Literature review of the acute toxicity and persistence of brodifacoum to invertebrates and studies of residue risks to wildlife and people

SCIENCE FOR CONSERVATION 177

Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

Science for Conservation presents the results of investigations by DOC staff, and by contracted science providers outside the Department of Conservation. Publications in this series are internally and externally peer reviewed.

This report was prepared for publication by Science Publications, Science & Research Unit; editing by Jaap Jasperse and Lynette Clelland, layout by Lynette Clelland. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

ISSN 1173-2946
ISBN 0-478-22127-4

Preface

This issue of the *Science for Conservation* monograph series reports on two related research projects carried out for the Department of Conservation by Landcare Research Limited. Both projects deal with the side-effects of the use of brodifacoum to control mammal pests in New Zealand, and are presented here in alphabetical order of first author. The files are separately available for DOC staff from the Intranet at http://docintranet/content/sru/pdfs/sfc177X.pdf, where X stands for the identifying letter shown in the running footer of each article.

The collection of papers may be cited as follows:

Department of Conservation 2001: Literature review of the acute toxicity and persistence of brodifacoum to invertebrates and studies of residue risks to wildlife and people. *Science for Conservation 177*, vi + 23 p.

Individual items may be cited as follows:

Booth, L.H.; Eason, C.T.; Spurr, E.B. 2001: Literature review of the acute toxicity and persistence of brodifacoum to invertebrates. *Science for Conservation 177A*: 1–9

or in full as:

Booth, L.H.; Eason, C.T.; Spurr, E.B. 2001: Literature review of the acute toxicity and persistence of brodifacoum to invertebrates. Pp. 1–9 in: Department of Conservation 2001: Literature review of the acute toxicity and persistence of brodifacoum to invertebrates and studies of residue risks to wildlife and people. *Science for Conservation 177*, vi + 23 p.

Contents

LABORATORY AND FIELD STUDIES OF BRODIFACOUM RESIDUES IN RELATION TO RISK OF EXPOSURE TO WILDLIFE AND PEOPLE

C.T. Eason, G.R.G. Wright, L.M. Milne and G.A. Morriss

Literature review of the acute toxicity and persistence of brodifacoum to invertebrates

L.H. Booth, C.T. Eason and E.B. Spurr

Landcare Research, P.O. Box 69, Lincoln 8152, New Zealand

ABSTRACT

Invertebrates have been identified on toxic baits containing brodifacoum following operations for vertebrate pest control. However, few quantitative data are available to determine the risk of primary or secondary poisoning that may result from these exposures. Of the species tested, insects do not appear to be at risk from brodifacoum poisoning. However, brodifacoum did cause mortality in two species of mollusc. These findings should be further evaluated in the light of the extensive use of brodifacoum bait in New Zealand. A series of studies should be conducted to provide data on the risk of brodifacoum exposure to native New Zealand snails and earthworms and the subsequent risk of secondary poisoning to animals eating these invertebrates.

Keywords: Brodifacoum, toxicity, invertebrates, persistence.

Booth, L.H.; Eason, C.T.; Spurr, E.B. 2001: Literature review of the acute toxicity and persistence of brodifacoum to invertebrates. *Science for Conservation 177A*: 1–9.

or in full as:

Booth, L.H.; Eason, C.T.; Spurr, E.B. 2001: Literature review of the acute toxicity and persistence of brodifacoum to invertebrates. Pp. 1–9 in: Department of Conservation 2001: Literature review of the acute toxicity and persistence of brodifacoum to invertebrates and studies of residue risks to wildlife and people. *Science for Conservation 177*, vi + 23 p.

1. Introduction

A literature review of the toxicity and persistence of brodifacoum to invertebrates was prepared by Landcare Research, Lincoln, for the Department of Conservation (DOC) in June 2000. This was done to provide data on the risk of brodifacoum exposure to non-target invertebrates prior to evaluation of the toxicity of brodifacoum to native snails and earthworms, and the subsequent risk of secondary poisoning to other animals.

2. Background

Brodifacoum is widely used in New Zealand to control vertebrate pests such as the brushtail possum (*Trichosurus vulpecula*) and rats (*Rattus* spp.). Brodifacoum is extremely water insoluble and persists in the environment and in vertebrate tissues for extended periods of time. This toxicant can therefore pose a risk of primary and secondary poisoning to ground-dwelling non-target species. The risk of widespread brodifacoum use to non-target wildlife is a controversial issue, with only limited quantitative data available to determine the sensitivity of exposed species, especially indigenous invertebrate populations. Brodifacoum in the form of cereal baits (Talon®, PESTOFF®) is used in bait stations, but in special cases it can also be aerially applied, e.g. on offshore islands. Aerial application of baits increases the risk of primary and secondary poisoning to ground-dwelling non-target species.

