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Using pest monitoring data to inform the location and intensity of invasive-species control in New Zealand

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ABSTRACT

Improving decision-making about where and how invasive species management is conducted requires a better understanding of spatial variation in pest abundance and the extent to which different pest control regimes reduce those abundances. We measured how the relative abundance of invasive rats and possums, indexed at 147 forest sites in northern New Zealand, varied in response to environmental variables, and to the category of pest control at the site: no control (NC), periodic possum (PP), low-intensity rat and possum (LRP), and high-intensity rat and possum (HRP). We found that climate and topography strongly influenced the rat index, while vegetation characteristics strongly influenced both indices. These variables may therefore be useful for predicting pest impacts and prioritising locations for pest control. HRP control substantially reduced pest abundance indices, with model-predicted values for the rat index that were 99% lower than in areas of no control, and 91% lower for the possum index. In contrast, indices did not differ significantly among NC, PP, and LRP. PP and LRP regimes dominate pest control in New Zealand, but may be of limited conservation value, at least in terms of the 'average' operation in our study region. Globally, conservation agencies with limited budgets frequently avoid monitoring pest populations, since resources spent on monitoring are no longer available for management. However, our results highlight the value of collecting and analysing pest monitoring data, both for informing the location of future management and for ensuring that scarce resources are not wasted on ineffective control.

1. Introduction

Invasive species are one of the major threats to biodiversity worldwide (Sala et al., 2000), but their management ('pest control') is rarely straightforward. Pest control is expensive, and there are typically only sufficient resources available to control a fraction of the area in which threats from invasive species occur (Wilson et al., 2007). Moreover, there are often multiple methods available for controlling a given invasive species, and these may vary in their efficacy, resource-intensiveness, humaneness, and risk to non-target species (Shea et al., 2002; Parkes and Murphy, 2003; Govindarajulu et al., 2005; Reddiex et al., 2006; Beausoleil et al., 2010; Massei et al., 2011). The challenge for conservation managers working with limited resources is to select locations for pest control where conservation gains will be the greatest, then to use control methods that will predictably and efficiently reduce pest abundances to the levels necessary to meet conservation objectives.

The collection and analysis of pest monitoring data may play an important role in meeting this challenge. First, analysis of the distribution and abundance of pests may reveal that easily-measured environmental variables can be used to predict pest occurrence or impacts. This information has typically been used to predict where future invasions are likely to occur (e.g. Ficetola et al., 2007; Zhu et al., 2007; Roura-Pascual et al., 2009), but can also be used to prioritise locations for control within the existing range of an invasive species (e.g. Porphyre et al., 2014). Second, monitoring how pests respond to control operations improves understanding of whether a particular control regime is likely to achieve conservation objectives, which is important both for designing effective pest management programmes and for increasing the ethical defensibility of pest control that kills sentient animals or poses risks to non-target species (Reddiex and Forsyth, 2006; Warburton and Norton, 2009). However, conservation agencies often do not monitor pest populations, or collect monitoring data but do not analyse them (Shea et al., 2002; Reddiex et al., 2006; Possingham, 2012; Walsh et al., 2012). There is a need for increased monitoring and analysis of pest populations, to improve understanding of where limited pest control resources should be spent and to validate assumptions about the type of control required to achieve conservation

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objectives (Shea et al., 2002; Reddiex et al., 2006; Warburton and Norton, 2009; Walsh et al., 2012).

As in many parts of the world, the control of invasive mammals is a central part of conservation management in New Zealand (Clout, 2001). On the mainland (North Island and South Island), this control primarily targets the ship rat (*Rattus rattus*), a globally invasive species which threatens native biodiversity on islands worldwide (e.g. MacFarland et al., 1974; Monteiro et al., 1996; Martin et al., 2000; Jouventin et al., 2003; Harris and Macdonald, 2007), and the brushtail possum (*Trichosurus vulpecula*), which is invasive throughout New Zealand (Wright, 2011). These species consume a wide range of plant and animal taxa, and are believed to be the primary threat to many native species (Craig et al., 2000; Innes et al., 2010a; Wright, 2011). An enormous amount of time and effort is spent attempting to reduce their abundance, with control covering more than a million hectares and costing of tens of millions of New Zealand dollars each year (Wright, 2011).

