THE SENSITIVITY OF THE BRUSHTAIL POSSUM (*TRICHOSURUS VULPECULA*) TO 1080 POI SON

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SUMMARY: A knowledge of the sensitivity of the brushtail possum *(Trichosurus vulpecula)* to 1080 poison is important as a basis for planning effective control campaigns. This study assesses the effects that experimental procedure may have on determining the LD50 of 1080 for brushtail possums and reports on the variation in sensitivity within and between different populations of the species in Australia, where it is indigenous. LD50s obtained ranged from 0.39 - 0.92 mg kg-1, with 95 % confidence limits of from 0.29 - 1.20 mg kg-1. These figures are similar to those obtained by Ministry of Agriculture and Fisheries researchers in New Zealand but are less than those obtained by the New Zealand Forest Service and bring into question which figures are valid for free-roaming possums in the bush. This is important in regard to the toxic loading of baits, particularly given the reported aversion by some possums to baits containing the recently increased concentration of 1080 recommended for possum control in New Zealand forest areas.

KEYWORDS: pest control; poisoning; toxicity; 1080; sodium monofluoroacetate; possum; Trichosurus vulpecula; Phalangeridae; Australia; New Zealand.

INTRODUCTION

The brushtail possum *(Trichosurus vulpecula),* introduced into New Zealand from eastern Australia during the nineteenth century, is now regarded as a major pest there because of its damage to native forests and exotic *Pinus* plantations and its role as a reservoir of bovine tuberculosis (Rammell and Fleming, 1978). Control methods used against it include trapping, poisoning with cyanide and, on a larger scale, aerial poisoning with 1080 (sodium monofluoroacetate).

One of the basic facts that should be determined before any poisoning campaign is carried out is the pest's sensitivity to the poison. Without this knowledge a campaign may be a 'hit or miss' affair, possibly resulting in wasted efforts, an increased number of 'bait-shy' animals in the population and the creation of an unnecessary hazard to non-target animals. 1080-poisoning campaigns against possums have caused deaths of birds in New Zealand (Harrison, 1978; Spurr, 1979). Although this problem has now been partly overcome by reducing the amount of 'chaff' in carrot bait and by dyeing bait to make it less attractive to birds, accurate data about the sensitivity of possums to 1080 are needed as a basis for deciding on the toxic loading of baits. At present, though, there is some disagreement in the literature about which sensitivity data are correct for the brushtail possum.

Initially, Bell (1972) obtained an LD50 (50% death rate) of 0.79 mg kg^{-1}, with 95% confidence limits of 0.69 - 0.91 mg kg^{-1}, for possums in New Zealand. Rammell and Fleming (1978) later obtained a similar value (0.8 mg kg^{-1}) from further trials. However, in 1978, the New Zealand Forest Service (NZFS) reported that "acute and chronic toxicity studies of Compound 1080 have indicated a need for re-evaluation of the levels of toxic loading in bait materials for control of opossum populations" (Anon, 1978). According to the report, regional and seasonal variations occurred in the toxic susceptibilities of possum populations. These variations were described further a year later (Anon, 1979) with LD50s of from 1.3 - 2.1 mg kg^{-1} being reported from eight trials on possums from North and South Islands.

Factors listed as possibly responsible for the differences between the NZFS LD50s and those reported earlier by Bell (1972) and Rammell and Fleming (1978) were the type of possum, its age, sex and perhaps physical condition, weather, degree of acclimatisation to captivity, season, time of day of dosing and the technique of administering the poison. The shock of capture, transport, captivity and strange surroundings, were thought to be especially important. Since then, the approximate LD50 of 1080 for brushtail possums in New Zealand has been stated to be 1.5 mg kg-1 and the approximate LD95 to be 2.5 mg kg^{-1} (J. A. Peters, pers. comm. to Batcheler, 1982).

