

**Effect of sodium monofluoroacetate (1080) on non target
invertebrates of Whitecliffs Conservation Area,
Taranaki.**

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INVESTIGATION NO: 1414
KEY OUTPUT:

Mike Meads

Ecological Research Associates of New Zealand Incorporated
P.O. Box 48-147, Silverstream 6430
New Zealand

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PREPARED FOR:
Director, Science and Research
Conservation Sciences Centre
Department of Conservation
P.O. Box 10-420, Wellington

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Scientist's reputation in tatters

By BRENDAN COLE
Conservation reporter

MIKE MEADS does not need to be told 1080 poisoning of possums is a hot political topic.

The Wellington-based former Landcare Research scientist found that out the hard way after completing a survey of how 1080 affected the Whitecliffs area in North Taranaki more than two years ago.

Some anti-1080 activists believe he lost his job after presenting evidence from the survey that 1080 damages the environment, which angered the Department of Conservation so much they declared it invalid and did not publish it.

Subsequently his competence as a scientist was questioned and his reputation scripped to bloody remains.

But what actually happened? Were the results covered up as some claim or were they declared false because of genuine testing inaccuracies?

Commissioned to survey the Whitecliffs area in North Taranaki in 1991, Mike Meads' mission was to find out how 1080 affected invertebrate populations. The survey was carried out after preliminary findings by the DOC Wanganui Conservancy showed many invertebrates and insects were killed by 1080.

Nine and a half tonnes of 1080 were spread over Whitecliffs by helicopter and invertebrate populations were assessed by Mr Meads using pitfall traps, before, during and after the operation from June 21, 1991 to February 28, 1993.

Samples were collected every two weeks and the pit trap contents sorted by hand. The results made disturbing reading.

Meads noted dust from poisoned grain pellets dropped by helicopter flew across the control block. Subsequently, forest floor insect numbers plummeted and remained low for a year after the drop.

Low insect numbers in the area would in turn decrease food for birds and that population would decrease. Insect populations that fed on leaves on the cool forest floor had decreased the most and insect larvae dropped dramatically.

"DOC Wanganui claimed a 90-91% kill of possums and a better than 80% kill of rats, and yet two weeks after the baits were dropped over the study site 73% of baits were still present," the report stated.

"This suggests that procedures for aerial delivery require modification."

It also said that breakdown and degradation of 1080 were longer than previously thought.

"About 25% of the 1080 may therefore have perished more than three months after the poison drop at Whitecliffs."

In the 1990s, 1080 is an emotive topic for New Zealanders. On one side of the fence stand environmentalists and the Department of Conservation who, under the guidance of government policy, are eager to control the 70 million pests which destroy a huge amount of New Zealand forest and bush each year.

On the other side stand anti-1080 lobbyists who believe DOC have done what would be considered in PR circles a marvellous job in promoting the poison, but have gone some way to conceal its dangers from the public.

Both sides have a close affinity with the environment, but it could be said caught in the middle of this wrangle was Mike Meads.

The 1080 poison kills by interrupting the Krebs cycle — the process by which animals convert food into energy — and it leads to a buildup of waste products in the body affecting the central nervous system. It's not a fast killer, death takes between one and 10 hours.

It is used by DOC and the Animal Health Board (AHB) which contracts regional councils around the country to control the 70 million possums.

Each year 7000 tonnes of 1080 poisoned baits are spread over 2.88 million hectares, the annual production of 1080 is five tonnes and New Zealand imports 70% of that, costing \$700,000.

It's a huge operation to solve a huge problem. But it was not Mike Meads' problem. His loyalties lay with neither side, and his Whitecliffs report was approved five times through a peer group review process by his Landcare Research colleagues.

However, a sixth peer group review by a scientist, who DOC will not name, rendered the survey invalid.

Meads admitted the report was disturbing. "Results show that insects that feed on leaf litter are the most severely impacted by 1080."

This was a reminder to the potential of a relatively untested poison. "Further investigation of the effects of aerial 1080 poisoning is urgently required," the report said.

He reflected on what the report had done to his career.

"It's given me nothing but heartache and trouble. I would rather forget all about it. The whole thing hinged on that one DOC scientist and we do not know who it is," he said.

DOC science contract manager Bob McColl (Wellington) said Mr Meads was criticised for the type and number of pitfall traps he used to catch insects and the way non-toxic control baits were arranged around the experiment.

And he said all six reviews found Mr Meads' scientific research wanting.

He said the baits had not fallen correctly so he moved the baits closer to the traps which he should not have done.

He also made a mathematical error in how he calculated how many baits fell per square metre, therefore he had a much higher concentration. "These are called design errors," Mr McColl said. "We found deficiencies. Landcare wrote to us and told us the paper did not meet scientific criteria which made the paper unacceptable. If your control is destroyed then you should abort the experiment," he said.

However, Meads said, the control was not contaminated until six weeks after the poison drop and only data compiled in that first six weeks was used.

After Meads' rejected report, fellow Landcare researcher, ornithologist Eric Spurr, was commissioned

to do another insect experiment. He found that 1080 had little effect on insect life. Ironically he used the same type of traps and a similar bait pattern to Meads.

