Changes in Possum Den-Site Use Following Density Reduction: Implications for Conservation and Bovine Tuberculosis Control

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ABSTRACT: The Australian brushtail possum is a pest in New Zealand, as it has caused the decline of a number of native bird species and has become the greatest barrier to the eradication of bovine tuberculosis (bTB) from livestock. As such, possum populations are reduced (i.e., controlled) at a cost of millions of dollars every year. Yet, control is still timely, costly, and not always 100% effective. Behavioral changes in possums have the potential to substantially affect the ability to control possum populations. For example, it is currently unknown whether possums change their behavior, such as den-site use, following control. How possums use dens is an important consideration in controlling bTB, as dens are a potential infection reservoir for both possums and livestock. Knowledge of any changes in den-site use may allow the design of more targeted and efficient control operations that identify potential increases in transmission risk. To investigate changes in den use due to control, possums were fitted with VHF devices, and were tracked to their den sites before and after a control operation that killed approximately 54% of the adult population. The total number of dens they used and the number of times they changed dens were recorded. Density reduction resulted in an increase in the number of times possums changed dens. However, den use was more strongly influenced by the sex of an individual, with males changing their dens more often than females. Density reduction did not appear to result in a change in the number of dens used. Instead, this behaviour was also largely driven by the sex of an individual, with males using more dens than females. This potential increase in transmission risk does not mean that control strategies should not be undertaken, but that managers should keep in mind the likely responses of possums to control and adapt their strategies accordingly. For example, control measures may need to be targeted towards those individuals that use more dens, such as males. This research also further highlights the need for efficient control that reduces populations to very low densities, to negate this potential increase in transmission risk.

KEY WORDS: bovine tuberculosis, brushtail possum, control, den-site use, density reduction, New Zealand, radio-tracking, *Trichosurus vulpecula*

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The Australian brushtail possum (*Trichosurus vulpecula*) was first introduced into New Zealand (NZ) in the 1800s to establish a fur trade (King 1990). However, since then this species has become a major pest, causing the decline of a number of native bird species, by both competition and direct predation (Nugent et al. 2000). Possums have also become the greatest barrier to the eradication of bovine tuberculosis (*Mycobacterium bovis*, bTB) from livestock (Animal Health Board 2011, Coleman and Caley 2000), as they transmit this disease to cattle and farmed deer. Possums are consequently controlled (i.e., culled) over millions of hectares of NZ at a cost of millions of dollars every year (Animal Health Board 2011). Yet, despite advances in our knowledge of possum behavior and control strategies, control is still time-consuming, costly, and not always 100% effective. In addition, although the incidence of bTb has been reduced, there are still infected herds within NZ, attributed to 'hot spots' of infection in possum populations.

Behavioral changes in possums have the potential to substantially affect the ability of managers to control and monitor possum populations (Arthur et al. 2002). One of the current gaps in knowledge is how possum spatial ecology changes in response to density reductions due to control operations. In particular, little is known whether possums change their habitat use and behavior, such as den-site use. How possums use dens is an important consideration in controlling bTB, as it has previously been shown that cattle grazing in possum denning areas are more susceptible to bTB infection than those grazing in foraging, non-denning areas (Paterson et al. 1995). In addition, bTB may be transmitted among possums through environmental contamination of dens (Coleman and Caley 2000, Ji et al. 2003). It has been shown that possums in populations recovering from density reduction use more den sites than possums in populations where no density reduction has occurred (Ji et al. 2003). However, no study has specifically looked at changes in den-site use in the same individuals before and after a large density reduction.

Possums change their dens frequently and use many per year (Cowan 1989). They also share their dens with both live and dead possums (Caley et al. 1998, Day et al. 2000, Fairweather et al. 1987), and use dens previously occupied by others (Cowan 1989, Ji et al. 2003, Pfeiffer 1994). Research has shown that bTB can survive within dens (Jackson et al. 1995). One study investigating the denning behaviour of possums concluded that given a survival period of bTB bacilli of less than 10 days, possums at their site would have had a minimum of a 50% chance of occupying dens within this survival time (Cowan 1989). Research by Paterson et al. (1995) has also shown that bTB in possums was limited in their study site to individuals which denned in certain areas,

regardless of overlapping foraging areas between infected and non-infected possums. They concluded that transmission of bTB may be associated with denning (Paterson et al. 1995). If denning behavior changes following density reduction (for example, if possums increase the total number of dens they use following control), then this may increase exposure to this disease for both possums and livestock, if bTB infected possums survive. These changes may vary between male and female possums, as males generally use more dens than females (Cowan 1989), which may mean that transmission risk varies between sexes. Knowledge of whether or not possums change their den-site use may therefore allow the design of more targeted and efficient control operations, which identify potential increases in bTB transmission risk due to control.

