

Changes in marsupial herbivore densities in relation to a forestry 1080-poisoning operation

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Summary

Tasmanian forestry companies commonly manage browsing damage to seedlings on plantations through the lethal control of native mammalian herbivores, using '1080' (sodium monofluoroacetate). Although this practice is controversial, there is a lack of published quantitative data on its success in reducing animal numbers. We present the first published study quantifying the effects of a poisoning operation on the densities of mammalian herbivores both on a poisoned plantation and in the surrounding environment.

Line transect surveys were used to monitor species densities before and after poisoning. The species targeted by the poisoning operation were the red-bellied pademelon (*Thylogale billardierii*), the red-necked wallaby (*Macropus rufogriseus* subspecies *M. r. rufogriseus*), the common brushtail possum (*Trichosurus vulpecula*) and European rabbit (*Oryctolagus cuniculus*). One non-target species, the common wombat (*Vombatus ursinus*), was also monitored.

Poisoning significantly reduced pademelon density on the poisoned plantation (decline of 98%). A significant decrease in red-necked wallaby density was also detected at this time (decline of 60%) but a general declining trend was present within the data, so we interpret this result with caution. No significant effects were detected for possums, rabbits or wombats. The high kill-rate for pademelons may reflect the dominance of this species over others at bait stations and/or greater sensitivity to 1080. Six weeks after poisoning, the density of pademelons on the treated plantation had increased but was still significantly lower than before poisoning. At the same time, red-necked wallaby density on the treated plantation had increased, with animals moving onto the plantation from surrounding habitats. The decline of pademelons was hypothesized to enable an influx of red-necked wallabies onto the poisoned site, through reduced inter-specific dominance behaviour.

Keywords: poisoning of animal pests, pesticides, population control, forest management, population ecology, wild animals, *Thylogale billardierii*, *Macropus rufogriseus*, *Trichosurus vulpecular*, *Oryctolagus cuniculus*, *Vombatus ursinus*, Tasmania, Australia

Introduction

Vertebrate browsing damage has long been recognized as reducing productivity in eucalypt plantations (Mollison 1960; Gilbert 1961; Cremer 1969; Montague 1996). Browsing damage can lower plantation productivity by reducing seedling growth

and survival and by promoting the development of multiple leaders (Wilkinson and Neilson 1995; Montague 1996; Bulinski and McArthur 1999). Within Tasmania, management of browsing damage commonly involves reducing local herbivore populations immediately before seedlings are planted, and sometimes after planting while they are still small enough to be vulnerable. These control measures involve poisoning with '1080' or shooting animals, and are based on the assumption that fewer animals will result in less damage. As animals targeted by the poisoning or shooting operations include native species, and operations are conducted without population monitoring, there is public concern over the use of these practices. Consequently, quantitative data on the effects of these methods are important, but such data are rare and are contained mainly within unpublished reports.

The only two previous studies in the scientific literature investigating the effects of 1080-poisoning programs on herbivore populations in commercial forestry in Australia have used indices of relative abundance to monitor differences in herbivore numbers between poisoned and unpoisoned plantations. Bulinski (2000) used scat surveys to compare a range of poisoned and unpoisoned plantations, and Marsh (1998) used strip transect surveys collected along tracks to compare one poisoned and one unpoisoned plantation. While these methods provide some information on patterns of abundance within species, they do not enable accurate estimates of population sizes, and comparisons between species are not valid (Southwell 1989). In addition, both studies only monitored herbivore numbers on the targeted plantations; species' abundance in the surrounding environment was not investigated, and Bulinski (2000) did not collect pre-poisoning data. Hence, the present study aimed to (1) obtain estimates of absolute density before and after poisoning on a plantation, which could then be compared between species, and (2) determine changes in densities both on the poisoned plantation and in the surrounding environment.

Five species of herbivore were monitored: the four target species (the red-bellied pademelon, the red-necked wallaby, the common brushtail possum and the introduced European rabbit) and a non-target species, the common wombat. Wombats are not known to browse seedlings but they are abundant within the herbivore community in forestry environments and have been killed incidentally during previous 1080 operations (McIlroy 1982; Triggs 1996).