DOC accepted this report although the control in Spurr's experiment was 7km away in a different forest. A control where the soil and insect life was different would be enough to render it invalid, Mr Meads said.

"I was able to prove that 1080 by air was damaging in the long term to the forest and undoing what they were trying to do. They are just wantonly killing invertebrates."

DOC's misgivings towards Mr Meads also raised the question among many why a respected scientist of some 27 years standing who has had extensive experience and more than 100 articles published would present a document that he believed was false.

"DOC did not look at the answers I had discovered. The baits that I sited was exactly the same number as the work done by Eric Spurr who is quoted by DOC. I have made publications that have made their

mark, this publication happens to affect DOC's poisoning programme.

"I was able to prove that 1080 spread by air was damaging in the long term to the forest and undoing what they were trying to do."

He recommended the same kills could be achieved with less bait which would in turn lessen the danger to invertebrates and out-casts.

Any reduction in the amount of fragments and dust produced would lessen the impact on insects, the report said.

Ten days before Meads was scheduled to present his report to the Royal Society of New Zealand's international symposium on 1080 in Christchurch, he was made redundant.

Although his reputation and 27-year career as a scientist is in tatters, he is not bitter. He was coy about the request for an interview, had no grudge against DOC and wants to put it behind him.

"I was a naive scientist. I had not researched anything so politically sensitive. It did not dawn on me that these sorts of things go on in politics," he said.



NAIVE: Mike Meads admits he was a political novice.

INVESTIGATION TITLE: Long-term effects on the ecology of invertebrate populations.

STUDY VENUE: Whitecliffs Conservation Area, Taranaki, Wanganui Conservancy.

INVESTIGATION LEADER: M.J. Meads

INVESTIGATION STATUS: Completed

CLIENT: DoC, Science & Research Division

FINISH DATE: 30 June 1994

INVESTIGATION OVERVIEW:

Preliminary findings by Meads and Notman, working with the Wanganui Conservancy of DoC, showed that invertebrates in many orders (particularly insects) were killed during a sodium monofluoroacetate (1080) field operation in the Whitecliffs Conservation Area and that populations of insects and their predators were seriously depressed in the short term. The longer-term effects on these insect populations of 1080 were investigated by Landcare Research for the Department of Conservation.

OBJECTIVES:

1. To report the short-term effects of an aerial 1080 poison operation on non-target invertebrate populations at Whitecliffs Conservation Area, Taranaki.
2. To assess the potential for using data from other similar untreated forests as baseline information for evaluating the longer-term effects of the poison operation.

METHODS:

1. Invertebrate populations were assessed before, during, and after a 1080 poisoning operation in Whitecliffs Conservation Area, using pitfall traps from 21 June 1991 to 28 February 1993.
2. Samples were collected fortnightly for 3 months and monthly thereafter. Pit-trap contents were sorted by hand. Invertebrate samples were sorted initially to taxonomic order, and then to family and species.
3. Counts were analysed for 23 orders of invertebrates over six time periods (21 June - 30 August 1991) approximately 2 weeks apart before and after poisoning.
4. Seasonal abundance over 12 months of springtails, spiders and all insect larvae were compared with the same groups in other lowland podocarp/broadleaved forest to show longer-term effects, after contamination of the Whitecliffs control plots.

FINAL RESULTS:

During the pre-poisoning period the numbers of invertebrates found in pitfall traps were similar for the poisoned and control areas. Generally, more invertebrates appeared in the second sampling than the first

and this increase was similar for both the control and poisoned traps. This is consistent with the expected rise in invertebrate numbers as spring progresses.

Following the 1080 aerial application the total counts of all invertebrates showed a highly significant difference between 1080 and control plots at 2 and 4 weeks, but not for subsequent periods. For the control plots the counts rose markedly during the two weeks following the 1080 aerial drop, and peaked during the next two weeks at more than four times the initial level, then fell steeply to about the initial level, six and eight weeks after the 1080 aerial drop.

The dramatic fall of insects in the control area fell dramatically to a level almost as low as that of the poisoned areas, suggests that the control area became contaminated with 1080 after heavy rain fell about 1 month after the main 1080 aerial drop.

Comparison of the Whitecliffs data with that of other lowland podocarp/broadleaved forests over 1 year, showed that 1080 had a severe impact on many invertebrates. At Whitecliffs, insect larvae, comprising coleoptera, hymenoptera, diptera and lepidoptera dropped dramatically from July through to October, then stabilised for the remainder of the year at around the crash level. Insect larvae in other forests followed the normal pattern of continual rise from July until the onset of the following winter.

FINAL CONCLUSIONS:

Insects were affected most and molluscs least by 1080 poison. In descending order the taxa most severely suppressed were: Coleoptera, Collembola, Diptera, and Opiliones. Hymenoptera, Orthoptera, and earthworms showed a slight suppression, but not at a significant level. Mollusca, Amphipoda, Acarina, and Araneida showed no significant change.

The significant drop in insect numbers on the control plots after heavy rain suggests strongly that these plots had become contaminated with 1080.

