

## Estimating disease survey intensity and wildlife population size from the density of survey devices: Leg-hold traps and the brushtail possum



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### ABSTRACT

Wildlife disease surveillance requires accurate information on the proportion of managed populations sampled or their population density, parameters that are typically expensive to measure. However, these parameters can be estimated using spatially explicit modelling of capture probabilities, based on the distribution and deployment times of capture devices, given accurate information on the relationships between these variables. This approach is used in New Zealand's surveillance programme aimed at confirming areas free of bovine tuberculosis (bTB<sup>1</sup>) in brushtail possums (*Trichosurus vulpecula*). However, there is uncertainty about the accuracy of the underpinning parameters characterizing possum trappability ( $g$ ), given the distance between where a trap is placed and the possum home range centre. Sampling intensity (SI: the percentage of the population sampled during a population survey) and sigma ( $\sigma$ ; 95% home range radius/2.45) were measured, using leg-hold traps deployed under a set protocol to standardize survey effort, at four sites containing previously radio- and GPS-collared individuals. Those data were used to derive an estimate of the nightly probability of capture of possums in a trap set at their home range centre ( $g_0$ ). Those estimates were compared to the standard assumptions currently used as defaults in the day-to-day approach used by bTB managers. Home-range size (and therefore  $\sigma$ ) varied widely between sites (range 3.6–49.4 ha), probably largely in response to differences in possum density. Field measured SI also varied widely between sites, and was closely positively correlated with home range size ( $R^2 = 0.967$ ;  $P = 0.017$ ); wide-ranging possums were more trappable than sedentary ones. We found that  $g_0$  was inversely related to  $\sigma$ , but the magnitude of increases in  $g_0$  with declining  $\sigma$  appeared to be insufficient to compensate for the fewer places at which each possum could be trapped when those home ranges were small. SI was, therefore, not constant across sites where a standard survey effort was applied. The assumed relationship between  $g_0$  and  $\sigma$  in the current spatial model may, therefore, need reassessment. The management implication of these result is that the sampling effort required to attain a target sampling intensity is dependant on the target animal density, and for bTB management of possums in New Zealand, is under-estimated by the current default parameters in a model of freedom-from-disease for higher density possum populations.

### 1. Introduction

For a given survey technique with a known diagnostic sensitivity, the key parameter for quantifying the likelihood of disease eradication in wildlife is sampling intensity (SI), the proportion of the total population surveyed and found disease free (Martin et al., 1987). Estimates of population size are required to determine SI, and population density where wildlife disease management models predict the population density above which disease persists – (e.g., Barlow, 2000). Population size and SI are difficult to measure in wildlife (Artois et al., 2009).

There has therefore long been interest in finding ways of using the harvest or removal data collected during management (culling or survey) to estimate population size or density (e.g; Zippin, 1958; Lancia et al., 1996; Boitani et al., 1995; Gove et al., 2002; Ramsey et al., 2005) and, from that, sampling intensity (the proportion of the population sampled) because that does not require further manipulations or actions, such as tagging and recapture (Davis et al., 2017).

Anderson et al. (2013) have shown how kernel-based spatial modelling of capture probabilities can be used to estimate SI from survey effort (e.g., number of trap-days) alone without having to undertake

*Abbreviations:* bTB, bovine tuberculosis;  $g$ , probability of capture;  $\sigma$ ,  $r/2.45$ ;  $r$ , 95% home range radius; SI, sampling intensity;  $g_0$ , probability of capture of possum 'x' in a trap set for one night at the home range centre of possum 'x'; SS, surveillance sensitivity; DK, detection kernel; KDE, kernel density estimator; LSCV, least-squares cross-validation;  $h$ , smoothing factor; TC, trap capture

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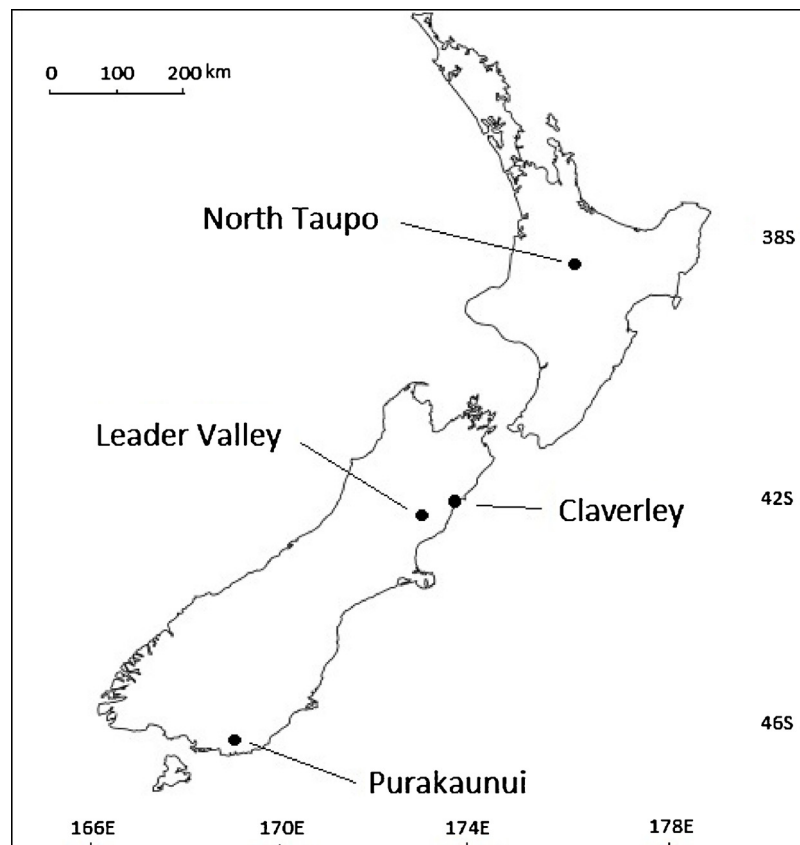


