SHORT COMMUNICATION

Changes in Australian brushtail possum (*Trichosurus vulpecula*) den site use following density reduction

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Abstract: The den use of possums (*Trichosurus vulpecula*) may be density dependent, meaning that individuals change their denning behaviour in response to changes in population density. Increases in den use due to changes in density may result in increases in bovine tuberculosis (*Mycobacterium bovis*; bTB) transmission among possums, as infection has previously been correlated with den use. In this study, the den use of a possum population was monitored in 2011 before and after a density reduction event. Females increased their den use following density reduction, but males did not. However, den use was more dependent on the sex of the individual than density reduction, with males having greater den use than females. A second site of different habitat where density reduction was not carried out was also monitored for den use, in 2012. In contrast to the manipulated site, den use did not differ between monitoring events or possum sex at this site. Possums at this site also had greater den use than possums at the manipulated site. This research suggests that bTB transmission risk may not be uniform among habitats. In addition, to prevent potential increases in transmission risk from bTB-infected possums surviving control, pest control operations should aim to remove the majority of possums in a population.

Keywords: bovine tuberculosis; control operations, density-dependent resources; pest species; radio-tracking

Introduction

Male and female Australian brushtail possums (*Trichosurus vulpecula* Kerr) preferentially choose dens (Cowan 1989; Ji et al. 2003) and defend these if challenged (Day et al. 2000). Therefore, in some habitats, den availability for individuals may be density-dependent (Clout 1977; Fairweather et al. 1987; Caley et al. 1998). Density reduction may consequently result in possums changing their den use (e.g. the number of dens used and the number of den changes) to take advantage of a greater availability of better quality den sites following the removal of other possums. Alternatively, because possums change their home ranges following density reduction (Brockie et al. 1997; Ramsey et al. 2002; Morgan et al. 2007; Whyte 2013), den use may change due to individuals altering their movement patterns (Ji et al. 2003). One study has previously recorded higher den use in populations recovering from density reduction, compared with populations not subjected to density reduction, although sample sizes were too low for statistical analysis (Ji et al. 2003). Another study in Australia anecdotally recorded neighbouring possums expanding their denning ranges into areas of experimentally removed individuals (Clinchy 1999; Clinchy et al. 2001). However, neither of these studies compared den use of the same individuals before and after density reduction.

The possum is the greatest wildlife barrier to the eradication of bovine tuberculosis (*Mycobacterium bovis*; bTB) from livestock in New Zealand (Coleman & Caley 2000; Animal Health Board 2011). Possum densities are consequently reduced (i.e. 'controlled'); however, bTB-infected herds remain, attributed to 'hot spots' of infection in possum populations. Therefore, it is important to obtain a thorough understanding of possum behaviour and bTB dynamics, as this may help identify ways to increase control effectiveness. A study by Paterson et al. (1995) suggested that bTB infection in possums was correlated with denning areas rather than foraging areas. Cattle grazing in possum denning areas in this study were also more susceptible to bTB infection than those grazing in possum foraging, non-denning, areas (Paterson et al. 1995). This may be due to excretion and transmission of bTB by possums while in dens (Green & Coleman 1987; Paterson et al. 1995; Coleman & Caley 2000; Ji et al. 2003). Therefore, if den use increases following density reduction, this may increase bTB transmission between possums and livestock.

The primary objective of this study was to investigate whether possums change their denning behaviour following density reduction, specifically the type of den used (ground versus above-ground), the total number of dens used, and the number of den changes. It was hypothesised that den site use by possums would be density-dependent, and therefore that den use would change following density reduction. The secondary objective was to assess whether there were intersexual differences in den site use. Very-high-frequency (VHF) collars were used to radio-track individual possums at a site before and after density reduction. A second site was also monitored where density reduction was not undertaken, but this site was not treated as an experimental control due to differences in habitat, density, and year of research. However, comparisons between these two sites allow investigation into the variations in denning behaviour due to these site-level differences. In addition, if den use changed at the second site, this would suggest that other factors (e.g. breeding) are potentially determining changes in den use.

Methods

Both the manipulated site (where density reduction was carried out) and the non-manipulated site were located at Hororata, Canterbury (43°32′50.03″ S, 171°54′35.96″ E and 43°30′56.38″ S, 171°53′23.74″ E, respectively). These sites were both 15 ha in size. Habitat at the manipulated site consisted of English oaks (*Quercus robur*) and sycamores (*Acer pseudoplatanus*), and the habitat at the non-manipulated site consisted of pine (*Pinus radiata*) and gorse (*Ulex europaeus*). Research was conducted in January−April 2011 and January−April 2012, respectively.

