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THE TOXICITY OF SODIUM MONOFLUOROACETATE (1080) TO *HUBERIA STRIATA*, A NEW ZEALAND NATIVE ANT

Summary: Although many species of native invertebrates have been identified on toxic baits containing sodium monofluoroacetate (1080) following aerial operations for possum control, few quantitative data are available to determine the risk of primary or secondary poisoning that may result from these exposures. This paper reports on a series of studies conducted to determine the risk of 1080 exposure to one such non-target insect, the native ant *Huberia striata*. Subsequent risk of secondary poisoning to insectivorous animals is extrapolated. Ants were exposed in the laboratory to cereal baits containing 0.15% sodium monofluoroacetate, with and without alternative sources of food, and mortality was compared with controls after 24 and 48 h. Acute mortality was significantly greater in both exposed groups and ants that died contained 1080 residues, indicating that some ants could consume lethal amounts of 1080 in cereal baits. However, the increase in mortality was relatively small (7% after 24 h and 12% after 48 h), indicating either that palatability of 1080 bait to this species is low, or that the toxin is not readily absorbed from this matrix. Additional trials were conducted to expose ants to 1080 in sugar-water, in order to determine the acute toxicity dose range. The oral LD_{50} at 48 h was 42 mg kg^{-1}, which was comparable to previous results obtained for the large-headed weta, *Hemideina crassidens*. The persistence of 1080 in ants consuming a sub-lethal dose was also determined, in order to assess risks of secondary poisoning to insectivores. Residues in ants receiving approximately 36 mg kg^{-1} of 1080 declined rapidly, from a peak of 5.51 mg kg^{-1} 1 day after exposure, to 0.27 mg kg^{-1} after 7 days. Potential risks to insectivorous birds were calculated using worst-case exposure assumptions, and were determined to be negligible.

Keywords: Hymenoptera; *Huberia striata*; 1080; invertebrate toxicity; secondary poisoning.

Introduction

Cereal-based pellets or carrot baits containing 1080 have been widely used for almost 50 years to control rabbits (*Oryctolagus cuniculus* L.) and brushtail possums (*Trichosurus vulpecula* Kerr) in New Zealand (Rammell and Fleming, 1978). The risk of widespread 1080 use to non-target wildlife is a controversial issue, with relatively few quantitative data available to determine the sensitivity of exposed species, especially indigenous invertebrates. Recent studies have identified about 130 different invertebrate taxa on 1080 bait after aerial possum control operations (G. Sherley, *pers. comm.*). Two species of indigenous insects comprised the majority of these. The common forest ant *Huberia brouni* Forel (Hymenoptera: Formicidae) made up nearly 60% of all invertebrates identified on cereal bait, while the scarab beetle *Saphobius squamulosus* Broun (Coleoptera; Scarabeidae) comprised 55% of all observations on carrot baits (Sherley *et al.*,1996, *unpubl. data*). Preliminary studies of ant populations following two 1080 operations indicated that bait exposure did not have a significant effect on ant numbers (Spurr, 1994a, b), but the sample size was small. Only minimal information is available on the sensitivity of any invertebrate taxa to 1080 (Notman, 1989).

Ants that have consumed a sub-lethal dose of 1080 may also pose a risk of secondary poisoning to insectivorous birds, reptiles, or predatory invertebrates (McIlroy, 1984). Several native and introduced bird species are known to eat ants, including the rifleman (*Acanthisitta chloris* Sparraman), hedge sparrow (*Prunella modularis* L.), grey warbler (*Gerygone igata* Quoy and Gaimard), and pied tit (*Petroica macrocephala* Gmelin) (Moeed and Fitzgerald, 1982). Predatory insects, spiders, and lizards, including skinks and geckos, are also likely to eat ants. Birds died after eating ants that fed on brodifacoum baits (Godfrey, 1985). A North American study indicated that ants killed by exposure to 1080 may have caused secondary poisoning in birds (Hegdal, *et al.*, 1986). In spite of these examples, the risk of secondary poisoning of insectivorous animals from 1080 is largely unknown. Information is therefore needed on the persistence of 1080 in insects. The aims of this study were to determine if the native ant, *Huberia striata* Smith would be lethally poisoned when exposed to 1080 cereal baits, to determine the acute toxicity of 1080 to this ant, and to determine the persistence in ants that had consumed a sub-lethal dose of 1080, in order to estimate the risk of secondary poisoning to insectivorous animals.

