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# WHY DO POSSUMS SURVIVE AERIAL POISONING OPERATIONS?

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ABSTRACT: Major causes of failure of aerial poisoning operations against possums identified were: sublethal toxic loading, undersize sublethal baits, nonlearned behavioural aversion to 1080, and failure to encounter bait. Dislike of bait was not a major cause of failure.

Progress has been made towards solving these problems, but failure to encounter bait remains a likely major reason for possums surviving aerial poisoning. Improvements in the aerial sowing of bait are essential if the full benefit of this progress is to be realised.

## INTRODUCTION

The Australian brush-tailed possum (Trichosurus vulpecula), a nocturnal, predominantly arboreal herbivore, was first introduced to New Zealand in 1840 for the establishment of a fur trade. Major liberations occurred at the end of last century (Pracy 1962), and the species flourished so that by the 1940s damage to the indigenous forests was becoming serious (e.g., Zotov 1949). More recently, damage to pine plantations (Farmer 1973), erosion control plantings (Jolly and Spurr 1981), and crops and pasture (Spurr and Jolly 1981) has become widespread. Possums have also been identified as an important reservoir of bovine tuberculosis (Mycobacterium bovis) (Julian 1981).

Large-scale aerial baiting techniques were developed for possum control in the late 1950s (Batcheler et al. 1967), and have been used ever since. The aim of control is to provide all possums in the poisoning zone with at least one lethal bait that they will eat (Peters 1975). Operations monitored during the 1970s gave reductions in possum numbers that varied from 55 to 100% (Batcheler, 1978 unpubl. report). Monitoring of four recent operations showed close to 70% reductions (Morgan, unpubl. data). After a 70% reduction, a possum population with an intrinsic rate of increase of 1.4 would be expected to recover to 90% of its former level within 11 years (Spurr 1981). Our objective has been to improve the effectiveness of poisoning operations so that the period not requiring possum control is extended. The question posed was, "Why do possums survive aerial poisoning operations?"

Batcheler and Bell (1974) discussed the effect of possum density, condition, and behaviour on aerial poisoning success. This paper summarizes work that has identified deficiencies in aerial poisoning practice and has improved the chances of all possums eating at least one lethal bait.

The likely reasons for possums surviving aerial poisoning operations were investigated in a logical sequence which is outlined in Figure 1.

## STAGE 1. PALATABILITY OF BAITS

Chopped-carrot baits and a range of commercially prepared pellets have been used for aerial poisoning since 1956. The palatability of carrot and two types of grain-based pellets was tested. Bait types were used separately in field trials, as is done in control operations. Known weights of bait were spaced 40 m apart and the weight taken by possums overnight was recorded the following day. Trials were conducted over 3-night periods and the bait types at each plot were changed nightly. Palatability measured in this way is therefore the relative preference for bait types by an unknown proportion of the possum population. It gives a quick, rough assessment of the potential usefulness of baits for control.

Carrot was the most or equally preferred bait in 14 of 20 trials. A pollard-jam-molasses moist pellet was most or equally preferred in 10 of the trials, but a proprietary, oven-dried pollard pellet was preferred in only four trials (Morgan, unpubl. data).

## STAGE 2. WHAT PROPORTION OF THE POPULATION ACCEPTS NONTOXIC BAIT?

The proportion of a population that accepts bait (i.e., acceptance) is of more relevance to understanding operational failures than bait palatability per se. Acceptance was tested in five field trials (Morgan 1982) by adding Rhodamine B fluorescent dye at 0.5% w:w (Morgan 1981) to the nontoxic baits tested in Stage 1. In each trial, the different bait types were sown in separate 20 to 100-ha blocks of possum habitat at approximately 5,000 baits/ha. In four of the trials, an average of 95% of possums caught 3 to 7 nights after baiting showed traces of Rhodamine, indicating that all the bait types were accepted by most possums. In a summer trial, however, only 68% of the possums accepted bait. This was attributed to the abundance of natural foods, indicated by the good condition of the possums, and showed that control operations in summer may fail.

*D. R. Morgan and C. L. Batcheler regret the death of J. A. Peters in September 1985.

