Effectiveness of aerial baiting of possums in different seasons and different forest types

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CONTENTS

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ABSTRACT

Each season for two years, populations of possums, in three widely separate forests of New Zealand with distinctly different plant assemblages and possum history, were aerially baited with non-toxic rhodamine-dyed cereal pellets at 5 kg/ha to determine the probability of success of aerial control operations. Each baiting trial was conducted over 100 ha of possum-inhabited forest, and after one night of feeding, possums were trapped, killed, and inspected for evidence of the dye. At the same time, the condition of each possum was assessed using two indices, and its stomach contents were removed for possible later analysis. Finally, at each trial site, the phenology and levels of possum browse were scored on forest tree and shrub species favoured by possums. Bait acceptance was not influenced by seasons as high proportions (i.e. 85–100%) of possums ate bait in all of the 24 trials conducted, thus preventing examination of the influence of condition on bait acceptance, and acceptance was less than 90% in only three trials. Bait acceptance was similar in all three forests. Little variation was recorded in the condition of possums within populations. The phenology of possum-preferred plants varied seasonally according to expected patterns, but given the high levels of bait acceptance in all trials, it was not possible to determine the influence of plant-food phenology. Browse on the foliage of palatable trees varied in each region with season and species. The findings support the practice of conducting aerial baiting operations against possums in 'non-traditional' seasons. However, other research suggests that possums may be less susceptible to 1080 in warmer temperatures, and this warrants further experimental investigation. Additionally, since fruit-masting did not occur during this study, the influence of an abundance of preferred foods on likely control effectiveness remains untested. We therefore strongly recommend that bait acceptance trials are conducted before scheduled aerial control operations if possum-preferred plants exhibit fruit-masting before control.

Keywords: possum control, possum condition, possum browse, bait acceptance, rhodamine B, Herekino Forest, Moki Forest, Cobb Valley

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1. Introduction

Bait acceptance was used as a measure of the likely effectiveness of aerial 1080 poisoning for controlling possums in different seasons by conducting rhodamine-B bait acceptance trials. These trials were conducted at three widely separated and distinctly different forest sites each season for two years. The effect of the seasonal occurrence of natural foods and of the physical condition of possums on bait acceptance were also examined. The study was conducted by Landcare Research between October 1996 and June 1999 for the Department of Conservation.

2. Background

Large-scale toxic baiting from aircraft has underpinned the management of brushtail possum (*Trichosurus vulpecula*) populations in New Zealand since the 1960s (Morgan & Hickling 1999). Aerial baiting is carried out by the Department of Conservation (DOC) over Crown-owned conservation lands to protect vulnerable animal and plant species (e.g. giant land snails, kokako, mistletoes) and vulnerable ecosystems (e.g. rata/kamahi forest, coastal pohutukawa). Historically, baiting of possums has mostly been conducted in winter, when the condition of male possums is poor and that of female possums is declining (Bamford 1970). At this time, the foods favoured by possums, particularly fruits and new foliage, are thought to be in shortest supply, and pest managers intuitively argue that possums are most likely to accept artificial foods. In addition, in winter, disruptions to patterns of livestock management caused by the sowing of toxic bait over forest adjacent to farmland is minimal, carrots (the traditional and cheapest bait) are most readily available and, in some regions, the weather is most settled.

In the last decade, however, an increasing number of aerial control operations have been conducted (particularly by the Animal Health Board (AHB) for Tb control), and this has placed a greater demand on the services of possum managers and their staff, the manufacturers of alternative cereal baits, and aerial operators. Furthermore, aerial control has been considered inappropriate in winter in some regions due to the likelihood of extended periods of rainfall at that time of the year (e.g. Northland). These factors have encouraged possum managers to spread the increased workload outside the traditional winter baiting season (Kelton 1995).

While experience has shown that acceptably high levels of control (i.e. of around 80% kills) could normally be expected in winter operations (Batcheler 1975), few data were available to support aerial control at other times of the year. In one of the few studies conducted on seasonal bait acceptance by possums, Morgan (1982) found that in four of five trials, over 90% of possums accepted aerially sown non-toxic bait. Only at Kaingaroa Forest (a pine plantation) in summer was acceptance (68%) inadequate, and this contrasted with high acceptance (95%) in the same area during winter. More recently, Coleman et al. (1999) examined bait acceptance by possums in forest adjoining pasture in central Westland. There was no evidence that baiting outside of winter would result in operational failure. Further data, particularly from deep forest sites, are therefore needed to indicate whether bait acceptance outside of the traditional winter season is generally likely to be sufficient to ensure operational success.

This report provides data collected in an extensive series of bait-acceptance trials conducted deep in native forest in each season at three sites over two years. We assessed possum condition as a possible indicator of bait acceptance, and we monitored the availability of forest foods preferred by possums to determine if any were sharply seasonal and associated with reduced bait take. Stomach contents were also collected from trapped possums so that if baits were not readily accepted in any of our trials, the foods eaten at such times could be identified and used in future operations as 'indicators' of likely operational failure.

3. Objectives

To determine the likely influence of bait acceptance on the success of aerial possum-control operations in each of four seasons, by:

- conducting replicated bait acceptance trials in each season in each of three major forest habitats threatened by possums for two consecutive years,
- determining the relationship between possum condition and levels of bait acceptance,
- collecting stomachs for later dietary analysis in the event that any trials indicate likely operational failure, and
- assessing the availability of possum-preferred foods in each trial.

4. Methods

4.1 SITE SELECTION AND TIMING OF TRIAL

In consultation with DOC staff, we selected three areas that were considered to be broadly representative of much of the forest habitat over which the Department conducts aerial control of possums, but where no possum control had been conducted for at least two years, thus avoiding the possible confounding effect of bait shyness on bait acceptance assessments. The Herekino Forest, Northland, was selected as a mixed hardwood/broadleaf forest with rich plant diversity, no history of ungulates, and a recently established (i.e. colonised around 1960, Pracy (1974)) possum population. The Moki Forest in inland Taranaki represented a tawa/kamahi forest of average plant diversity, with a well-established ungulate and possum population (possums established around 1920, Pracy (1974)). The Cobb Valley in Nelson is vegetated with low-diversity beech forest, in which ungulates are common and the possum population has been long-established (since around 1900, Pracy (1974)) but remains at low density.

In each area, we selected adjacent 100-ha sites for bait acceptance trials conducted in each season (i.e. summer (January), autumn (April), winter (July), and spring (October)). Trials were replicated in a second year to provide for greater statistical rigour. The Herekino and Moki trials were conducted from October 1996 to July 1998. The Cobb trials were conducted from July 1997 to April 1999, to stagger the cost and complexity of establishing trials.