Methods

Study site

The 428 ha study area is in North Forest Product's Surrey Hills Tree-Farm, north-west Tasmania (41°28'S, 145°48'E). Four habitats dominated this site: (1) a young *Eucalyptus nitens* plantation with relatively high weed cover, 17.8 ha; (2) older plantations of *E. nitens* (5-7 years of age, about 5 m tall), 274.7 ha; (3) grassland, 38.4 ha; and (4) native forest (rainforest and wet eucalypt forest), 89.1 ha (Fig. 1). The young plantation was planted with *E. nitens* seedlings (about 20 cm high) in November 1997, three months before this study began. It had not been treated with 1080 poison or herbicide before planting, but vegetation within a 0.5 m radius of individual seedlings was treated with Roundup® (glyphosate) herbicide about one week after the *E. nitens* seedlings were planted.

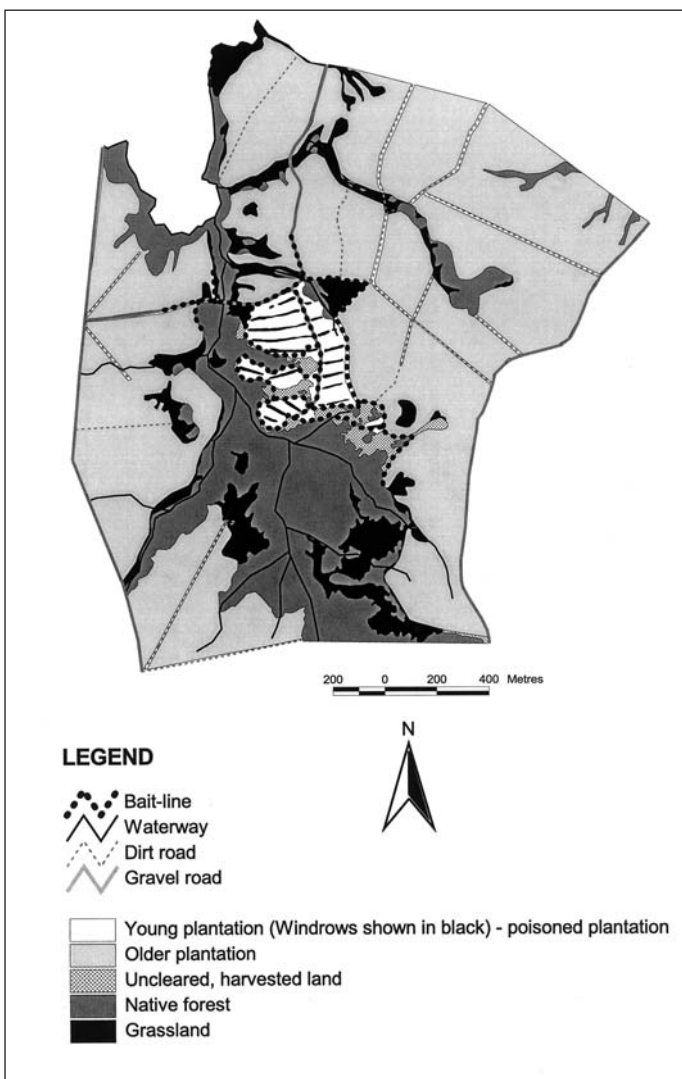


Figure 1. Map of the study site, showing the four dominant habitats and the location of the bait-line

1080 poisoning

Three weeks before 1080 poisoning, bait stations were established at 10 m intervals along the young plantation's centre and boundary, and along nearby firebreaks. Fresh chopped carrot was placed at bait stations on five occasions (referred to as 'free-feeds'), 3-6 days apart, over a period of 17 days in April 1998. Fifty kilograms of bait was distributed on and around the

young plantation during each of the first two free-feeds; 60 kg was used in each of the last three free-feeds. Sixty kilograms of poisoned bait (chopped carrot mixed with 0.014% 1080 in liquid solution and blue dye) was distributed at the bait stations (referred to as the 'bait-line' in Fig. 1) three days after the final free-feed. Bait stations were checked for remaining poisoned bait 24 hours after distribution.