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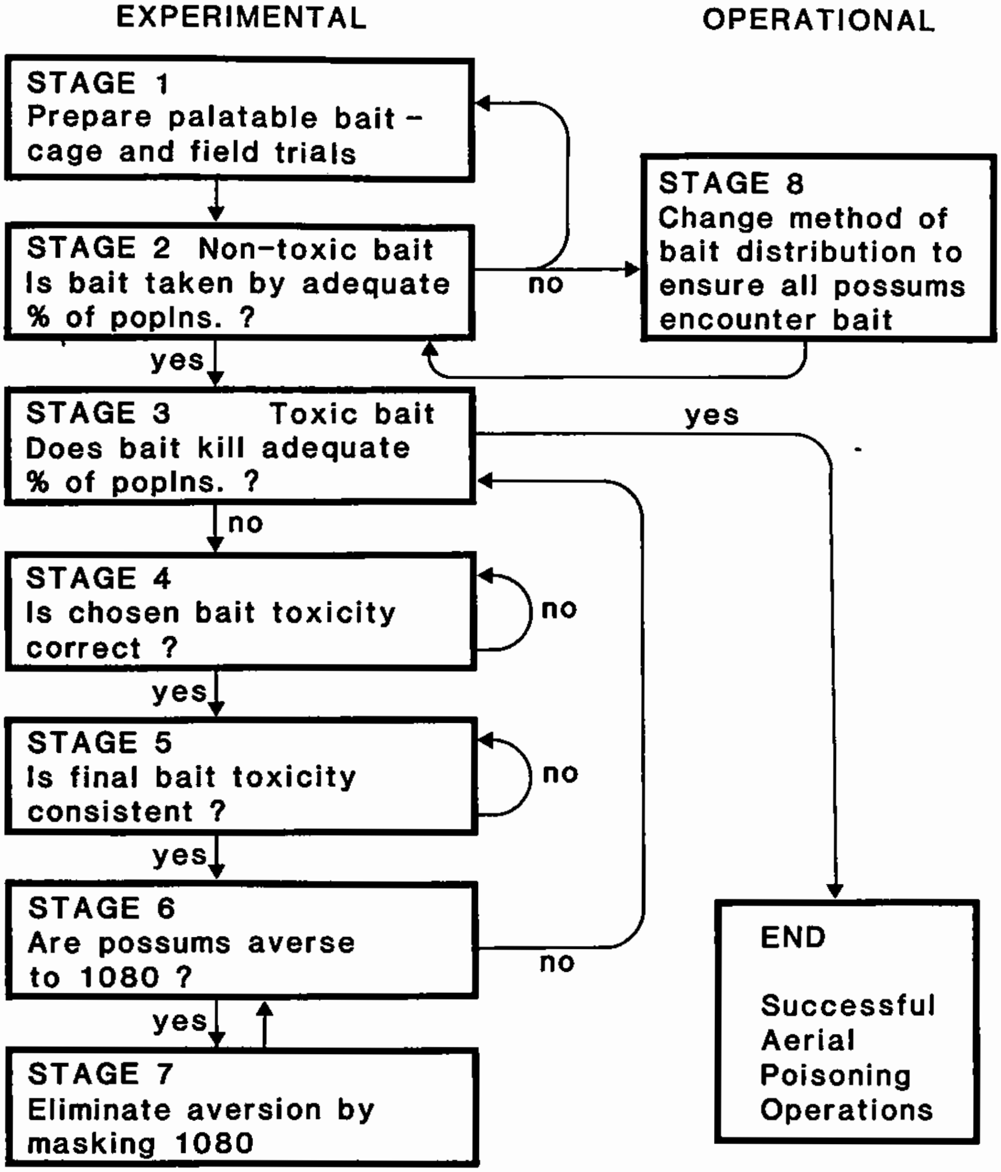


Figure 1. Problem analysis of factors likely to influence effectiveness of possum control.

Although the palatability (Stage 1) had shown differences in preferences for bait types, the Stage 2 trials revealed no differences in the proportions of the population that accepted the different bait types. The relevance of palatability testing to control is therefore limited when it is intended that target animals should receive a lethal dose by eating one bait only. In such cases palatability testing is useful only for the initial selection of bait types.

STAGE 3. WHAT PROPORTION OF THE POPULATION ACCEPTS TOXIC BAIT?

Compound 1080 is generally regarded as an outstanding pesticide because it is colorless, odorless, and (nearly) tasteless (e.g., Atzert 1971). These assumptions were tested for possums in a field trial (Morgan 1982). Three treatments were applied: nontoxic carrot with Rhodamine, carrot with approximately 0.1% 1080 and Rhodamine, and carrot with approximately 0.2% 1080 and Rhodamine. Ninety-eight percent of 94 possums trapped 3 to 8 nights after sowing the nontoxic bait showed traces of Rhodamine. Fecal pellet counts (as a measure of relative density) indicated that 32% of the population survived the 0.1% operation, and 17% survived the 0.2% operation. The survivors in the 0.2% block comprised mainly the proportion of the population that refused to eat bait (13 to 14% in both poisoned blocks). This suggested, indirectly, that some possums could detect 1080 by smell and found it unpleasant, particularly at the higher concentration. The survivors of a sublethal dose (i.e., those that showed only slight traces of dye), may have eaten only a small portion of bait before the onset of toxic symptoms, or were able to detect the 1080 as an unpleasant taste.

