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The Reaction of *Sminthopsis crassicaudata* to Meat Baits Containing 1080: Implications for Assessing Risk to Non-Target Species

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Abstract

Sminthopsis crassicaudata is a small dasyurid marsupial that may be exposed to 1080 poison during the baiting of dingoes with fresh meat baits. A group of *Sminthopsis* were conditioned to feed freely on meat in the laboratory, but when they were offered meat poisoned with 1080 their intake was significantly reduced and they vomited. Some of them refused to eat meat altogether even when a choice of poisoned and unpoisoned meat was provided. Fewer *Sminthopsis* died after eating poisoned meat than expected from the LD_{50} estimated by a standard technique of oral dosing with 1080 in water. Loss of appetite and aversion to the taste and/or smell of meat containing 1080 are discussed as reasons for the low intake of poisoned meat. Implications of these results are considered in the light of assessing risk to other non-target species exposed to baits containing 1080.

Introduction

In the arid north of South Australia, fresh meat baits treated with sodium monofluoroacetate (1080) are laid in the vicinity of the dingo barrier fence to kill dingoes that might enter sheep country to the south. Seven species of small dasyurid marsupials inhabit the area where 1080 is used (Bird and Sinclair 1980) and because they eat meat in captivity (Sinclair and Bird 1980; McIlroy 1981*b*), they are considered potentially at risk from the dingo baiting campaigns. On the basis of their susceptibility to 1080 (LD_{50}), as estimated by a standard technique of orally dosing animals with 1080 in water (McIlroy 1981*a*, 1981*b*), these dasyurids would need to ingest very little of a dingo bait to receive a lethal dose.

However, the toxicity of 1080 to these species feeding freely on poisoned meat has not been investigated. McIlroy (1981*b*) found that 1080 given orally or intraperitoneally caused dasyurids to vomit. It is not known whether the poison administered in meat has a similar effect or how much might be absorbed before vomiting occurs. Furthermore, in chemical analyses to estimate the 1080 content of field-prepared baits, lower recoveries (*c.* 80%) of 1080 were obtained from meat than from formulations (>96%) used to treat the meat. Recent work by Livanos and Milham (1984), using similar analytical techniques, has shown this lower recovery is due to incomplete extraction of 1080 from the meat. If some of the 1080 ingested by an animal feeding on a dingo bait is similarly so strongly held within the meat that it cannot be absorbed during digestion, then the threat to the animal will be less than an equivalent dose given orally.

The first experiment reported here was to compare the toxicity of 1080 when offered in meat to one of the non-target dasyurids, *Sminthopsis crassicaudata*, with that when administered orally. The second experiment was to test whether the *Sminthopsis* could detect poisoned meat which had been treated with 1080 at a level similar to that currently used in dingo baits, and if they would consume a lethal amount of that meat when offered no alternative.

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Methods

General Procedures

Laboratory-bred male *S. crassicaudata*, 8–18 months old and weighing 12–19 g, were maintained under natural lighting conditions at temperatures normally between 18 and 24°C. The temperature occasionally dropped to 14°C for a short time but no evidence of torpor was observed. Over 4 weeks, lean minced beef gradually replaced their normal laboratory food, which consisted of mealworms and commercial pet food supplemented with vitamins and minerals. They accepted the meat freely and consumed amounts equivalent to one-third or more of their body weight in a night. Food, but not water, was withheld on the night before the experiments began to ensure that animals would be hungry when offered treated meat.

Stock solutions were prepared by dissolving in distilled water pure 1080 powder (manufactured by Tokyo Kasai) that contained 96% sodium fluoroacetate (G. Livanos, personal communication). Eight hours before dosing, stock solution or distilled water was thoroughly mixed with the required amount of finely minced meat. The meat was placed in a glass dish and flattened into a 30-mm circular pat. The outline of the meat was marked on the underside of the dish to enable an estimate to be made later of the amount of meat eaten.

Oral doses were delivered *per os* into each animal's stomach via a blunt-ended needle fitted to a 0·25-ml syringe.