Density estimates

Nocturnal line transect sampling was used to monitor changes in species' density over time. Data were collected during four sampling periods: (1) before free-feeding, (2) during free-feeding, (3) immediately post-poisoning, and (4) six weeks post-poisoning. Each sampling period consisted of six nights spotlighting, 2-3 nights apart, over 17 days. Sampling methods are described in detail in le Mar *et al.* (2001). In brief, 84 permanent transect lines were located within four habitats: 24 on the young plantation, 30 in older plantations, 10 in grassland and 20 in native forest.

Only one young plantation was available within this study area, consequently, several steps were taken to maximise independence of data from transect lines and hence avoid problems with pseudoreplication in this habitat. Firstly, the site was surveyed using many short transect lines rather than a few long transect lines. Second, transect lines were distributed at random throughout the habitat but with a minimal distance of 50 m between transect lines.

Transect lines were surveyed at night by a two-person team walking in single file at 1 km h⁻¹, using a 100 W spotlight. Both ground and canopy were searched for animals. Perpendicular distance to sighted animals was recorded using established distance categories marked by wooden stakes and reflectors. Data collection began one hour after sunset and was completed within six hours.

Data analysis

Probabilities of detection were calculated from distance data using line transect methodology (Buckland *et al.* 1993) and the computer program DISTANCE (Laake *et al.* 1998). To accurately estimate a sightability parameter ($\hat{f}(0)$) for a given species in a particular habitat type, 60-80 sightings are recommended (Buckland *et al.* 1993). This sample size was not achieved during individual sampling periods for any species in any habitat. Consequently, $\hat{f}(0)$ was calculated from data collected during the present study, pooled with data from a longer 11-month study immediately preceding this one, at this site. Data were pooled over time for each species in each habitat type, on the assumption that variation in sightability across time was likely to be small relative to variation between species and habitats.

The use of markers for distance estimation resulted in grouped data and no further grouping was attempted. Data were truncated to strip half-width distances of 70 m for the young plantation, 50 m for grassland, 35 m for native forest and 21 m for older plantation. Strip half-width (w) is the width from the transect line to the outermost edge of the survey area on one side of the line, and therefore half of the total width sampled for a transect line. Data were analyzed for individuals rather than clusters (Buckland *et al.* 1993), as the five species consist of

essentially solitary animals that may feed in close proximity but do not behave as a unit (Calaby 1991; Johnson and Rose 1991).

Akaike's Information Criterion was used to select the best of four candidate line transect models (key function/adjustment: uniform/cosine, uniform/polynomial, half-normal/hermite and hazard-rate/cosine) (Buckland *et al.* 1993). Where too few sightings were collected to produce valid sighting histograms for line transect analysis, densities were estimated using strip transect analysis (Buckland *et al.* 1993).

Regional density

Population stability in the entire 428 ha study area (region) was examined for each species by graphing regional density (\hat{D}_R) over time. Regional density was calculated for each sampling period, from the estimated densities for the four separate habitats and the proportion of habitat available as:

$$\hat{D}_R = \sum [\hat{D}_i \cdot (A_i / A)] \text{ and } SE_{(\bar{x})} \hat{D}_R = \sqrt{[\sum \{(A_i / A)^2 \cdot \text{var}(\hat{D}_i)\}]}$$

(G. McPherson, *pers. comm.*) where *A* is the area of the entire study site.

Habitat use

Species' mean densities within the four habitats were calculated for each sampling period and examined for patterns within and between habitats over time. Density data could not be normalized by transformation, due to the predominance of zeros (absence) within data sets. Differences in density estimates within habitats between sampling periods of interest were therefore compared with the null hypothesis of no difference, using the non-parametric Wilcoxon Signed Ranks test, with a $\alpha=0.012$ after Bonferroni adjustment for multiple comparisons. Statistical analyses were conducted using the univariate procedure in SAS (SAS Institute Inc. 1990).

Results

Line transect analysis was possible for pademelons in three habitats (young plantation, grassland and older plantations), red-necked wallabies in two habitats (young plantation and grassland) and wombats in one habitat (young plantation). The other species/habitat combinations were analyzed using strip transect analysis. Rabbits were observed in only one habitat (young plantation), while wombats were observed in three habitats (no sightings in native forest).

