue.

A number of respondents argued that the humaneness of 1080 is a crucial aspect that must be addressed. Research into alternative methods, such as use of the prolactin inhibitor cabergoline or the M44 ejector, was highlighted.

A minority of respondents to the review were not comfortable with the use of 1080, with some favouring a ban or tighter restrictions. Issues raised included that distribution to landholders should be banned because of risks to dogs. Some contended that 1080 should be banned completely because of impacts on native fauna. These views were more prevalent in Tasmania, where many people are opposed to the use of 1080 to control native fauna, particularly during the establishment of forestry plantations. Decisions should be based on the precautionary principle.

Note that the Tasmanian community has already recommended that 1080 be phased out. Tasmania *Together* is a community owned 20 year Social, Environmental and Economic Plan that was launched in September 2001 following an extensive public consultation phase. It contains 212 benchmarks grouped under 24 goals, the last of which is to "ensure our natural resources are managed in a sustainable way now and for future generations". This goal encompasses a range of standards, including to "reduce reliance on chemical use by primary, secondary and tertiary industry and the domestic sector". Usage of 1080 has been selected as an interim indicator, and is to show a reduction of 50% from 1999/2000 levels (around 15 kg/annum) by 2005 and 75% by 2010 with cessation of use by 2015. The following rationale is provided: "The continued use of 1080 is not acceptable. However, time is needed to develop viable alternatives to 1080 and phase it out in a non-disruptive way. In choosing the level of use of 1080 as an indicator against this standard, the benchmarking committee did not consider it the most relevant, but one for which data was readily available".

9.2 Responses to preliminary review findings

A total of 50 responses to the preliminary review findings was received, as listed at the end of this report. Most were supportive of the continued use of 1080, although not necessarily of the proposed label variations, but a significant proportion remained opposed to various degrees.

Supporters of 1080 emphasised its vital importance in protecting the Australian environment and its agricultural industries from introduced vertebrate pests, noting the high effectiveness of 1080 and minimal harmful impact on nontarget native animals. The main concern of opponents was the perceived cruelty of this poison. Concerns were also expressed that 1080 may not be effective, and that its use is harmful to nontarget native animals and valued domestic animals.

The major issues raised in the responses to the preliminary review findings are discussed in more detail below. The responses to the issues raised are italicised for clarity. As well as these major issues, many smaller points of a more technical nature were raised. Where appropriate, the technical report has been amended in line with these comments, and with the broader arguments that are presented below. The detail of these arguments, and the new research that has been conducted since the technical report was drafted, are collected in this section of the technical report rather than being distributed through the report.

9.2.1 Bait shyness and free feeding

Several respondents (1, 10, 12, 13, 15, 16) argued that the review findings are based on the false premise that substantial bait shyness occurs in Australia with 1080 use. A registrant (2) argued that bait shyness is not well supported by fact and is often used as a scapegoat for other failures. For example, dogs may refuse a bait unless the bait matrix matches the food source on which they are relying in a particular area, or may fail to locate a bait because it has been taken by a fox or other nontarget, particularly birds for surface laid baits.

Although bait shyness, a conditioned food aversion, is less likely to occur with 1080 use than with other acute poisons because of the lag phase that precedes the onset of symptoms, bait shyness has been reported in the eastern States, particularly in canids (eg Allen et al, 1996). It is acknowledged that there are many reasons why a dog may refuse a bait, and that failure to take a bait does not necessarily indicate bait shyness. Because bait shyness has a precise definition based on sublethal bait exposure, this term will be removed from the technical report, except where mentioned in references.

The single dose baits used for dogs and foxes can be consumed rapidly by the target animals, while more time will usually elapse before a lethal amount of the laced grain and carrot baits is ingested by herbivores and feral pigs. The uptake of grain and carrot baits is usually encouraged by free feeding with nontoxic bait. Several respondents (7, 21, 24) affirmed their use of free feeding as a technique for ensuring bait uptake by the target pests, although there was a general preference for this to be a recommendation rather than a requirement. A registrant (2) cautioned that there is little requirement for free feeding in fox or wild dog operations unless there is a need to check for quoll or other high risk animals being able to access the baits. A local pest animal control group expressed the view that pre-poison monitoring, correct bait type and bait location by experienced personnel (9) are a more effective alternative to free feeding when baiting for wild dogs. Some respondents (3, 5, 16, 38) suggested that free feeding may be counterproductive in that it could encourage nontarget species to feed on the bait.

It is acknowledged that free feeding is not intended to address problems of bait shyness, but rather is a technique for overcoming neophobia, or the natural reluctance of some target animals to take a bait. It is also useful to determine how much toxic bait to lay, and can assist in determining where baiting should not occur because of the risk of non-target uptake. Free feeding is not particularly useful for canids, except where required to address non-target risks, and is obviously impractical where baits are aerially deployed. Free feeding appears most advantageous with the ground baiting of pigs, and is also important for rabbits and other herbivores, except when using the one-shot product.

Note that free feeding feral pigs with meat is illegal, because of the risk of disease transmission. Although this does not apply to poison baiting, users should be mindful that meat baits could be a means of spreading exotic disease if the meat is sourced from outside the property where baiting is conducted.

9.2.2 Risk to nontarget native animals

Several respondents (1, 10, 12, 13, 15, 16) argued that the review findings are based on the false premise that there is a substantial risk to native Australian nontarget animals with 1080 use.

It is true that there may be a substantial risk of harm to some individual nontarget animals if they consume certain baits. It is equally true that with careful use, the risk to native nontarget populations is low, while benefits may be expected from the removal of feral predators and competitors. The review findings are based on the need to protect populations, including locally isolated populations of sensitive species such as Tasmanian bettongs and potoroos, but with recognition that avoidance of harm to individual nontarget animals is also desirable provided that it does not compromise effective control of the target pests.

Some respondents (3, 38) criticised the review for concentrating on preventing harm to populations rather than individual animals.

The approach taken in the report is consistent with that generally adopted for environmental risk assessment, that is, environmental risk assessment differs from human health risk assessment in that the aim is to protect populations or ecosystems rather than individuals (DEH, 2003). The US EPA's working definition of risk assessment is "a process in which information is analyzed to determine if an environmental hazard might cause harm to exposed persons and ecosystems" (US EPA, 2004).

The focus on populations rather than individual animals was also criticised (38) on the basis that data are inadequate to demonstrate that the use of 1080 does not harm nontarget populations. It was argued that the technical report contains numerous unsupported assertions regarding the efficacy of 1080 baiting and the supposed benefit of bait-targeting techniques. Furthermore, it was contended that DEH has a conflict of interest in providing advice to the APVMA regarding the environmental risks of 1080 baiting given the large scale use of 1080 as a part of conservation and pest animal control programmes.

There is no conflict of interest in DEH advising the APVMA of the likelihood of environmental harm from the use of 1080. The DEH assessment was conducted by the Chemical Assessment Section, which is entirely separate from the areas that oversee wildlife management issues. It followed a weight-of-evidence approach based on scientific knowledge and practical experience of how 1080 behaves in the environment and its effects on living organisms. If there was evidence that the use of 1080 is causing harm to the Australian environment, DEH would advise the APVMA of this without hesitation and insist that action be taken to prevent or minimise the harm.

Similarly, Animals Australia, the peak body representing various animal advocacy organisations, argued that the review has no scientific basis for concluding that mortality in individual nontarget animals will not harm their populations, and that the killing of target animals by 1080 will assist in the conservation of biodiversity (3). According to Animals Australia, 1080 baiting should be discontinued because of the precautionary principle.

Principle 15 of the Rio declaration (UN Conference on Environment and Development, 1992) says that a lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there are threats of serious or irreversible environmental damage. Contrary to the Animals Australia position, preventing the use of 1080 baiting to protect threatened native species from introduced animals could be an action in conflict with the Principle, where such a restriction would threaten serious or irreversible damage to those native species. The view held by many wildlife biologists is that the risks posed to some native species by unchecked populations of introduced animals are much larger than the risks posed by current control methods, including 1080 baiting which is well researched and tightly regulated by the States.

9.2.3 Efficacy

RSPCA Australia asked where the relevant scientific analyses are relating to efficacy (particularly in terms of impacts at the population level for the pest species and impacts in predation and stock losses). Particular concern was expressed regarding the very limited data available regarding the effect of baiting on dog numbers or signs. Scientific evidence regarding the efficacy of aerial baiting and other techniques for dingoes was requested. RSPCA Australia contended that the effectiveness of 1080 has never been adequately determined.

Under national registration, the APVMA's efficacy evaluation of pest control chemicals is generally outsourced to State department and external reviewers. State reviewers are employed in the State departments of agriculture. The efficacy of 1080 in controlling the target pests was not raised as a concern for the review.

The environmental assessment did not evaluate the efficacy of 1080, except to the extent that the effectiveness of 1080 in biodiversity conservation was considered. This consideration is discussed in the following section. Note that wild dogs are primarily a problem for agricultural production rather than biodiversity conservation; although it is logical to assume that they can also harm native species, and there are high profile examples of such threats, such as to the northern hairy-nosed wombat. State agricultural authorities and other respondents (eg 10, 13, 36) affirmed in their responses to the review that 1080 is effective at controlling the target pests, including wild dogs.

