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IMPROVING AERIAL CONTROL OF POSSUMS BY PRECISION BAIT DELIVERY

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ABSTRACT: Aerial delivery of 1080 (sodium monofluoroacetate) baits is the main technique for reducing populations of New Zealand's foremost vertebrate pest, the Australian brushtail possum, in large areas of inaccesible country. Surveys after pilot-controlled aerial sowing of baits in seven operations in forests showed that inaccurate navigation along the swaths left up to half the target zone untreated. Kill was estimated to average 75 %. Inadequate coverage with baits was therefore believed to be a major factor in the survival of possums during aerial control operations. This was confirmed in field trials using rhodamine B as a biomarker to reveal acceptance of non-toxic baits. More possums were unmarked in partially treated blocks than in completely treated blocks. After a large-scale aerial control operation, proportionally more possums survived in untreated gaps than in treated areas.

Six operations that used navigation guidance systems (Decca Flying Flagman and GPS) yielded complete coverage and high levels of kill (mean of 92 *%)* in five. Precision sowing of possum baits prevents survival of possums by failure to encounter baits, and enables lower rates of bait application. This will give large cost savings and improved environmental safety. A small proportion of a population may still not be targeted because of individual dislike of bait or failure to encounter baits because animals stayed in the forest canopy during operations. Development of more palatable and longer lived baits may facilitate local extermination of possums.

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INTRODUCTION

The Australian brushtail possum *(Trichosurus vulpecula)* is one of 35 exotic vertebrate species introduced to New Zealand by European colonists last century. Now numbering 60 to 70 million, this species is distributed over most of the country, except mountainous regions above 1000 m altitude. It is recognized as the foremost vertebrate pest in New Zealand because of its extensive damage to indigenous forests (e.g., Rose et al. 1992), destruction of avifauna (Brown et al. 1993), and its role as a vector of bovine Tb (Coleman 1993). About 25 % of the country is currently occupied by Tb-infected possums (Eason 1992).

Control of Tb-infected possums has recently been intensified as new government policy aims to eradicate Tb from farmed cattle and deer (Animal Health Board 1993) and long-term priorities have been identified for forest conservation (Department of Conservation 1993). It is expected that NZ$27.5 million will be spent on possum control in the current year (Livingstone 1994).

Since 1956, pest control agencies have favored the use of aerial poisoning with 1080 (sodium monofluoro-acetate) baits to gain rapid reductions of possum populations over areas as large as 20,000 ha. Carrot baits, prepared by dicing carrots and coating them with 1080, or factory-prepared cereal-based pellet baits with 1080 incorporated are used in these large-scale operations. Over the past 20 years, such operations have met with varied and unpredictable success (25 to 98 *%* kill) (Spurr 1993). Bait characteristics identified as likely to govern success (Morgan et al. 1986) led to the development of baits that killed more than 95% of possums that encountered them in controlled trials (Morgan 1990a). Since few operations achieved this level of success, efforts were made to determine what other factors could be responsible. These were believed to be:

- Poor bait quality (e.g., high proportions of small sub-lethal particles).
- Unexpected bad weather after bait sowing.
- Abundance of alternative foods.
- Failure of possums to encounter bait, either because of gaps in aerial sowing or because some possums live predominantly in the canopy.

Improvements in the design and performance of carrot-cutting machinery (Batcheler 1982) and establishment of specifications for the manufacture of pellet baits (MAFTech/FRI, unpublished data) have been reinforced by laboratory-based quality assurance procedures (e.g., Eason et al. 1990), and poor bait quality should no longer contribute towards possum survival. The problems caused by unexpected rain causing deterioration of bait or high winds causing baits to be buried by leaf litter cannot be completely resolved. However, if control operations are started only when the weather forecast for the following three days is fine, failures due to bad weather are unlikely. Bait acceptance trials have shown that operations may be unsuccessful if they are conducted when natural foods are in abundance, especially in summer (Morgan 1982), and the sudden availability of highly palatable foliage or fruits, predominantly in the forest canopy, was suspected as the reason for failure of an operation in 1992 (Morgan 1992).