Regional density results showed that pademelons were the dominant species within this environment, followed by red-necked wallabies, wombats, possums and rabbits (Table 1). The five species' populations were relatively stable throughout the study (Fig. 2).

Before free-feeding the ranking of species' densities on the young plantation was consistent with the regional pattern (Table 1). Estimated densities of pademelons and rabbits on the young plantation did not change significantly during, compared with before, free-feeding (Fig. 3) ($S = 13$, d.f. = 23, $P = 0.528$; $S = 0.00$, d.f. = 23, $P = 1.00$, respectively). Estimated densities of red-necked wallabies and wombats on the young plantation tended to be lower during, compared with before, free-feeding but the differences were not significant (Fig. 3) ($S = 25.4$, d.f. =

23, $P = 0.116$; $S = 5$, d.f. = 23, $P = 0.25$, respectively). No possums were observed on the young plantation throughout this period.

All poisoned bait was taken within 24 hours of distribution.

Table 1. Species' densities (\pm S.E.) at a regional scale and on the young plantation before free-feeding

Species	Regional density (\pm S.E.) (animals ha ⁻¹)	Density (\pm S.E.) on the young plantation (animals ha ⁻¹)
Pademelon	1.12 \pm 1.51	7.73 \pm 1.70
Red-necked wallaby	0.41 \pm 0.79	1.83 \pm 0.40
Wombat	0.05 \pm 0.11	1.07 \pm 0.53
Possum	0.03 \pm 0.09	0.00 \pm 0.00
Rabbit	0.00 \pm 0.00	0.11 \pm 0.07

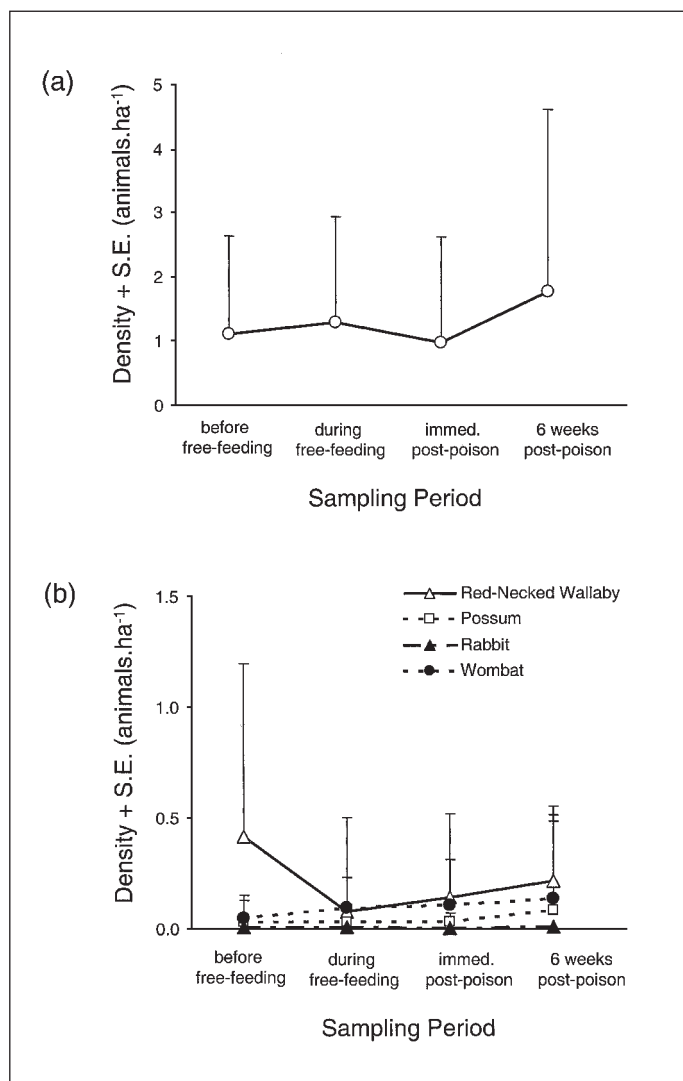


Figure 2. The estimated regional densities (\pm S.E.) of (a) pademelons and (b) red-necked wallabies, possums, rabbits and wombats before free-feeding, during free-feeding, immediately post-poisoning and six weeks post-poisoning

Pademelon density declined significantly between pre-free-feeding and immediately post-poisoning on the young plantation ($S = 65$, d.f. = 23, $P = 0.000$) (Fig. 3a), but not in other habitats ($P \geq 0.34$, in all cases). Red-necked wallaby density on the young plantation also declined significantly during this period ($S = 32$, d.f. = 23, $P = 0.008$) (Fig. 3b), while density in other habitats remained unchanged ($P \geq 0.5$, in all cases).