4.2 TREATMENTS

4.2.1 Bait preparation

Non-toxic, cinnamon-flavoured No. 7 cereal-based pellet baits (Animal Control Products, Wanganui) were used in all trials. The baits were treated with 0.1% wt:wt rhodamine-B dye as a marker to indicate the percentage of possum populations eating bait in each trial (Morgan 1981, 1982). A solution of dye was prepared by mixing 60 mL of 'Been there' (a spray marker product containing 40% rhodamine—FIL Industries) with 1.44 L of water, and 1.5 L of the solution was slowly added to 25 kg of pellet baits (i.e. 1 bag) in a concrete mixer and gently mixed until all baits were evenly coated. Baits were then spread on a sheet of plastic for several hours until dry and then rebagged. Baits were dyed within 1 month of manufacture and were used no longer than two months after dyeing.

4.2.2 Bait quality

The effects of dying and subsequent drying on bait palatability were assessed in a series of trials using captive possums. Pellets were tested before dyeing, while damp following dyeing, and at intervals of 1, 4, 30, and 60 days after dyeing and drying. In each trial, 100 g of No. 7 pellets and 100 g of fresh (i.e. less than months old) RS5 pellets (Animal Control Products, Wanganui) were presented to 20 individually housed possums for 16 h overnight. Palatability was defined as the mean of individual possums' consumption of No. 7 pellets expressed as a percentage of their combined consumption of No. 7 and RS5 pellets.

4.2.3 Bait distribution

Baits were distributed by helicopters fitted with sowing buckets calibrated to sow baits at a rate of 5 kg/ha, the average rate used for aerial control of possums when the study started in 1996 (Morgan et al. 1997). Pilots used GPS guidance systems to minimise the likelihood of gaps occurring in baiting coverage. Each trial was conducted in a previously unbaited 100-ha block of forest. In the Herekino and Moki forest trials, blocks were surrounded by forest, but in the Cobb Valley trials, blocks were located on alpine valley slopes with lower boundaries along the forest edge at the valley bottom.

4.2.4 Assessment of bait acceptance

After allowing possums one night to feed on baits, a sample of up to 60 possums were trapped using Victor No. 1½ leg-hold traps lured with a mixture of flour and icing sugar treated with approximately 0.1% wt:wt orange oil (Bush Boake Allen, Auckland). Traps were placed only at locations where several baits were visible, and were set for up to four nights. The trapped possums were killed humanely by one or two firm blows to the back of the head and removed to a central necropsy site. There, the proportion of the population eating at least one bait and thus becoming marked with rhodamine-B dye was assessed by inspecting the paws, mouths, and stomach contents (Morgan 1981). Those that were not clearly marked were inspected under UV light for the presence of the orange fluorescence characteristic of rhodamine B. Possums showing minor traces of rhodamine-B dye were not regarded as bait acceptors, as it is likely that they had either only nibbled bait (i.e. eaten only the equivalent of a sub-lethal quantity) or had been marked inadvertently by standing on baits. At the same time, stomachs were collected from all possums in each sample and frozen for possible later determination of favoured foods that may 'indicate' poor bait acceptance.

The acceptance of bait by possums in each trial was expressed as the proportion of trapped possums showing clear dye-marking, and 95% binomial confidence intervals were applied to this proportion. Differences in bait acceptance between trials, between areas, years, and seasons were tested using logistic regression. Models were fitted using maximum likelihood, and tested for effects using likelihood ratio tests.

4.2.5 Possum condition

The condition of possums was assessed using two indices of the total amount of stored body fats (Bamford 1970). Firstly, the fat surrounding the stomach (mesenteric fat) was removed and measured, and differences in the mean weight of mesenteric fat compared by analysis of variance (ANOVA). Differences in mean mesenteric-fat weights between year and season (within each area) were tested using ANOVA with 'year' and 'season' as fixed effects. Fat weights were square-root transformed to satisfy assumptions of ANOVA. *Post-hoc* Bonferroni pairwise comparisons were used to identify where differences existed. Secondly, the body weight and length of each possum was measured and the regression of ln(weight) on ln(length) generated a slope which was used as an index of condition. Analysis of covariance was used to determine if the weight/length relationship varied between year and season. Where there was an overall difference between years and seasons, *t*-tests were used to make further comparisons. These two measures of condition were then separately regressed against bait acceptance to determine if body condition influenced possums' response to bait. To normalise data for analysis, the proportion of animals accepting baits was arcsine-square-root transformed and mesenteric fat was square-root transformed.

4.2.6 Food availability and usage by possums

At the same time as each field baiting trial was conducted, the availability of natural foods preferred by possums was assessed in the treatment block. A list (see Appendix 1) was compiled of 10–12 forest plants occurring commonly in each area and whose foliage, flowers, or fruits had been identified as preferred by possums (e.g. Fitzgerald & Wardle 1979; Coleman et al. 1985). The occurrence of such preferred species was assessed during our initial selection of sites.

The phenology (abundance of new leaves, flower buds, flowers, green fruit, ripe fruit, and fruit on the ground) of these favoured possum-food plants was assessed on at least thirty 5-m radius plots located at 20-m intervals (40-m at Cobb Valley) on transects within each block. For each species, we selected the nearest scorable specimen to the plot centre to describe its phenology. To boost sample sizes of uncommon selected species, additional specimens were scored off plots as encountered along the transects. Phenology descriptions were adapted from methods described by Payton et al. (1996), and were compared subjectively using a 5-point scale (0–4). Indices of possum-use of these species were tabulated by recording possum browse in the canopy (Payton et al., 1996), and the abundance of fresh possum faecal pellets beneath the same trees scored on a 4-point scale (0–3).

High phenology scores (3 or 4) were rare, particularly for flowers and fruits, so for analysis, phenology descriptions were reduced to two classes: 'absent or rare' (scores 0 and 1), and 'common' (scores 2, 3, or 4). The percentage of trees with 'common' phenology scores was calculated for new leaves, buds, and flowers, and for green, ripe, and fallen fruit of all species monitored combined. Only data from the first 20–50 plots were used, as once 20 specimens of a species were scored, the phenology of this species was ignored on subsequent plots. These percentage data were graphed, and the data tested for seasonal differences using χ^2 (8×2) contingency tables.

The percentage of trees with possum browse was calculated for common species (at least 15 specimens on and off plots) scored in each of the four seasons (both years combined). The data were graphed, and tested for seasonal differences using χ^2 (4×2) contingency tables for those species that were frequently browsed (at least 20% browsed in at least one season). There was insufficient data to test for seasonal differences for less common or less frequently browsed species.

4.2.7 Animal Ethics approval

The use of captive possums for assessing bait palatability, and the use of leg-hold traps and humane killing for sampling possums, were approved by the Landcare Research Animal Ethics Committee.