STAGE 4. SUSCEPTIBILITY OF POSSUMS TO 1080

Until 1980, 1080 was applied at 0.08% w:w (equivalent to 3.6 mg/4g bait), on the basis of an $LD_{50}$ estimate of 0.79 mg/kg and $LD_{100}$ <1.2 mg/ha (Bell 1972). These $LD_{50}$s were re-examined, using captive possums allowed to acclimatize for 6 weeks before dosing (New Zealand Forest Service 1982). In contrast, Bell's animals were not acclimatized. Possums of both sexes and different ages and weights were lightly anesthetized, then dosed at night, without forcible restraint (New Zealand Forest Service 1980). Under these conditions, the $LD_{50}$ values for 12 samples of 16 animals from different New Zealand regions varied from 1.0 to 2.2 mg/kg. The average was approximately 1.5 mg/kg, and the $LD_{95}$ approximately 2.2 mg/kg (Peters and Fredric, unpubl. data). These results have led to the introduction of a recommended standard toxicity level of 0.15% w:w (equivalent to 6 mg/4 g bait)--nearly double that previously used.

Although these dose-response results suggested that a concentration of over 0.2% was necessary to kill relatively tolerant or large possums, 0.15% became the standard concentration as it was recognized that most possums would eat more than one average-sized (4 g) bait, and that an $LD_{95-100}$ might cause smell or taste aversion.

STAGE 5. IS BAIT TOXICITY CONSISTENT?

Sublethal poisoning of possums could also be the result of variation in the size and toxicity of baits manufactured for standard operations. Most carrot-bait cutters used a decade ago produced large numbers of sublethal fragments. Studies of bait sown at 34 kg/ha revealed over 100,000 baits/ha, of which about 82% were less than 0.2 g. Less than 3% by numbers, and only 50% by weight, of all baits contained an $LD_{50}$ dose for an average adult possum (Batcheler, 1978 unpubl. report). A "bait quality index" (BQI) was developed to estimate the number of baits of all sizes which would have to be eaten by a 3-kg possum for the likelihood of death to exceed 99%. Early carrot cutters produced bait with BQI values ranging from 4.8 to 15.6, depending on whether the median (i.e., $LD_{50}$) or tolerant (i.e., $LD_{95}$) susceptibility of possums was used in the calculations. Improvements in screening to eliminate sublethal bait fragments reduced the range of BQI values to 2.4 to 5.7 (Batcheler 1982).

A newly designed, dual-purpose bait processor (New Zealand Forest Service 1985) produces carrot bait with BQI values of 1.5 to 2.0, and screens out most sublethal fragments. BQI values of pellets also now range from 1.5 to 2.0 (Batcheler, unpubl. data). Monitoring systems in the machine permit on-site control of bait quality.

These improvements in bait quality have reduced sublethal poisoning in possum control operations. In the past, possums had to eat up to 16 pieces of bait before receiving a lethal dose, so that high sowing rates (in excess of 30 kg/ha) were necessary. Since anorexia occurs within 41 ± 3 min (Morgan, unpubl. data) of eating a lethal bait, the increased probability of eating baits that are nearly all lethal should significantly reduce survival. Indeed, the quality of bait is now so much improved that the sowing rate could be reduced to as little as 3 kg/ha. This would reduce the cost of control operations by about one-third.

STAGE 6. AVERSION TO 1080 - EVIDENCE FROM PEN TRIALS

Once it was established that the toxicity of baits needed to be much higher, the aversion to 1080 shown in Stage 3 needed to be re-examined. The responses of groups of 40 captive possums to baits were observed (New Zealand Forest Service 1985). Each possum was used once in an overnight test. Using either nontoxic carrot or pellets, or toxic carrot or pellets, the behavioural response of a possum to 12 baits was recorded. Of the possums exposed to 6-g carrot baits containing 9 mg of 1080 (i.e., 0.15% w:w), 27.5% survived. Over half the survivors had refused the toxic carrot after smelling it (i.e., smell aversion); the remainder had rejected it after one or two nibbles (i.e., taste aversion). Only 7.5% of possums refused nontoxic carrot baits. Toxic pellets, loaded at approximately 0.2% w:w (11.3 mg 1080/6-g pellet) were rejected by 34% of possums, mainly by taste rather than by smell since 1080 was incorporated in the pellets, not in a surface coating as applied to carrot. Only 5% of possums rejected nontoxic pellets.