The insects associated with the breakdown of leaf-litter were the most severely affected by 1080, which adsorbs to cellulosic leaf-litter, and persists in the litter for at least 3 months. Although breakdown of 1080 can be complete at 30 days at 23°C, breakdown rates of 1080 at field temperatures in winter are much slower than at laboratory temperatures exceeding 20°C. Mean maximum litter temperature during winter is 10.6°C and the mean minimum is 4.3°C.

Comparison of the Whitecliffs data with that of 2 other forests over 1 year, showed that 1080 had a severe impact on insect larvae (coleoptera, hymenoptera, diptera and lepidoptera), collembola and araneida.

RECOMMENDATIONS:

Further investigation of the effects of aerial 1080 poisoning on invertebrate populations is urgently required. In particular longer-term monitoring is necessary to determine not only which taxa are most susceptible to 1080, but also how long-lasting the effects are, and the likely ecological consequences. It is important in future studies that sufficient time is allowed prior to the poison operation for researchers to obtain good sequences of samples from both the control and the poisoned area.

The role of bait fragments/dust in poisoning non-target species needs further investigation, and future studies should monitor the distribution of baits and bait fragments/dust.

Two weeks after the baits were dropped over the study site, 73% were still present even with a possum kill exceeding 90%. This indicates that it may be possible to modify the procedure for aerial delivery to both minimise risk to some invertebrates while still killing as many possums.

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2. Introduction

Preliminary findings by Meads and Notman, working with the Wanganui Conservancy of DoC, showed that invertebrates in many orders (particularly insects) were killed during a sodium monofluoroacetate (1080) field operation in the Whitecliffs Conservation Area and that populations of insects and their predators were seriously depressed in the short term. This investigation examines the longer-term effects of 1080 on forest invertebrates after 1080 was aerially distributed to control possums in the Whitecliffs Conservation Area, Taranaki.

3. Background

Sodium monofluoroacetate (1080) is widely used for animal pest control in New Zealand. As possums are strongly implicated in the spread of bovine tuberculosis 1080 bait is being aerially distributed over large areas of native forest.

Research has concentrated on the most efficient and cost effective methods for applying the poison, its persistence, degradation and residues, but largely over-looked the longer-term effects to non-target species. Investigations on the effects of this poison on non-target species has mostly been confined to its direct impact on birds, with little or no research on the effects on lizards, bats, or invertebrates. Few studies have dealt with the direct impact of 1080 on native insects and other invertebrates, and there is no research on the effect of 1080 on populations or communities of invertebrate species.

Sodium monofluoroacetate (1080) was patented as an insecticide in 1927 (Twigg & King 1961), and can act as a systemic and contact insecticide (David 1950). The compound has been tested on and used in the field for aphid control in several countries (Atzert 1971, Dunning and Winder 1961). Aphids were killed in 2 days when 1080 was applied as a contact insecticide at a concentration of 0.001% (David 1950), and a 0.0005 per cent solution of 1080 was effective systematically against aphids. Whether applied to the leaves or roots 1080 proved an extremely effective systemic insecticide (David & Gardiner 1951), and was considered too dangerous to use as an insecticide in Britain (David & Gardiner 1958). During an outbreak of bubonic plague in Peru 1080 acted as a secondary poison that killed fleas on the poisoned rats (Macciavello 1946). In New Zealand 1080 has recently been used for controlling common (*Vespula vulgaris*) and German wasps (*V. germanica*) (Spurr 1991). Notman (1989) in a review of the literature, found that invertebrate species from 10 different orders were affected by 1080. Fluoroacetate, from which 1080 is derived is a naturally occurring toxin found in 33 species of *Acacia*, *Gastrolobium* and *Oxylobium* in Australia, and was isolated in the South African plant, *Dichapetalum cymosum* (Marais 1944). Leaf material can contain as much as 2.5 g fluoroacetate/kg, and seeds more than 6.5 g fluoroacetate/kg (Twigg and King 1991).

Sodium monofluoroacetate has a high degree of secondary toxicity in mammals (Hudson *et al* 1984).

4. Objectives

- To report the short-term effects of an aerial 1080 poison operation on non-target invertebrate populations at Whitecliffs Conservation Area.
- To assess the potential for using data from other similar untreated forests as baseline information for evaluating the longer-term effects of the poison operation.

5. Methods

5.1 Whitecliffs poisoning operation

The poison operation was carried out by DoC Wanganui, in the Whitecliffs Conservation Area, Taranaki, a coastal podocarp/broadleaved forest.

Toxic baits (9.5 tonnes of 4-g Wanganui No.7 cereal-based baits - Animal Control Products, Wanganui), containing 0.08% 1080 were spread at 4 kg bait/ha (= 1 bait/10 m²) by helicopter on 4 July 1991.

The weather was fine and clear with a moderate southerly breeze across the top of the forest, and a heavy frost occurred that night. Heavy rain fell in July-August: 32 mm 8-9 July; 48 mm 17-22 July; 133 mm 23-31 July; 178 mm of rain 31 July-16 August. By August the baits were almost completely assimilated into the leaf litter.

The percentage of possums killed at Whitecliffs was estimated at 90-91%. The percentage of rats also killed was better than 80% (Les Stanley pers.comm.).