5. Results

5.1 BAIT QUALITY

After dyeing with rhodamine-B solution, drying and storage of the pellets resulted in palatability changes typical of No. 7 pellet baits (see Henderson & Frampton 1999). Trials with captive possums (see 4.2.2) indicated that there was a short-lived increase in palatability after pellets were dampened during dyeing, but after drying and over the next 60 days, there was a slow but consistent reduction in palatability (Table 1). However, even after these 60 days, palatability was still above the 40% threshold suggested as the minimum recommended specification for effective possum baits (Henderson & Frampton 1999). Baits used in the trials can therefore be considered to have been representative of baits routinely used in possum control operations.

TABLE 1. PALATABILITY OF NO. 7 PELLETS TESTED AGAINST FRESH RS5 PELLETS AS A CONTROL. ALL NO. 7 PELLETS WERE APPROXIMATELY 1 MONTH OLD BEFORE DYEING.

TRIAL NO.	TREATMENTS OF NO. 7 PELLETS	PALATABILITY (%)
1	Undyed	43.2
2	Dyed and still damp	72.6
3	Dyed, dried and stored for 1 day	51.7
4	Dyed, dried and stored for 4 days	50
5	Dyed, dried and stored for 7 days	43.2
6	Dyed, dried and stored for 30 days	42.3
7	Dyed, dried and stored for 60 days	41.2

5.2 BAIT ACCEPTANCE AND POSSUM CONDITION

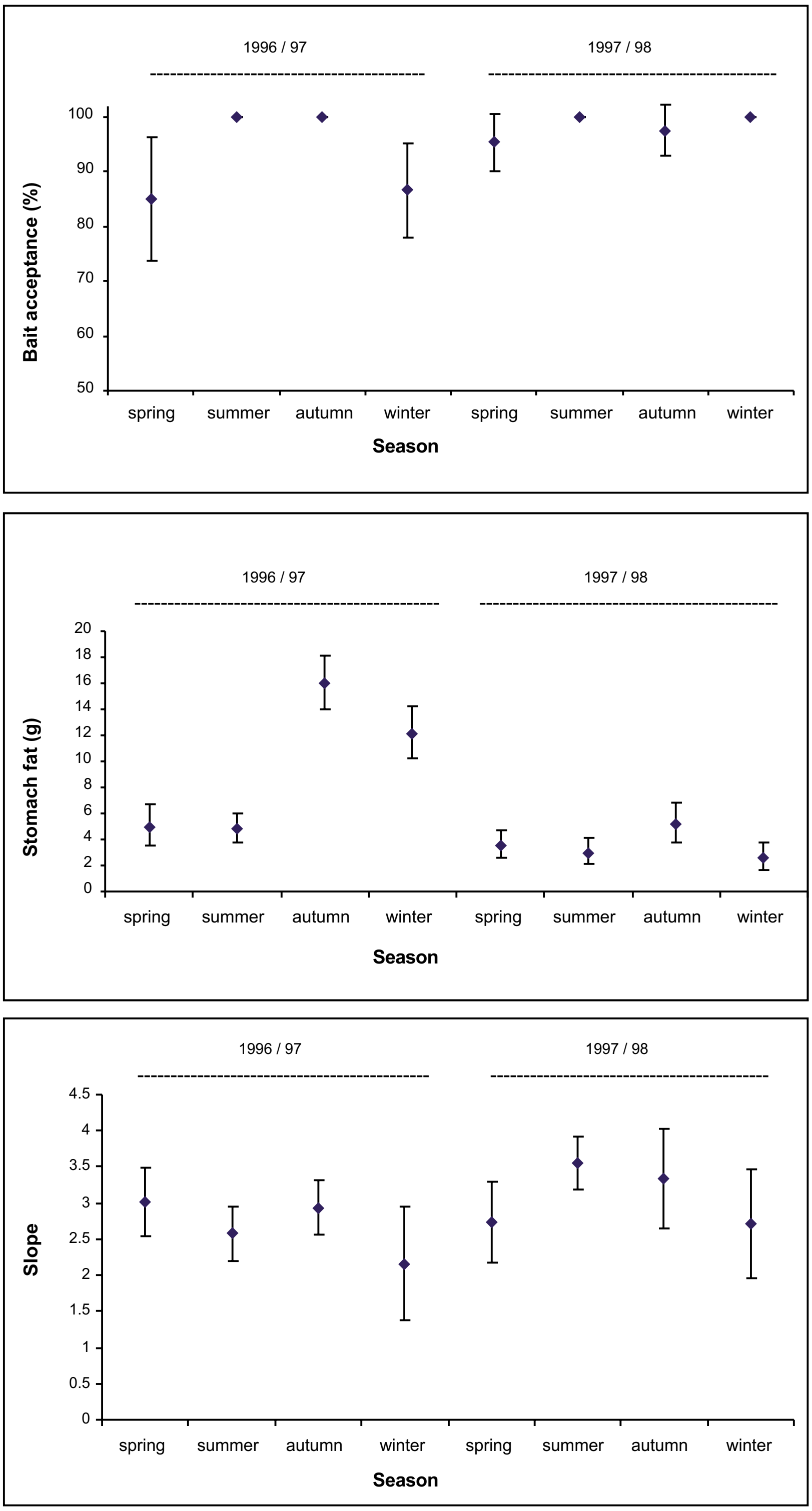
High levels (i.e. 85–100 %) of bait acceptance were recorded for trapped possums in all of the 24 trials conducted, with acceptance less than 90% in only three trials. Differences in bait acceptance between seasons varied with area ($\chi^2_3 = 22.91$, $P < 0.001$). This is not surprising as the areas were selected to provide a broad representative range of the different forest types in which aerial control of possums is undertaken by DOC. The three areas were therefore treated separately for further analysis. Results are summarised in Figures 1–3. Significant differences are indicated where confidence intervals do not overlap other central values.

5.2.1 Herekino Forest

Bait acceptance was consistently very high in Herekino Forest. At least 90% of possums were clearly marked on all sampling occasions and 100% on half the occasions (Figure 1a). There was no evidence of a significant difference in bait acceptance between seasons ($\chi^2_3 = 7.43$, $P = 0.060$) or between years ($\chi^2_1 = 0.90$, $P = 0.343$, interaction effect: $\chi^2_3 = 1.42$, $P = 0.699$).