Several respondents (1, 11, 12, 13, 15, 16) endorsed the view that scale is an important consideration when evaluating the suitability of a control method. While warren ripping is useful in broad scale rabbit control operations, most of the alternative techniques to 1080 baiting are not practical or suitable for broad scale control of vertebrate pests, although they may be viable for small areas. Because of the broad distribution of feral animals and their capacity to repopulate, particularly into small areas, broad scale methods are often needed for control of feral animals in Australia. Aerial application is advantageous when conducting broad scale baiting programs as it enables treatment of large areas within a short timeframe, including rugged terrain where ground baiting would be difficult. The Australian Dingo Control Association (5) asked that no large scale baiting including aerial baiting be permitted, particularly in remote regions, arguing that there is no justification for such activity except that it is the easy option. RSPCA Australia noted that no data are provided to support the assertion that smaller baited areas are more susceptible to reinvasion by foxes.

It is difficult to understand why the advantages of broadscale baiting would be questioned. An area from which foxes have been removed will more easily be recolonised by them if a source of *recolonisation is located nearby, as tends to be the case when only small areas are baited. The success of large scale programs such as Western Shield provides strong evidence for the advantages of treating large areas. Experts in wildlife management were unanimous in their support for the benefits of 1080 for biodiversity.* For example, the Australian Mammal Society (42) emphasised the critical importance of broad scale 1080 baiting programs to the conservation of Australia's mammal fauna.

9.2.4 Biodiversity conservation

As noted above, Animals Australia argued that negligible evidence has been presented to demonstrate that lethal control of feral animals assists in the conservation of biodiversity (3).

This group has argued elsewhere (SCAFF, 2005) that feral animals with established populations in Australia must be permitted to settle into their new niches and stabilise their populations with a minimum of human interference, even if this entails the extinction of some native species. This peak body has correctly identified that some native species would face a serious risk of extinction if 1080 baiting of feral animals were to be curtailed.

Strong evidence exists to demonstrate that feral animal control using 1080 is likely to assist in the conservation of biodiversity. It appears contradictory to argue in favour of the precautionary approach while insisting that human interference with feral animal populations be minimised, given the serious and irreversible environmental damage that can be expected from uncontrolled feral populations. Competition and land degradation by feral rabbits, predation by the European red fox, predation, habitat degradation, competition and disease transmission by feral pigs and predation by feral cats are listed as key threatening processes under the Environment Protection and Biodiversity Conservation Act 1999. Poison (1080) baiting is the most effective way of reducing numbers of these pests, particularly for rabbits and foxes.

Concerns regarding the scientific evidence supporting the importance of 1080 for biodiversity conservation were also expressed by RSPCA Australia (38). The technical report was criticised for its reliance on unsupported assertions regarding the efficacy of 1080 baiting and the supposed benefit of bait-targeting techniques.

It is true that the evidence for the benefits of 1080 in protecting native species is largely observational in nature, rather than based on replicated trials in which the effects of baiting are determined by comparison of treatment and control sites. A recent survey of pest animal control operations conducted mainly for biodiversity conservation concluded that because of poor experimental design there is "almost no reliable knowledge concerning the consequences of pest animal control, including benefits or otherwise to native species" (Reddiex et al, 2004). Although the benefits of fox control have been demonstrated experimentally for several native species, largely in Western Australia, the benefits of feral rabbit and feral pig control are largely derived from observational studies, while no information is available on the benefits of wild dog control. Standard protocols are needed for estimating kill rates and absolute or relative abundances of pest animals and native species. Unless studies are carefully designed, with the results of baiting evaluated over treatment and control sites, it is difficult to determine whether any benefits that may arise are due to baiting or include other factors such as habitat change, climate or disease.

A recent review of progress on invasive species (Agtrans, 2005) has identified some of the reasons why there are few hard scientific data to underpin the use of 1080. Information on the abundance of established animal pests tends to be patchy and inconsistent, with interpretation difficult because of seasonal variability, and trends not easy to identify. Assessing and quantifying impacts is difficult as knowledge of the precise contribution of an invasive species to the impact on native species or the wider ecosystem is not always particularly well understood or described.

Notwithstanding the lack of hard scientific data, there is a widespread understanding that feral animals are a major threat to the conservation of biodiversity and agricultural production. It is reasonable to expect that threatened species will benefit when the threats posed to those species are controlled, particularly given the outstanding results from flagship programs such as Western Shield. While it is true that the benefits of 1080 for biodiversity conservation are often not known with full scientific certainty, the cessation of 1080 use would entail a strong likelihood of *serious or irreversible damage to some native species.* The dangers of foxes in particular to Australia's native mammals are well illustrated by one respondent (47) who recalled the surplus killing of more than a hundred bettongs by a single fox in a period of days before it was eliminated.

Shortcomings in the data supporting the benefits to native species of feral animal control measures are not unique to 1080. The field of wildlife management has been strongly criticised for its heavy reliance on information generated from descriptive studies and its slow adoption of experimental designs to examine the effects of management actions. That does not mean that wildlife management should be discontinued until such time as complete data are available, particularly as such data may often best be derived from wildlife management programs (including 1080 baiting) conducted in an adaptive management framework.

9.2.5 Humaneness

A number of respondents (3, 4, 5, 29, 33, 37, 38, 41, 46) were opposed to the use of 1080 because of their strong belief that it is cruel and inhumane. Another (48) argued that 1080 may be inhumane, and that the APVMA should amend legislation so that the humaneness of a pest control agent must be a specific criterion with which the APVMA is satisfied.

RSPCA Australia (38) provided detailed scientific argument to support the contention that 1080 is inhumane, including evidence from human exposures (Sherley, 2004). These cases have identified symptoms of pain or distress, such as anxiety, irritability, agitation, hyperactivity, epigastric pain, headache, nausea and vomiting, faecal incontinence, respiratory distress, hyperaesthesia, muscular pain and tetanic spasms.

It is important to note that the technical report did not find that 1080 is humane. The review noted that some pain and distress is always likely to occur in poisoned animals, but there is conflicting argument in the literature on whether pain from 1080 poisoning is severe. Although not explicitly stated in the review, there is a general understanding that some alternative poisons such as strychnine do cause severe pain and should not be used where more specific and humane alternatives such as 1080 are available.

RSPCA Australia (38) argued that it would be better to remove any discussion of animal welfare from the review report rather than presenting allegedly false and misleading information based almost entirely on a highly biased conference proceeding, the author of which set out with the stated intention of demonstrating 1080 baiting to be humane. Several respondents (1, 11, 12, 13, 15, 16) endorsed the view that all reference to animal welfare should be deleted except for the statement that humaneness of a pest control agent is not a specific criterion under the Agvet legislation. These respondents contended that the current presentation of the animal welfare issue is biased as only the "opponents to 1080-use" view is included in the executive summary.

It is reaffirmed that humaneness is not a criterion that can be considered by the APVMA when determining the acceptability of vertebrate pest control agents. The issue of humaneness is contentious, as illustrated by accusations of bias from groups opposed to and supportive of the use of 1080, and unlikely to be resolved through science alone.

Accordingly, the discussion of animal welfare issues in the technical report has been amended to focus on the scientific information available. The information presented has been more clearly referenced, and has been expanded to include the findings of Sherley (2004) which should have been included but were overlooked in the draft that was released for public consultation.

9.2.6 Secondary poisoning

A key finding of the review was that the secondary poisoning risks of 1080 are much lower than has previously been believed, with native species considered unlikely to be secondarily poisoned by 1080 residues, except for the dingo. Older residue data were obtained by a nonspecific analytical method that did not allow for the detoxification of fluoroacetate to fluoride in living animals. Newer data obtained using an analytical method that detects only fluoroacetate indicate that residue levels in rabbits and rats are low, although the stomach and contents may retain higher residues.

This finding has been criticised by RSPCA Australia on the basis that it is impossible to determine the extent to which the older analytical method overestimated the actual residues present. Furthermore, it is claimed that the carcasses analysed with the more specific method were in some cases weeks or even months old.

While the former criticism is correct, the more recent analyses clearly indicate that the older data substantially exaggerate the residues present. Thus mean residues measured in muscle samples from rabbit carcasses recovered from the field were determined to be 23 mg/kg using the nonspecific method but only 0.35 mg/kg using the specific method. The criticism that the more recent data were obtained on old carcasses is unfounded. The carcasses were collected 2 days after death, based on radio-telemetry, and within 6 days of bait laying. Samples were kept frozen until analysis. The review also noted that, in contrast to living animals, fluoroacetate residues tend to be persistent in carcasses. Studies on rabbits poisoned in the laboratory have confirmed that tissue residues of 1080 are low, even though the doses administered were high enough to kill most of the rabbits within 3 hours.

Recently published residue data for free-ranging pigs recovered after baiting in northern rangeland and agricultural areas of WA confirm the low risk of secondary poisoning for native animals even where bait concentrations are high (Twigg et al, 2005). The pigs were baited with grain (wheat or malted barley) laced with 670 mg/kg 1080. Fluoroacetate residues were determined by gas chromatographic analysis of the dichloroanilide. The maximum residues recorded in muscle and liver were 2.42 and 4.28 mg/kg, with mean residues of 0.70±0.54 and 0.64±1.09 mg/kg, respectively. Carcasses were scavenged by birds of prey with no apparent lethal effects, but the gut contents were infrequently consumed. Only dogs, cats and foxes were predicted to be at risk of secondary poisoning from consumption of pig meat or liver (15% of body weight) contaminated at the highest recorded levels. Most pig carcasses were recovered within 24 hours of baiting. Although 1080 residues are usually stable in carcasses, they appeared to decline in the pig carcasses, as mean residues were close to 1 mg/kg in 41 carcasses discovered within 24 hours from the rangeland sites but fell to around 0.5 mg/kg in 13 carcasses sampled 24-48 hours after death, and further to 0.2 mg/kg in 3 carcasses discovered at 48-72 hours. Residues were much lower (0.38±0.22 mg/kg) in 17 carcasses recovered from the agricultural site, all within 24 hours of death.