In an earlier study (McIlroy, 1981) I examined the effects of some of the above factors on the sensitivity

TABLE 1. *Details of experimental conditions for trials to determine the* LD50 *of* 1080 *for brush tail possums.*

Trial	Sex	N	Body weight (kg)		Pen type	No./pen	Captivity before dosed (weeks)	Timing of dosing (h)	Season	Ambient temp. (°C)	Daylength (h)
			Mean	Range							
Regional source											
Tasmania	M+F	12	2.60	2.00--3.34	A	5	5-12	1010-1030	Winter	- 4-17	10.5-11.1
Bombala NSW	F	12	2.19	1.78-2.96	A	5	10-11	0948-1228	Winter	- 3-15	10.2-10.4
Time of dosing											
Morning	M+F	20	2.43	1.46-3.80	A	6	10-15	1012-1110	Winter	- 3-15	10.2-10.5
Evening	M	20	2.71	1.92-3.38	A	6	10-15	1746-1827	Winter	- 3-15	10.2-10.5
Temperature						5	3-7				
Cold	M	20	2.76	2.01-3.85		1	2	0955-1122	Spring	10-11	10.0
Moderate	M	20	2.13	1. 95-2.35	A	5-7	6	0915-0937	Winter	22	12.0
Handling routine	M + F										
Anaesthetic		20	2.84	1.90-3.40	C	5	5	0930-1015	Summer	21-27	12.0

Pen types: A = outdoor, 4.6 x 1.8 x 2.5 m; B = small indoor cages, 50 x 50 x 50 cm; C = medium indoor cages, 1.5 x 1.5 x 0.5 m.

of brushtail possums in eastern Australia to 1080 and obtained LD50s ranging from 0.57 - 0.86 mg kg^{-1} with 95 % confidence limits of from 0040 - 1.09 mg kg-:. Because these results conflicted with the toxicity data obtained by NZFS, another series of LD50 trials were planned to investigate whether other factors were responsible for the differences in LD50 values. The four experimental factors evaluated in this study were the 'type' or strain of possum (i.e. its regional source), the time of day at which the 1080 was administered, the ambient temperatures prevalent during the trials and the handling routine during administration of the poison.

METHODS

Capture and handling

One hundred and thirty-six of the possums used in the trials were caught in weldmesh box traps, baited with apple~, set in or around rural buildings and shelter-belts in the Bombala area, New South Wales. Traps were checked early each morning and captives transferred to large weldmesh cages (1.5 x 1.5 x 0.5 m). The walls of the cages were lined with hessian bags which the possums quickly began using for shelter. After three - four days acclimatisation to these conditions the possums, in their weldmesh cages, were transported in the covered back of a truck to Canberra, 190 km away. Another 15 possums were obtained from Tasmania and air freighted to Canberra in hessian bags placed inside masonite 'pet-pak' containers.

All possums were weighed upon arrival in Canbena as a guide to any subsequent changes in condition. They were then either liberated in large outdoor enclosures (type A, see Table 1), containing nest boxes, hollow logs and branches, and hessian bags hanging from the walls or transferred to cages (type C) in a controlled environment room. Some possums were also later moved from the large enclosures to small cages (type B) in another controlled environment room. Details of the size of pens or cages, numbers of possums kept in each pen and the duration of captivity before dosing are included in Table 1. Food provided included a variety of fruits and vegetables, bread, and lucerne hay. All animals were provided with water *ad libitum*.

One possum died shortly after capture and seven died from an outbreak of a bacterial disease (possibly soil-borne *Clostridium* spp.) in the large enclosures. The remainder appeared to adjust readily to captivity. Some degree of social re-organization and possibly stress occurred in the larger enclosures, judging from the vocalisations occurring after dark, but there was no evidence of serious fights taking place. Minor fights initially occurred at feeding time late each afternoon but subsequently were mostly overcome by scattering the food around the enclosures. In many cases animals could be fed from the hand and readily climbed onto humans in the enclosures in their search for food.

Dosing

At dosing time (5-15 weeks after capture) groups of either three or five animals were given graded doses of 1080, the number depending upon the trial involved. At least four dose levels were administered to different animals in each trial with a ratio of 1.26 between each dose level. All 1080 used was AR

TABLE 2. *Times until signs of poisoning appeared, death or recovery and* LD50s *of* 1080 *for bushtail possums. Value in parentheses are numbers of individuals observed,* 95 % *confidence limits follow the* LD50s.