Possum condition as indicated by mesenteric fat showed an annual cyclical pattern (Figure 1b) varying significantly between seasons ($F_{3,327} = 28.89$, $P < 0.001$) and between years ($F_{1,327} = 24.53$, $P < 0.001$). The annual pattern

Figure 1. (a) Percentages of possums accepting bait, (b) mean weights of possums' mesenteric stomach fat, and (c) slopes of the regression of possum body length and weight at Herekino Forest in each season over 2 successive years. Vertical bars are 95% confidence intervals.



was similar between the two years ($F_{3,327}$ = 2.35, P = 0.072), with possums carrying significantly more fat in autumn of the second year. Lowest fat weights were recorded in spring of both years and the first summer. Comparisons of the slopes of body weight/length (Figure 1c) showed that this index of condition remained constant throughout the year. Although significant overall variation was detected between the length/weight regression slopes ($F_{7,355}$ = 10.50 P < 0.001), subsequent comparison of slopes found no difference between any individual pairs of slopes (P > 0.05).

In examining the relationship between bait acceptance and condition, there was a significant positive correlation with the length/weight slope ($F_{1,6}$ = 117.9, P < 0.001) which explained 95.2% of the variation in the proportion of possums that ate bait. However, there was no relationship between acceptance and mesenteric fat weight ($F_{1,6}$ = 1.00, P = 0.356).

5.2.2 Moki Forest

In Moki Forest, 95–100% of all possums ate baits except in spring and winter of the first year (Figure 2a). Overall, there were significant differences between seasons (χ^2_3 = 24.49, P < 0.001), due to the significantly lower acceptance in spring and winter of the first year compared with all other sampling occasions. Acceptance overall was higher in the second year (χ^2_1 = 4.66, P = 0.031). The pattern in seasonal variation was, however, consistent between years (χ^2_3 = 7.17, P = 0.067).

The mean weight of mesenteric fat varied jointly with both season and year ($F_{3,444}$ = 13.61, P < 0.001) (Figure 2b). Possums had significantly more stomach fat only in autumn and winter in the first year. Analysis of covariance showed that the length/weight slopes varied between the eight sampling occasions ($F_{7,355}$ = 16.95, P < 0.001), though with no similarity in pattern between years (Figure 2c).

There was no correlation between bait acceptance and either mesenteric fat ($F_{1,6}$ = 0.183, P = 0.684) or length/weight slope ($F_{1,6}$ = 0.756, P = 0.418).

5.2.3 Cobb Valley

Bait acceptance in the Cobb Valley was consistently high, exceeding 93% in all but the second spring trial when 87.5% of possums ate bait (Figure 3a). There was no significant difference in bait acceptance between years (χ^2_1 = 0.07, P = 0.791) or seasons (χ^2_3 = 5.40, P = 0.145), and no interaction effect (χ^2_3 = 3.02, P = 0.389).

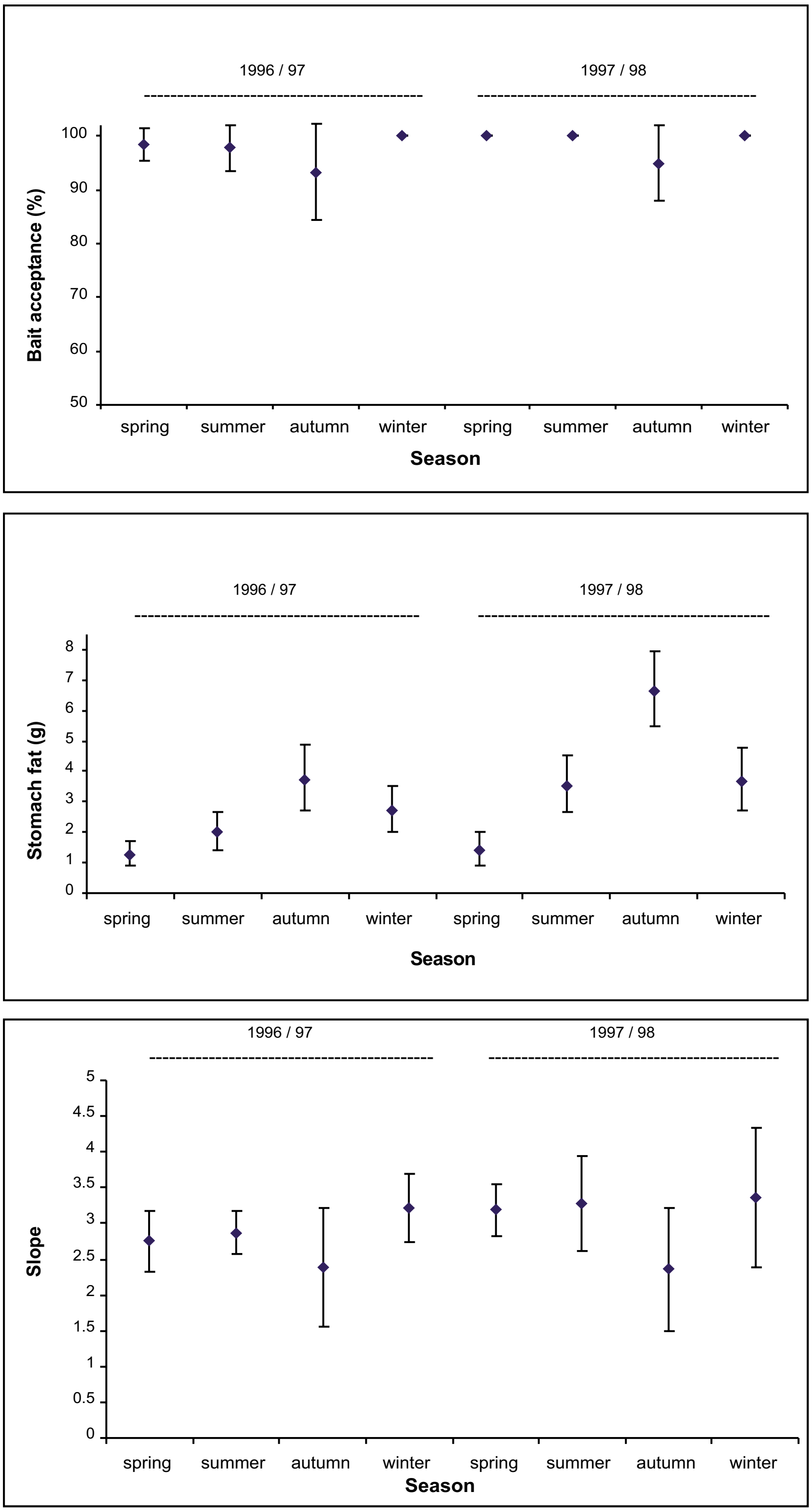
Mesenteric fat weights varied throughout the sampling period, differing significantly in seasonal pattern between years ($F_{3,359}$ = 7.52, P < 0.001) (Figure 3b). Generally mean weights were similar between winter, spring and summer, and then increased in autumn. This increase was significant only in the second year. Analysis of covariance showed that length/weight slopes varied between the eight sampling occasions ($F_{7,355}$ = 8.335, P < 0.001) (Figure 3c), though with no similarity in pattern between years.