Methods

Collection and maintenance of ants

Huberia brouni is difficult to maintain in captivity (the colony died out when maintained in laboratory conditions), and due to its small size, would require very large numbers of individuals in each group to obtain enough tissue for 1080 residue analysis. Therefore, a related species of the same genus, *H. striata,* was used as a surrogate. *H. striata* appears to have similar feeding habits to *H. brouni*, but is approximately 4 times larger, is easy to maintain in captivity, and is common in the South Island.

In order to verify that *H. striata* would be attracted to (and potentially feed on) 1080 bait, non-toxic No. 7 cereal baits (Animal Control Products Ltd., Wanganui, New Zealand) were placed on the soil surface near colonies in the Port Hills on Banks Peninsula. The baits were checked after 24 h. Ants were observed on about 30% of the baits, indicating that *H. striata* was suitable as a surrogate for *H. brouni*.

Ants were collected from three large colonies by sucking them into an insect pooter, and each colony was housed in a separate "plastic aquaria" containing soil from the area of the colony. Ants had *ad libitum* access to water (soaked tissue placed on the soil surface) and canned meat- or fish-based pet food, and were maintained in a darkened room at 15°C to simulate natural conditions.

Toxicity of 1080 cereal bait to *H. striata*

A study was conducted to determine whether native ants, which were shown to investigate 1080 cereal baits in the field, would actually consume a sufficient amount of toxin to be lethally poisoned. Ants were divided into three treatment groups consisting of three replicates of 100 ants each (i.e., a total of 300 ants exposed to each treatment). Ants in the first treatment group were offered a standard No. 7 cereal bait containing 1080 at 0.15% along with water, but no additional food source (unfed group). Ants in the second treatment group were offered the same bait, but also had access to their maintenance diet of canned pet food and water (fed group). Ants in the third group were offered canned pet food only (controls).

Ants were monitored and percent mortality was determined at 24 and 48 h after exposure. Ants that died were frozen at -20°C for 1080 residue analysis.

Acute toxicity of 1080 to *H. striata*

Pilot toxicity experiment

The toxic dose of 1080 to *H. striata* was difficult to derive from studies involving exposure in a cereal bait matrix, because the amount of bait (and thus the amount of toxin) ingested could not be readily quantified. Therefore, a pilot study was conducted to determine if ants would ingest 1080 in sugar-water (based on methods of Klotz and Moss, 1996), and to determine the appropriate dose range for the full-scale acute toxicity and 1080 persistence trials.

For the pilot study, ants were divided into four groups of 10 each and fasted for 24 hr. They were subsequently offered a 10% sucrose solution containing 1080 at 0.00 (control), 0.01, 0.03, 0.06, 0.09, 0.12, or 0.15% (standard 1080 bait contains 0.15% 1080). Solutions were offered in shallow plastic Petri dishes. Percent mortality was determined 24 h after exposure. Surviving ants (in groups receiving 0.01, 0.03, or 0.06% 1080) were moved to fresh plastic aquaria with soil, food, and water, and were maintained for 4 additional days, to determine the optimal sublethal dose for the persistence study.

Full-scale acute toxicity experiment

Ants were divided into five treatment groups and fasted for 24 h as before. They were offered a 10% sucrose solution containing 1080 at 0.00 (control), 0.03, 0.06, 0.09, or 0.15%. There were four replicate groups of 50 ants each (i.e., a total of 200 ants) at each exposure level. Ants were monitored as before, and percent mortality was determined at 24 and 48 h after exposure. Ants that died were frozen at -20°C for 1080 residue analysis.

In order to compare the sensitivity of *H. striata* to that of other animals, the lethal concentration data must be converted to lethal doses, in mg of 1080 per unit body weight. In order to obtain this, the average amount of sugar-water consumed per ant needs to be measured. This proved difficult because the amount of sugar-water consumed by 50 ants was insufficient for accurate measurement. Therefore, an additional trial was conducted with a larger group of ants. A total of 300 ants were fasted for 24 h, weighed, and offered a 10% sucrose solution. The ants were reweighed after 6 h of exposure (the usual length of time that ants were observed to feed on sugar-water in the acute toxicity trials), and the average amount consumed per ant was calculated.

Persistence of 1080 in ants

The persistence of 1080 in ants was determined by dividing ants into 12 treatment groups of 100 each, fasting them for 24 h, and offering each group 10% sucrose solution containing 1080 at 0.03%. The 1080/sugar solution was removed after 24 h, and ants had access to their maintenance diet. At 1, 4 and 7 days after exposure, ants from four replicate groups (400 ants each time) were killed by rapid freezing, and the carcasses stored at -20°C for 1080 residue analysis.