Trial	Time until signs of poisoning (h)	Time until death (h)	Time until recovery (h)	LD50 (mg kg^{-1}) and 95 % confidence limits
Regional source				
Tasmania	4.6-14.0 (4)	14.1-38.2 (7)	-	0.92 (0.70-1.20)
Bombala, NSW	-	12.0-37.0 (5)	-	0.42 (0.29-0.60)
Time of dosing				
Morning	38.0-38.2 (2)	13.4-123.7 (11)	-	0.48 (0.39-0.60)
Evening	7.2-31.0 (7)	16.3-126.6 (10)	-	0.39 (0.34-0.45)
Temperature				
Cold	2.5-14.9 (7)	5.0-38.1 (12)	-	0.47 (0.34-0.64)
Moderate	1.4-29.1 (15)	15.0-97.0 (9)	11.6-34.5 (6)	0.68 (0.59-0.78)
Handling routine				
Anaesthetic	2.6-14.9 (12)	10.7-38.3 (11)	27.3-27.9 (4)	0.79 (0.61-1.03)
Total	1.4-38.2 (47)	5.0-126.6 (65)	11.6-34.5 (10)	-

sodium monofluoroacetate (*c.* 95.8 % purity, as assayed by E. J. Gifford, Division of Wildlife and Rangelands Research, CSIRO, Canberra, according to an unpublished method developed by C. L. Batcheler, Forest Research Institute, NZFS, Christchurch, New Zealand), dissolved in deionized water at a rate of 1 mg ml^{-1}. Deionized water was added to the stock solution given to each animal at the rate of 1 ml per 200 g body weight to increase the accuracy of administration. Animals being dosed were held in a hession bag and a wooden mouth gag was used to facilitate oral dosing via a hypodermic syringe and oesophageal catheter. Although most animals struggled briefly when first held, the whole handling and dosing procedure took from only two - eight minutes per animal (mean four minutes) and, several minutes later, none of the animals appeared unduly disturbed. One additional animal at each dose level was given an equivalent dose of water as an experimental control; none of these possums subsequently showed any visible signs of disturbance. In one trial the possums were dosed while lightly anaethetised with ether.

Only adult possums were used and where possible, only males. Details of sex, numbers, body weights, time of dosing, season, ambient temperatures and daylengths during the trials are given in Table 1. Dosed animals were inspected hourly (and more frequently if showing signs of poisoning) during the first eight hours after dosing and then less frequently (e.g. four times per day) over the rest of a seven--day observation period. If the time at which the first signs of poisoning or death occurred was not known, the average of the times of the last 'healthy' and first 'morbid' inspections was recorded. LD50s were calculated according to the moving average method of Thompson (1947) and Weil (1952).

RESULTS

Signs of poisoning

The first signs of poisoning observed amongst the possums occurred 1.4 - 38.2 h after dosing (Table 2). Deaths occurred from 5.0 - 126.6 h after dosing and eventual survivors began recovering 11.6 - 38.9 h after being dosed. In 27 cases signs of poisoning were not observed and the individuals concerned were found dead at the next inspection. Limited data were obtained on times until recovery apparently began because 37 out of the 47 possums showing signs of poisoning subsequently died.

Almost 64 % of those possums that showed signs of poisoning first exhibited visible symptoms within 12 h of being dosed and 89% showed visible symptoms within 24 h (Table 3). Approximately 66 % of all deaths occurred within 24 h of dosing and 91 % within 48 h but 6% occurred after 72 h (i.e. 97.0-126.6 h or up to five days later). Half the possums that eventually recovered began to do so within 12 h of being dosed.