5.2 Bait distribution and invertebrate sampling

Two parallel 100 m pit-trap lines were placed north-south 50 m apart in areas of similar soil and vegetation type within the forest. One line was designated as the control and marked with helium-filled balloons strung above the canopy to indicate a "no-1080" zone to the helicopter pilot. The poison line was not marked for the pilot and was treated with 1080 in the same way as the rest of the forest.

On each line (1080 and control) 10 pit traps (Moeed & Meads 1985) were placed 10 m apart. The traps were open continuously to 30 September 92. They were emptied fortnightly from 5 June 91 to 30 August 91, and then monthly from 30 August 91 to 30 September 92. From 30 December 92 to 28 February 93 the traps were re-activated for 2 months to obtain an additional summer sample. Trapped invertebrates were counted and sorted into orders and to species level for wetas, snails, and scarab and ground beetles.

Counts were analysed for 23 orders of invertebrates over six fortnightly samples (21 June - 30 August 1991) two before and four after the poison operation.

Bait distribution in forest immediately north of the 1080 pit-trap line was determined by counting the number of baits within 1-m radius plots sampled at 5-m intervals along 4x100 m lines. Bait distribution along the 1080 pit-trap line was determined by counting the baits within a 2-m radius of each trap. To check whether any baits had accidentally fallen on or near the control line, baits were searched for in 1-m radius plots spaced at 5-m intervals along seven 100-m lines running at right angles across both pit trap lines.

Distribution of baits were far from even, with two baits frequently clumped and occasionally three clumped. It was not unusual to have gaps of up to 80 m between baits.

Within the poisoned area only four baits fell within 5 m of the poison line (two pit-traps had a single bait within 2 m and a third trap had two baits within 1 m, and 80 m of the trap line failed to receive any baits within 5 m of the line. Three baits were therefore moved to about 1 m of each trap, each spaced well apart. This is equivalent to an application rate of 0.38 baits/10m², less than the "average" spread of 1 bait/10 m² throughout the forest. The day following the drop, 4 baits from near two of the pit traps had been removed (presumed to have been eaten overnight by possums) and were not replaced.

5.3 Statistical analysis

Trap-count data are typically Poisson rather than normally distributed. They cannot be readily transformed to induce a normal distribution of errors because the distribution is discrete rather than continuous and zero counts in individual traps are common. Accordingly, a generalised linear model (McCullagh & Nelder, 1983) was used to compare the total number of invertebrates for the 1080 and control treatments at each sampling period. In this now standard approach the number of invertebrates N_{ijk} counted in trap k for treatment i in time period j is modelled explicitly as a Poisson random variable with mean μ_{ij} . The analysis of deviance arising from the generalised linear regression model allows estimates of μ_{ij} and their standard errors, from which tests of significance of differences between mean trap counts can be constructed in a similar fashion to the usual analysis of variance for normally distributed data. The model was fitted using the Genstat statistical package (Genstat 5 Committee 1987).

6. Results

6.1 Short-term effects of the 1080 poison operation on invertebrates

During the pre-poisoning period the numbers of pitfall trapped invertebrates were similar for the poisoned and control areas. Generally, more invertebrates appeared in the second sample than the first for both the control and 1080 traps, and is consistent with the expected rise in invertebrate numbers as daylight increases.

For total counts of all invertebrates, there was a highly significant difference between 1080 and control traps 2 and 4 weeks after the poison operation but not for subsequent periods. Counts in the control traps rose markedly during the 2 weeks after the operation, and peaked during the next 2 weeks at more than 4 times the initial level, but then returned to about the initial level; 6 to 8 weeks after the 1080 drop. The counts for the 1080 traps remained fairly constant throughout the first month, and showed a modest drop 6 weeks after the poison operation (Fig. 1, Table 1).

Table 1. Total mean number of invertebrates (individuals), and associated standard errors, as estimated from generalised linear model.

date	1080 Poison		Control		result
	mean	(s.e)	mean	(s.e)	
21.6.91	54.7	(11.5)	39.7	(9.8)	ns
4.7.91	75.0	(13.5)	67.0	(12.7)	ns
19.7.91	45.7	(10.5)	126.4	(17.5)	<i>P</i> < 0.001
2.8.91	57.8	(11.8)	229.7	(23.6)	<i>P</i> < 0.001
15.8.91	18.5	(6.7)	25.4	(7.8)	ns
30.8.91	25.4	(7.8)	30.4	(8.6)	ns