Invertebrates have been observed feeding on cereal-based baits containing brodifacoum, and brodifacoum residues have been measured in some invertebrates (see below). Brodifacoum is perceived as lacking insecticidal properties because invertebrates do not possess the same blood clotting systems as vertebrates (Shirer 1992). However, there is a paucity of data on the effects and persistence of brodifacoum in invertebrates. Furthermore, the risk of secondary poisoning of other animals that prey on invertebrates needs to be considered by determining the persistence of residues in these invertebrates.

3. Objective

To review the literature on the acute toxicity and persistence of brodifacoum in invertebrates.

4. Methods

A literature review was conducted on the toxicity and persistence of brodifacoum to invertebrates. Data sources included current published literature, unpublished data, and anecdotal evidence from network contacts. Data from the National Wildlife Residue database were also summarised.

5. Results

5.1 LABORATORY DATA

5.1.1 Weta

The toxicity of brodifacoum has been investigated in the New Zealand native large-headed tree weta *Hemideina crassidens* (Landcare Research unpubl. data). Weta were orally dosed up to a maximum of 62.5 µg/g body weight with brodifacoum dissolved in 10% DMSO (dimethyl sulphoxide) in 60% monopropylene glycol. Due to the inherent low solubility of brodifacoum, the maximum concentration achievable was 62.5 µg/g. No mortality was observed over 3 weeks at this concentration, indicating that brodifacoum does not exhibit insecticidal properties in this invertebrate species (unpubl. data). Weta were also dosed at 10 µg/g to evaluate persistence of brodifacoum over time. Four days after dosing, brodifacoum residues had declined to below the limit of detection (0.02 µg/g).

5.1.2 Land crabs

Pain et al. (2000) investigated the toxicity of brodifacoum to the land crab *(Gecarcinus lagostoma)* on Ascension Island. Crabs were fed Talon 20P® and 7–20 pellets containing 0.002% brodifacoum to simulate maximal exposure. Crabs readily consumed bait, but no crabs died as a result of this consumption. Samples of whole bodies (minus claws, shell, and stomach), and claws only were analysed for brodifacoum residues. Low levels of brodifacoum residues were found in the bodies (≤ 0.13 µg/g), but not in the claws, immediately after exposure. No brodifacoum was detected in any tissues 1 month after exposure.

5.1.3 Snails

Gerlach & Florens (unpublished data) evaluated bait consumption and toxicity of brodifacoum to a number of non-target species, including two snail species (*Pachnodus silhouettanus* and *Achatina fulica*), a cockroach (*Pycnoscelus indicus)*, and a species of tenebrionid beetle. All species consumed the bait. Brodifacoum did not cause any mortality in the insects, but it caused 100% mortality in both snail species. A dose of 0.01–0.2 mg was sufficient to cause the death of *P. silhouettanus* in 72 h, while 0.04 mg of brodifacoum resulted in the death of *A. fulica* in the same time (J. Gerlach unpubl. data).

5.2 FIELD RESIDUE DATA

5.2.1 Stewart Island 1991

Beetles (Coleoptera sp., *Holcaspis stewartensis* and *Mecodema* were collected live from bait stations containing Talon 50WB® over a period of 14 days (Wright & Eason 1991). A total of 22 beetles were collected and residues of 0.28 to 3.3 µg/g brodifacoum were found in five of these beetles.

5.2.2 Coppermine Island (80 ha) 1992

Live invertebrates were collected from plots on the island before and 2, 3, 9, 30, and 240 days after application of Talon 50WB® in bait stations (Morgan et al. 1996). No residues of brodifacoum were found in any of the samples.

5.2.3 Red Mercury Island (225 ha) 1992

Live invertebrates were collected from plots on the island before and 13, 27–31, 57, and 101 days after aerial application of Talon 20P® (Morgan et al. 1996). No residues of brodifacoum were found in most (99%) of the invertebrate samples. However, one sample of slugs (Gastropoda) collected 2 days after application of baits contained 0.12 µg/g brodifacoum.

5.2.4 Lady Alice Island (120 ha) 1994

Live tree weta (*Hemideina thoracica*) and cockroaches (Blattidae) were randomly collected 2, 12, and 34 days after aerial application of Talon 20P® (Ogilvie et al. 1997). One cave weta (*Gymnoplectron* sp.) and beetles (Coleoptera) were also collected from on baits. No brodifacoum was detected in the invertebrates collected randomly, or in beetles found on the baits. However, 4.3 µg/g of brodifacoum was detected in the cave weta found on the baits.