TABLE 3. *Distribution in time of the onset of visible symptoms of* 1080 *poisoning, death and recovery amongst bushtail possums.*

Symptoms	Time since dosed (h)						
	<12	12-24	24-36	36-48	48-60	60-72	>72
Onset	30	12	3	2	-	-	-
Death	1	42	8	8	2	-	4
Recovery	5	-	5				

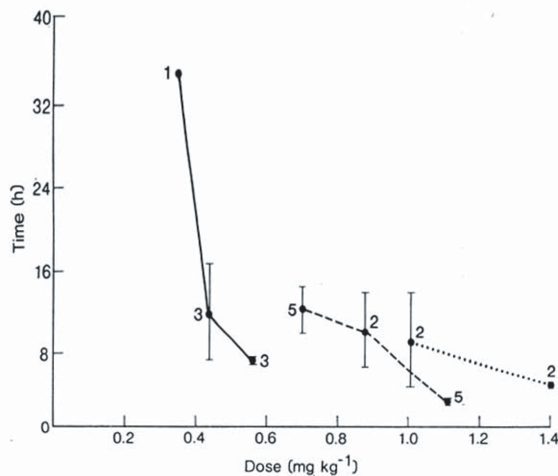

FIGURE 1. *Relationship between amount of 1080 ingested and mean time (±) S.E. until onset of visible symptoms of poisoning for possums dosed in the evening (——), anaesthetised (— — —) and from Tasmania (. . .). The number of animals that showed symptoms at each dose level are included.*

In four of the trials the length of time before signs appeared was positively related to the amount of 1080 administered, becoming shorter as the dose increased (examples for three trials are shown in Fig. 1). The time until death was not related in that way. Signs of poisoning observed were similar to those previously described by McIlroy (1982).

LD50s

The LD50s obtained for the possums in these trials ranged from 0.39 - 0.92 mg kg^{1-} with 95% confidence limits ranging from 0.29 - 1.20 mg kg^{-1} (Table 2).

DISCUSSION

Signs of poisoning

Although there was considerable variability in the times until signs of poisoning appeared and death occurred for possums in each trial, the overall ranges were similar, if slightly larger than the respective 1.0 - 19.8 hand 4.0 - 97.0 h periods, reported by Bell (1972), Rammell and Fleming (1978) and McIlroy (1982) and fall within the general range reported for marsupial herbivores by McIlroy (1982).

LD50s

In a previous study (McIlroy, 1981) I showed that the sex, breeding condition and nutritional state of brushtail possums in eastern Australia did not affect their sensitivity to 1080. Age also did not generally affect sensitivity although there were indications that the pouch young might be more sensitive than adults. In this same study (McIlroy, 1981) I also found that the 95 % confidence limits were wider when only three animals (compared with five) were used per dose level and the LD50 was lower for animals given intraperitoneal injections compared with those given 1080 orally, but in both cases the differences were not significant.

In this current study, no significant differences occurred in the sensitivity of possums dosed with 1080 either in the morning or 0.5 - 1.0 h after sunset (Table 2). Similar results have also been found for rabbits *(Oryctolagus cuniculus)* dosed with 1080 during the morning and 1.6 - 2.4 h after sunset (McIlroy, unpublished data). Possums kept in ambient temperatures of 10. 11°C for two weeks were slightly, but not significantly, more sensitive to 1080 than those kept at 22°C. However, Oliver and King (1983) found that the Western Australian brushtail possums they tested were significantly more sensitive to 1080 at lower ambient temperatures (10.5°C compared with 23°C). Unfortunately the LD50s they obtained are not really helpful in resolving the dilemma about the LD50 for possums in New Zealand because possums in Western Australia have acquired a much higher tolerance to 1080 through their exposure to local food plants containing fluoroacetate (King, Oliver and Mead, 1978). Despite this, it is clear that ambient temperature is unlikely to be the factor responsible for the higher LD50s obtained by NZFS compared with those obtained at low and medium temperatures in this study.

It is difficult to define and measure the 'stress' that wild animals may experience by being trapped, kept in captivity and then handled at dosing time and to determine whether this affects the LD50 obtained for 1080. Stoner (1969) found that the LD50 of 1080 for laboratory rats was not significantly affected by traumatic injuries (limb ischaemia and scalding) while McIlroy (1982) obtained similar LD50s for both captive and free-ranging wombats *(Vombatus ursinus)*. In the latter study captive wombats were kept in outdoor enclosures for four - eight weeks before being manually restrained and orally dosed, while the free-ranging wombats were briefly restrained immediately after capture, orally dosed and then released.