This paper examines the final factor listed: that incomplete bait coverage leads to lower effectiveness of control operations.

METHODS

Assessing Bait Coverage and Possum Kill

Bait coverage and possum kill were monitored after seven aerial control operations conducted at seven locations between 1985 and 1991 (Table 1).

The dispersion of baits on the ground after aerial sowing by a variety of aircraft was measured by searching for baits along a series of 2 m wide transects 100 to 200 m apart orientated at 90° to the direction of flight paths. When no baits were seen along the transect for more than 20 m, the starting distance from the start of the transect (measured by hip-chain) and length of the gap were

Table 1. Bait coverage and possum kill in aerial control operations where navigation guidance systems were not used.

Operation	Bait sowing rate (kg/ha)	Percent Coverage	Maximum recorded gap width (m)	Percent Kill
Granite Hill, block 1	15	59.5	180	64.4
Granite Hill, block 2	15	76.0	200	73.3
Granite Hill, block 3	15	51.6	210	69.8
Copland Valley	20	51.9	170	62.0
Pureora Forest	10	79.0	210	80.0
Slopedown Forest	9	70.0	194	86.0
Waipoua Forest	5	82.0	400	86.0

recorded. Diagrams of coverage were drawn by interpolating recorded gaps along adjacent lines, and percent coverage was calculated after digitising treated and non-treated areas. Where gaps in lines did not clearly link, an approximation of the total coverage was made from the mean percentage of each line, in 20 m segments, that was baited.

Possum kill was assessed from the reduction in fecal pellets accumulating on marked plots, from changes in the number of possums seen in spotlight counts, or from changes in the numbers caught in leg-hold traps before and after poisoning (Baddeley 1985).

The Effect of Gaps on Bait Acceptance

Three field trials were conducted at three North Island sites to determine whether bait acceptance was lower in areas that were incompletely treated than in areas completely treated. Non-toxic cereal-based pellet baits (Animal Control Products) were sown at 5 kg/ha in each trial. Pellets were treated with rhodamine B dye (0.1 % wt:wt) as a biomarker (Morgan 1981) and cinnamon oil (0.1% vol:wt), which is normally incorporated in toxic pellets to mask 1080 (Morgan 1990).

At both Waimahia Forest (young *Pinus radiata* plantation) and Puketi Forest (mixed indigenous hardwood forest), two blocks (each approximately 100 ha) were treated with pellet baits, one block completely and the other on alternate 100 m wide swaths. At Waipoua Forest (similar forest type to Puketi), a single 100 ha block was treated. A large part of the block was unintentionally left untreated as a result of poor aircraft navigation, so the opportunity was taken to compare bait acceptance in possums captured in treated and partially-treated areas.

In all three trials, two nights were allowed after aerial sowing for possums to feed on bait, then traps and cyanide poison were used to collect a sample of possums. Bait acceptance (i.e., the proportion of possums eating bait) was determined by presence of the rhodamine dye (Morgan 1981). At Waimahia, a search was made at 90° to the direction of aerial sowing for the nearest bait along a i m wide transect from each possum caught. This was used as a relative measure of bait availability at all capture sites.

Survival of Possums in Gaps

The significance of gaps for possum survival was investigated during a large-scale (13,000 ha) winter control operation in the Copland Valley, Westland. Four weeks after the operation, carrot baits (well-preserved because of cold weather) and possum fecal pellets were counted in three parts of the forested catchment on a total of 4000 circular 2 m^2 plots, spaced 10 m apart. Where baits were not found on a minimum of five successive plots, a gap in the bait distribution was accepted. The presence of possum pellets in treated areas and gaps was then compared.

Use of Aerial Navigation Guidance Systems

Reduction of the possum population was monitored in six control operations since 1991 in which navigation guidance sytems were used.

The Decca system, used in two operations, relies on radio triangulation to calculate aircraft position using an on-board transmitter/receiver and remote transponder stations that require line-of-sight communication with the aircraft. GPS (Global Positioning System) based systems, used in three operations, utilize signals from satellites to establish position by triangulation. Both systems include software and instrumentation to indicate to the pilot any deviations from pre-determined flight paths. Data logging the flight paths can also be down-loaded from both systems to produce diagrams of the flight-paths. Scaled correctly, these provide a rapid means of assessing overall coverage of the target area. Any gaps that are revealed can then be treated with baits by programming coordinates into the guidance system for relocation.