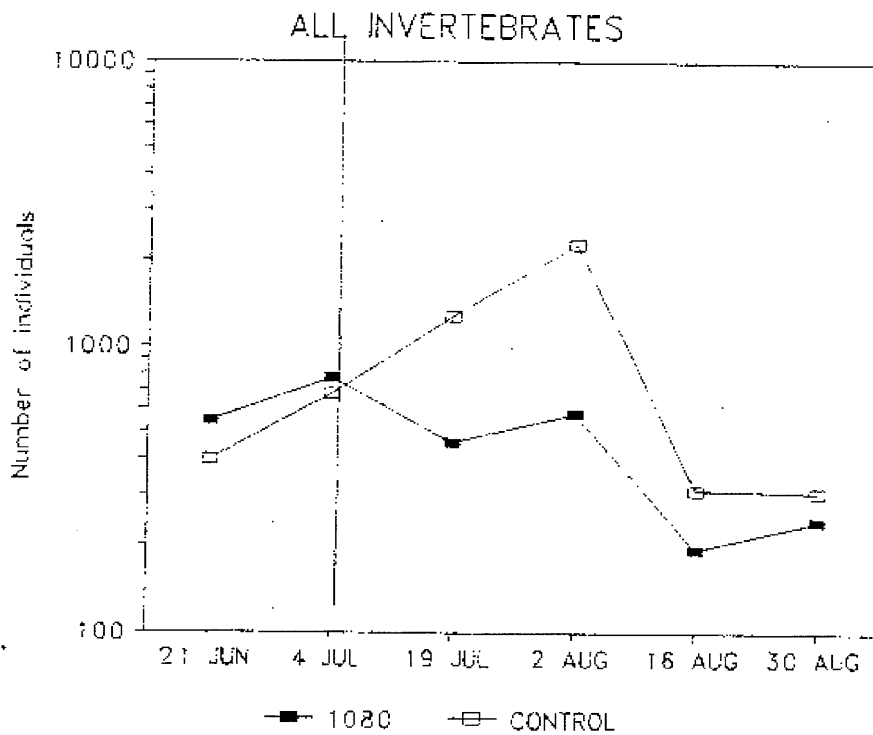
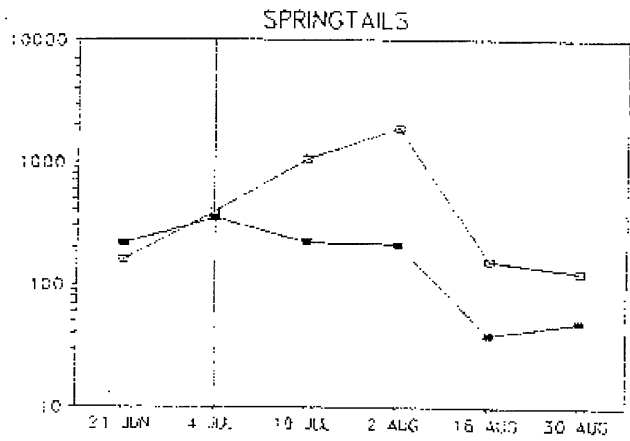
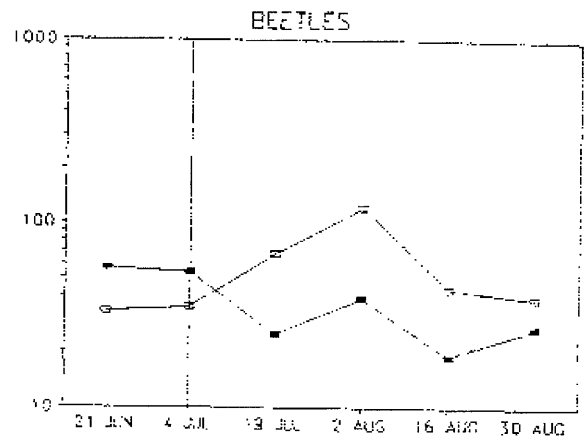


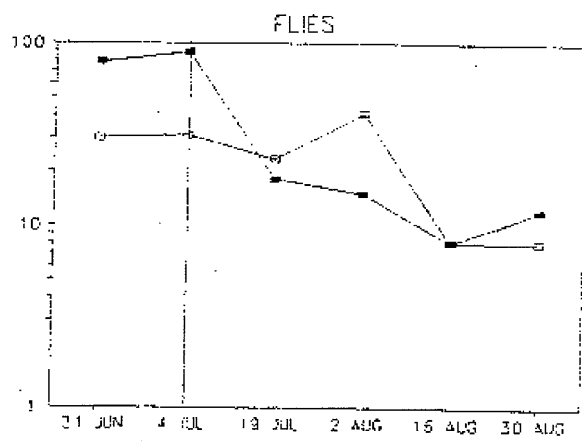
Figure 1. The total number of all invertebrates trapped before and after an aerial application of 1080 poison for possum control in Whitecliffs Conservation Area (21 June to 30 August 1991).



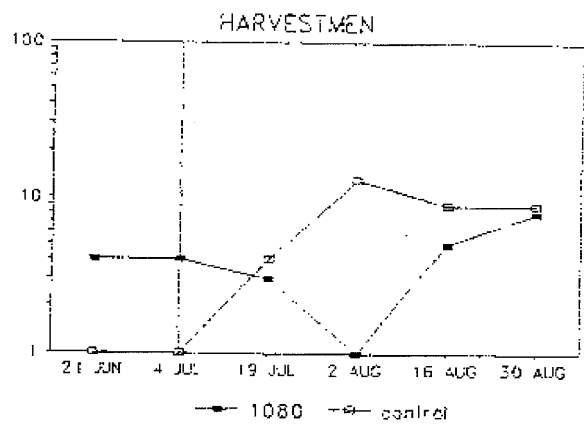
A



B



C



D

Figure 2. The total numbers of A: springtails; B: beetles; C: flies; D: harvestmen, trapped before and after an aerial application of 1080 poison for possum control in Whitecliffs Conservation Area (21 June to 30 August 1991).