Statistics

Mortality data were analysed by probit analysis (Finney, 1971) to determine lethal concentration and dose ranges. Results of toxicity experiments were compared by two-way analysis of variance with Tukey's test to determine differences between treatment groups and time points.

Results

Toxicity of 1080 cereal bait to *H. striata*

There was evidence that mortality differed between the three treatments ($F_{2,12} = 6.77$, $P = 0.011$). However, there was no difference in mortality between fed and unfed groups of ants ($F_{2,12} = 6.77$, $P = 0.776$). Acute mortality in both groups of ants exposed to 1080 bait was significantly greater than in the control ($F_{2,12} = 6.77$, $P = 0.011$ [fed], $P = 0.049$ [unfed]). Increase in mortality in 1080-exposed groups compared with controls was only 7% after 24 h, and 12% after 48 h. There was no difference between time points ($F_{1,12} = 3.11$, $P = 0.103$). These results indicate that some individual ants of this species will consume a lethal dose of 1080 when exposed to cereal bait at 0.15%, but that the acute mortality rate appears to be relatively low.

Fragments of 1080 bait were found spread over the soil of the "aquaria", indicating that ants will move bait, and perhaps take it into the nest. The risk associated with this behaviour is unknown. The concentration of 1080 residues in pooled carcasses of ants killed by exposure to cereal bait was 4.78 mg kg^{-1}.

Table 1: *The acute toxicity of 1080 in sugar-water to* Huberia striata

	Dose (mg kg^{-1})	95% Confidence Interval (mg kg^{-1})
24 h LD_{10}	30	24 - 46
24 h LD_{50}	72	57 - 79
24 h LD_{90}	126	104 - 174
48 h LD_{10}	25	16 - 31
48 h LD_{50}	42	34 - 49
48 h LD_{90}	70	59 - 94

Acute toxicity of 1080 to ants

Pilot toxicity experiment
No mortality was observed after 24 h in groups exposed to 0.00, 0.01 or 0.03% 1080, while all ants exposed to 0.12 or 0.15% 1080 solutions were killed. The optimal sublethal concentration for the persistence study was determined to be 0.03% 1080.

Full-scale acute toxicity experiment
Results of this experiment indicate a steep dose-response curve for 1080 in *H. striata*, at least when the toxin was delivered in sugar-water. The LC_{50} at 48 h was 0.037%. The average consumption of the sugar-water bait by ants was 0.24 mg per ant, and this was used to convert lethal concentrations to lethal dose values (Table 1).

The concentration of 1080 residues in pooled carcasses of ants killed by exposure to sugar-water containing 0.15% 1080 was 56 mg kg^{-1}. This value is more than 10 times greater than the 1080 residue concentration (4.78 mg kg^{-1}) measured in ants killed by exposure to 0.15% cereal bait in the previous study.

Persistence of 1080 in ants

One day after exposure to sugar-water containing 0.03% 1080, the mean concentration of 1080 residues in sublethally dosed ants was 5.51 mg kg^{-1}. Residue concentrations declined rapidly during the week following exposure, but were still detectable (0.27 mg kg^{-1}) after 7 days.

Discussion

Our results indicated that some individual *H. striata* would consume a lethal dose of 1080 when exposed to cereal bait at 0.15%, whether or not they have alternative food available. However, the acute mortality rate appeared to be relatively low, with only 12% increase in numbers found dead after 48 h in the exposed groups, compared to controls. This suggests that either 1080 cereal bait was not very palatable to *H. striata*, or that the toxin was not easily absorbed.