These authors also found a very low incidence of vomiting, suggesting that this may reflect differences between the natural diet in the field and the laboratory diet in earlier studies where pigs vomited frequently.

As well as criticising the interpretation of residue data, RSPCA Australia argues that secondary poisoning should be given an appropriate weighting as the technical report demonstrates that secondary poisoning does occur.

It is true that the technical report included reports of secondary poisoning in Australia and elsewhere. However, the species involved in Australia (dogs, foxes and perhaps cats) and New Zealand (ferrets and cats) are introduced, and more sensitive to 1080 than are Australian native carnivores (with the exception of dingoes). Similarly, the native species (coyotes, bobcats, skunks and kit foxes) reported to have died of secondary poisoning in the US are more sensitive than their Australian counterparts (except dingoes). Given the focus of the review on Australian native fauna, it is considered that adequate weight has been given to the available reports of secondary poisoning in determining the environmental safety of 1080.

The Conservation Council of Western Australia (10) correctly noted that the secondary poisoning of foxes during rabbit baiting programs should be seen as value adding rather than a risk. Another respondent from WA (21) advised that baiting programs are set up to intentionally increase the secondary poisoning of foxes through rabbits.

One respondent (41) maintained that Tasmanian devils are common victims of secondary poisoning through lethal and sublethal ingestion of poisoned carcasses.

This assertion is unfounded. The sensitivity of Tasmanian devils to 1080 has been determined scientifically. Tasmanian devils are much less sensitive to 1080 than are the target animals, and unlikely to suffer secondary poisoning even if it is assumed that 1080 is not metabolised in the target animal.

9.2.7 Spotted-tailed quolls

The Managing Ranger for the Cooma RLPB (9) noted that recent studies in Kosciuszko National Park had shown that aerial baiting at 10 baits/km does not impact on quolls, and that similar results had been obtained from trials in New England. Mr Seears recommended that this work be considered in recommendations. The NSW Department of Environment and Conservation (DEC) also referred to this research, and confirmed that no aerial baiting would be conducted by them without site-specific risk assessments, because of potential impacts on individual quolls and other native animals.

It is agreed that the recent trial results, which are described on the website for the NSW DEC, must be considered when reformulating the review recommendations. Information on quoll impacts was limited when the review was circulated for public comment. Published work from New England had shown low uptake of Foxoff baits by spotted-tailed quolls, while unpublished research results from Queensland included the recovery of two quoll carcasses testing positive for 1080 within seven days of laying fresh meat baits on a 500 m spacing for wild dog control. The deaths in Queensland were recorded over three baiting campaigns during which 56 quolls had been radio-tracked, and were consistent with earlier reports that a quoll carcass had been recovered following baiting for wild dogs in SE NSW, with residue analysis confirming that it was killed by 1080 poisoning.

The more recent trials were conducted with fresh meat baits, dried overnight before injection with 6 mg 1080 and the bait marker Rhodamine B. This marker temporarily stains the mouth and digestive tract of an animal that eats bait, and is subsequently incorporated into the animal's whiskers as a fluorescent band, provided that the animal survives. Quolls in the study area were trapped, equipped with identity transponders and radio-transmitters, and radio-tracked from the ground and from helicopters for several weeks after baiting.

The first trial was conducted on the Northern Tablelands of NSW in an area with a continuous history of aerial baiting for 30 years. Results have been published (Körtner and Watson, 2005). Seven quolls died from the 31 animals that were monitored after baiting at 40 baits/km. Only one of these quolls tested positive to 1080 (0.85 mg/kg in stomach and contents, and 0.28 mg/kg in the liver). This animal died 23 days after baiting, when bait toxicity would have dropped to sublethal levels, but had also suffered severe injuries before death. Whisker analysis indicated that a further five quolls from the 35 animals sampled after baiting had eaten bait and survived. The low rate of bait consumption compared with trials using nontoxic baits raised questions as to whether the quolls in this regularly baited area may have developed an aversion to baits.

To address this question, further studies were conducted at sites on the Northern Tablelands and in Kosciuszko National Park where aerial baiting had not been used for some years.

On the Northern Tablelands, two mortalities were recorded from the 14 radio-collared quolls that were monitored. These deaths occurred 29 and 34 days after baiting at 40 baits/km. Neither tested positive for 1080. The first appeared to have been killed by a large predator, probably a dog, while the second possibly succumbed to exposure during a prolonged cold and wet period. Exposure to baits was high in this study, with 13 quolls (including the two dead males) having eaten 1080 baits and survived based on markings in the whiskers sampled from 19 trapped quolls. Most whiskers displayed more than two bands, with six bands in one female, but the markings were faint.

In Kosciuszko National Park, a single quoll died from the 16 that were equipped with radio-collars, but did not test positive for 1080. Six of eighteen whisker samples collected from live quolls after baiting were positive for rhodamine B, but as single bands except for one animal with two bands. Again, the markings were faint. Note that this trial used a lower application rate of 10 baits/km because it was conducted in National Park.

The results of these trials indicate that aerial baiting at 40 baits/km, or 10 baits/km in National Park, had a minimal impact on the quoll populations studied, irrespective of whether the areas studied had a recent history of aerial baiting.

Preliminary work (Claridge et al, 2006) in a known (trappable) population of spotted-tailed quolls in Kosciuszko National Park using nontoxic baits provides some insights into the likely risks to quolls associated with increased bait density along transects. Because of their territorial nature, *not all animals within a population will have ranges that overlap with bait transects. There may be a high availability of alternative and preferred food for quolls in some baited areas. Not all quolls will be behaviourally inclined to eat carrion. Other animals (dogs, foxes, cats and various forest-dwelling birds) are also likely to encounter and consume baits. This means that increasing the bait density along a transect should not be assumed to lead to a higher incidence of exposure in a quoll population, but would increase the likelihood of multiple bait encounters by individual quolls that are inclined to take baits and have ranges that overlap with the bait transect. Thus the encounter rates for nontoxic baits in earlier work by Murray and Poore (2004) and in these investigations were very similar at 63%, 67% and 47%, respectively, at rates of 40, 4 and 10 baits/km. Whisker samples, where positive for the biomarker in the bait, contained only a single band at the lowest rate, but some contained multiple bands at the higher rates.*

These authors caution that the encounter rates in nontoxic bait trials only assess extreme risk, rather than actual mortality. The use of toxic baits would not necessarily lead to the same level of bait consumption as some native animals appear to be able to detect the presence of 1080 in baits and reduce their consumption in response. Bait toxicity is likely to decline before quolls discover a bait, and questions remain as to how much 1080 is assimilated following consumption of a meat bait. Furthermore, any losses from toxic baiting may be fewer than would occur due to direct or exploitation competition by canids in the absence of baiting. The relationship between theoretical risk and actual mortality needs to be evaluated during aerial baiting in the field, as has been done in the toxic bait studies described above.

It is considered that this recent research confirms that the risks to spotted-tailed quolls from 1080 wild dog baiting are much lower than had previously been suspected. This largely reflects the relatively low levels of consumption of toxic baits by quolls. Although some quolls may be killed by 1080 wild dog baits, most quolls are likely to die of other causes. The low level of mortality is not likely to harm populations, particularly when considered against the likely benefits from canid removal.

9.2.8 Dingoes

The Australian Dingo Control Association (5) is opposed to the use of 1080 as a means of eradicating wild dogs and dingoes, noting that the dingo was listed in 2004 by the IUCN as a vulnerable species, with 1080 poison baiting and hybridity identified as the key threatening processes. This group asked that dingoes be listed as a nontarget species on all wild dog labels, arguing that the killing of dingoes tends to exacerbate hybridity by allowing introgression by feral dogs. Similarly, Wildlife Advocate Inc (46) called for the deregistration of 1080 for dingo control, noting that pure dingoes are rare in southern and north-eastern regions and probably extinct in the south-eastern and south-western regions, although they remain common in northern, north-western and central regions.

One issue that was not discussed in detail in the technical report is the need to discriminate between wild dogs and dingoes, as the latter are usually regarded as native mammals. This is generally a minor consideration for pastoral enterprises, as the dogs that are targetted in order to protect sheep tend to be feral or hybrid animals, but is a significant issue for the NT.

It is thought that over 90% of wild dogs in the NT are pure dingoes, with hybrid and feral domestic dogs occurring mainly in the vicinity of human habitation. This differs from eastern and southern Australia where over half the wild dog population are hybrids. The relatively undisturbed status of NT dingoes reflects in part the less intensive wild dog control measures that have been conducted in that jurisdiction, largely because livestock production mainly involves cattle which are less susceptible to dingo predation than are sheep. The dingo is classified as protected wildlife under the Territory Parks and Wildlife Conservation Act 2000, and of cultural significance to Indigenous people in the NT. Access to 1080 baits and control of the use of concentrate is therefore restricted in the NT.

The need to find a balance between protecting stock and native wildlife from wild dog predation while meeting expectations that the dingo will be conserved because it arrived in Australia prior to European settlement is recognised in the southern States. In addition, it is recognised that wild dogs may play an important ecological role in preventing some fauna from becoming over *abundant. For example, the NSW DEC established a wild dog policy in 1997, and updated it in May 2005.*

The policy notes that populations of wild dogs in NSW, including dingoes, mainly occur along the great dividing range and coastal hinterlands, and in Sturt National Park in the far north-west, but that the proportion of pure dingoes among these populations is unknown. It is often difficult to distinguish a pure dingo from a dingo-like wild dog, and available control methods generally do not discriminate between them. The DEC does not have the means to prevent further dilution of the dingo gene pool by domestic dogs.