The animals were orally dosed or given meat shortly after sunset, when they normally became active. They were housed individually and during the hours of darkness were examined under red light to minimize disturbance. Observations were made at frequent intervals for the first 12 h (10 min, 20 min, 30 min, 1 h, then 2-hourly), then 6-hourly for 2 days and finally twice per day up to the 7th day. No animal succumbed more than 6 days after dosing. Symptoms of poisoning were recorded together with estimates of the amount of meat eaten and disgorged. Time of death was taken as halfway between the last two observations.

Experiment 1: To Compare the Toxicity of 1080 Offered in Meat with that Administered Orally

Ten *Sminthopsis* were orally dosed with 1080 in water, 29 were each offered approximately 1·5 g of meat mixed with 1080, and a control group of 10 were each offered 1·5 g of unpoisoned meat. Animals receiving 1080 were dosed at 2·38 mg kg^{-1}, which was an estimate of the LD_{90} obtained by probit analysis on data supplied by J. C. McIlroy from his standard LD_{50} trials on *S. crassicaudata*. An LD_{90} was chosen rather than a LD_{50} because the dose–response line was so steep that even with a small reduction in effective dose below the estimated LD_{90} (e.g. 20%) few *Sminthopsis* (<30%) would be expected to die.

Stock solution was prepared so that an animal of average weight (14 g) would receive the estimated LD_{90} in 0·1 ml of solution. When added to 1·5 g of meat, the concentration of 1080 in the meat was 0·002%. Immediately before dosing, the animals were weighed and the volume of solution or weight of meat adjusted to ensure that each animal received the estimated LD_{90}.

Experiment 2: To Determine whether Sminthopsis *could Differentiate Poisoned and Unpoisoned Meat and Consume Lethal Amounts when Offered no Alternative*

The *Sminthopsis* used in this experiment were survivors of those offered poisoned meat in the first experiment. They were fed fresh meat daily for 3 weeks before being offered poisoned meat again.

Ten animals were each offered 5 g of meat containing 0·009% 1080 plus, in a separate dish, 5 g of meat to which distilled water had been added. Another group of 10 animals were each offered 5 g of the 1080-treated meat alone. Five days later, having been fed normal laboratory food in the interim, all survivors of this experiment were offered 5 g of unpoisoned meat to confirm that they would still eat meat.

Results

Experiment 1

Significantly fewer animals died ($\chi_1^2 = 13·31$, $P < 0·001$) when 1080 was offered in meat than when it was administered orally in water (Table 1). The oral dose resulted in mortality not different from the expected 90% ($\chi_1^2 = 0·31$, $P > 0·5$) but times of death ranged from 2 to 63 h (mean 29 h).

Although the 29 *Sminthopsis* offered poisoned meat ate some of it (5–100%), only six animals ate all of their ration and only one of the six died. Comparing this mortality (1 of 6) with the seven out of ten animals that died after being orally dosed does not necessarily indicate the relative toxicities of 1080 in meat and water, because all of the animals offered poisoned meat vomited after eating. Animals orally dosed retched, but no vomitus was found.

Table 1. Mortality in *S. crassicaudata* from a dose of 1080 estimated to be a LD_{90}

Dose of 2·38 mg kg^{-1}, administered orally in water or mixed with 1·5 g of meat and offered to the animals. N.A., not applicable

Treatment	No. of animals	No. eating some meat	No. eating all meat	No. that died
1080 orally administered in water	10	N.A.	N.A.	7
1080 fed in meat	29	29	6	2[A]
Fed unpoisoned meat	10	10	10	0

[A]One ate all of its meat, the other ate *c.* 80%.

Table 2. Response of *S. crassicaudata* offered poisoned and unpoisoned meat

Animals were offered either 5 g of poisoned meat containing 0·009% 1080, or a choice between the same amounts of poisoned and unpoisoned meat. Survivors were offered 5 g of unpoisoned meat 5 days later, to determine whether they had any aversion to meat. Sample sizes, 10 animals. Percentages are approximate only