Insects (Insecta), springtails (Collembola) and beetles (Coleoptera), showed a highly significant difference between 1080 and control traps at 2 and 4 weeks after the poison operation, but not for later sampling periods. Counts of flies (Diptera), were significantly higher in 1080 traps than in control traps at the two sampling periods before the poison operation.

Harvestmen (Opiliones) were the only non-insects to show a significant difference between 1080 and control traps, at 4 weeks after the poison operation (Fig.2, Table 2).

Table 2. Statistical significance of differences in total counts for springtails (Collembola), beetles (Coleoptera), flies (Diptera), and harvestmen (Opiliones).

ns: no significant difference between 1080 and control
%: 1080 > control

Date	Springtails	Beetles	Flies	Harvestmen
21.6.91	ns	ns	$P < 0.05\%$	ns
4.7.91	ns	ns	$P < 0.01\%$	ns
19.7.91	$P < 0.001$	$P < 0.001$	ns	ns
2.8.91	$P < 0.001$	$P < 0.001$	ns	$P < 0.01$
15.8.91	ns	ns	ns	ns
30.8.91	ns	ns	ns	ns

In the third post-poisoning sample, numbers of invertebrates (6 weeks after the poison operation) decreased markedly in the control traps (a trend reversal), but showed little change or continued the same downward trend as for the previous period in the 1080 traps. This trend reversal was most marked for springtails and beetles, i.e., control trap numbers increased significantly after the poison operation, but several weeks later the trend reversed and these numbers decreased just as dramatically, to levels approximating those in the 1080 traps.

For Chilopoda (centipedes), Blattaria (cockroaches), Archaeognatha (bristletails), and Homoptera (mealy bugs), showed small decreases but too few were trapped to show a statistical difference between 1080 and control traps. Mollusca (snails), Amphipoda (land hoppers), Acarina (mites), and Araneida (spiders) showed no change.

6.2 Longer-term effects of 1080 (comparison with other forests)

- 17 Observation on the day of the poison operation showed that fine bait particles and dust were blown across the forest canopy from the helicopter bait bucket. As the control area was only 100 m from the poisoned area, it is likely that this dust blew across the control area and lodged in the tree canopy. In the first fortnight after the aerial drop only 32 mm
 12 of rain fell, but 181 mm fell in the second fortnight after the poison operation. Thus an influx of 1080 may have washed from the tree tops to the ground.

The highly significant reduction in insect numbers after this heavy rain (181 mm) strongly suggests that the control area had become contaminated with 1080. Predation by rodents and possums would have been reduced substantially after the poison drop and thus cannot be invoked to explain this reduction in insect numbers.

Before the probable contamination of the control area, significant changes had been revealed for total counts of springtails, beetles, flies, and harvestmen.

Although the effect of contamination of the control plot eliminated any chance of monitoring the longer-term changes between the poison and control plots at Whitecliffs Conservation Area, a valid comparison can be made by comparing the trends of seasonal activity in abundance of invertebrates in other forests with the effects of 1080 on seasonality at Whitecliffs.

The Whitecliffs data were compared with those from the lowland podocarp/broadleaved forests of Orongorongo Valley (Wellington), and Karangarua (south Westland) over one year. Counts of insect larvae and spiders did not show a significant difference between the 1080 and control traps at Whitecliffs. In contrast data from the Orongorongo Valley and Karangarua, showed a seasonal rise through spring reached a peak during summer (Fig.3).