There was a significant positive correlation between bait acceptance and the mean weight of mesenteric fat recorded in each trial ($F_{1,6}$ = 26.74, P = 0.002) that explained 81.7% of the variation in the proportion of animals that ate bait. There was no relationship, however, between bait acceptance and the length/weight slopes ($F_{1,6}$ = 0.388, P = 0.556).

5.3 PHENOLOGY OF FAVOURED PLANTS

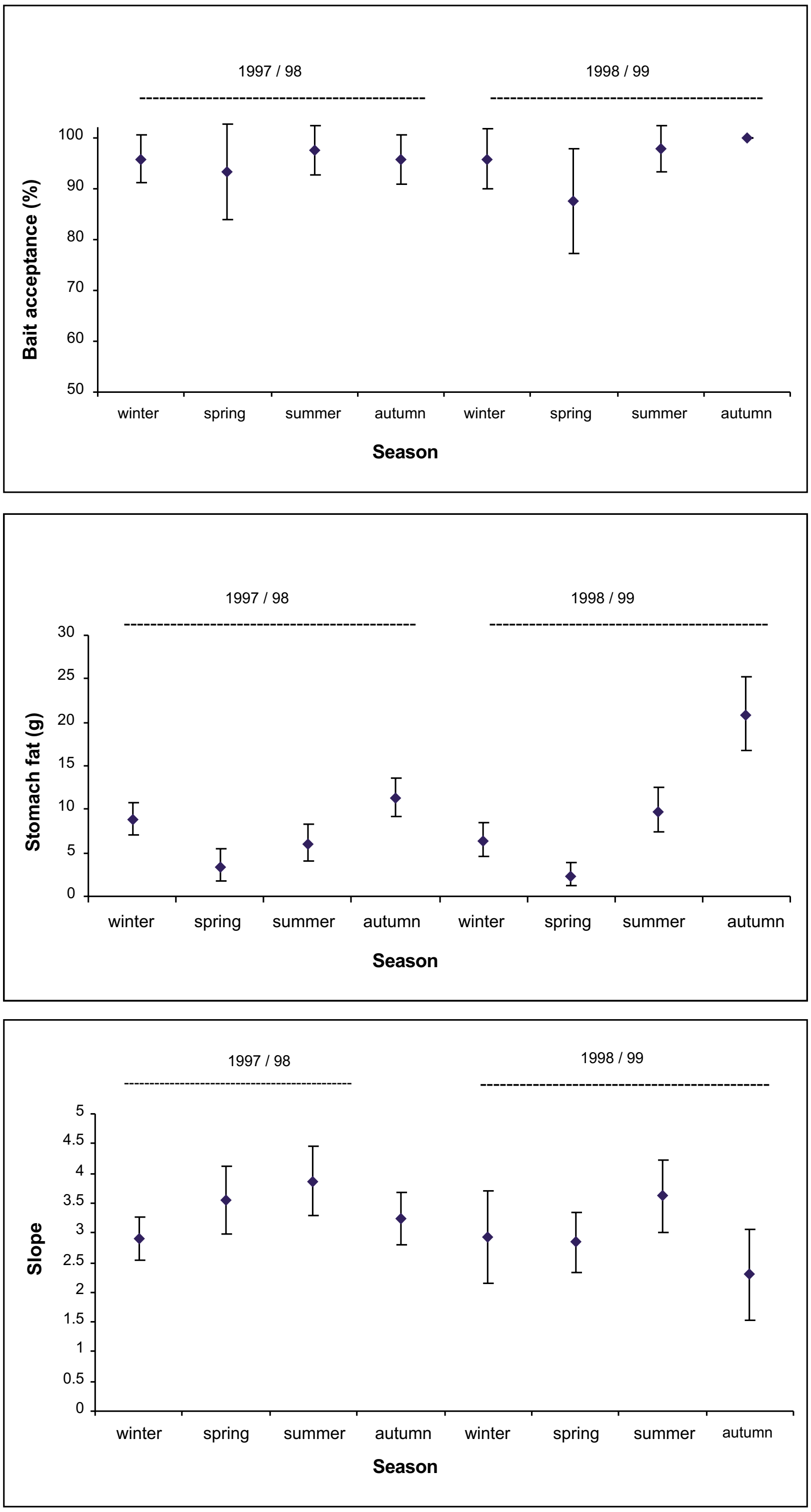
The species monitored in each area together with their scientific names are listed in Appendix 1. They included forest emergents such as taraire, rewa rewa, rata, and tawa; canopy species such as towai, kamahi and hinau;

Figure 2. (a) Percentages of possums accepting bait, (b) mean weights of possums' mesenteric stomach fat, and (c) slopes of the regression of possum body length and weight at Moki Forest in each season over 2 successive years. Vertical bars are 95% confidence intervals.



subcanopy species; lianes (bushlawyer), and forest herbs. As there was a consistently high level of bait acceptance in the three study areas, we were unable (and saw no reason) to test the influence of variable availability of particular species on bait acceptance. We have therefore presented a broad description of the changing phenology of these species combined to demonstrate differences between sites.

Figure 3. (a) Percentages of possums accepting bait, (b) mean weights of possums' mesenteric stomach fat, and (c) slopes of the regression of possum body length and weight at Cobb Valley in each season over 2 successive years. Vertical bars are 95% confidence intervals.



The range, frequency, and identity of trees and shrubs palatable to possums varied sharply between our field study sites. Herekino Forest was botanically the most diverse and because of its recent colonisation by possums, species palatable to them were abundant. Moki Forest best represented a 'typical' hardwood/softwood forest modified by the presence of possums over a prolonged period. The Cobb Valley Forest typified the low diversity normally encountered in beech forests but did contain some rare species that are vulnerable to possum browsing (e.g. *Pittosporum patulum*).

5.3.1 Herekino Forest

New leaves were abundant in spring and summer of both years, being recorded as common on 49% to 87% of measured plants, but were fewer in autumn and winter ($\chi^2_7 = 317$, $P < 0.001$; Figure 4a). Compared with new leaves the overall abundance of flower buds was relatively low. However, the amount of flower buds also varied significantly between seasons ($\chi^2_7 = 39$, $P < 0.001$), being least abundant in summer and most abundant in winter in the first year. Very few flowers or fruits were recorded at Herekino throughout the study, resulting in insufficient data to perform contingency table tests (Figures 4a and 4b).