Treatment	Percentage of meat eaten: Poisoned	Percentage of meat eaten: Unpoisoned	Approx. dose ingested: In mg kg^{-1}	Approx. dose ingested: Percentage of LD_{50}	Percentage of intake vomited	Time to death (h)	Percentage unpoisoned meat eaten 5 d later
Poisoned only	0		0	0	0		55
	0		0	0	0		100
	1		0·4	20	—[A]		100
	2		0·6	30	—[A]		100
	2		0·6	30	—[A]		85
	5		1·5	70	50	150	
	5		1·7	80	100	40	
	10		3·0	150	—[A]		100
	15		4·5	220	50		100
	40		9·9	490	30	7	
Choice	0	0	0	0	0		100
	0	0	0	0	0	—[B]	
	0	50[C]	0	0	0		100
	3	0	1·1	50	—[A]	40	
	5	0	1·6	80	100	40	
	5	60[C]	1·6	80	—[A]		60
	8	0	2·4	120	60		85
	10	0	4·0	200	50	50	
	15	0	4·8	240	50	30	
	50	95[C]	12·7	620	—[A]	16	

[A]No estimate of amount vomited. [B]This animal died after 60 h but had a small injury before the trial and is unlikely to have succumbed to 1080. [C]Unpoisoned meat eaten first.

Ingestion of as little as 2 μg of 1080 in meat caused vomiting which was first observed 0·5–2 h (mean 1·2 h) after feeding began. The amount vomited by individuals was estimated to range from 5 to 50% (mean 20%) of intake but was not a function of it ($r_{29} = -0{\cdot}21$). The two animals that died after eating poisoned meat neither retained their food longer nor vomited less than others ingesting similar amounts.

Experiment 2

Sminthopsis offered poisoned and unpoisoned meat showed no obvious first preference ($\chi^2_2=0{\cdot}53$, $P>0{\cdot}5$). Three animals ate unpoisoned meat first, five ate poisoned meat and two ate nothing at all (Table 2). No animal switched to unpoisoned meat having first sampled meat containing 1080. In contrast, two of the three animals that ate unpoisoned meat first, later went on to eat poisoned meat.

When no alternative food was provided, eight out of ten animals ate some of the meat poisoned at a concentration similar to dingo baits. Their consumption of meat was much the same as the group that were offered a choice ($F_{1,29}=0{\cdot}03$, $P>0{\cdot}50$). However, as can be seen from Fig. 1*b*, the maximum amount of poisoned meat eaten by any individual of either group was less than half the amount most survivors ate when offered unpoisoned meat 5 days later.