Under the policy, the DEC will only undertake wild dog control on its lands where the impact on the dingo population will not threaten the viability of that population within certain lands identified under the Pest Control Order for Wild Dogs. Wherever possible, wild dog control will focus on the perimeter of lands acquired or reserved under the National Parks and Wildlife Act 1974. Wild dog control will only be conducted as part of a coordinated and strategic campaign, albeit with provision for swift control responses. A conservation risk assessment must be conducted for all wild dog control programs. Aerial baiting is restricted to rotary winged aircraft.

As noted above, pressures on dingoes are not restricted to 1080 but include hybridity. Control activities on the perimeter of conservation estate are likely to affect hybrid animals rather than pure dingoes.

9.2.9 Domestic dogs

A number of respondents (8, 25, 26, 29, 30, 33, 50) criticised the review for not paying more attention to the risks of 1080 for domestic dogs. Some were concerned for the safety of their own domestic animals, noting the lack of an effective antidote. It was suggested that 1080 fox baits are simply too potent and dangerous to be made available to landholders.

The focus of the technical report was on native rather than domestic animals. Concerns had been expressed regarding the effects of 1080 on native species such as the spotted-tailed quoll. Although the death of any domestic animal from 1080 poisoning is undesirable, there are no suggestions that such incidents have any adverse consequences for biodiversity conservation, except to the extent that they engender opposition to the use of 1080.

Some respondents (10, 28) expressed strong opposition to any restriction on 1080 baits based on the risks to domestic dogs, noting that domestic dogs impact on biodiversity by killing native species such as bandicoots, shingleback lizards and waterfowl. It was suggested that closer attention to warning signs would reduce the incidence of dogs being poisoned on private or government owned land.

9.2.10 Human safety

RSPCA Australia criticised the review for not addressing human safety issues. Concerns were expressed by others (8, 29, 35) for the possible poisoning of young children. One respondent (29) advised in relation to fox baiting on Ballina Beach that "a child only has to touch a bait and lick its hands and you know the consequences", that such usage "could have a devastating effect on non-target animals and human beings – especially children", and that "local communities are not made aware that any unrecovered baits are still able to kill animals, birds or human beings". Some other respondents (4, 46) argued that 1080 should be banned because of its dangers to humans.

Human health issues were not included in the review as they were determined to be of low priority. Although 1080 is clearly too dangerous to be made generally available in its pure form, it has a very good human safety record because of the tight restrictions on its supply. This was specifically noted by one respondent (22). *There is far too little 1080 in a fox bait to be harmful to humans, including small children. Suggestions that children may be harmed by 1080 if they touch a fox bait and lick their hands are unfounded.*

9.2.11 South Ballina beaches

Several respondents (8, 26, 29, 30) raised specific concerns regarding the use of 1080 baits to control foxes on beaches in the Ballina region. A Ballina Shire Councillor (29) called for 1080 to be banned on public beaches and public land, noting the Tasmanian policy that use of 1080 on public land would cease at the end of 2005.

The South Ballina beaches are known as one of the most important breeding areas for pied oystercatchers in NSW, but are facing increasing human pressures. Fox baiting has been conducted in this area since 1997 in order to protect threatened shorebirds, particularly pied oystercatchers, that nest on the beach. Baiting is regarded as the most effective means of controlling foxes. Chicken heads are injected with 1080 and buried in the sand.

This issue is the responsibility of the State of NSW. It is noted that the baiting program has significantly improved fledgling success rates of threatened shorebirds. Dogs are at high risk of poisoning if they consume a bait that has been laid for foxes. Signs are posted to warn visitors of this risk. The risk to native wildlife is low because the baits only contain 3 mg 1080, and are buried to improve selectivity for the target pest. Ballina residents can assist this program by restraining dogs on beaches so that they do not disturb nesting shorebirds.

Off-lead dog exercise areas are proposed to be tightly restricted with dogs prohibited from other beach areas under the Draft Threatened Species (Pied Oystercatcher) Management Strategy that has been developed by an interagency group, led by the NSW Department of Lands and including the Ballina Shire Council.

It is noted that the Ballina Shire Council considered the Draft Strategy on 23 March 2006. It was recommended that Council inform the Department of Lands that it does not object to those aspects of the draft strategy that apply exclusively to public land.

9.2.12 Tasmania

Specific concerns were also raised regarding the use of 1080 in Tasmania (41, 46). The Tasmanian Conservation Trust disagreed with the review finding that use of 1080 in Australia does not give rise to widespread or serious impacts on native fauna and expressed disappointment that the review did not recommend reducing or terminating the use of 1080 in Tasmania for control of native herbivores. This group asked why the APVMA applied different standards to Tasmania and to the mainland, where the poisoning of marsupials with 1080 is regarded as unacceptable.

The suggestion that Tasmania has been treated differently under the review is unfounded. The objective of the 1080 review was to ensure that its use does not threaten nontarget native animals at the population level, including locally isolated sub-populations. The review examined only the registered uses of 1080. The use of 1080 for control of native herbivores has been phased out from mainland Australia, where pest pressures are different and involve less abundant species such as swamp wallabies. Common criteria were used for Tasmania and mainland Australia, namely that use according to label would not be likely to have an unintended effect that is harmful to animals. The scientific evidence presented for review indicated that overall populations of target and nontarget wildlife in Tasmania are not harmed by the use of 1080 to reduce local populations. Harmful effects had been recorded for local sub-populations of Tasmanian bettongs, but not for ten years. The review proposed label warnings to minimise the risk that such incidents would be repeated.

It is true that the use of 1080 to control native animals is unacceptable to broad sections of Australian society, including in Tasmania. However, social acceptability is not a criterion that can be considered under the national registration scheme. The APVMA must base its decision on scientific evidence. Social acceptability is a separate matter to be considered by governments. Under the Tasmanian Community Forest Agreement, the Australian government has provided $4 million to fast track research, set up demonstration sites and encourage greater research into practical alternatives to 1080.

9.2.13 Proposed review recommendations

The proposed label variations attracted many comments, including a whole of government response from Western Australia that was supported by several respondents. For example, the Agriculture Protection Board (1) noted that the authorised persons who can access 1080 solutions in WA are not limited to staff from Government agencies, but include licensed pest control officers who, after suitable training, are licensed by the Commissioner for Health. The NSW DEC queried the proposed label statement that only authorised personnel can have access to baits on the basis that the terminology is ambiguous, and suggested that it be rephrased to "Only personnel authorised under State/Territory legislation can have access to baits". The NSW Department of Primary Industries (DPI) noted that it is necessary to distinguish between authorised persons, who are allowed to access the concentrate and prepare baits, and approved end-users, who are usually different people.

Comments on the proposed review recommendations were mainly provided by State authorities in WA, Tas, SA, NSW and Qld, with support from community conservation organisations.

There was a general view that mandatory label statements were too inflexible, given the wide range of situations in which 1080 is used. For example, it may be desirable to relax some conditions, such as distance restrictions, provided that the decision is made by an authorised person after first determining that risks would not be increased. One option suggested for addressing this was to qualify label statements with the phrase "unless otherwise approved by State authorities".

Most of the proposed label variations relate to human sensitivities, including risks to domestic dogs, rather than environmental protection. These are largely based on the findings of the VPC review, but nevertheless encountered widespread criticism. DEH will confine any specific comments on the proposed label variations to those intended for environmental protection, but notes that the views expressed by respondents appear generally to be reasonable, and that flexibility in label instructions is desirable as it allows precautions to be tailored to local circumstances by local pest control groups who are best placed to understand and manage the risks for a particular area. While local groups should be encouraged to consider whether relaxation of particular requirements may improve the effectiveness of baiting without increasing the risks, this should be considered and endorsed by State authorities before any implementation. The suggestion that label instructions be qualified with the phrase "unless otherwise approved by State authorities" is considered sound.

Neighbour notification

The requirements that all adjacent landholders be notified in writing at least 72 hours in advance of a baiting operation, unless other arrangements such as media notices are in place for large scale projects, and that baiting occur within 7 days of notifying neighbours were criticised as too restrictive, particularly for broad scale operations. It was suggested that notification not be limited to written notices, particularly as local community newspapers may only be printed once or twice a month, and that the 7 day period be extended to 10 days to allow for delays such as those caused by adverse weather. Telephone or personal contacts are preferred for initial approaches to neighbours in NSW. The requirement to notify all adjoining landholders was criticised, with the suggestion that this be limited to those whose property boundaries are within 1 km of where baits are to be laid.

Signage

Clarification was sought regarding the proposed label instruction that signage be placed at every entry to the property where baiting is to occur. Western Australia suggested that this be restricted to designated road entrances. The NSW DEC raised concerns in relation to the placement of 1080 notices at every entrance to a national park or other conservation area, noting that baiting in reserves is usually restricted to small areas, and that cats and dogs are prohibited from entering national parks in NSW. It was suggested that 1080 notices are only required at the entrance to any access road or formal walking track through the baiting area. The NSW DEC also suggested that ambiguity regarding the length of time for which 1080 notices should be retained can be resolved by requiring them to remain posted for at least 4 weeks after the last bait is laid.