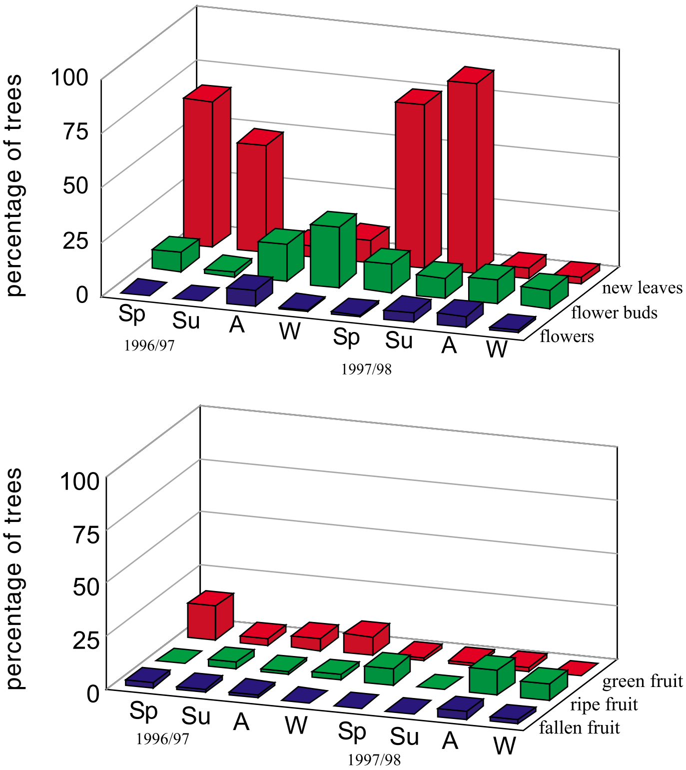


Figure 4. The mean phenology index for (a) new leaves, flower buds, and flowers, and (b) fruit of plant species favoured by possums at Herekino Forest in each season over 2 successive years.

5.3.2 Moki Forest

At Moki Forest new leaves were the most abundant of the six phenology variables assessed, and showed very marked seasonal patterns. They were most abundant in summer and also abundant in spring in both years, but were uncommon in autumn and winter ($\chi^2_7 = 208$, $P < 0.001$, Figure 5a). Compared with new leaves, the overall abundance of all the other phenology variables was low. Flowers, and ripe and fallen fruit were rarely recorded throughout the study, resulting in there being insufficient data to perform contingency table tests for these variables. Abundance of flower buds varied significantly between surveys ($\chi^2_7 = 40$, $P < 0.001$), with a peak in the spring of the second year (Figure 5a). Green fruit abundance also varied seasonally ($\chi^2_7 = 87$, $P < 0.001$), being recorded as common on 27% to 50% of plants in summer of both years, but on only 10% or less during all other seasons (Figure 5b).

5.3.3 Cobb Valley

As for both Herekino and Moki forests, new leaves were most abundant in summer, when they were common on over 50% of measured plants in both years. In contrast, new leaves were absent or rare on all trees in autumn of the

Figure 5. The mean phenology index for (a) new leaves, flower buds, and flowers, and (b) fruit of plant species favoured by possums at Moki Forest in each season over 2 successive years.

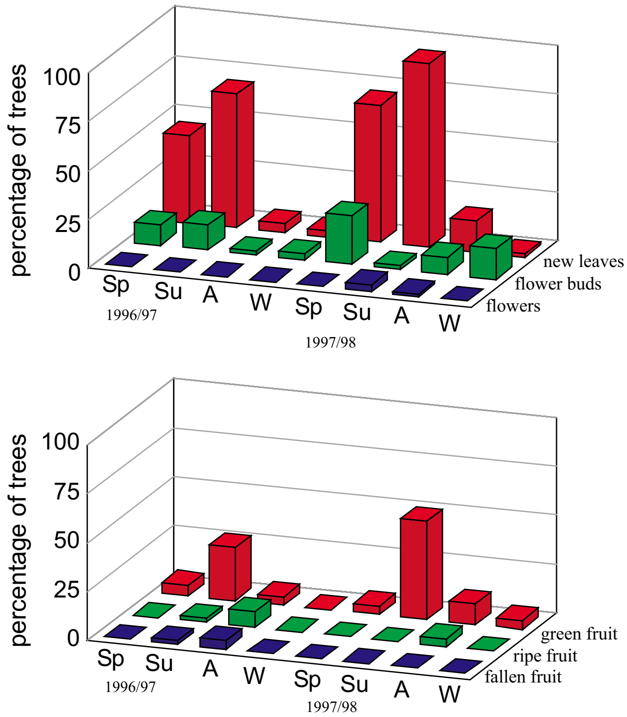
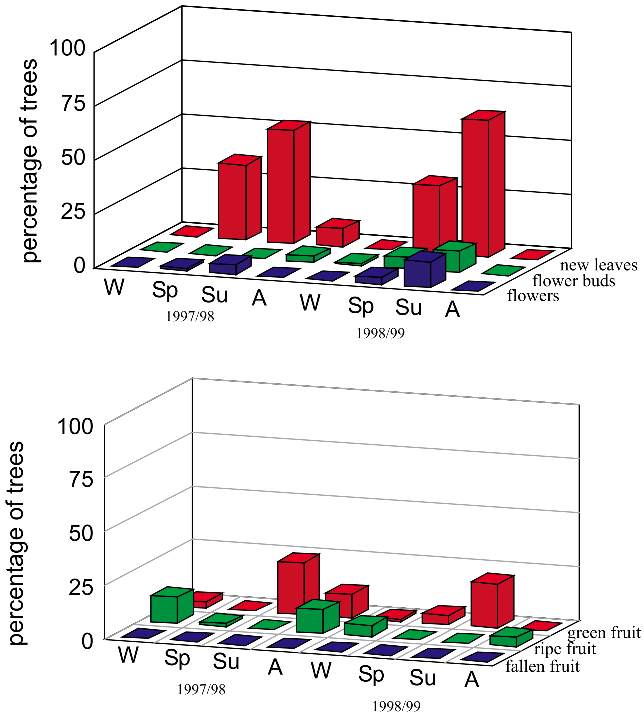


Figure 6. The mean phenology index for (a) new leaves, flower buds, and flowers, and (b) fruit of plant species favoured by possums in forest, Cobb Valley, in each season over 2 successive years.



second year and winter in both years (Figure 6a). These seasonal differences were significant (χ^2_7 = 212, $P < 0.001$). Very few flower buds or flowers were recorded in any season, with there being insufficient data to perform contingency table tests. Green fruit (χ^2_7 = 68, $P < 0.001$) and ripe fruit (χ^2_7 = 30, $P < 0.001$) abundance varied significantly between seasons (Figure 6b), with most green fruit recorded in summer and most ripe fruit recorded in autumn in both years. No fallen fruit was recorded in any season.