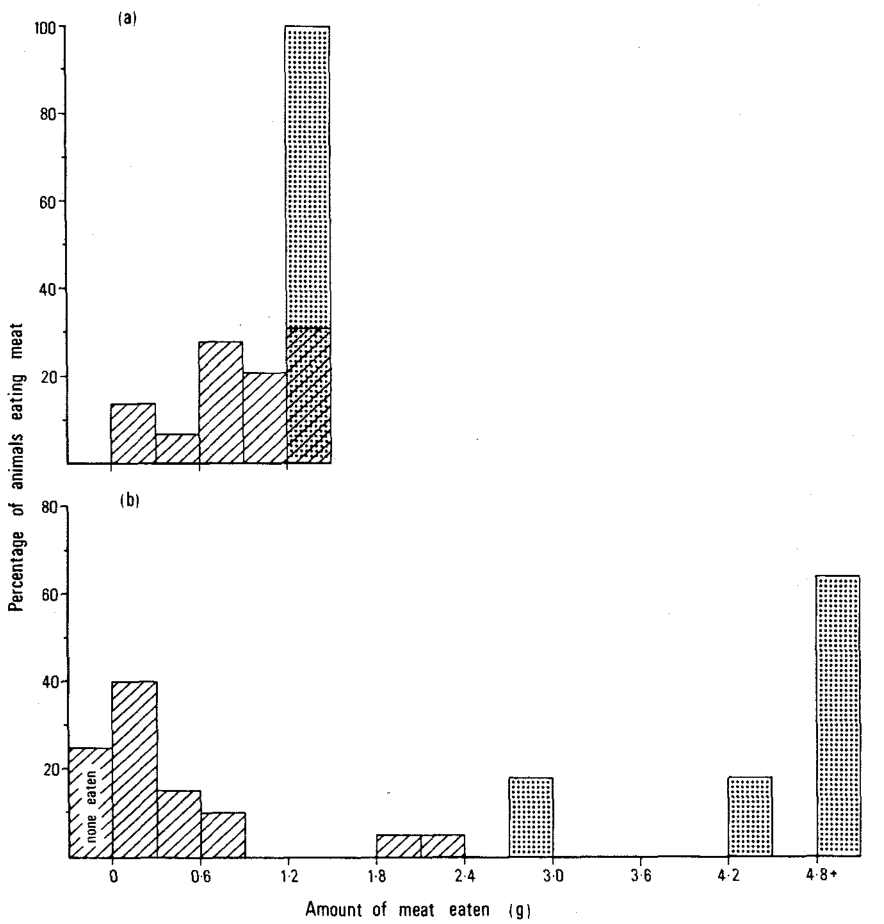

Fig. 1. Percentages of *S. crassicaudata* that ate various amounts of poisoned meat (hatched bars) and unpoisoned meat (stippled bars). (*a*) Experiment 1; 1·5 g 0·002% 1080 meat given to 29 animals, 1·5 g unpoisoned meat given to 10 animals. (*b*) Experiment 2; 5 g 0·009% 1080 meat given to 20 animals (10 of which received unpoisoned meat), 11 survivors given 5 g unpoisoned meat 5 days later.

As in experiment 1, the fate of an animal was a simple function neither of the amount of poisoned meat ingested nor of the amount vomited. One animal died after consuming only 0·2 g of meat but two others survived having eaten three and five times that amount. Four others consumed about 5% of their poisoned meat, thereby ingesting *c.* 80% of the presumed LD_{50}. Two of them vomited most of the meat but died 40 h later. The third vomited only half of its meat and died 150 h after feeding. The fourth animal, one of the three which ate unpoisoned meat first, vomited relatively little and survived. Furthermore, times to death were only weakly related ($r_8 = -0.53$, $0.05 > P > 0.10$) to the estimate of the dose ingested.

Symptoms of Poisoning

Symptoms of poisoning were similar to those described by McIlroy (1981*b*) for small dasyurids receiving oral doses of 1080, except that no convulsions were observed. In all cases, apart from that where the animal died 150 h after feeding, death was preceded by a period (5–40 h) during which the animals were immobile and breathing was very slow and shallow.

Discussion

Sminthopsis conditioned to feed freely on meat significantly reduced their intake ($\chi^2_4 = 61.97$, $P < 0.001$) when 1080 was added, and ingestion of even minute amounts of 1080 caused vomiting. As a result, mortality among animals offered meat containing an estimated LD_{90} of 1080 was only one-tenth of that in animals orally administered the same dose in water.

Reasons for a Limited Intake of Meat Containing 1080

The limited intake of poisoned meat may have been due to a suppression of appetite or to an ability to smell and/or taste food treated with 1080 poison.

Suppression of appetite. Sminthopsis given unpoisoned meat did not eat it all at once but ate at several 'feeding sessions' during the night. In contrast, when offered poisoned meat, they fed only once. Since the initial symptoms of poisoning were apparent within 30 min of feeding, toxic effects from the consumption of even small amounts of 1080 may have developed fast enough to suppress appetite and deter further feeding. In a similar way, the reduced intake of rabbits feeding on 1080-treated bait has also been attributed to a poison-induced feeling of physical discomfort (Rowley 1960, 1963*a*).

Aversion to the odour of 1080-treated meat. Several authors state that 1080 either has no odour (Atzert 1971; Rammell and Fleming 1978) or only a slight acetate smell (Pattison 1959; Clark 1975). Yet, of the 20 starved *Sminthopsis* exposed to meat poisoned with 1080 in experiment 2, four did not eat at all and one other ate only unpoisoned meat. There was no aversion to meat itself, as the animals fed freely on meat between the two experiments and again after the second one. Hence, it is difficult to interpret their refusal to eat poisoned meat other than as a reaction to its odour. Morgan (1982) also concluded that a small proportion of possums, *Trichosurus vulpecula*, have a strong olfactory aversion to bait treated with 1080.