The Stage 3 field experiment and these pen trials gave evidence of a nonlearned behavioural aversion to 1080. The mechanism, sensory detection of an unpleasant substance, is quite different to the learned aversions towards 1080 recorded in *Peromyscus maniculatus* (Howard et al. 1977), or those reviewed by Riley and Clarke (1977). More recently, Sinclair and Bird (1984) have shown a nonlearned aversion to 1080 in meat baits for a small nontarget marsupial, *Sminthopsis crassicaudata*, which is at risk during dingo control operations.

STAGE 7. ELIMINATION OF AVERSION BY MASKING 1080

Forty fruit, savory, or spice flavors were applied to barley and offered, three at a time, to penned possums to determine whether any might be used to mask the smell or taste of 1080. Relative preferences were assessed by comparing the weights eaten of each type of flavored barley with the consumption of nonflavored barley also offered in each test.

Since many of the flavors tested are used by hunters as lures, it was surprising that only orange-flavored barley was preferred to nonflavored. This suggested that either possums were cautious of new smells or tastes, or they particularly liked the nonflavored barley. Because cinnamon ranked fifth of the forty flavors, and has the added advantage of repelling some birds (Udy and Pracy 1981), it was also tested further.

Flavored pellets and carrots, nontoxic and toxic, were offered to groups of 30 possums, using the procedure described for Stage 6. Aversion was eliminated. No possums refused to eat lethal doses of cinnamon-flavored toxic carrot, and the small level of rejection of cinnamon or orange toxic pellets matched the rejection of nonflavored pellets.

Cinnamon oil is now used routinely in poisoning operations. As well as its value as a mask, its repellent value reinforces the addition of green dye to bait (Caithness and Williams 1971) as a precaution against accidental poisoning of birds.

STAGE 8. DO ALL POSSUMS ENCOUNTER BAITS?

If the toxic bait is acceptable to all or nearly all possums and is lethal, the remaining major reason for possums surviving is failure to encounter bait. Since this can be investigated only at the operational level, the problem was avoided in the small-scale experiments by sowing bait carefully at high rates.

The success of aerial bait distribution was measured in a poisoning trial in mixed hardwood/podocarp forest on steep, broken terrain. The proprietary pellet used in earlier trials was distributed at a nominal rate of 15 kg/ha from an aircraft traversing the hillside along approximately 30 swaths between 150 m and 650 m above sea level. The distribution of bait was determined by counting baits on 80-cm radius plots at 8-m intervals along systematically spaced lines up the hillside. If no baits were found on at least five successive plots, the sample sequence was considered untreated.

Even though a pilot experienced in bait sowing was engaged for the operation, about 38% of the entire area was untreated. Interpolation between the sample lines revealed many gaps of up to 80 to 200 m wide. Untreated areas of 2 to 5 ha extended for as much as 300 m along the contours. Studies of possum movements in habitat similar to the trial area (Crawley 1973; Green, unpubl. data) have indicated that such gaps could encompass the expected range of movements of some possums during the 5 to 20 days over which bait remains palatable and toxic.

DISCUSSION

These investigations have shown several reasons why possums survive aerial poisoning operations. Sublethal toxic loading, sublethal undersized baits, and taste or smell aversion to 1080 have undoubtedly been major causes of failed control operations in the past. However, dislike of bait, which had been widely implicated, proved an unlikely cause of failure. Improvement in the quality of bait, revision of the required toxicity, and preventing aversion to 1080 by masking should virtually ensure death for any possum, provided it finds bait. The most obvious remaining problem is to ensure that all possums encounter at least two baits.

Aircraft guidance systems, such as tested by Hedderwick and Will (1982) may be useful in improving the spacing of sowing swaths. Improved equipment for aerial distribution of bait in uniform, wider swaths and the use of aircraft with larger payloads would reduce pilot error as fewer swath spacings would have to be judged. Only when bait distribution techniques are improved will the full benefit of the other findings be realized.

The analytical approach used in this study to integrate work spread over a decade has proved effective in the solving of the complex problems underlying operational failures. It may be an appropriate approach for improving or reassessing control of other pest species.

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