5.2.5 Coppermine Island (80 ha) 1997

Live invertebrates were collected randomly before and 1 day and 1 month after aerial application of Talon 20P® (G.R.G. Wright unpubl. data). In addition, approximately 1000 baits were checked 1 day after poisoning, and invertebrates, mainly ants and weevils, were collected as one sample. No brodifacoum residues were found in any of the weta or beetles collected randomly, but 0.04 µg/g of brodifacoum was found in cockroaches collected randomly 1 day after poisoning, and 0.03 µg/g of brodifacoum in cockroaches collected randomly 1 month after poisoning. No brodifacoum residues were found in invertebrates collected from baits.

5.2.6 National Wildlife Residue database

Of 76 samples of invertebrates, including beetles, cockroaches, and weta, collected live after operations using Talon® bait, and subsequently submitted to the National Wildlife Residue database, 39 (51%) contained brodifacoum residues (Table 1). The presence of residues indicates that the invertebrates had fed on bait or on other invertebrates that had eaten bait. The highest residue (7.47 µg/g) was detected in a 4.3-g weta.

TABLE 1. BRODIFACOUM RESIDUES (μg/g) FOUND IN INVERTEBRATES IN NEW ZEALAND (DATA FROM THE NATIONAL WILDLIFE RESIDUE DATABASE)

TAXA	NO. SAMPLED	NO. (%) POSITIVE	RANGE (μg/g)
Beetles	41	12 (29)	0.02-3.30
Cockroaches	17	16 (94)	0.03-2.34
Weta	24	11 (46)	0.06-7.47
Others	16	5 (31)	0.03-3.61
Total	76	39 (51)	0.02-7.47

5.3 FIELD POPULATION DATA

5.3.1 Chetwode Islands 1993

Invertebrates were monitored before and after aerial application of small (2 g) Wanganui No.7 pellets containing 20 ppm brodifacoum on Nukuwaiata (Inner Chetwode Island) in August 1993 (Brown 1997). Tree weta (*H. crassidens*) numbers increased by 50% in 1 year, and 80% in 2 years, presumably as a result of the eradication of rats.

5.3.2 Pelorus Bridge 1993

Invertebrates were monitored by pitfall trapping before and after simulated aerial application of Talon 20P® in a 4.8-ha scenic reserve, and bait station application of Talon 50WB® in an 18-ha scenic reserve, near Pelorus Bridge in November 1993 (Spurr 1996). The treatments had no obvious impacts on any of 16 invertebrate taxa caught in sufficient numbers for data analysis. The relative numbers of invertebrates caught in treatment and non-treatment areas 1 year after poisoning were similar to those before poisoning, suggesting that poisoning rodents had neither a detrimental nor beneficial effect on invertebrate populations. However, the rodents were not eradicated in this trial. Benefits to invertebrate populations would be expected where rodents were eradicated; for example, on offshore islands such as Chetwode Island.

5.3.3 Mauritius Island 1995

Snails (*Pachystyla bicolor*) were monitored in an area of forest on Mauritius Island where brodifacoum poisoning for rat control had been ongoing for a number of years and in an area of forest not poisoned but only 100 m away (Gerlach & Florens unpubl. data; V. Florens unpubl. data). Snails were observed eating bait containing poison, and dead snails were found in the vicinity of the bait tubes. The number of live snails recorded on plots was lower in the poisoned area compared with the non-poisoned area (3 vs 14). However, because of the small number of snails, this result can be regarded only as preliminary.

6. Discussion

The presence of high concentrations of brodifacoum in live invertebrates collected after brodifacoum-poisoning operations indicates that invertebrates will eat significant quantities of brodifacoum; for example, the weta that contained 7.47 μg/g brodifacoum must have consumed at least a quarter of a 6-g Talon 20P® bait. Weta dosed orally in the laboratory were given a dose equivalent to a 4-g weta consuming two 6-g Talon 20P® baits and no toxicity was observed after 3 weeks, even in this worst-case scenario. These results indicate that brodifacoum is not toxic to weta, cockroaches, beetles, and land crabs. However, the acute toxicity of brodifacoum should be evaluated in a wider range of invertebrates. These results also show that brodifacoum is not as inherently toxic to invertebrates as to mammals (LD_{50} for the possum is 0.17 μg/g (Eason & Spurr 1995). However, the sub-lethal effects of brodifacoum to these invertebrates has not been considered. For example, fecundity can be affected by some pesticides in the absence of mortality, which over time could result in population effects.