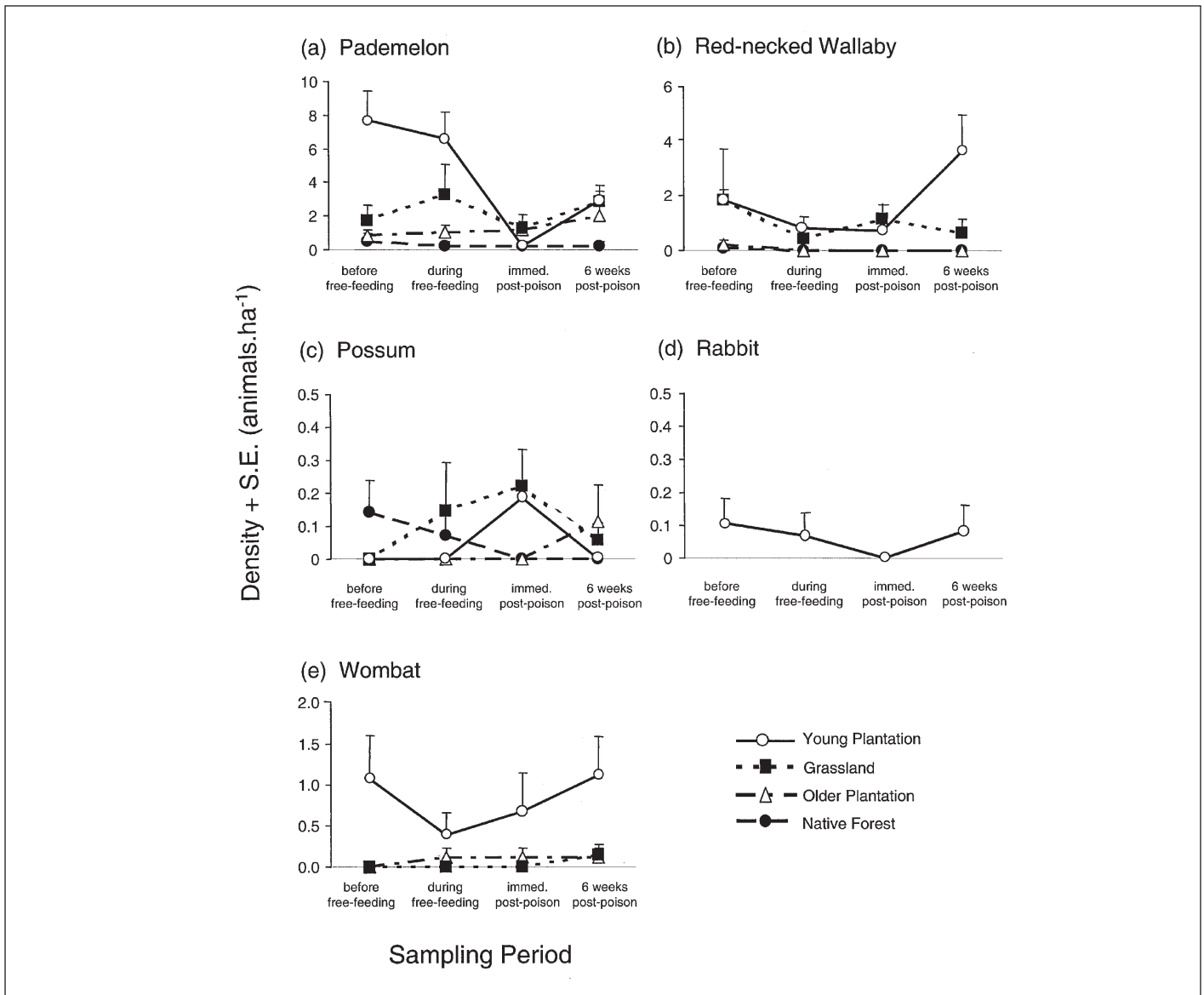


Figure 3. The estimated densities (mean + S.E.) of (a) pademelons, (b) red-necked wallabies, (c) possums, (d) rabbits and (e) wombats in four habitats (young plantation, grassland, older plantations and native forest) before free-feeding, during free-feeding, post-poisoning and six weeks post-poisoning