Consequently, the aim of this study was to investigate whether possums change their denning behavior following density reduction. This research was conducted within a 15-hectare forest fragment in Hororata, Canterbury (43°32'50.03"S, 171°54'35.96"E), consisting of predominantly English oaks (*Quercus robur*) and sycamores (*Acer pseudoplatanus*). Possums were live-captured, anaesthetised and fitted with either Sirtrack® VHF collars, or Sirtrack® GPS collars (Sirtrack, Hawkes Bay, NZ) that also contained VHF units. Both these collar types allowed the possums to be radio-tracked to their individual den sites. Twenty-seven adult possums (13 males and 14 females) were fitted with collars. Possum den sites were then monitored for 5 weeks prior to a control operation and 5 weeks following the control operation, during January - April 2011. Control was conducted for a week using a combination of cage trapping and shooting. Monitoring involved tracking each individual to their den site approximately 3 times per week. These data were then collated to establish the total number of dens used before and after control, as well as the number of times individuals changed between these dens. The population size of the site before and after control was estimated using mark-recapture techniques and Program Capture within 'MARK' (Cooch and White 2011, Lettink and Armstrong 2003, Pryde 2003).

Due predominantly to collar failure, data could only be analysed for 22 possums (9 males and 13 females). These possums were radio-tracked on 598 occasions to 83 den sites. The adult population of the site before and after control was estimated to be 7 (SE ± 1.3) and 3 (SE ± 0.3) possums per hectare respectively, resulting in approximately a 54% density reduction. Dens were predominantly located above-ground in trees (80% of all dens), with only a small proportion of dens located on the ground (for example, in hollow logs or within vegetation). Denning behavior differed between the sexes, with males denning on the ground 29% of the time and females never denning on the ground. The proportion of dens that were above-ground was similar before and after control (86% and 83% of all dens, respectively).

Both males and females used a similar number of dens before control as after control (males before control: $\bar{x}$ = 3.1, SEM ± 0.6; males after control: $\bar{x}$ = 2.9, SEM ± 0.4; females before control: $\bar{x}$ = 1.2, SEM ± 0.1; females after control: $\bar{x}$ = 1.6, SEM ± 0.2). Statistical modelling confirmed that density reduction did not result in changes in the number of dens used by possums. Instead, the number of dens used was more influenced by the sex of the individual, with males using more dens than females, regardless of the monitoring event.

Male and female possums both changed their dens more often on average following control than they did before control (males before control: $\bar{x}$ = 3.6, SEM ± 1.0; males after control: $\bar{x}$ = 4.3, SEM ± 1.0; females before control: $\bar{x}$ = 0.2, SEM ± 0.2; females after control: $\bar{x}$ = 1.5, SEM ± 0.7). Statistical modelling showed that the density reduction resulted in possums changing their dens more frequently. However, den changes were more strongly influenced by the sex of possums, with males changing their dens more often than females, before and after density reduction.

One significant limitation of this study was the lack of replication. However, this work is a beneficial starting point, highlighting the possibility for den site changes to occur in response to control. This study therefore provides a good framework for which to base additional research. This future research should involve replication in locations with similar densities and habitats, and the incorporation of experimental controls where density reduction is not carried out. These sites should also be monitored simultaneously to negate any temporal effects. This replication would definitively test the occurrence and magnitude of den site changes due to density reduction. Longer-term studies would also allow an assessment of whether any changes are permanent, or whether den use returns to pre-reduction levels.

The breeding season in NZ is approximately March - November, although this varies by region (Fletcher and Selwood 2000). Therefore, it is possible that the observed changes in den use were due to breeding and not density reduction, as a captive study has shown that possums share their dens more frequently during this time (Day et al. 2000). Future studies that incorporate the above-mentioned replication would allow the effect of breeding to be assessed and experimentally controlled for.

Understanding changes in denning behavior is important to allow the efficient control of possums and to help prevent the ongoing transmission of bTB to livestock (Cowan and Clout 2000). If changes in den site use do occur due to density reduction, this may not result in the need to change specific possum monitoring or control strategies, but it poses some interesting questions regarding transmission risk. Increases in the number of times possums change between dens (as potentially shown in this study), may increase the risk of bTB transmission among surviving possums, and between possums and livestock. This research therefore further highlights the need for efficient initial control that reduces populations to very low densities, to negate any potential increase in transmission risk.

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