Study possums were caught using treadle (Trappers Cyanide, Canterbury, NZ) and trigger (Grieve Wrought Iron, Christchurch, New Zealand) live-capture traps. These traps were set up on transects that were evenly distributed throughout both sites to allow sampling of the entirety of the sites. The location of these traps remained consistent between monitoring events. The live-captured possums were anesthetised using gaseous halothane to allow handling under sedation then fitted with either VHF (very high frequency) or GPS (global positioning system) collars that also contained VHF transmitting units (Sirtrack, Havelock North, NZ). Twenty-seven adult possums (13 males and 14 females) were fitted with collars at the manipulated site and 16 adult possums (8 males and 8 females) at the non-manipulated site. All research was carried out with the approval of the Lincoln University Animal Ethics Committee (Approval No. 373).

Density reduction at the manipulated site was undertaken for a week using live-capture trapping. A week of trapping was also conducted at the non-manipulated site, but individuals were released after capture. This was to remove possible behavioural biases due to trapping itself. As no density reduction was undertaken at the non-manipulated site, the monitoring periods before and after this trapping week are referred to as mock 'pre-reduction' and mock 'post-reduction'.

Possums were radio-tracked to their dens three times per week for 5 weeks before and 5 weeks following density reduction, using an Australis 26k™ VHF receiver and a Yagi™ multi-directional antenna (Titley Scientific, Australia). Population sizes at each of the sites before and after density reduction were estimated using mark–recapture techniques and closed population estimation models in 'Program MARK', Version 6.1 (Lettink & Armstrong 2003; Pryde 2003; Cooch & White 2011). The data were analysed using generalised linear mixed-effects models, which accounted for non-normal count data by using a Poisson error structure and logarithmic link function (Crawley 2007). Models could not be run for 'den type', due to a lack of variation in the dataset; the majority of dens were above ground for the manipulated site and on the ground for the non-manipulated site. Individual possum identity was included in each model as a random effect, as well as their change in denning behaviour between events (i.e. before and after density reduction) to account for any temporal autocorrelation. Models were run with the following fixed effects: null model (intercept only), event (pre-reduction and post-reduction), bodyweight and sex (male and female), as well as the second-order interactions between these effects. Models were then ranked using the sample-size-corrected Akaike Information Criterion (AICc) (Burnham & Anderson 2002; Anderson 2008). The weights of all models in the set sum to one and the model with the highest Akaike weight is considered to have the best fit for the available data (Burnham & Anderson 2002). Due to differences in habitat type and possum densities, the data from the two sites were analysed separately.

Results

Sample sizes and population density assessments

Due predominantly to collar failure, data were only analysed for 22 possums (9 males and 13 females) at the manipulated site and 14 possums (8 males and 6 females) at the non-manipulated site. Possums at the manipulated site were radio-tracked on 598 occasions to 64 den sites; possums at the non-manipulated site were radio-tracked on 405 occasions to 69 den sites. The population density of the manipulated site (±SE) before and after density reduction was estimated to be 7 (±1.27) and 3 (±0.26) possums ha^{-1}, respectively. This resulted in approximately a 50% density reduction. As expected, the density of adults at the non-manipulated site was the same pre-reduction (1.5 possums ha^{-1}; ± 0.00 SE) and post-reduction (1.5 possums ha^{-1}, ± 0.10 SE).

Den type

Although males at the manipulated site were recorded denning on the ground, they predominantly denned above ground in trees, both before and after density reduction (Fig. 1). Females at this site always denned above ground. Conversely, both male and female possums at the non-manipulated site denned predominantly on the ground in gorse and other vegetation, both before and after mock density reduction (Fig. 1).

Number of dens

Individuals at the non-manipulated site used a greater number of dens on average than those at the manipulated site, both before and after mock density reduction (Fig. 2). The best linear model for the manipulated site was the 'Sex' model (Akaike weight of 0.89; Table 1). This was because males used more dens than females, irrespective of the monitoring event. There was also minor support for the 'Event × Sex' interaction model at this site (Akaike weight of 0.10; Table 1). This was due to females using more dens following density reduction. Den number did not appear to vary between events for males. In contrast, the null model had the majority of support for the non-manipulated site data (Akaike weight of 0.52, Table 1). This indicates that there was no major difference in the number of dens used at this site between events, sexes or different-sized individuals.

Number of den changes

Possums at the non-manipulated site changed their dens more often on average than those at the manipulated site, both before and after control (Fig. 2). The mixed-effects linear model set for the manipulated site, recorded the 'Sex' and 'Event × Sex' models as having the majority of support (Akaike weights of 0.61 and 0.37 respectively; Table 1). This was due to male possums changing their dens more frequently than females, irrespective of the monitoring event, and females changing their dens more frequently following density reduction (Fig. 2). Males did not differ in the number of den changes between monitoring events. In contrast, the null model had the highest Akaike weight for the non-manipulated site (0.41, Table 1). This suggests that there was no support for differences in den changes between events, sexes or different-sized possums at this site.