Densities of possums, rabbits and wombats on the young plantation did not change significantly following poisoning compared with before free-feeding ($P = 0.5$, $P = 0.5$ and $P = 1.0$, respectively) (Fig. 3c-e).

Six weeks after poisoning, pademelon density on the young plantation had increased compared with immediately post-poisoning ($S = -47.5$, d.f. = 23, $P = 0.001$), but was still significantly lower than before free-feeding ($S = 61$, d.f. = 23, $P = 0.012$). Pademelon density in other habitats was unchanged throughout this period ($P > 0.1$, in all cases) (Fig. 3a). Six weeks after poisoning, red-necked wallaby density on the young plantation was again similar to before free-feeding ($S = -22$, d.f. = 23, $P = 0.268$). Red-necked wallaby density in other habitats did not change significantly during this period ($P \geq 0.5$) (Fig. 3b). No significant changes were detected for possum, rabbit or wombat densities on the young plantation between immediately post-poisoning and six weeks after poisoning ($P = 0.5$, $P = 1.0$ and $P = 0.9$, respectively) (Fig. 3c-e).

Discussion

Data presented here provide the first quantitative information on absolute changes in animal densities in relation to a poisoning operation. Ideally we would have compared a large random sample of poisoned and unpoisoned plantations, or a single closely matched unpoisoned plantation as a control (as discussed in Hurlbert (1984) and Stewart-Oaten *et al.* (1986)). Neither situation was logistically possible. Equivalent difficulties in obtaining between-site replication are inherent in many large-scale ecological studies (for example, Efford *et al.* (2000) and Pople *et al.* (2000)). We can be confident of results of density changes in all such studies, provided the methods are satisfactory. Generalizations about effects, in our case about the effects of 1080, however, can only be built up by comparing single site results with results from other studies, if available. Where possible, we do this in the following sections.

Pademelons

The relative stability of the regional density of pademelons over time suggests that any effects of the poisoning operation were

localised. Free-feeding did not draw new pademelons into the region during free-feeding. There was also no shift in densities between habitats within the region, indicating that animals were not attracted onto the young plantation from surrounding habitat. This suggests that only animals within the local population near the bait-line were targeted during this operation. Poisoning effectively targeted pademelons on the young plantation. The 98% decrease in density following poisoning was assumed to reflect animal deaths and not a general population trend due to other factors, because densities in other habitats did not change at this time, and carcasses had been found on site ($n=25$, K. le Mar *pers. obs.*; le Mar and McArthur 2000). This result is similar to findings from Marsh (1998) and Bulinski (2000). Marsh (1998) estimated pademelon densities were 97% lower on one poisoned plantation compared with a nearby unpoisoned plantation. Bulinski (2000) found that at 80 days after planting, cumulative pademelon scat density on poisoned plantations was lower than on unpoisoned plantations.

A very high kill-rate for pademelons may be related to two factors. First, pademelons have a relatively low tolerance to 1080 compared with the other herbivores present (McIlroy 1982). Second, pademelons may dominate bait stations, restricting other species from accessing bait. Nocturnal filming at bait stations has shown that pademelons aggressively defend bait stations from red-necked wallabies (N. Marsh *pers. comm.*). The possible dominance of pademelons over red-necked wallabies was unexpected, given that pademelons are the smaller species (Calaby 1991; Johnson and Rose 1991). This potential dominance requires further investigation because it has important implications for the effectiveness of 1080 at targeting red-necked wallabies, and the subsequent impact on browsing damage (discussed below).