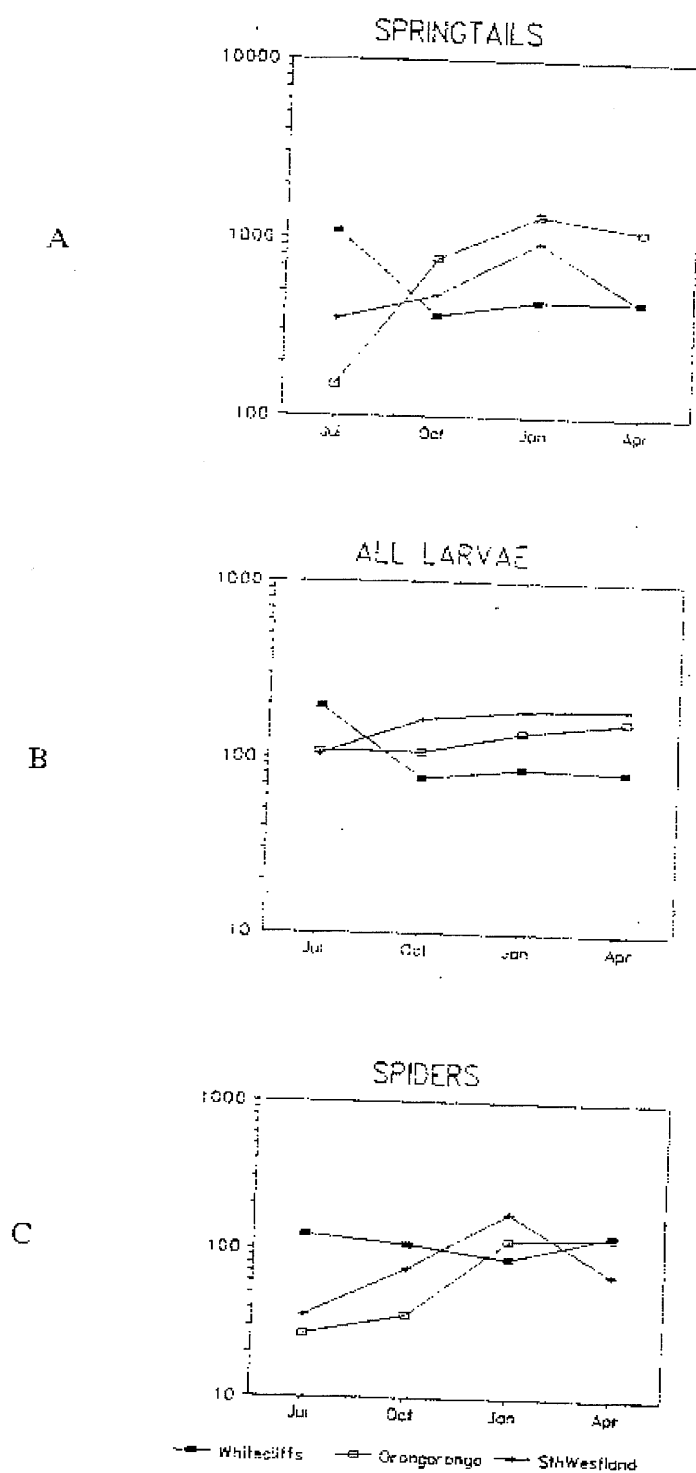


Figure 3. Comparison of the seasonal abundance over one year of A: springtails; B: all insect larvae; C: spiders from the lowland podocarp/broadleaved forests of Whitecliffs, Taranaki, Orongorongo Valley, Wellington, and Karangarua, south Westland.

Similarly the insect larvae at Whitecliffs, comprising Coleoptera, Hymenoptera, Diptera and Lepidoptera dropped dramatically from July through to October, then stabilised at around the crash level for the remainder of the year. Insect larvae in the other two forests followed the normal pattern of invertebrate breeding cycles, continually rising from July until the end of summer and onset of the following autumn.

7. Discussion and conclusions

7.1 Short-term trends

When data from all traps are totalled invertebrate numbers were significantly reduced in the 1080 traps immediately after the poison operation. However, those insects that overwinter as adults in forest (beetles, springtails, and flies), accounted for most of the difference and were clearly affected by 1080. Counts for those species present in low numbers in forest, seasonally in diapause, or not present as adults during the winter, were too few to reach any conclusion. Similarly, there were often too few data for statistical analysis at specific or generic level.

Insects were affected most and molluscs the least. In descending order the taxa most severely affected were: Coleoptera (beetles), Collembola (springtails), Diptera (flies), and Opiliones (harvestmen). Hymenoptera (wasps and ants), Orthoptera (wetas and crickets), and Lumbriculida (terrestrial earthworms) showed small, but not significant, differences between 1080 and control areas.

7.2 Longer-term trends

During the pre-poisoned period the two lines of pitfall-trapped invertebrates showed similar rising patterns. After poisoning, the number of most groups continued to increase in the control traps, but decreased in the 1080 traps. This trend continued for two post-poisoning samples. The trend reversal in the control area in the third sampling period suggests that the longer-term data were compromised by heavy rain washing 1080 bait dust and particle drift from the canopy into the control area.

I expected catches in the control traps to continue to increase, or at least stabilise with the onset of spring. If this trend reversal was the result of some widely operating environmental factor (earthquake, storm or drought), poisoned traps should also have been affected. The pattern of less proportional decrease in population size in the poisoned area is consistent, and is good evidence that the effect was a result of 1080 contamination.

7.3 Possible explanations for the insect decline

My results show clearly that those insects associated with leaf litter breakdown (springtails, beetles and dipterans) are the most severely impacted by 1080. This suggests that some effect specific to litter is a more likely explanation than direct consumption of bait or feeding on plants that had taken up poison. The effect is not confined to predators although secondary poisoning is a possibility. A possible mechanism can be inferred from the work of Hilton *et al.* (1969) on the uptake of 1080 by sugarcane. They state: "The high degree of adsorption of monofluoroacetate to leaf and root tissue, as well as to other cellulose such as filter paper, was entirely unexpected in view of its water solubility and volatility. It can be assumed that fluoroacetate would remain adsorbed to fibrous bait components, probably would not be washed off the bait formulations by moderate rainfall, and would not readily leach into soils, especially into those with considerable organic content. Desorption of treated plants decreased over a 3-month period". Thus it is possible that the fibrous bait components are assimilated into the forest litter after rain, and therefore suggest that 1080 became attached to the highly cellulose and fibrous leaf-litter where it remained for at least three months.