Distance restrictions

The requirement that baits be placed at least 5 m from the edge of formed public roadways was widely criticised, on the basis that bait placement along tracks rather than in fringing vegetation maximises their uptake by the target canids that use these tracks. The NSW DEC suggested that this requirement be restricted to sealed public roadways, and expressed strong opposition to any intention to introduce such requirements for unsealed roads and tracks.

Western Australia recommended that the 20 m restriction for water courses and water bodies be limited to permanent or flowing water bodies. Canid baits are often laid along dry watercourses in order to target the dogs that travel along them.

DEH reaffirms the finding of the review that the risks of 1080 to the aquatic environment are low because of the low application rates and low toxicity to aquatic life. While best practice use of 1080 includes the avoidance of aquatic contamination, the concentrations of 1080 that may occur in water are too low to harm aquatic life, or birds or mammals that may drink the water, even if baits fall directly into a water body.

Bait storage

The requirement that baits not be stored was widely criticised on the basis that bait storage is necessary where baiting programs are ongoing or where emergency baiting situations are likely to arise. It was suggested that the label statement be modified to require that end-users must not store baits once a baiting campaign is complete. The Queensland Department of Natural Resources and Mines (NR&M) supported the prohibition on bait storage, but only for short-life baits.

Use of baits in-crop

The prohibition on baiting in-crop was widely criticised. For example, the Australian Wildlife Conservancy noted that aerial baiting for broad scale fox control is often conducted on agricultural lands to provide a baited buffer zone to minimise reinvasion of conservation estate. Western Australia recommended that the statement be restricted to crops in mid to late developmental stages. The Qld NR&M noted that control of pigs may require the placement of bait stations within sugarcane crops where the pigs are feeding, and suggested that prohibition on the contamination of foodstuffs by baits was sufficient.

Bait and carcass recovery

The apparent requirement for bait and carcass recovery was criticised as impractical for many operations, particularly where baits are dropped from aircraft.

As the secondary poisoning risks of 1080 for native wildlife (except dingoes) are low, it is agreed that these activities should not be mandatory, noting that the concerns with unrecovered carcasses relate mainly to their attractiveness to other feral predators or scavengers. The statement has been modified accordingly, with the word must replaced by should.

Untaken baits can continue to present a potential risk to some nontarget animals. However, this report has shown that the actual level of harmful impact on native animals from current use patterns, with the possible exception of meat baiting for pigs, is low and restricted to a few individuals rather than populations. There is no pressing need from the environmental perspective to make bait recovery mandatory, but State authorities may wish to retain this option in situations where domestic animals and livestock are otherwise likely to be exposed.

Disposal

The requirement that empty containers be destroyed was criticised as not reflecting best practice waste management. Reuse of the same clearly labelled container was preferred over disposal and replacement (6).

The suggestion that dedicated bait containers be reused for the same purpose rather than disposed of and replaced is sound. Disposal is only warranted for containers that are no longer to be used for their original purpose.

Burning continues to be a recommended disposal method in some jurisdictions. For example, up to 10 kg of bait packaging may be burnt by open fire in NSW without written approval, subject to fire regulations and distance restrictions from human habitation. Note that recovered and unused baits can only be disposed of by burial in NSW (or by return to the point of supply for untaken Doggone baits). Although burning of farm chemicals and their containers is generally undesirable because of the risk of harmful exposures to volatilised residues, such considerations do not pertain to 1080 because it is a salt that is unstable above 110^{o}C and decomposes at 200^{o}C (Atzert, 1971).

Laying of herbivore baits

The proposed requirement that baits be laid late in the day was criticised as impractical for large properties, given the travelling times involved, and likely to be ineffective in many situations given the crepuscular habits of many birds. Similarly, the statement that these baits are toxic to birds and other wildlife was criticised on the basis that many native species are relatively tolerant of 1080 and unlikely to be harmed by baiting.

These criticisms are considered to be valid, and to justify modification of the statement along the following lines: "This product may be toxic to some birds and other native wildlife. Baits should not be laid at times when, or in locations where, birds or other nontarget wildlife are likely to be harmed by them".

Laying of native herbivore baits

Tasmanian authorities (19) advised that the proposed instruction that bait not be laid in areas likely to contain isolated populations of bettongs or potoroos is supported in principle, but that it should be noted that the identification of such likely habitat may be difficult and impose unrealistic demands on landholders or Tasmanian authorities in some circumstances.

There is no intention to place unrealistic demands on landholders or State authorities. The word likely means that the presence of such isolated populations be a realistic and not remote possibility. Consistent with the statement for rabbit baits on the mainland, the statement could be modified along the following lines: "This product may be toxic to some birds and other native wildlife. Avoid baiting in areas likely to contain isolated populations of bettongs or potoroos. Baits should not be laid at times when, or in locations where, birds or other nontarget wildlife are likely to be harmed by them".

Laying of non-meat baits for pig control

The proposed requirement that pig baits be laid late in the day was criticised by Western Australia as impractical for large properties, given the travelling times involved, and likely to be ineffective in reducing avian exposure in many situations given the crepuscular habits of many birds. Bait recovery the next morning was also rejected as unsuitable, in that human presence can reduce visitation rates to baits. In addition, the advice to bury baits in order to restrict nontarget access was criticised on the basis that 1080 is less stable in buried baits, particularly if the baits are buried in the moist soils that are favoured by feral pigs. It was noted that other options exist for restricting nontarget access to pig baits, and that burial is impractical for aerial baiting. Similarly, free-feeding is impractical for aerial baiting, although there was widespread support for it as a means of maximising bait uptake by rabbits and pigs when ground baiting. Although aerial baiting is currently limited to meat baits in Queensland, non-meat baits for pigs that would be suitable for aerial deployment are currently under development.

These criticisms are considered to be valid, and to justify modification of the statement along the following lines: "This product may be toxic to some birds and other native wildlife. Bait placement and/or bait station design should be such that nontarget access is minimised. Ground baiting for pigs should always be preceded by free feeding to maximise bait uptake".

Laying of carnivore baits

There was strong disagreement with the proposed restriction to 2 baits/km for wild dog and fox baits when laid in areas where carnivorous native mammals are active, with numerous respondents asking that the reasons for this restriction be more clearly explained. Western Australia advised that this limit would need to be changed to 5 baits/km^2 as that is the rate used for the Western Shield program, which drops baits on a 200 m spacing along linear transects separated by 1 km. Changing to lower bait densities may result in ineffective fox control and a reversal of the outstanding successes achieved by Western Shield. The NSW DEC considered that a limit of 10 baits/km would be more appropriate, noting that recent research had shown that quoll populations are not harmed by baiting at this intensity. Similarly, the NSW DPI recommended that the maximum rate should be at least 10 baits/km. The Cooma RLPB recommended an upper limit of 40 baits/km, reducing to 20 baits/km where carnivorous native mammals are active. The latter condition was criticised as operationally impractical by the Qld NR&M because the locations where carnivorous native mammals are active are often unknown. An upper limit of 4 baits/km was suggested in locations where baits can not be recovered.

It is agreed that the reasoning behind this recommendation was poorly articulated, and that there is now more information available to support a less conservative approach. Although not clearly stated in the technical report, the proposal was a precautionary measure intended to protect the spotted-tailed quoll, the south-east mainland population of which was uplisted from vulnerable to endangered in May 2004. In its listing advice to the Minister for the Environment and Heritage, the Threatened Species Scientific Committee identified habitat loss and degradation and competition with introduced predators as the key threats to the SE mainland population, noting that inappropriate application of 1080 baits may also be contributing to declines. As noted above, dead quolls had been recovered following 1080 baiting operations with evidence that they had been killed by 1080, but the extent to which this may have compromised populations was not known. More recent research has confirmed that some quolls may be killed by 1080 baiting for wild dogs, but that bait consumption does not generally appear to be fatal for quolls. Most quolls die from other causes with these occasional poisonings considered unlikely to harm populations.

It is acknowledged that concerns for the spotted-tailed quoll have no bearing on the use of 1080 in Western Australia. As noted in the technical report, field studies in Western Australia have shown that 1080 baiting for foxes and wild dogs does not harm populations of the two quoll species in that State, the western quoll (chuditch) and the northern quoll, while laboratory testing suggests that these two quoll species are less sensitive to 1080 than is the spotted-tailed quoll. Western Australia noted in its response to the preliminary review findings that populations of chuditch are clearly benefiting from 1080-based fox control programs.

Western Australia also advised that restricting bait density to 2 baits/km would make 1080 totally ineffective for cat control. Cats generally only consume their food when hungry. Bait density, distribution and intensity therefore need to ensure that cats will encounter baits at such times. Research to date has shown that efficacy against cats is poor at 10 baits/km^2 but successful at 50 or 100 baits/km^2, with further trials to be conducted in order to determine optimal bait density.

The review of 1080 examined only the products that were registered when the review was announced. There are no 1080 products registered for feral cat control. The safety of 1080 for use against feral cats will be considered when a registration application is received for a feral cat product. There is no intention to foreclose options for feral cat control. The research conducted to date and its implications for likely baiting densities have been noted.

These criticisms are considered to be valid, and to justify modification of the statement along the following lines: "This product may be toxic to some marsupial carnivores. Where appropriate, potential risks can be reduced by careful bait placement, selection of the minimum effective rate, and avoidance of baiting during the main breeding season". The term marsupial carnivores is preferred as these baits are clearly toxic to dingoes. A specific recommendation for application rate is not favoured, as current evidence indicates that the use of these baits is not likely to be harmful to quoll populations. The question of application rate relates to efficacy and should therefore be determined by State authorities. As noted above, it can be argued that increased rates of lay along a transect will not necessarily lead to increased exposure of spotted-tailed quolls, given their territorial nature.