Fig. 1. Location of four study sites in New Zealand where possum home-range size, trapping effort, and possum sampling intensity were measured before or during possum population control undertaken between 2015 and 2017.

expensive mark – recapture or other repeated survey techniques that are usually needed to estimate density. Indeed, such modelling can be used to estimate density if the total number of animals ( $N$ ) captured from the given surveyed effort is known (as it usually is), because  $N/SI$  equates to a simple mark – recapture estimator.

Here survey effort data (trap density, distribution, and deployment time) is used to estimate  $SI$  during trapping-based surveys of brushtail possums (*Trichosurus vulpecula*) in New Zealand. The possum is an introduced arboreal herbivore that is the primary wildlife vector of bovine tuberculosis (bTB, caused by *Mycobacterium bovis*), and is implicated in spreading the disease to domestic cattle in New Zealand (Nugent et al., 2015). Surveys were aimed at quantifying the probability that bTB has been eradicated from local long-controlled wild possum populations.

Anderson et al. (2013, 2014) document the development of a Bayesian framework for ‘proving’ (quantifying) bTB freedom in a given possum population using estimates of  $SI$  from field surveys, provided those surveys did not detect infection, to update prior estimates of the probability that bTB is absent. The  $SI$  estimates are derived solely from trapping effort used to obtain a sample of the population for necropsy (to diagnose *M. bovis* infection). The trapping effort data comprise information on the number and location of traps and the number of nights for which they were set (i.e., using only information derived from trapping effort rather than any of the other monitoring or manipulations usually required to estimate population size). The Anderson et al. (2013) approach involves spatially explicit modelling via detection kernels (the DK model) of the probability that a possum would be captured when a trap is set within its range for a single night.

The key model parameters are  $g_0$  (the probability of capture of a possum when a single trap is set at its home range centre for one night), and sigma ( $\sigma$ ; a scalar of home range size where  $\sigma = 95\%$  home range radius/2.45). Since the use of DKs became routine in possum-

management practice in about 2012 (Anderson et al., 2014), single estimates of each parameter have been used as defaults, based on historical capture data. The implicit assumption is that either these two parameters are universal constants regardless of possum density or habitat type, or, more realistically, they vary inversely in a manner that maintains a constant  $SI$  for any given trapping effort. We aimed to test the latter assumption by estimating  $\sigma$  and  $SI$  from field data (measured values) at four sites with different habitat types and initial possum densities and subjected to population survey. Measuring  $SI$  and  $\sigma$  enabled us to estimate ‘measured’  $g_0$ , and then to compare measured  $g_0$  and  $\sigma$  against the standard default values. We also compared the field-measured  $SI$  against the  $SI$  estimated by DK modelling of the sampling effort (trap locations used during population survey) using default values for  $g_0$  and  $\sigma$  (kernel  $SI$ ).

Ultimately, disease surveillance requires estimating surveillance sensitivity ( $SS$ ), which combines  $SI$  and diagnostic sensitivity (the proportion of truly infected animals in which disease is detected during the surveys). Where diagnostic sensitivity is perfect (the test always detects the disease when present),  $SI = SS$ . This paper focuses on  $SI$  rather than  $SS$ , with diagnostic sensitivity assumed to be constant.

### 1.1. Study design and areas

The study design involved live capture, radio-collaring and release of possums ahead of a simulated possum necropsy survey in which possums were captured and killed as they would be during a bTB survey of the population. A proportion of collared possums were fitted with GPS receivers to measure home-range size, from which we derived a measure of  $\sigma$ . The proportion of the radio-collared possums captured and killed during the nominal bTB survey provided the measured- $SI$  estimate, with the DK model used to determine a ‘measured’ estimate for  $g_0$  that would generate the measured  $SI$ , given the measured  $\sigma$

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