5.4 POSSUM 'SIGN' (BROWSE, FAECAL PELLETS)

5.4.1 Herekino Forest

The level of possum browse observed varied seasonally on two of the three frequently browsed common species monitored in Herekino Forest. Browse on kohekohe was highest in summer ($\chi^2_3 = 10.7$, $P = 0.13$), while browse on towai was highest in summer and winter ($\chi^2_3 = 47$, $P < 0.001$). Browse on five-finger did not vary seasonally ($\chi^2_3 = 4.2$, $P = 0.24$), with high levels recorded in all seasons.

5.4.2 Moki Forest

Three common species were frequently browsed by possums present at Moki Forest: kamahi, mahoe, and tawa. Levels of browse on all three varied seasonally ($\chi^2_3 = 18.34$, $P < 0.002$), with high levels of browse recorded in spring and summer on tawa and in spring, summer, and autumn on both kamahi and mahoe.

5.4.3 Cobb Valley

Only two possum-preferred plant species, bush lawyer and lancewood, were common within the study blocks in all four seasons in the Cobb Valley. Possum browse on bush lawyer varied seasonally from a high of 47% of plants in winter to a low of 4% of plants in autumn ($\chi^2_3 = 15.7$, $P = 0.001$). Although the percentage of lancewood trees browsed by possums varied from 52% in winter to 0% in summer and autumn, there was insufficient data to perform a contingency table test.

Few recognisable possum faecal pellets were recorded on our plots in any season at Cobb Valley, and during some surveys in both Herekino and Moki forests. This paucity of faecal pellets was due to low possum densities at Cobb Valley, and at Herekino and Moki forests heavy rain immediately prior to some surveys apparently destroyed or washed away most faecal pellets.

5.5 STOMACH COLLECTIONS

Stomachs were collected from all possums trapped, and they have been stored frozen for possible later analysis.

6. Conclusions

6.1 SEASONAL BAIT ACCEPTANCE

The most important finding from this 2-year study is that, in three different forest types, possum populations showed very high levels of bait acceptance in all seasons. We would therefore expect that had toxic baits been used (instead of non-toxic baits), equally high acceptance of bait would have been achieved, assuming that baits were adequately masked to conceal the 1080 (Morgan 1990). Nevertheless, we caution against drawing a generalised conclusion from these results to support aerial control anywhere in DOC-managed forests at any time.

6.1.1 Validity and generality of results

Bait acceptance trials are based on the fact that possums remain marked for about 7 days after consuming at least one rhodamine-dyed bait (Morgan 1981). However, this dye technique does not permit estimation of the amount of bait eaten by each possum. It is possible that some marked animals may have eaten less than the equivalent of a lethal quantity of bait (i.e. one 6-g bait). Inspection of stomach contents showed that almost all possums captured had extensive dye marking or fluorescence in the stomach. Only in 40 of 1160 possums inspected (i.e. 3.4%) were we unsure if marking represented consumption of one 6-g bait (i.e. representing a lethal amount for most possums). These possums were classified as non-acceptors so as to not over-estimate acceptance. Despite this caution, some possums may still have been wrongly interpreted as having eaten at least one bait, leading to some over-estimation of acceptance. Equally, we may have falsely rejected a few possums and marginally underestimated acceptance. On balance, we believe the two possibilities tend to negate each other, thus reducing the overall error in estimated acceptance.

That such errors in interpretation are likely to have been minor is supported by the finding that little variation occurred in bait acceptance in this study; in other studies using the rhodamine technique, greater differences in acceptance were found (e.g. Morgan 1982; Coleman et al. 1999). Thus the technique is clearly capable of revealing lower levels of bait acceptance, where they exist. We therefore conclude that in the present study, high proportions of possums ate bait in all seasons at all three sites. This result therefore supports the year-round use of aerial baiting in a variety of forest types.

Since the study began, an additional reason for conducting aerial control outside of the 'traditional' winter season has become apparent. While possums are usually the main target of such operations, high by-kills of rodents and mustelids can normally be expected (and are desired). Rodents are killed by primary poisoning (i.e. by eating the bait; Innes et al. 1995), mustelids by secondary poisoning (i.e. when scavenging contaminated carcases; Alterio 1996; Murphy et al. 1999). Therefore, where protection of native birds is intended by aerial control of possums, and also rodents and mustelids, maximum benefit can usually be obtained if control is carried out in spring before chicks hatch. This strategy provides relief from predation during the critical first two months of many birds' lives when they are confined to the nest before fledging. Our results suggest that managers can confidently programme baiting operations in this season.

While our data indicate that bait acceptance is likely to be high in forest habitats in any season, we caution against the expectation that aerial control will succeed in all forest habitats at all times. In a recent AHB-commissioned study, we similarly assessed bait acceptance among possums inhabiting a typical Westland farm/forest interface. We conducted nine trials from late spring to early autumn over two consecutive years and found again that, while there was no strong evidence that baiting outside of winter would lead to operational failures, bait acceptance was consistently lower (mean 84%; range 73.1–91.4%) than in the present study (Coleman et al. 1999). The availability of highly favoured pasture species during the warmer months was considered to be a likely cause of the lower level of bait acceptance among possums living on the forest edge. This result reinforces the conclusion drawn from an earlier study (Morgan 1982) in which five acceptance trials were conducted in a range of forest habitats. In only one trial, conducted in summer in an exotic forest, was bait acceptance significantly poorer than in all others. Possums were in very good condition and abundant highly favoured exotic grasses and herbs were noted in the plantation. In the present study, possums in the Cobb Valley were sampled from the forested slopes adjoining tussock grassland in the valley floor. That no seasonal effects on acceptance were noted, however, would suggest that possums were less inclined to feed on native grasses and herbs of mixed origin in the Cobb Valley.

6.1.2 Possible effects of temperature on operational success

While our study used acceptance of non-toxic bait as a measure of likely poisoning success, empirical data gathered by Henderson et al. (1999) for both DOC and regional council control operations showed that effectiveness of toxic bait varied seasonally. Combining aerial and ground-based operations, kills were ranked winter (86.1%, n = 28) > summer (82.3%, n = 32) > spring (81.5%, n = 12) > autumn (74.3%, n = 14). As these operations were not conducted as replicated trials, some of the seasonal variation in the data may be attributable to other factors such as the type of bait used, toxic loadings, baiting coverage, climatic variables, or habitat differences. There is, however, new evidence that ambient temperature may have influenced poisoning success in DOC operations from 1994 to 1999 (C. Veltman, pers. comm.) Operational variables like 1080 concentration, sowing rate, size of treated area, month and night-time temperature were employed in a model to predict possum mortality, and temperature was found to contribute significantly to operational outcome (Veltman & Pinder, in press). Possum mortality was lower after operations conducted at warm temperatures (Veltman & Pinder, in press). As explained by Veltman & Pinder (in press), their finding is consistent with laboratory studies that showed a higher LD_{50} value for 1080 in possums at warmer temperatures.