Discussion

Female possums at the manipulated site increased their den use following density reduction. Males, however, did not change their den use. This suggests that den use was density-dependent. However, overall den use was more strongly dependent on the sex of the individual than density reduction, with males using more dens than females and changing their dens more often. This study supports previous anecdotal evidence recording an increase in total den use of possum populations following density reduction (Ji et al. 2003). There was no difference in den use between the two monitoring events or sexes at the non-manipulated site.

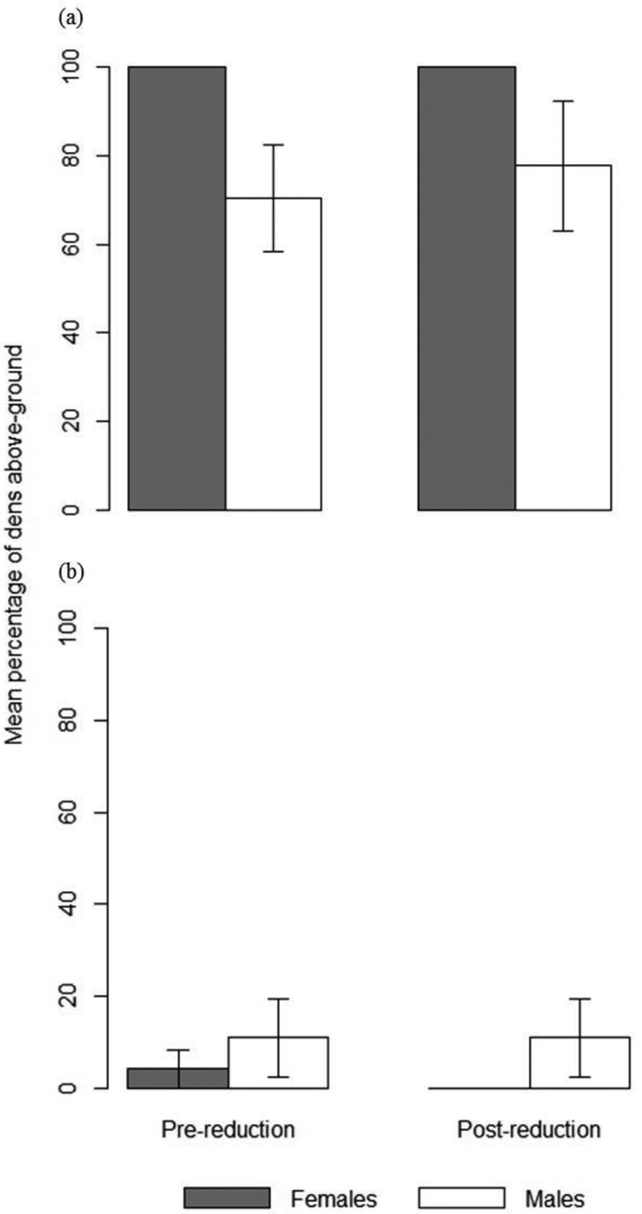

Figure 1. Mean percentage of dens above ground, before and after density reduction, for possums (a) at the manipulated site and (b) the non-manipulated site. Error bars are ± SE. Means without error bars had no variation (i.e. possums either denned solely above ground or solely on the ground).