As the risk of 1080 carnivore baits to quolls appears to be low based on this research, and as burial may reduce their efficacy, there is no need from the environmental perspective to require such precautions. However, State authorities may wish to make burial mandatory in some situations, as domestic dogs are likely to be killed if they can access baits.

Short-life baits

There was general confusion regarding the proposal that short-life baits be authorised by permit. Western Australia argued that short-life baits prepared from registered concentrates should be outside the jurisdiction of the APVMA, which regulates 1080 up to the point of retail sale.

The short-life permit proposal is a mechanism to authorise the use of short-life baits when they are supplied for use by others, and is regarded as a legal requirement. Where baits are prepared and used by the same person, as occurs in WA, no permit would be required.

The NSW DEC queried the distinction between shelf-stable baits and short-life baits, noting that pellet baits for rabbits and pigs would fall in either category depending on whether they were manufactured or prepared from aqueous concentrate for immediate use. It was suggested that the definitions be refined, noting that landholders may store short-life meat baits for several days in special refrigerators where replacement baiting is used or where time and property size preclude the laying of all baits on the one day. WA also asked for clarification as to which baits are considered to be short-life, specifically mentioning rhodamine oats for canid control, injected eggs for fox control, and grain based baits for controlling feral pigs.

Dosage issues

As noted in the technical report standardisation of bait dosage rates across Australia has yet to occur. In particular, Queensland uses 10 mg 1080 in dog baits in western and far northern areas. The Qld NR&M advised in its response to the preliminary review findings that the purpose of this higher dose rate is to minimise sublethal dosing in consideration of factors such as bioavailability, degradation, binding and target animal weight range. The aim is to ensure that the fresh meat baits will deliver a toxic dose to the target animal for the amount of time that the bait is available to it in the field. The NR&M is reluctant to reduce the dose used in these areas to the standard 6 mg unless there are well-documented non-target impacts that can not be mitigated by other means.

The NR&M is correct that there are no well documented non-target impacts from the use of wild dog baits containing 10 mg 1080. There remains a theoretical risk to the northern quoll from such practices. However, field studies in WA have shown that northern quoll populations are not harmed by wild dog baits containing 6 mg 1080, while studies in eastern Australia indicate that the more sensitive spotted-tailed quoll is similarly unharmed at the population level and apparently able to moderate bait consumption at the individual level where 1080 is present. National uniformity remains desirable and problems of degradation may to some extent be alleviated by using a more stable bait medium. However, it does not appear likely based on current evidence that the dosing of dog baits at 10 mg 1080 in western and far northern areas of Queensland would be harmful to nontarget populations, particularly given the rapid degradation of 1080 that is to be expected in the demanding tropical environment of these areas.

Meat baits for feral pigs

The question of bait medium may also solve the ongoing disagreement regarding the aerial deployment of fresh meat baits containing 72 mg 1080 for control of feral pigs in northern Queensland. This issue remains the greatest concern that the Qld NR&M has with the 1080 review.

As noted in the technical report, the sensitivity of some native carnivores to 1080 entails a strong likelihood that they will be killed if they consume baits of such potency. The use pattern for these baits (surface baiting, often from aircraft and across large areas) makes it likely that significant numbers of carnivorous animals other than the target pests will be exposed to them.

Unlike the canid baits, the meat baits for feral pigs are likely to be toxic to predatory and scavenging birds as well as to mammalian carnivores because of their much higher loading, and may even be toxic to goannas. Although the NR&M has reaffirmed that it has not received reports of wildlife deaths despite laying some 100000 to 200000 baits annually, the nature of the deployment (dropped from the air into remote areas) and the mobility of birds makes it unlikely that such reports would be received even if avian mortality were widespread. Similarly, mortality in mammalian carnivores such as the northern quoll or the yarri (north Queensland subspecies of the spotted-tailed quoll) would be unlikely to be reported in these circumstances, particularly as quolls are rare and cryptic. It is noted, however, that recent marked declines in these two quoll species are more likely to reflect the effects of cane toads than of 1080 baiting, and that recent research in SE Australia suggests that these baits may not be consumed in significant quantities by quolls.

Informal advice from Queensland is that 1080-laced meat is often scavenged by magpies and corvids during bait preparation, but that little appears to be consumed and no harm appears to result in these species. Anecdotal recollections that birds of prey, such as wedge-tailed eagles, were common and visible casualties of this form of baiting during its developmental phase when much higher bait loadings were employed, have been contrasted with the absence of such observations when using the 72 mg baits.

As noted in the technical report, applications to register such products would face significant issues in respect of nontarget animals. Data would be needed to demonstrate target specificity and/or a lack of impact on native carnivores, particularly birds of prey, in order to be satisfied that use of these baits would not be likely to have an unintended effect that is harmful to animals. In reporting on the sensitivity of feral pigs to 1080, McIlroy (1983a) listed numerous species of raptor feeding on meat baits (poisoned or non-poisoned) or pig carcasses and noted that two black kites were found dead after baiting. Field studies were recommended to determine the actual impact of different pig-poisoning campaigns on nontarget animal populations.

If new studies are to be undertaken to demonstrate the environmental safety of meat baits containing 72 mg 1080 for feral pig control, birds should be given higher priority than mammals. Although it is acknowledged that pig baits contain an order of magnitude more 1080 than the dog baits, previous research showing low or minimal impact on various quoll species from wild dog baiting suggests that similar outcomes are likely with the pig baits. In contrast, there is no information to suggest that birds of prey are able to moderate their food consumption when the food contains 1080. Available data as described in the technical report indicate that wedge-tailed eagles are more sensitive to 1080 than other birds of prey, with an LD50 of about 10 mg/kg. Furthermore, as this endpoint was determined in birds from Western Australia that have evolved in the presence of 1080 bearing plants, it is possible that wedge-tailed eagles from other parts of Australia may be more sensitive, notwithstanding that such tolerance is less pronounced in carnivores than in herbivores. A large wedge-tailed eagle could easily consume a 500 g meat bait containing 72 mg 1080 (much more than the LD50).

The NR&M has reaffirmed that the aerial distribution of meat baits for feral pig control is an important Queensland management practice in terms of pest management and biodiversity conservation. The NR&M further advises that aerial baiting remains an important contingency for controlling exotic disease outbreaks. The NR&M is adamant that the use of meat baits containing 1080 needs to be maintained until alternatives are available.

Alternative 1080 pig baits that can be deployed from aircraft and that are unlikely to be taken by carnivorous birds and mammals are under development. The better target selectivity makes it more likely that these baits would satisfy registration requirements from the environmental perspective. Such baits would be preferred, provided that they are effective.

The shortage of data to demonstrate the environmental safety of the meat baits, and the likely difficulty and expense of obtaining such data, makes it difficult for meat baits for feral pigs to meet legislative requirements for national registration.

Currently this use pattern is practised only in Queensland. This practice was originally authorised through a Queensland Board permit before the advent of the national registration scheme when pesticides were regulated by individual States/Territories. After the national registration scheme *came into existence, the Queensland Board permit has been transferred to the APVMA. Thus, the use of meat baits containing 72 mg for feral pig control in Queensland is now carried out under the APVMA permit.*

Biosecurity Queensland, with in the Department of Primary Industries has indicated to the APVMA that it has commenced research to generate data to assess non-target effects. The continuation of the APVMA permit is subject to satisfactory progress and the results of the on-going research project.

Note that meat baits have also been used in South Australia (Kangaroo Island) under APVMA permit to control feral pigs that were predating on livestock. In this case, meat baits were preferred over grain because of potential risks to macropods. Carnivorous native mammals are not an issue on Kangaroo Island. Potential risks to native birds were manageable as the baits were laid from the ground, which allowed them to be buried. Potential risks to reptiles were managed by baiting in winter when reptiles are not active at these southern latitudes. These management options are not available for the broadscale control of feral pigs in northern Queensland.

Recent research (Twigg et al, 2005, 2006) has shown that use of grain baits with free-feeding provides very good control of feral pigs at the landscape level in tropical Australia. In addition, early results with 1080 pig baits in a new matrix, deployed aerially in Queensland without free-feeding, are promising (Cowled et al, 2006).

10 CONCLUSIONS

Baits containing sodium fluoroacetate (1080) are used to control a range of vertebrate pests in Australia. Application rates are low, a few grams per hectare for herbivore control and a gram or less for carnivore control. Application rates need to be higher for feral pigs because of their large size, but remain relatively low (for example, around 10 g 1080 along a 50 m transect). Significant contamination of air, soil or water by 1080 is not expected to occur from these uses as the toxin is susceptible to microbial degradation, except under arid conditions when microbial activity is low. The ready microbial degradation under moist conditions conducive to microbial activity and the low treatment rates mean that significant leaching through soil is not expected to occur. Low level contamination of water is possible, particularly if baits fall directly into watercourses, but any contamination that may occur will be at low levels and rapidly diluted to insignificant concentrations, as confirmed by monitoring and simple calculation. Such levels would not present any risk to human or other animal health.

The main concern with the use of 1080 is the potential risk of nontarget poisoning from consumption of baits and, to a lesser extent, poisoned animals. However, differences in sensitivity between species means that, with careful attention to bait preparation, placement and timing, a degree of target selectivity can be achieved. This is particularly the case for canids, as outlined below. It is difficult to make specific recommendations for how 1080 should be used as the risk will vary with geography and season. Nontarget risks need to be evaluated for each area where baiting is proposed before any baiting occurs, and baiting methods should be continually adapted and improved in response to these evaluations.