While brodifacoum does not appear to be toxic to insects or crabs, it has caused rapid mortality (within 4 days) in at least three snail species (*Pachnodus silhouettanus*, *Achatina fulica*, and *Pachystyla bicolor*). The two species tested in the laboratory showed differing sensitivity to brodifacoum, but this could be due to body size: i.e. *A. fulica* was dosed at 5 mg/kg bodyweight compared with 2.5–5 mg/kg for *P. silhouettanus* (J. Gerlach unpubl. data). The mechanism of action of the toxicant did not appear to be due to a blood clotting problem but, rather, a collapse in the osmotic balance. Autopsy of the poisoned snails revealed gas bubbles in the oesophagus of all individuals. The *P. silhouettanus* exposed to the high dose showed no other cause of death, while in other individuals thinning of the oesophagus wall was apparent and the hepatopancreas was soft and appeared to have degenerated (J. Gerlach unpubl. data).

Native snail numbers have declined throughout New Zealand over a number of years, and this is thought to be due to predation and habitat destruction and modification (Meads et al. 1984). However, in light of the apparent toxicity of brodifacoum to the tree snail species above, brodifacoum could also be a factor in this decline. Outside New Zealand, fresh dead-snail shells have been found in the vicinity of bait stations containing brodifacoum in the forest of Brise Fer; this, combined with other anecdotal evidence on the decreased abundance of snails found in brodifacoum-treated areas, is a cause for concern. Therefore, the toxicity of brodifacoum to native New Zealand snails should be investigated.

Brodifacoum has not been found to persist in invertebrates tested to date (weta and land crabs), which is in contrast to mammals, where brodifacoum can persist in the liver of possums for up to 9 months (Eason et al. 1996). However, invertebrates lend themselves to accumulation of fat-soluble compounds; for example, snails and earthworms are known to accumulate fat-soluble compounds such as pesticides (Serrano et al. 1995; Wagman et al. 1999). Further investigation of brodifacoum persistence is necessary.

Predators of snails include rats, pigs (*Sus scrofa*), weka (*Gallirallus australis*), kaka (*Nestor meridionalis*), and kea (*N. notabilis*) (Meads et al. 1984). Predators of earthworms are likely to be similar and include other native birds; for example, earthworms are an important part of the diet of the kiwi (*Apteryx* spp.) (Heather & Robertson 1996). In order to estimate the risk of secondary poisoning to other animals, the persistence of brodifacoum in snails and earthworms should be evaluated.

The risk of secondary poisoning to large insectivorous mammals (e.g. pigs) is low, but smaller animals, such as insectivorous bats, birds, lizards, and frogs, may be at more risk from consuming insects that have fed on brodifacoum bait. For example, insectivorous birds have been killed after eating ants (Hymenoptera: Formicidae) and cockroaches that had fed on brodifacoum baits (Godfrey 1985). Robertson et al. (1999) suggested that brodifacoum residues in brown kiwi (*Apteryx mantelli*) chicks may have arisen from feeding on invertebrates that had eaten Talon 20P® or PESTOFF® baits in Northland. Stephenson et al. (1999) suggested that the ingestion of brodifacoum-contaminated invertebrates might have contributed to the deaths of moreporks (*Ninox novaeseelandiae*) after aerial application of Talon® 7-20 baits on Mokoia Island. There are no data on toxicity of brodifacoum to native bats, lizards, or frogs. Telfair's skinks (*Leiolopisma telfairii*) on Mauritius were considered to be susceptible to secondary poisoning from brodifacoum (Merton 1987). However, both on Mauritius and New Zealand's offshore islands, lizard numbers have increased after eradication of rabbits and/or rats using baits containing brodifacoum (Eason & Spurr 1995). Nevertheless, due to the insectivorous diet of bats, lizards, and frogs, and their occurrence in areas where brodifacoum could be used for rat control, secondary poisoning by eating invertebrates that have consumed brodifacoum is a possibility and should be investigated.

DOC no longer uses brodifacoum on the mainland in a widescale fashion because of concerns about residues accumulating in non-target species.

7. Recommendations

The authors recommend that:

- The toxicity and persistence of brodifacoum to native molluscs and other soft-tissue invertebrates (earthworms, for example) be investigated.
- The database on brodifacoum toxicity for invertebrate species known to be attracted to toxic bait be improved. The sensitivity of early life stages should be included in these studies.
- The secondary poisoning risks of brodifacoum to native insectivorous species be investigated.