By six weeks after poisoning, pademelon density on the young plantation had increased but was still lower than before free-feeding. The long-term implications of this trend are not known, but will depend upon the source of the density increase. If the increase represents neighbouring animals extending their home-range as a result of a vacuum effect, as previously reported for brushtail possums (Efford *et al.* 2000), then poisoning may reduce pademelon density in the long term. If, however, the increase represents dispersing pademelons migrating into the area, density on the young plantation may continue to increase until it reaches pre-poisoning levels. This situation would not reduce pademelon density in the long term, but it may create a window of time in which seedlings are relatively free of browsing damage. Consequently, the source of the density increase on the young plantation following poisoning is worthy of investigation as it has important implications for managing damage to seedlings, and site utilization by other species (see below).

Red-necked wallabies

As with pademelons, regional densities results for red-necked wallabies suggested that any effects of the poisoning operation were localised. Free-feeding appeared to cause a slight but not significant decline in red-necked wallaby density on the young plantation. If this trend is real, it may reflect a change in foraging behaviour at this time, rather than a true density decline. Red-necked wallabies appeared to be active earlier in the day than usual during this period (K. le Mar *pers. obs.*), and

hence fewer animals may have been active during spotlighting. Red-necked wallaby density declined 60% from before free-feeding to immediately post-poisoning on the young plantation. However, because the declining trend was already apparent during free-feeding, it is not clear whether the poisoning operation was totally responsible for this change. Furthermore, only three carcasses were found on the young plantation after poisoning (K. le Mar *pers. obs.*; le Mar and McArthur 2000). Mixed results have been reported for the effectiveness of 1080-poisoning on reducing red-necked wallaby abundance on plantations. Marsh (1998) reported a 75% lower density on one poisoned plantation than one unpoisoned plantation, while Bulinski (2000) found no significant difference in cumulative scat density at 80 days between poisoned and unpoisoned plantations.

Six weeks after poisoning, red-necked wallaby density increased again on the young plantation, presumably reflecting movement of individuals from surrounding habitat. We hypothesize that this influx was triggered by the sustained lower (albeit increasing) density of the more dominant pademelon.

The impact of replacing many pademelons with some pademelons and some red-necked wallabies is currently unknown. *Eucalyptus nitens* seedlings are not a preferred food item for pademelons (Procter 1998; McArthur *et al.* 2000). Preferences for plantation species by red-necked wallabies have not been investigated, but are clearly important before the relative impact of these two species can be determined.

Possums and rabbits

Densities of the two other target species (possums and rabbits) were not reduced significantly by the 1080-poisoning operation. However, their densities were extremely low, which may have precluded any decline from being detected. No change in possum and rabbit density due to poisoning, however, is consistent with Marsh's (1998) and Bulinski's (2000) results. Seven possum carcasses and one rabbit carcass were found after poisoning (K. le Mar *pers. obs.*; le Mar and McArthur 2000).

Wombats

Density changes for wombats on the young plantation followed a similar pattern to red-necked wallabies, but no trends were significant. On this basis, the 1080-poisoning operation did not cause a detectable decline in wombat density either on the treated plantation, or within the larger region. No other studies have quantified population changes in similar situations, so that no comparisons are possible at this population level. No wombat carcasses were found after poisoning (K. le Mar *pers. obs.*), although it cannot be inferred that no animals were killed, since carcasses may have been in burrows.

Conclusion

Although statistical differences in densities cannot alone infer that the 1080 operation caused any changes, it is reasonable from a biological basis (including the presence of carcasses) to conclude that 1080 was responsible for reducing local macropod populations during this study. Our results indicate a large effect of 1080 on the local pademelon population and at least some effect on the red-necked wallabies. The fact that these patterns are similar to those found by Marsh (1998) and Bulinski (2000) using other methods for estimating animal densities on other

plantations suggests that these patterns may be reasonably common.

Although the proximate aim of any 1080 operation in forestry is to reduce animal numbers, the ultimate aim is obviously to reduce browsing damage to seedlings. This study raises a number of questions that need to be investigated in this regard. These include the potential long-term effects of poisoning on animal numbers and species interactions. Both of these factors influence population dynamics between species that forage on a plantation, and ultimately may affect the amount of browsing damage that occurs.

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