As noted earlier in this report, users of 1080 follow best management practices as outlined on labels and in associated extension material, but improved ecological knowledge and changes in social expectations and land use practices mean that use patterns are continually being reevaluated, updated and refined. Controls over how 1080 can be used need to be flexible so that use patterns can be continually adapted and improved in light of experience and improved understanding. The finer details of use patterns can best be improved and adapted at the State level through changes to extension material, with consideration of local knowledge and experience regarding particular issues that may arise during individual campaigns.

Ideally, a range of bait types should be available for each target pest, provided that nontarget risks have been carefully evaluated for each bait type. For example, fox baits have traditionally been prepared in NSW from a range of materials, including chicken heads and wingettes. These would probably be unsuitable for use in quoll habitat given the well known predilection of quolls for chicken. It is general policy in NSW to avoid chicken baits in areas where quolls may be found.

The following comments can be made by way of general guidance for specific pests, but baiting strategies for a particular situation need to be tailored for that situation, with maximum use of local knowledge as to the nontarget species likely to be present and their likely response to baiting. It is recognised that these comments may not be amenable to inclusion on product labels, and they are intended as general guidance to maintain the flexibility of baiting, rather than as rigid prescriptions. Specific recommendations for labelling are outlined above and at the end of this report.

Rabbit control

This is achieved by deployment of oat, carrot or pellet baits, usually after an initial free-feeding period to encourage rabbits to feed on the baits and provide an indication of how much bait needs to be laid.

The main concern with grain based rabbit baits is probably the potential effect on granivorous birds, particularly sensitive species such as parrots and ducks. A preliminary free-feeding phase will assist in determining whether birds are likely to be attracted to poison baits. Bait stations are an option where significant avian exposure appears likely to occur, although impractical for large scale programs. Free-feeding does not occur with the One-shot product used in WA. Where practical, baiting should occur late in the day, so that rabbits consume the baits overnight and minimise the amounts left available for birds. For carrot baits, it is important that baits be cut to a uniform size, avoiding small fragments and chaff that would contain proportionally more 1080 and may therefore lead to higher exposure of birds. These small fragments can be removed by screening before the baits are dosed with 1080. Use of a dye to colour the baits may also reduce avian consumption. Because of their dietary preferences, carrot baits are likely to be dangerous for potoroos, and should not be laid in areas where the presence of these animals raises concerns. Oat baits should be preferred in such situations.

Recent research in Western Australia (Twigg *et al*, 2003b) has identified potential shortcomings in the use of oats for rabbit baiting. The tendency for some rabbits in WA to dehusk oats and eat only the kernel may reduce the effectiveness and selectivity of oat baits. Animals that consume the whole grain, including the husk, will ingest more 1080 than will those animals, such as rabbits and parrots, that dehusk the oat bait. Furthermore, dehusking by rabbits could lead to sublethal dosing and resistance development. Use of an alternative grain such as barley has been identified as a possible solution to this problem. This needs to be further investigated, and implemented across Australia as required if found to be feasible.

Native herbivore control (Tasmania)

Options for achieving target selectivity are much more limited, as a broad range of native fauna share the high sensitivity of the target wallabies and possums. Target selectivity depends on free-feeding to encourage consumption by target pests, the placement of baits away from bush edges where nontarget animals such as bettongs are more likely to be active, and avoidance of baiting in or near known bettong habitat.

It is difficult to determine whether the above strategies are successful as poisoned animals tend to take cover and routine carcass searches are unlikely to be effective. Broadscale population monitoring indicates that target and nontarget herbivore populations are stable, but the risk remains that isolated populations of bettongs may be eliminated by baiting. The Tasmanian authorities are currently considering an amendment to the Code of Practice that would enable an authorised officer to restrict the laying of carrot baits in areas known to contain populations of nontarget species that have been identified as potentially at risk from 1080.

Control of native herbivores is essential for protection of horticultural crops and newly planted forestry plantations, and poisoning with 1080 is regarded as the most effective option. Development of more acceptable control strategies should be given high priority.

Fox and wild dog control

Target selectivity in eastern and northern Australia is achieved by careful dose selection, so that a single bait will contain just enough to ensure an efficient kill of the target animals, placement along tracks where dogs and foxes are likely to travel, and wide separation between baits (ideally at least 200 m) to avoid multiple bait takes by a single animal (target or nontarget). Burial of baits reduces nontarget bait takes, and construction of sand pads over the burial site in sensitive areas assists in identifying which animals are taking baits during a preliminary free-feeding phase. Poison baiting can then be avoided at sites visited by nontarget animals. These precautions are only practical for smaller scale operations.

Spotted-tailed quolls are of particular concern with respect to these baits as they are known to dig them up and occasionally consume them, both in the wild and in captivity. Aerial baiting using biomarkers indicates that a high proportion of resident quolls are likely to locate baits deployed at high rates by this method, and trapping results in some studies with small sample sizes indicate substantial reductions in tiger quoll populations after aerial wild dog baiting. Wild dogs are a particular issue around Kosciuszko National Park, with adjacent landholders calling for a restoration of aerial baiting within the park because of a perception that resident wild dog populations are increasing, with attendant stock losses. However, recent research with toxic baits as described in section 9 of this report has indicated that, in contrast to the response with nontoxic baits, quolls do not consume large quantities of toxic baits, and except for a few individuals are not harmed by them.

To avoid harming individual animals, ground based buried bait operations using sand pads to identify which species are visiting may be preferred for fox and wild dog control in and around spotted-tailed quoll habitat, particularly where populations appear vulnerable. If spotted-tailed quolls or other sensitive nontarget native animals are not active in an area, these precautions do not need to be observed, and may be counterproductive as the additional time and labour required to service bait stations reduces the area that can be baited. The NSW threat abatement plan for predation by the fox (NPWS, 2001) is an excellent guide to fox baiting in that State.

Further research also needs to be conducted to better define the risk that 1080 poisoning poses to phascogales, as the results of studies using nontoxic baits can not be relied on. Such bait marker studies have indicated significant exposure of phascogales, and populations of these small marsupial carnivores remain in decline for reasons that are not well understood. However, studies in various parts of Australia have shown that phascogale populations in areas baited for foxes remain stable or increase in number and range. As a precaution until the risk has been clarified, baits may be buried in phascogale habitat.

Note that these issues do not arise in south-western WA because the indigenous fauna have adapted to 1080. Native animals in this part of Australia may still be susceptible to 1080 but are generally of lower sensitivity compared with their counterparts in the eastern States. Broadscale aerial baiting for fox control in south-western Australia is supported, as local native fauna are known to have a greater tolerance to the poison and their populations have been shown to respond positively to fox control. Similarly, aerial baiting by the NPWS in western NSW where additional environmental impact assessment has been conducted is supported.

Fox control benefits biodiversity conservation, provided that most foxes are killed and that population reductions are maintained. There are anecdotal reports that foxes may refuse some bait types when exposed to them over extended periods. Sole reliance on a single bait form is inadvisable when baiting at higher intensities. In order to maximise the efficiency of fox control, operators should consider switching bait types, particularly where there is evidence that foxes are present but not taking baits, or are caching them. For example, operators could use shelf-stable commercial preparations to target foxes initially, and then switch to more palatable but less stable baits such as deep fried liver to control the remaining foxes in an area. The use of buried egg baits should also be considered, particularly in wetter environments, as their extended stability compared with meat baits reduces the risk of sublethal dosing. Nontarget risks may also be increased with different bait types, and this needs to be investigated where nontarget exposures are of concern, for example in quoll or phascogale habitat.

It is likely that similar principles would apply to wild dog control, given that dogs are intelligent and wary animals and that shooting or trapping is often needed to control individual animals.

Feral pig control

Target selectivity with feral pigs is more difficult to achieve because of their large size and lower sensitivity to 1080 compared with other target pests. Selectivity appears especially problematic with meat baits as they contain high loadings which are likely to be hazardous to birds of prey and possibly to goannas. Meat baits may be preferred in pastoral areas because they are more likely to be taken by pigs that have been predating on livestock, and are probably less likely to be eaten by goannas in such situations. However, they would still preferably be covered to minimise uptake by birds of prey, or laid in the evening and recovered the next morning in order to avoid exposure of these diurnal feeders. Further research needs to be conducted before routine use of aerially deployed 1080 meat baits for pig control in sensitive environments can be supported.

Alternative poisons that are more specific to pigs also need to be, and are being, explored. The need for pig control in order to protect environmental values is recognised, however, and use of 1080 is accepted, particularly when used with grain and a free-feed period, as it remains the most practical and effective control method for large areas. Research to improve target selectivity needs to continue. Until a more target specific bait is available, grain baiting would appear generally to be the preferred method for baiting pigs, and prior establishment of regular free-feeding as currently practiced with these baits would seem essential. Where the main nontarget concerns are for herbivores such as macropods, meat baits may be preferred. Where practical, baits should be laid late in the day and untaken baits should where possible be recovered before birds begin to feed the next day. Use of fermented grain appears to improve target selectivity and can be used as an attractant, but extra care is required when applying the water soluble toxin to wet grain when wet grain is used as the bait substrate.

Recent research (Twigg *et al*, 2005, 2006) has shown that use of grain baits with free-feeding provides very good control of feral pigs at the landscape level in tropical Australia. In addition, early results with 1080 pig baits in a new matrix, deployed aerially in Queensland without free-feeding, are promising (Cowled *et al*, 2006).