8. Acknowledgements

This research was funded by the Department of Conservation (Investigation No. 2454, Landcare Research Contract Report LC 9900/135). The authors wish to thank Geoff Wright for compiling the residue data, Peter McGregor for comments on the draft manuscript, Christine Bezar for editing the manuscript, and Wendy Weller for final word processing.

9. References

Brown, D. 1997: Chetwode Island kiore and weka eradication project. *Ecological Management 5*: 11–20.

Eason, C.T.; Spurr, E.B. 1995: Review of the toxicity and impacts of brodifacoum on non-target wildlife in New Zealand. *New Zealand Journal of Zoology 22*: 371–379.

Eason, C.T.; Wright, G.R.; Batcheler, D. 1996: Anticoagulant effects and the persistence of brodifacoum in possums (*Trichosurus vulpecula*). *New Zealand Journal of Agricultural Research 39*: 397–400.

Godfrey, M.E.R. 1985: Non-target and secondary poisoning hazards of 'second generation' anticoagulants. *Acta Zoologica Fennica 173*: 209–212.

Heather, B.D.; Robertson, H.A. 1996: The field guide to the birds of New Zealand. Penguin Books, Auckland, New Zealand, 432 p.

Meads, M.J.; Walker, K.J.; Elliott, G.P. 1984: Status, conservation, and management of the land snails of the genus *Powelliphanta* (Mollusca: Pulmonata). *New Zealand Journal of Zoology 11*: 277–306.

Merton, D. 1987: Eradication of rabbits from Round Island, Mauritius: a conservation success story. *Dodo—Journal of Jersey Wildlife Preservation Trust 24:* 19–43.

Morgan, D.R.; Wright, G.R.; Ogilvie, S.C.; Pierce, R.; Thomson, P. 1996: Assessment of the environmental impact of brodifacoum during rodent eradication operations in New Zealand. Pp. 213–218 in Timm, R.M., Crabb, A.C. (Eds): Proceedings of the seventeenth Vertebrate Pest Control Conference, University of California, Davis, USA.

Ogilvie, S.C.; Pierce, R.J.; Wright, G.R.G.; Booth, L.H.; Eason, C.T. 1997: Brodifacoum residue analysis in water, soil, invertebrates, and birds after rat eradication on Lady Alice Island. *New Zealand Journal of Ecology 21*: 195–197.

Pain, D.J.; Brooke, M.D.; Finnie, J.K.; Jackson, A. 2000: Effects of brodifacoum on the land crab of Ascension Island. *Journal of Wildlife Management 64*: 380–387.

Roberston, H.A.; Colbourne, R.M.; Graham, P.J.; Miller, P.J.; Pierce, R.J. 1999: Survival of brown kiwi (*Apteryx mantelli*) exposed to brodifacoum poison in Northland, New Zealand. *New Zealand Journal of Ecology 23*: 225–231.

Serrano, R.; Hernandez, F.; Pena, J.B.; Dosda, V.; Canales. J. 1995: Toxicity and bioconcentration of selected organophosphorus pesticides in *Mytilus galloprovincialis* and *Venus gallina*. *Archives of Environmental Contamination & Toxicology 29*: 284–290.

Shirer, M. 1992: In poison's defence. *Terra Nova 17*: 3.

Spurr, E.B. 1996: Environmental effects of rodent Talon® baiting. Part II: Impacts on invertebrate populations. *Science for Conservation 38*. Department of Conservation, Wellington, Pp. 12–27.

Stephenson, B.M.; Minot, E.O.; Armstrong, D.P. 1999: Fate of moreporks (*Ninox novaeseelandiae*) during a pest control operation on Mokoia Island, Lake Rotorua, North Island, New Zealand. *New Zealand Journal of Ecology 23*: 233–240.

Wagman, N.; Strandberg, B.; van Bavel, B.; Bergqvist, P.A.; Oberg, L.; Rappe, C. 1999: Organochlorine pesticides and polychlorinated biphenyls in household composts and earthworms (*Eisenia foetida*). *Environmental Toxicology & Chemistry 18*: 1157–1163.

Wright, G.R.; Eason, C.T. 1991: Residue analysis of invertebrate samples for brodifacoum (Talon). Forest Research Institute contract report, FWE 91/94 (unpublished), 5 p.

Go to pg. 11
Laboratory and field studies of brodifacoum residues in relation to risk of exposure to wildlife and people