RESULTS

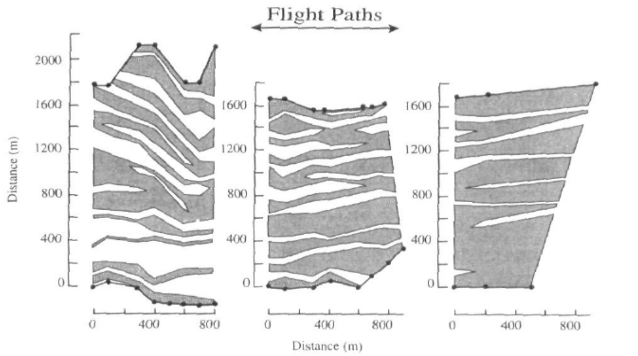
Coverage Achieved by Aerial Sowing

The seven aerial sowing operations monitored between 1985 and 1991 all experienced incomplete bait coverage, which varied from 51 to 83% (Table 1). Poor coverage was obtained at Granite Hill and in the Copland Valley, and the best overall coverage achieved was 82% at Waipoua Forest. The average coverage obtained in the seven operations monitored was 71 %.

The maximum gaps between sowing swaths recorded were 170 to 240 m except at Waipoua, where a gap of

400 m was recorded. Gaps usually extended across the full width of the surveyed blocks and presumably, therefore, beyond the block boundaries (see Figure 1 for a typical example of coverage).

Figure 1. Coverage (shaded areas) achieved by aerial sowing on three blocks of Pureora Forest. Gaps and covered areas are



distorted by differences in topography and hence distance measured along survey transects. Dots mark the ends of transects.

For the seven operations kill was significantly correlated with coverage (Figure 2). Assuming that bait sown is of good quality and sowing is followed by a period of at least two fine nights, the correlation predicts that if 70 % of the area is sown with baits, a kill of around 75% can be expected, but if complete coverage can be achieved the kill will increase to around 95 %. A small proportion of possums (about 6%) may be expected to survive.

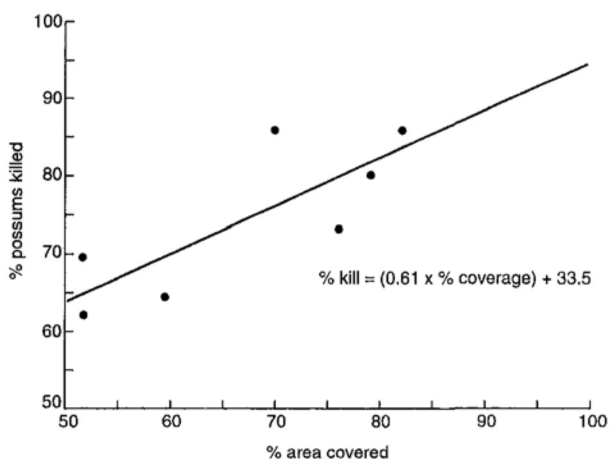


Figure 2. Correlation between coverage and kill in seven aerial control operations (r = 0.80, p = 0.02).

Effect of Coverage on Bait Acceptance

Gaps in coverage affected possums' access to bait (Table 2). In the Waimahia sowing trial, bait acceptance in the partly sown block was lower (88.6%) than in the completely sown block (95.0%). Unmarked possums (i.e., that had not eaten bait) in the partly sown block were caught, on average, at almost twice the distance (85 m) from bait than marked possums (44 m), and this difference was statistically significant (t=3.1, d.f. = 138, p< 0.001). In the completely sown blocks both marked and unmarked possums were found, on average, less than 20 m away from baits. In the Puketi trial, more possums (29%) were unmarked in the area with gaps than in the completely sown block (17%), but this result was not statistically significant. In the Waipoua trial, one large and one small gap accounted for approximately one-third of the trial block. Regarding the entire block as an incompletely sown area, 13% of the 261 possums captured were unmarked. By comparison, only 3% of the 163 possums caught in the treated parts of the trial area were unmarked, which was significantly less.