Pig control is most successful during drought conditions when pigs congregate near water. Although pig populations may be relatively low during such times, strategic baiting can reduce the rate at which pig populations recover when good conditions return, and reduce the need for subsequent baiting when populations are increasing and dispersing.

Feral cats

Control of these pests is difficult because they are wary and reluctant to consume carrion. It is also important to fauna recovery. Currently approved control methods remain experimental, with further research needed before routine cat control using 1080 can be supported. Best results are likely to be obtained if baiting occurs when alternative food resources such as rabbit kittens are in short supply. Baits for cats are comparable in potency with those for wild dogs, but often laid at much higher density, which increases nontarget risks. The availability of a more cat specific toxin would ease concerns regarding the nontarget impact of 1080 baiting for cats, but it would need to be suitable for broadscale application if feral cat populations are to be controlled effectively across the Australian landscape.

11 RECOMMENDATIONS

DEH makes recommendations in respect of the APVMA's reconsideration of 1080 product registrations and label approvals. DEH also makes recommendations regarding 1080 management that fall outside the APVMA's reconsideration powers.

11.1 Reconsideration of Registration and Label Approval

DEH recommends that the APVMA not be satisfied that use of 1080 products in accordance with their recommendations for use (label instructions) would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment.

DEH recommends that the APVMA not be satisfied that labels for 1080 products contain adequate instructions to ensure that the use of the products in accordance with their recommendations for use (label instructions) would not be likely to have an unintended effect that is harmful to animals.

11.1.1 Variation to labels

Labels for 1080 products need to be updated to reflect current specifications and modern standards. Some States (for example WA) have recently revised their 1080 labels, but others continue to rely on outdated documents with little or no information on use patterns and risk precautions. For example, particulars for 1080 Baits (product no 42458, registered to DPIWE) indicate a 1080 concentration of 0.4 g/kg, but an operational concentration of 140 mg/kg has been used for at least the last 20 years.

While flexibility is needed to allow continual improvements in the efficiency and effectiveness of pest control using 1080, it must be acknowledged that 1080 baiting can be risky if certain precautions are not strictly adhered to. For example, research has shown that high intensity baiting for foxes is no more effective than low intensity baiting, but is much more likely to impact on native carnivores which can access multiple baits when baits are laid at high density. Users should be specifically restrained from practices where evidence of increased risk is strong but there is no demonstrable improvement in pest control. This is best achieved by ensuring that 1080 labels are updated as appropriate to meet modern standards, including specific label instructions to address the concerns raised in the VPC review and the environmental priorities identified in this report.

Note that the label instructions proposed in the preliminary review findings have been extensively revised based on the public comments received. These are mainly discussed in section 9 of this report.

DEH recommends that if labels are varied as set out below, the APVMA can be satisfied:

(i) that use of 1080 products in accordance with the recommendations for their use (new label instructions) would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment; and

(ii) that labels for 1080 products would contain adequate instructions to ensure that the use of the products in accordance with their recommendations for use (new label instructions) would not be likely to have an unintended effect that is harmful to animals.

All baits

As baits lose toxicity in the field, baits that are not recovered at the end of a campaign may deliver a sublethal dose. **DEH recommends** that labels for all 1080 products contain the following instructions: "To the extent possible, untaken baits should be recovered at the end of a baiting campaign and be destroyed by burning or burial according to the requirements of the State or Territory in which use has occurred".

Although the secondary poisoning hazard of 1080 for native species appears low, carcasses can remain toxic to domestic dogs, and may attract feral scavengers to baited areas if not recovered. **DEH recommends** that labels for all 1080 products contain the following instructions: "To the extent possible, animal carcasses should be recovered during and for 14 days after a baiting campaign and be destroyed by burning or burial according to the requirements of the State or Territory in which use has occurred".

Herbivore baits

To reduce the potential for harm to nontarget wildlife, **DEH recommends** that labels for rabbit bait products (42499, 42450, 42501, 49350, 49351, 49352, 50304 and 52954) include the following instructions: "This product may be toxic to some birds and other native wildlife. Baits should not be laid at times when, or in locations where, birds or other nontarget wildlife are likely to be harmed by them".

The carrot baits used in Tasmania for control of rabbits and native herbivores present similar hazards. **DEH recommends** that the label for this product (42458) is inadequate in respect of the circumstances in which it may be used. DEH recommends that the label be varied to identify specific target species.

To reduce the potential for harm to nontarget wildlife, **DEH recommends** that the Tasmanian label also include the following instructions: "This product may be toxic to some birds and other native wildlife. Avoid baiting in areas likely to contain isolated populations of bettongs or potoroos. Baits should not be laid at times when, or in locations where, birds or other nontarget wildlife are likely to be harmed by them".

Fox and wild dog baits

Labels for many of these products advise users to bury them to a depth of 8-10 cm, but burial does not appear to be a legal requirement. Although burial should generally be preferred, to make this a legal requirement would be impractical and counterproductive, given recent research indicating that some kinds of meat baits need not be buried in quoll habitat, and that to require this would reduce the efficiency of baiting because buried baits are more labour intensive, have reduced longevity and are less easily found by canids.

The meat baits used for canid control are likely to be toxic to native carnivores such as quolls, particularly if more than one bait is taken. **DEH recommends** that labels for these products (42498, 42500, 42538, 42720, 46434, 49354, 49355, 49384, 50911 and 54616) contain the following instructions: "This product may be toxic to some marsupial carnivores. Where appropriate, potential risks can be reduced by careful bait placement, selection of the minimum effective rate, and avoidance of baiting during the main breeding season".

Non-meat feral pig baits

DEH recommends that labels for non-meat feral pig bait products (42499, 49352) include the following instructions: "This product may be toxic to some birds and other native wildlife. Bait placement and/or bait station design should be such that nontarget access is minimised. Ground baiting for pigs should always be preceded by free feeding to maximise bait uptake".

11.2 Related matters

At the commencement of this review, 1080 products were registered by the APVMA with labels containing instructions for use against rabbits, native herbivores (possums/wallabies), foxes, wild dogs, feral pigs and feral cats. Use to control rats (the pale field rat) in Queensland hoop pine plantations was and remains authorised by APVMA permit.

11.2.1 Regulatory control

DEH suggests that it would be preferential that all 1080 products be registered in all States and Territories by the APVMA, provided that the APVMA can be satisfied that they meet the requirements for registration. Information provided for the review indicates that, with some exceptions as outlined below, use according to State Codes of Practice of 1080 baits for control of rabbits, foxes, wild dogs, feral pigs and (in Tasmania) brushtail possums, Bennett's wallabies and Tasmanian pademelons would not be likely to have an unintended effect that is harmful to animals, plants or things, or to the environment.

DEH is unable to advise that the use of meat baits containing 72 mg 1080 for feral pig control would not be likely to have an unintended effect that is harmful to nontarget animals. The sensitivity of some native carnivores to 1080 entails a strong likelihood that they will be killed if they consume baits of such potency. The use pattern for these baits (surface baiting, often from aircraft and across large areas) makes it likely that significant numbers of carnivorous animals other than the target pests will be exposed to them. This use pattern raises particular concerns for birds of prey.

Applications to register such products would face significant issues in respect of nontarget animals. Data would be needed to demonstrate target specificity and/or a lack of impact on native carnivores, particularly birds of prey. In the absence of such data, DEH recommends that the APVMA not be satisfied that use of meat baits containing 72 mg 1080 would not be likely to have an unintended effect that is harmful to animals, plants or things, or to the environment.

11.2.2 Adverse experience reporting program

DEH supports the APVMA's Adverse Experience Reporting Program for Agricultural Chemicals (AERP-Ag). While legal obligations apply, DEH encourages all persons to use 1080 products in accordance with their product labels. Where incidents of harm to nontarget animals are suspected, DEH encourages reporting to the APVMA's AERP-Ag. Doing so would provide a useful mechanism to confirm the conclusions of this review and the regulatory action foreshadowed.

11.2.3 VPC review recommendations

DEH endorses the recommendations of the recent VPC review of 1080. In particular:

- research to develop alternative control options for native herbivores in Tasmania needs to be accorded high priority
- bait loadings and baiting intensities should aim to minimise sublethal dosing and overdosing while maintaining effective control
- bait size, placement, 1080 concentration and delivery should take into account target species' behaviour and the presence, behaviour and susceptibility of non-target species. Potential effects on target and non-target species must be fully evaluated when baiting in new situations or with new bait types
- carrot baits should be sieved to remove small fragments that are likely to lead to higher exposure of birds.

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6 Australian Wildlife Conservancy (Jacqui Richards, Wildlife Ecologist)

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9 Cooma RLPB (Tim Seears, Managing Ranger)

10 Conservation Council of Western Australia Inc (Chris Tallentire, Director)

11 Department of Agriculture WA (Jon Glauert, Chairman, Katanning Zone Control Authority and District Advisory Group)

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16 Department of Health WA (Martin Matisons, Chairman, Western Australian 1080 Review Working Party)

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45 Western Australian Farmers Federation (Trevor De Landgrafft, President)

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47 Wildlife Research and Management, Kalamunda WA (Jeff Short, Director and Principal Research Scientist)

48 Wildlife Preservation Society of Queensland (Des Boyland, Policies and Campaigns Manager)

49 Wildlife Protection Association of Australia Inc (Pat O'Brien, President)

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51 Department of Water, Land and Biodiversity Conservation, SA (Mark Ramsey, Group Manager, Animal and Plant Control Group).