In this study, possums acclimatised to captivity for five weeks and then lightly anaethetised before being dosed were not significantly more tolerant to 1080 (0.79 mg kg^{-1}, 0.61 - 1.03, Table 2) than possums kept under similar conditions, particularly moderate ambient temperatures, but dosed without the use of an anaesthetic (0.68 mg kg^{-1}, 0.59 - 0.78, Table 2). They were also not significantly more tolerant than possums in two of the other trials with slightly different conditions (Tasmanian possums and the cold tem-

perature trial, Table 2) or possums in seven trials in an earlier study (McIlroy, 1981) including one where the 1080 was administered by intraperitoneal injection.

The final factor evaluated was the type of possum, or more correctly, a comparison of the LD50s for possums from two different regional populations-south-eastern mainland Australia and Tasmania. Possums were imported into New Zealand from both regions. Possums from Tasmania did not differ significantly in sensitivity to 1080 from possums from Bombala and Canberra that experienced more moderate ambient temperatures (with or without the use of an anaesthetic at dosing time) in this study (Table 2) or an earlier study (McIlroy, 1981). However, they were significantly more tolerant than Bombala possums in four trials where low ambient temperatures prevailed (Table 2). Thus, given the possible influence that low ambient temperatures may have on the sensitivity of possums to 1080, it would seem important that an LD50 is obtained for Tasmanian possums kept at more moderate ambient temperatures and this value is then compared with those obtained by the NZFS.

In summary, an evaluation of four of the other factors suggested by NZFS as causing the variation in LD50 values for brushtail possums has not revealed the reason for the 1.6 - 2.6 fold differences between the results of Bell (1972) and Rammell and Fleming (1978) on the one hand and NZFS (Anon, 1979) on the other. Even if the Tasmanian strain of possums are found to have a much higher LD50 at moderate ambient temperatures, this does not explain the different LD50s obtained by the Animal Health Research Laboratory and the NZFS for possums from the same two areas in New Zealand (Anon, 1979). Perhaps to solve this problem it may be necessary to more closely compare the experimental procedures used to obtain LD50s by each research group.

Experimental procedure

The LD50 and its 95% confidence limits are only an indication of the values that might be expected from repeated trials on the same strain of animals under the same experimental conditions. Weil et al. (1966) and Weil and Wright (1967) found that up to 3.2 fold differences occurred in the LD50s for various chemicals within and between different laboratories when differences occurred in experimental procedure. In Australia, significantly different LD50 values for 1080 were initially obtained for two of three groups of rabbits in Western Australia (0.63 and 0.68 mg kg^{-1}, Wheeler and Hart, 1979) compared wIth one group of rabbits from eastern Australia (0.35 mg kg^{-1}, McIlroy, 1981). The rabbits in Western Australia were kept overnight in cardboard boxes, dosed by intraperitoneal injection, then kept in the same boxes for another 48 h and inspected every half hour. Two of 33 rabbits given control doses of water died during this period. In comparison, the rabbits in eastern Australia were acclimatised to captivity for at least 2-5 weeks, orally dosed and inspected less frequently over a seven day period. However, no significant differences were found when the LD50s for rabbits from both regions were redetermined under similar experimental conditions (Wheeler and Hart, 1979) or when the initial LD50s for the Western Australian rabbits were compared with subsequent LD50s for other groups of rabbits from eastern Australia (McIlroy, unpublished data).