Combining the results from all three trials, on average 17.8% of possums in partially-sown blocks were unmarked, which was significantly more than the 8.2% in completely sown blocks (Table 2).

Survival of Possums in Gaps

The distribution of survivors of the Copland Valley aerial poisoning operation was influenced by the presence or absence of bait. Possums were present in significantly more of the gaps (65%, n=102) than in treated areas (48%, n=99) (x^2=5.4, d.f. = l, p=0.02).

Use of Aerial Navigation Guidance Systems

Diagrams of the flight paths in the six operations where navigation guidance systems were used confirmed that aircraft had been flown along regularly spaced flight paths (see Figure 3 for example), with few gaps over 50 m. Since no bait blockages in sowing equipment were reported, it is assumed that bait distribution was virtually complete. Department of Conservation surveys (unpublished data) conducted at Rangitoto island, Waipoua, and Egmont did not reveal any gaps in coverage.

The mean kill obtained in the six operations (Table 3) was 89.5%, significantly higher than the mean kill of 74.5% for the seven operations where navigation guidance was not used (t=3.2, df= 11, p<0.01). High levels of kill were achieved (mean = 92%) in five of the operations, but the operation at Egmont achieved a slightly lower kill of 78%, possibly as a result of an abundance of naturally preferred foods.

DISCUSSION

Improved Coverage and Its Effect on Operational Efficiency and Effectiveness

Large gaps usually occur in the distribution of baits during aerial control of possum populations when pilots have no navigation assistance. Gaps of 100 m width or more may lead to possums failing to find and eat baits, and survivors of control operations were found predominantly in such gaps. Furthermore, the poorer the coverage, the greater the degree of survival.

Table 2. Bait acceptance, as indicated by presence of rhodamine B biomarker, in completely and incompletely treated areas in three field trials.

Trial	Completely treated: Possums caught (n)	Completely treated: Possums not marked (n)	Incompletely treated: Possums caught (n)	Incompletely treated: Possums not marked (n)	X^2	p
Waimahia	130	6	140	16	4.2	0.04
Puketi	106	18	38	11	2.5	0.11
Waipoua	163	5	261	34	11.9	<0.001
Overall	399	29	439	61	9.6	0.002

Table 3. Bait coverage and possum kill achieved in aerial control operations where navigation guidance systems were used.

Operation	Nav-guidance system	Bait sowing rate (kg/ha)	Percent coverage	Percent kill
Titiraupunga	GPS	10	Assumed 100	97
Rangitoto	Decca	10	100	93
Moerangi	Decca	10	Assumed 100	92
Taupo	GPS	10	Assumed 100	89
Waipoua	GPS	5	100	88
Egmont	GPS	5	100	78

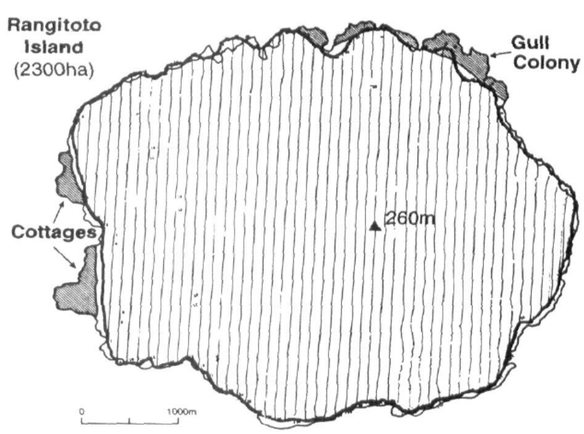


Figure 3. Printout of flight paths at Rangitoto Island produced from coordinates stored by the Decca Flying Flagman navigation guidance system. The flight paths are superimposed on an appropriately scaled outline map and show that baits were sown along regularly spaced paths throughout the entire island except areas inhabited by people and nesting gulls.