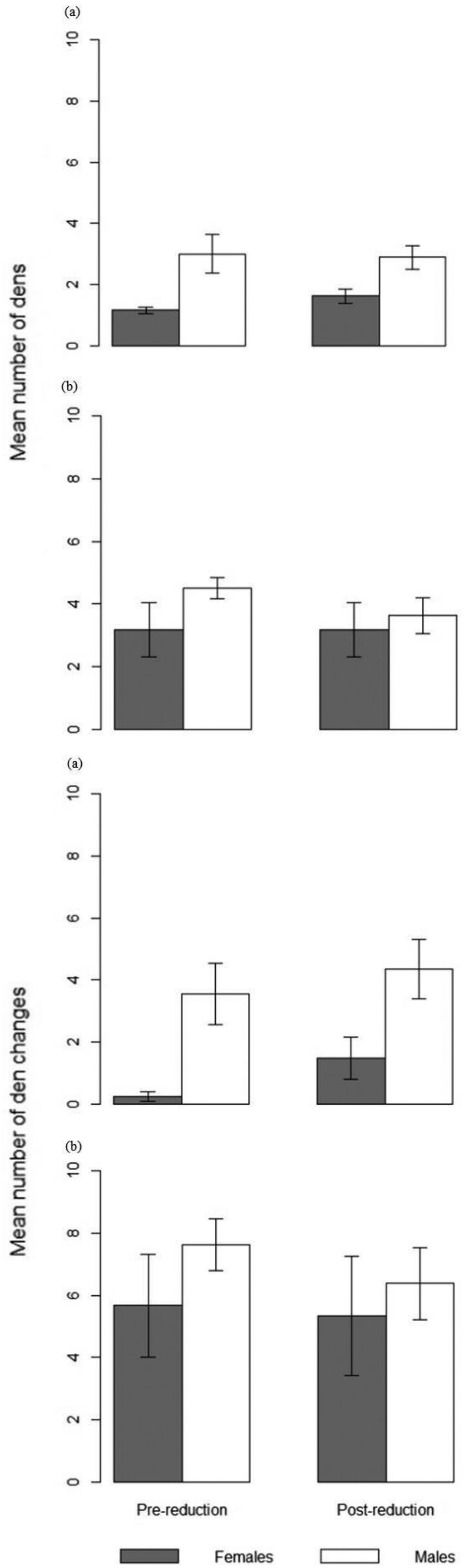

Figure 2. Mean number of dens and changes of dens, before and after density reduction, for possums (a) at the manipulated site and (b) the non-manipulated site. Error bars are ± SE.

Table 1. Akaike weights, with ΔAICc in parentheses, of the generalised linear mixed-effects models investigating number of dens and number of den changes by possums at two sites. Event is a categorical variable with two categories (pre-reduction or post-reduction for the manipulated site, and mock pre-reduction or mock post-reduction for the non-manipulated site), sex is a categorical variable with two categories (male or female) and bodyweight (BW) is a continuous variable. The density of the manipulated site was reduced by 50% to 3.0 possums ha^{-1}. The density of the non-manipulated site remained constant throughout the study at 1.5 possums ha^{-1}.

	Manipulated site						Non-manipulated site					
Model Set	Null	Event	BW	Sex	Event × Sex	Event × BW	Null	Event	BW	Sex	Event × Sex	Event × BW
Number of dens	0.0 (10.5)	0.0 (13.0)	0.0 (10.6)	0.89 (0.0)	0.10 (4.5)	0.0 (14.7)	0.52 (0.0)	0.14 (2.6)	0.10 (3.2)	0.21 (1.8)	0.01 (8.1)	0.01 (8.7)
Number of den changes	0.00 (12.0)	0.00 (10.0)	0.01 (8.9)	0.61 (0.0)	0.37 (1.0)	0.01 (9.3)	0.41 (0.0)	0.27 (0.9)	0.10 (2.9)	0.20 (1.4)	0.02 (6.2)	0.01 (7.7)

The majority of possums denned above ground at the manipulated site, whereas possums predominantly denned on the ground at the non-manipulated site. Possums at the manipulated site also used fewer dens and changed their dens less often. As den site choice is likely habitat-dependent (Green & Coleman 1987), these differences may be due to the oaks and sycamore trees at the manipulated site providing a greater proportion of preferential above-ground tree holes than the pine trees and gorse at the non-manipulated site. Males also had higher den use than females at the manipulated site, but not at the non-manipulated site. The reason for this is unclear, but may relate to a lack of 'better-quality' den sites at the non-manipulated site.

Although this work was unreplicated, it nonetheless allows us to hypothesise that den site changes in possums may occur in response to density reduction. Future research should involve replication in locations with similar population densities and habitats, and experimental non-manipulated controls. Longer-term studies would also allow an assessment of whether any changes are permanent, or whether den use returns to pre-reduction levels. This would also allow investigation into potential seasonal or annual variations.

The breeding season may have occurred during the study of the manipulated site, meaning that changes in den use may have been due to breeding, not density reduction. However, during the breeding season, male possums accompany females and sometimes share the female's dens (as cited in Day et al. 2000). Therefore, if breeding had occurred, one would have expected males to change their den use also, but this was not the case. However, changes due to breeding cannot be ruled out and future studies that incorporate the above-mentioned replication would allow this potential bias to be definitively controlled for.

The 50% possum reduction in this study allowed an assessment of partial density reduction, which likely occurs within New Zealand due to incidental trapping and/or harvesting. However, control operations commonly achieve reductions of 90% of the population (P. Livingston, Animal Health Board, Wellington, pers. comm., 2011). This higher level of reduction may result in more pronounced changes in den use. Therefore, further research where possum populations are reduced to such densities are necessary to investigate these potential changes.

In conclusion, this study suggests that density reduction might result in changes in den use and that pest control operations need to remove the majority of possums to reduce bTB transmission risk. Furthermore, this study implies that bTB transmission risk may not be uniform between sites of varying habitat type, due to differences in denning behaviour. Additional manipulative and non-manipulative experiments would be useful to further test these hypotheses.

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