Aversion to the taste of 1080-treated meat. Rowley (1960, 1963*a*) discounted the possibility that rabbits disliked the taste of 1080-treated bait, whereas Morgan (1982) considered its unpleasant taste was one reason why many possums failed to consume lethal quantities. There is also evidence from this study to suggest that *Sminthopsis* may limit their intake because of the taste of 1080-treated bait. As can be seen from Fig. 1, most animals ate even smaller amounts of poisoned meat the second time they were exposed to it ($\chi^2_2 = 29.24$, $P < 0.001$) and there was a tapering off in the number of animals that ate the 'larger' amounts of poisoned meat; a response that was not obtained in experiment 1. This lower intake of meat in the second experiment could have been either a consequence of the higher concentration of 1080 that the *Sminthopsis* were able to taste, or a bait-shy response stimulated by memory of the taste and/or smell of poisoned bait from experiment 1.

Bait-shyness to 1080 has been demonstrated in rats, *Rattus rattus* and *R. norvegicus* (Barnett and Spencer 1949), deer mice, *Peromyscus maniculatus* (Howard *et al.* 1977), and to a lesser extent in rabbits (Rowley 1963*a*). However, these aversions, produced under conditions far more severe than those the *Sminthopsis* experienced, were subsequently overcome by pre-feeding (Howard *et al.* 1977; Rowley 1963*b*). Since the *Sminthopsis* were effectively pre-fed for 3 weeks before re-exposure to 1080, their reduced intake of poisoned meat was unlikely to have been a response prompted by memory of their previous experience but simply a reaction to the taste of more concentrated bait.

Influence of Vomiting on Survival

All of the animals that ate meat poisoned with 1080 vomited, regardless of the amount of meat eaten or its concentration of 1080. However, vomiting was unlikely to have influenced survival. For example, two animals died even though they vomited most of their meal, but others that vomited little, survived (Table 2). Since the chemical properties of 1080 favour efficient absorption from the stomach, survival of an individual probably depends on its efficiency at 'extracting' poison from the meat matrix before gastric emptying, as well as its susceptibility to 1080.

Implications for Assessment of Risk to Non-target Animals

This study has important practical implications concerning the assessment of risk to species exposed to 1080-treated baits, whatever mechanisms result in a sublethal intake of poisoned bait. The lower mortality among *Sminthopsis* feeding on poisoned bait compared with that following oral dosing indicates that the laboratory-derived susceptibility (based on an oral LD_{50} of 2·06 mg kg^{-1} and bait consumption of 9·9 g day^{-1}; McIlroy 1981*b*) provides only a rough idea of the actual risk this species faces in the field. The concentrations of 0·002% and 0·009% 1080 used in the experiments reported here are similar to the range of concentrations (0·002–0·011%; McIlroy 1981*b*) in dingo baits generally used by vertebrate pest control organizations in Australia. Our results suggest that very few *Sminthopsis* would succumb if they were exposed to fresh meat baits prepared at the lower concentration. Where dingo baits with the higher concentration of 0·011% 1080 are put out, far fewer individuals would succumb than expected from the LD_{50}, since only 40% died after being offered meat containing 0·009% 1080. At even higher concentrations, the aversion to 1080-treated bait may be stronger than observed here.

It remains to be seen whether other non-target species react as *S. crassicaudata* have to 1080-treated baits. Others may, for instance, differ in their feeding behaviour by eating relatively large quantities of food at one time. *S. macroura* (formerly *S. larapinta*), another small dasyurid, apparently consumes most of its food at a single feeding session soon after emerging for the night (Crowcroft and Godfrey 1968). However, dingo baits are usually large chunks of red meat and the time taken to gnaw off pieces might be sufficient for symptoms of poisoning to develop, preventing the consumption of a lethal dose. Once baits dry out, they may be even more difficult to eat in a relatively short time.

Although studies such as those of Rowley (1963*b*) and Brunner (1983) indicate bait preferences of target and non-target species, it cannot be assumed that lethal quantities of bait will be consumed once it is treated with poison. In assessing the risk of poisoning to species, factors other than their laboratory-derived susceptibility to the poison and consumption of unpoisoned bait have to be considered (see Spurr 1979; McIlroy 1981*a*, 1981*b*). Our study suggests that the final outcome may also be influenced by the feeding behaviour of species and their reaction to bait that actually contains poison.

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