The immediate advantage of improving aerial sowing of possum baits is, therefore, an expected improvement in the level of control achieved and the degree to which possum damage is alleviated, whether it be, for example, damage to vulnerable forests or transmission of bovine Tb. A second advantage conferred by improved coverage, and hence improved control, is the longer period of relief from damage, and therefore control expenditure. During the 1970s and 1980s, the average kill achieved in control operations was about 70% (Morgan et al. 1986). At an average rate of breeding, and assuming no repopulation by immigration, recovery to 90% of the former population would take a minimum of 10 years. A kill of 95 %, however, would increase the recovery time to a minimum of 16 years (Spurr 1981).

A third advantage of improved coverage is the potential for reducing the amount of bait used. In the past, large amounts of bait (up to 40 kg/ha) were sown, partly on the assumption of a greater likelihood that some would remain palatable and toxic long enough for possums not immediately exposed to bait to eventually encounter and eat a lethal quantity. With complete bait coverage such large application rates are no longer necessary. Sowing pellets at 3 kg/ha, for example, reduces the cost of operations by one-third the cost of sowing at a rate of 10 kg/ha, a common practice just a few years ago (Spurr 1993), and is unlikely to reduce effectiveness (Morgan 1994b).

Overall, increased effectiveness and reduced sowing rates (from 10 kg/ha to 3 kg/ha) are expected to reduce the long-term costs of repeated aerial poisoning operations using pellets by at least 60% (Morgan 1994a).

An additional advantage of lowering sowing rates is the improvement gained in environmental safety, consistent with overseas trends of minimizing the rates at which pesticides are used (Greig-Smith 1993). Although 1080 operations were found to leave no detectable toxic residues in water (Eason et al. 1992), and several soil bacteria are known to rapidly degrade the toxin once baits break down (Bong et al. 1979), baits may occasionally be eaten by non-target species. While no impact on bird populations attributable to poisoning has been detected for common bird species (Spurr 1991; Miller & Anderson 1992), populations of less common species may be less able to sustain individual losses (Spurr 1994a), and effects on invertebrates are not yet understood (Spurr 1994b). Reducing sowing rates is therefore a sensible strategy for minimizing unwanted poisoning effects.

Navigation Guidance Systems

The Decca system is dependent on continuous line-of-sight signal transmission to and from transponders. Although the system functioned well over the relatively flat terrain of Waipoua forest and on the volcanic cone of Rangitoto Island, where continuous signal transmission was maintained, trials using the Decca system in hilly country showed that signal transmission was lost so frequently as to render the system of little value (Morgan 1988, 1990b). The system is therefore unsuitable for most possum control operations which are conducted over such terrain.

GPS-based systems are less dependent on line-of-sight communication, though a ground relay station is required for refinement of the positioning calculations, and this occasionally suffers from signal loss when aircraft are navigating over rugged terrain. GPS systems are being rapidly improved in New Zealand for aerial sowing with developments such as automatic compensation of sowing rate when aircraft speed is affected by wind.

Survivors

The correlation of survival with coverage predicted that when an entire area is covered, a few possums will still survive. Pen trials (Morgan 1990a) and field trials (Morgan 1982) indicated that a small proportion (0 to 5 %) usually refuse to eat bait. Others may ignore baits when natural foods are plentiful. Additionally a small proportion may fail to encounter baits because they spend their time in the canopy, particularly when canopy-borne foods are plentiful (this component was not assessed in earlier trials). As an indication, of five possums recovered from the canopy (by shooting) after rhodamine-treated baits had been distributed at Puketi, three (60%) were unmarked in contrast to those caught on the ground, of which significantly less (17% of 125) were unmarked (X^2=4.8, d.f. = 1, P=0.03). Presently, baits may be expected to remain viable for only a few days. Increasing the life of bait may therefore increase the chance that all possums will eventually encounter viable bait because possums that are predominantly canopy dwellers do occasionally visit the ground (Ward 1978)

It is important to attempt to target these two types of surviving possums, which probably represent the difference between effective control and local extermination. Research is therefore continuing to develop baits that are palatable to all possums and will remain palatable and toxic for longer in wet environments.

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