The persistence time is at present uncertain. Breakdown and degradation of 1080 (defluorination by micro-organisms) have been stated to be 3-4 weeks (Bong Chui Lien *et al.* 1978), but trials and tests are traditionally carried out in a laboratory at temperatures above 20°C. Tests carried out by DSIR, Taita, during 1991 similarly showed that breakdown of 1080 was almost complete at 30 days at 23°C, but that a concentration of 0.02 mmol/l was still present after 115 days at 10°C, and more than 1.5 mmol/l after 115 days at 5°C. (Parfitt *et al.* 1994). Moeed & Meads (1985, 1986) showed the *mean maximum* litter temperature during winter as 10.6°C and the *mean minimum* litter temperature during winter as 4.3°C. About 25% of the 1080 may therefore have persisted more than 3 months after the poison drop at Whitecliffs.

A second factor affecting the persistence of toxicity is rainfall. In a field experiment to test the effect of weathering on baits treated with 1080, Griffiths (1959) found that "after a fall of 1½ in. of rain, oats retained about half of the initial potency and showed no change up to the seventh week, in spite of two more falls, each of 0.9 in. of rain. The static level of 1080 in the oats suggested that the poison was not on the surface but was actually imbibed by the grain". After eight weeks of exposure a sample was husked and tested. "Curiously, all the 1080 appeared to be in the husks and none was detectable in the grain. Somehow a substantial amount of the 1080 becomes adsorbed on, or absorbed into, the husk so that it is impervious to the leaching action of rain." Clearly there is a need for further study to establish the way in which baits become detoxified.

7.4 Possible multiple effects of 1080

Pit trapping for surface-moving and litter-feeding invertebrates is just one way of sampling the terrestrial fauna of a forest, and can only be expected to indicate the presence or absence of a part of the total invertebrate fauna. It is however the most reliable method for estimating the specific community elements of primary ecosystem food and nutrient chains. In studying the effect (magnitude and direction of change) of 1080 on forest invertebrates only the presence or absence factor can be used in determining impact.

How the organism is killed by 1080 cannot be answered by a study of this nature. Tens of thousands of different species of invertebrates exist in a forest ecosystem and each one can be affected by 1080 in a different way. 1080 poisoning can be sublethal or acute and it can affect an insect by killing it or affecting its behaviour. This can happen from direct body contact, direct consumption of the bait, or through plant tissue as systemic poison (roots, leaves and litter), or secondarily through eating or coming into contact with prey, carrion or through coprophagy, or eating litter and detritus. How or when 1080 impacts on the egg, larval, nymphal or pupal stage of an insect is quite unknown, as is the effect on the delicate balance of communities, food webs, nutrient cycles, predators and prey, and other ecological relationships.

The amount of 1080 required to kill micro insects such as Collembola, whether from contact or ingestion is unknown. Residues in single small insects are not measurable with current techniques. Indeed, given the application rates of 3.2 g active ingredient per hectare, it is most unlikely that 1080 would be found in measurable amounts in leaf litter except in close proximity to baits. The dust, being so much finer than baits, is likely to be spread much more evenly following an aerial application and may contain a sufficient concentration (residue) of 1080 to affect insects, particularly in the leaf-litter. Although the rate of biodegradation of 1080 is somewhat dependent on moisture and temperature, the residues or amounts remaining that are measurable are more than enough to impact on micro insect fauna.

A feature of 1080 is that its toxicity and symptoms vary considerably between animals. In this study variability is shown in beetles of the family Carabidae; when analysed at the specific level the 10 different species showed different levels of impact.

1 It would be reasonable to assume that populations of those insects with short life cycles (springtails) would recover far more quickly than those that have life cycles of 3 years and more (some beetles, cicadas, hepialid moths).

7.5 Comparison with other forests

Comparing the trends of seasonal activity in abundance of invertebrates in other forests with the effects of 1080 on seasonality at Whitecliffs shows a seasonal trend reversal for some invertebrates at Whitecliffs. The differences over one year on springtails, spiders and insect larvae comprising flies, beetles, wasps and moths is compelling (Figure 3).

8. Recommendations

Substantial prior warning of future 1080 poisoning operations should be given researchers to enable an adequate sequence of samples to be collected from both untreated and treated areas before poisoning.

The role of bait fragments/dust in poisoning non-target species needs further investigation, and future studies should monitor the distribution of baits and bait fragments/dust.

Long term monitoring is necessary to determine which taxa are especially prone to 1080, how enduring the impact is, and what the likely ecological consequences would be.

DoC, Wanganui claimed a 90-91% kill of possums and a better than 80% kill of rats, and yet two weeks after the baits were dropped over the study site 73% of baits were still present. This suggests that procedures for aerial delivery require modification. Similar kills may be achievable with far lower densities of baits; this would minimise the risk to some invertebrates, and cut costs.

Even though continual tests and research has improved baits to a standard size and composition, the problem of frass (fragments and dust) produced from handling from store to site, tipping by hand into the aircraft's hopper and finally flung through a mechanical impeller at the base of the hopper, creates 1080 laden fragments and dust. Any reduction in the amount of fragments/dust produced will lessen the impact on insects.

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