The sugar-water bait containing 1080 was quite palatable to ants. Oral LD_{50} values derived from studies using this bait were 72 mg kg^{-1} at 24 h, and 42 mg k^{-1} g at 48 h. This was comparable to the only other data available on the sensitivity of a native insect to 1080. The estimated oral LD_{50} for the large-headed weta, *Hemideina crassidens* Blanchard (Orthoptera) is 91 mg kg^{-1} (Landcare Research *unpubl. data*). The acute toxicity of 1080 to other species of Hymenoptera has also been determined. The oral LD_{50} for the honey bee (*Apis mellifera* L.) is 0.8 mg bee^{-1} (Palmer-Jones, 1958). Assuming an approximate weight of 100 mg bee^{-1} (Root and Root, 1940), the LD_{50} on a body weight basis can be estimated as 8 mg kg^{-1}. Research to evaluate the use of 1080 to control two introduced wasp species, *Vespula vulgaris* L. and *Vespula germanica* Fabricus, showed that 0.5-1.0% 1080 was required to reduce wasp numbers by 78-89% (Spurr, 1991). This concentration is considerably higher than that used in 1080 baits to control mammalian pests. These literature results indicate that insects may be significantly less susceptible to 1080 than mammals and birds (Table 2). However, only the adult life stages of insects were tested in these studies. Early life stages may be more or less sensitive to the toxin. The reported LD_{50}'s for several species of immature insects ranged from 1.05 mg kg^{-1} for larval *Perga dorsalis* Leach (Hymenoptera) to 3.88 mg kg^{-1} for larval *Mnesamplea privata* Guenee (Lepidoptera) (Twigg, 1990).

Assuming that 1080 is equally available from a cereal bait and sugar-water solution, a single 6 g, bait containing 0.15% of 1080 has enough toxin to deliver an LD_{50} dose to >100,000 ants (mean body weight = 2 mg). However, the relatively low acute mortality rate observed would indicate that this magnitude of effect is unlikely. In addition, anecdotal evidence suggests that if forager ants are killed by a toxin, remaining ants from the same nest will avoid that food source (R. Harris, *pers. comm.*).

Results indicated that concentration of toxin residues in ants declined in a linear fashion to reach a low, but still detectable level, at 7 days after exposure to an estimated sublethal dose of 36 mg kg^{-1}. The depuration rate of 1080 in large-headed weta (*Hemideina crassidens*) dosed orally at 15 mg kg^{-1} was somewhat faster, with residue concentrations declining to baseline after 4–6 days (Eason *et al.*, 1993; Eason, Gooneratne and Rammell, 1994). Most mammals eliminate the toxin even faster (although there are significant inter-specific differences) with residues declining to below detection within 12–96 h (Eason *et al.*, 1994; Gooneratne, *et al.*, 1994).

The persistence of toxic 1080 residues in ants increases the potential risk of secondary poisoning to insectivorous birds. The LD_{50} for small passerines ranges from 2.7 to 9.25 mg kg^{-1} (McIlroy, 1994; Eisler, 1995). Assuming a 1080 concentration of 5.51 mg kg^{-1} in ants, and an LD_{50} of 3.0 mg kg^{-1}, a bird of 10 g body mass would receive an LD_{50} dose from the ingestion of 5.5 g of ants. Although this is potentially possible, since food ingestion rates for small passerines have been measured at 1 g g body $mass^{-1}$ day^{-1} (U.S. Environmental Protection Agency, 1993), is unlikely to happen, since it would require the ingestion of approximately 2750 ants that had eaten 1080 bait within the previous 24 h. Three of the four bird species that have been shown to eat ants are also unlikely to encounter ants in this number. The tomtit is the only one of the four bird species to feed mainly on the forest floor where ants will be common. Lizards such as skinks or geckos may also eat ants, but the LD_{50} for 1080 in most reptiles is >200 mg kg^{-1} (Eisler, 1995), making the risk of secondary poisoning very small.

In conclusion, while 1080 is toxic to this native ant species, the risk of lethal poisoning of an ant colony by 1080 cereal bait is low. The depuration rate of 1080 is comparable with other invertebrate species and is slower than in mammals. This increases the theoretical risk of secondary poisoning of insectivorous animals by ants containing sub-lethal doses of 1080, but due to the low apparent palatability of cereal bait to this species (as shown by low mortality in ants exposed to 1080 cereal bait), and the large number of ants with 1080 residues required to deliver a toxic dose, this risk is negligible.

Table 2: *LD_{50} values of 1080 for some common mammals and birds*[1]

Species	LD_{50} (mg kg^{-1} body mass)
Rabbit (*Oryctolagus cuniculus*)	0.37
Sheep (*Ovis aries*)	0.50
Possum (*Trichosurus vulpecula*)	0.80
House sparrow (*Passer domesticus*)	2.82
Starling (*Sturnus vulgaris*)	4.75
Goldfinch (*Carduelis carduelis*)	3.5
Blackbird (*Turdus merula*)	c. 9.5
Silvereye (*Zosterops lateralis*)	c. 9.25

[1]Source: McIlroy (1994). Reproduced with permission.

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