The differences in LD50s obtained for possums by different research workers in New Zealand are also probably due to differences in the experimental procedure adopted. Unfortunately, though, a full comparison of experimental procedures and results is not possible because few details, including 95 % confidence limits, have been published (Rammell and Fleming, 1978; Anon, 1979). From the limited details published by the NZFS (Anon, 1979), the only differences between the trial reported in this study in which possums were lightly anaethetised before dosing and the 'normal methods' of NZFS are in the predosing handling routine and post-dosing observation period. In the NZFS trials, possums were gradually introduced to being handled and fed both by day and by night over the acclimatisation period rather than only occasionally being handled and being fed once, late each afternoon, as in this study. The NZFS possums were also left undisturbed for 72 h after being dosed, (except for the removal of dead animals lying in the open) compared with the unobtrusive but more frequent inspections carried out in this study. Whether these factors are responsible for the different LD50s obtained is open to debate but certainly worth further investigation. The length of the post-dosing observation period may also be a critical factor. In this study four possums died from 97.0 - 126.6 h after dosing (Table 3). Although the exact length of the NZFS post-dosing observation period is not described (Anon, 1979), it is clear that any observation period shorter than 127 h might result in some mortality data being excluded from the LD50 calculation. This would result in a higher LD50 being obtained than if the additional mortality data had been included.

CONCLUSION

In practical terms, the ultimate concern in possum control is that each possum eats a lethal amount of bait. Many factors can influence this; the amount of

bait used, its pattern of distribution, the size or quality of the baits and. their palatability and acceptability to the population (Batcheler, 1982). Recently though, Morgan (1982) has shown that some possums can detect and reject carrot bait loaded with 1-2 mg kg-1 of 1080 and Batcheler (1982) has explained how, using the assumed 'LD95-100' of 2.5 mg kg^{-1} for possums, there appears to be a high risk of aversion to bait at the toxicity required to kill most members of a population. Consequently, it may prove necessary to either keep the toxic loading of baits to the minimum lethal level necessary or mask the baits with lures to overcome this problem.

At present the New Zealand Agricultural Chemicals Board allows a standard 1080 concentration of 0.8 mg g^{-1} carrot bait for possum control in farm areas but 1.5 m g^{-1} for control of possums in forest areas. This latter value was adopted on the basis of unpublished data by J. A. Peters on the acute toxicity of 1080 to possums (Batcheler, 1982). As indicated in this paper, however, other research workers in New Zealand have obtained different acute toxicity data for 1080 and possums from Peters. The aim of this study was to try and determine the reasons for these differences, not initiate a controversy about the merit of one research organization's results versus another's. Unfortunately this has not been achieved, apart from the general inference that predosing and post-dosing experimental routines are responsible and the question still remains of which value is most appropriate for free ranging possums.

The NZFS have attempted to solve this problem by not handling possums during dosing and allowing trap-habituated individuals, both in captivity and the wild, to enter traps and eat bait containing precisely measured doses of 1080 (Anon, 1979). The LD50s (1.48 and 1.5 mg kg^{-1}) they obtained, though, were not different from those obtained by their normal method (*c*. 1.2 - 1.6 mg kg^{-1}) which involved anaesthetising possums and administering the 1080 via a canula. In this and a previous study (McIlroy, 1981) I obtained LD50s of from 0.39 - 0.92 (0.34 - 1.20 mg kg^{-1}) for possums in eastern Australia which fall within the range of c. 0.1 - 1.0 mg kg^{-1} obtained for} all other marsupial herbivores tested in Australasia (McIlroy, 1982). Admittedly, apart from one trial, all these values were obtained by manually restrain.. ing the animals involved and administering the 1080 by intraperitoneal injection or an oral catheter, without the use of an anaesthetic, but an LD50 of 0.79 (0.61 - 1.03) mg kg^{-1} was obtained for anaesthetised possums. The only apparent differences in procedure during this trial, as mentioned earlier, were in the handling and feeding routines before dosing and obsenation routine afterwards.

Batcheler (1982) is probably correct in concluding that reducing the toxic loading of possum baits is not a practicable approach to minimising the risk to birds as virtually all fragments are likely to be lethal to small birds at any toxic loading which is likely to be effective against possums, particularly given the high sensitivity of most passerines to 1080 (McIlroy, unpublished data). In terms of possum control, however, especially in regard to the toxic loading of baits and avoiding bait refusal, there is an obvious need for more research on the sensitivity of possums to 1080.

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