6.2 THE INFLUENCE OF CONDITION AND FOOD AVAILABILITY ON OPERATIONAL SUCCESS

In the present study we measured what we intuitively believe, outside of adverse weather, to be the most important seasonal variables likely to affect bait acceptance, i.e. possum condition and food availability. Given the lack of variation in our bait acceptance data, we were unable to describe the influence of these parameters on likely operational success. However, the study has revealed some useful information on the applicability of the methods we used.

6.2.1 Condition

Our analysis of the relationship between two condition indices—stomach mesenteric fat and length/weight slopes—suggests (like our earlier study (Coleman et al. 1999)) that neither are sensitive enough to predict small changes in possum feeding behaviour. Significant variation in both indices was found in some trials, and yet significant relationships with bait acceptance were found only for length/weight slopes at Herekino Forest and mesenteric fat weights in the Cobb Valley. The indices therefore appear to be poor predictors of bait acceptance overall, as significant correlations were found in only two of the six analyses conducted. In part, this may reflect not only the lack of variation in bait acceptance data, but also the relatively good condition of possums in our study. For example, the length/weight slopes recorded in five populations by Morgan (1982) varied between 1.73 and 3.09, while the range in the present study was 2.2 to 3.7. Thus, in the present study, possum condition at each of the three sites remained high and relatively stable, compounding the difficulty of revealing a relationship with bait acceptance data of low variability. Where possum condition is more variable, predictive localised relationships with kill are possible, as demonstrated by Bamford & Martin (1971) who favoured the use of length/weight relationships for this purpose. Predictions of bait acceptance using these indices are, however, likely to be partly compounded by the depositing of fat that occurs before breeding to prepare females for lactation and males for periods of food storage when engaged in mating behaviour. If these indices are to be used comparatively as predictors of bait acceptance or kill, comparisons between seasons in a particular area should be made, recognising the possible compounding effect of breeding-related changes in fat. Nevertheless, the mesenteric fat index is likely to be more sensitive to recent seasonal environmental effects (mainly food abundance and climate) than length/weight slopes. The latter index is more likely to represent the combined effects of animals' genetic origin and long-term environmental influences.

6.2.2 Food availability

Phenology data demonstrated that production of new leaves follows very strong and predictable patterns at all sites (strong peaks in spring and summer). Therefore, we have good evidence that availability of new leaves of woody vegetation has little impact on bait acceptance by possums. However, we cannot be as confident regarding the potential effect of other seasonal foods, as relatively little, especially ripe fruit, was produced during the study. Many New Zealand forest species exhibit mast fruiting, where large fruit crops are produced at irregular intervals (often every few years), e.g. hinau (*Elaeocarpus dentatus*) (Cowan & Waddington 1990) and beech (*Nothofagus*) species (Wardle 1984). No mast events occurred in any species measured during this study. Masting of preferred fruit can cause dramatic changes in possum diet. For example, bush lawyer (*Rubus cissoides*) (foliage and fruit) comprised just 2% of possum diet at Waihaha, near Lake Taupo, in 1991–92, but during a heavy mast in March 1996, bush lawyer fruit comprised 80% of total diet, and more than 95% in 47% of stomachs (P. Sweetapple, unpublished data). If a mast event had occurred during our study, the bait acceptance results may have differed. However, mast events may be rare where possum densities are moderate or high, as possum browsing on foliage, flowers, and green fruit of fruiting species may suppress them. For example, the heavy fruiting of bush lawyer at Waihaha occurred immediately after possum control, and hinau fruiting was shown to be suppressed by possum browse in the Orongorongo Valley, Wellington (Cowan & Waddington 1990).

7. Recommendations

7.1 Management recommendations

- Managers should schedule aerial control seasonally to maximise the protection of conservation values.
- Bait acceptance trials should be carried out immediately prior to 20% of planned aerial control operations over the next five years to check that high levels of acceptance can be expected. Such trial data should be collected from a variety of regions in different seasons to extend the database we have initiated. To render operational data comparable between seasons and regions, it will be necessary to restrict comparisons to those operations that were conducted in a similar manner.
- It is particularly important that bait acceptance trials are conducted if fruit-masting of possum-preferred species is observed before scheduled control operations are conducted, as the present study was unable to test the influence of an abundance of highly favoured food on likely control success.

2.2 Research recommendation

- The contents of stomachs collected from Herekino Forest in autumn (both years), from Moki Forest in spring and winter (year 1 only), and from Cobb Valley in spring (both years) should be analysed and compared with those collected during seasons when bait acceptance was highest in each region. This may reveal possum foods that could be used as indicators of reduced bait acceptance.

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Appendix 1

POSSUM-PREFERRED PLANT SPECIES MONITORED IN EACH OF THE THREE STUDY AREAS

Herekino Forest

Taraire (*Beilschmedia tarairi*)
Kohekohe (*Dysoxylum spectabile*)
Rewarewa (*Knightia excelsa*)
Mahoe (*Melicytus ramiflorus*)
N. Rata (*Metrosideros robusta*)
Totara (*Podocarpus totara*)
Five-finger (*Pseudopanax arboreus*)
Lancewood (*Pseudopanax crassifolius*)
Nikau (*Rhopalostylis sapida*)
Towai (*Weinmannia silvicola*)
Lacebark (*Hoheria populnea*)
Toro (*Myrsine salicina*)

Cobb Valley

Lancewood (*Pseudopanax crassifolius*)
Tree fuchsia (*Fuchsia excorticata*)
Wineberry (*Aristotelia serrata*)
Marbleleaf (*Carpodetus serratus*)
Pokaka (*Elaeocarpus hooherianus*)
Bush lawyer (*Rubus cissoides*)
Small-leaved coprosmas (*Coprosma* spp.)
Herbs (herbaceous spp. on forest floor)
S. rata (*Metrosideros umbellata*)
Pseudopanax simplex
Pseudopanax linearis
Melicytus lanceolatus

Moki Forest

Tawa (*Beilschmiedia tawa*)
Hinau (*Elaeocarpus dentatus*)
Rewarewa (*Knightia excelsa*)
Mahoe (*Melicytus ramiflorus*)
N. rata (*Metrosideros robusta*)
Totara (*Podocarpus totara*)
Lancewood (*Pseudopanax crassifolius*)
Supplejack (*Ripogonum scandens*)
Kamahi (*Weinmannia racemosa*)
Pigeonwood (*Hedycarya arborea*)
Toro (*Myrsine salicina*)