The particular methods used for this control vary widely, involving a range of control devices (mostly utilising various traps and poisons) which are employed at widely varying intensities (i.e. variable spacing of devices and frequency of control) (Gillies, 2002; Parkes and Murphy, 2003; Beausoleil et al., 2010). However, although some of these pest control regimes demonstrably achieve conservation objectives (e.g. Innes et al., 1999; Gillies, 2002; Armstrong et al., 2006; Warburton and Norton, 2009), there is considerable uncertainty about the efficacy of others. For example, possum control is often repeated on a 1–8 year cycle, but return times longer than a few years may not provide benefits to native species (Parkes and Murphy, 2003; Brown and Urlich, 2005). Similarly, even relatively intensive rat control operations may not be able to reduce rat abundance to levels required to protect rat-sensitive species (Gillies, 2002). Lastly, there is increasing recognition that rats, possums, and other invasive mammals may negatively affect each other, so that control of one species may cause an increase in the abundance or impacts of others (Rayner et al., 2007; Sweetapple and Nugent, 2007; Ruscoe et al., 2011). In the face of this uncertainty, there is a need for increased monitoring and analysis of pest control operations, so that the efficacy of particular regimes can be better understood.

Despite the considerable resources spent controlling rats and possums over large parts of New Zealand, this control can still only cover a fraction of the area in which threats from these species are likely to occur (Craig et al., 2000; Wright, 2011). To aid in prioritising locations for pest control, several studies have examined determinants of spatial variation in rat or possum abundance in New Zealand. Fraser et al. (2003) examined how possum capture rates varied at a national scale, and found that this variation was primarily influenced by climatic variables. Similarly, Porphyre et al. (2014) found that climate, together with the presence of forest cover, strongly influenced possum capture rates in a montane grassland environment. Several studies have examined how ship rat capture rates vary within forests in New Zealand, and these suggest that rat abundance is influenced by a variety of factors, including distance from the forest edge, vegetation, topography, and altitude (King et al., 1996; Harper et al., 2005; Christie et al., 2006, 2009; Ruffell et al., 2014). However, little is known about how possum and rat abundances vary within lower elevation environments at the regional scale. This information would be helpful for prioritising areas for pest control, because these environments make up the majority of New Zealand's land area (MfE, 2002) and include a disproportionate number of New Zealand's threatened species (Walker et al., 2008), and because conservation management agencies frequently operate at a regional scale (regional councils and Department of Conservation regional conservancies, for example).

In this study, we measured rat and possum relative abundances at sampling stations systematically located in forest habitats throughout the Auckland region of New Zealand, as part of a region-wide biodiversity monitoring programme. We also quantified local vegetation characteristics (structure and composition), topography and climate, measures of forest fragmentation and urbanisation, and the presence and type of pest control at each sampling station. Our aim was to use this dataset to improve understanding of where and how pest control should be conducted in the region, by examining (1) which variables could be used to predict spatial variation in rat and possum abundance at a regional scale, and (2) how effectively the different pest control regimes in the region could reduce rat and possum abundance indices.

2. Methods

2.1. Study region

We conducted our study in the Auckland region of northern New Zealand. The region is c. 5000 km^2 in area, and comprises lowlands and hill country on a relatively narrow isthmus of land (<70 km at the widest point), together with a number of near-shore islands. The maximum mainland altitude is 722 m (McClure, 2012a). The climate is temperate–subtropical (McClure, 2012b), with a mean annual temperature ranging from c. 11–16 °C across the region as measured from Land Environments of New Zealand climate data (MfE, 2002). Auckland was largely forested prior to the arrival of humans (Ewers et al., 2006), but an analysis of the New Zealand land cover database version 2 ('LCDB2'; MfE, 2004) suggests that agriculture, pine plantations, and urban areas now cover approximately 48%, 9%, and 10% of its land area, respectively.

2.2. Selecting sampling station locations

We indexed rat and possum abundance at 147 locations throughout the Auckland region. These locations were selected as part of Auckland Council's Terrestrial Biodiversity Monitoring Programme, which measures biodiversity values by systematically sampling plant, bird, and pest mammal communities in native forest habitats throughout the region. 'Native forest habitats' included scrub and shrubland vegetation types (as defined by Atkinson, 1985) that were pre-cursors to mature forest vegetation or were stable vegetation types at the site. As part of this programme, sampling stations were placed at grid-intersection points on a 4 km grid overlaid across the entire region. Where grid intersections did not fall on native forest habitat, a sampling location was randomly selected within the nearest forest patch, provided that this patch was within 2 km of the grid intersection. In addition, we surveyed areas of special conservation interest (e.g. sites under intensive pest management) at higher spatial resolution by placing additional sampling stations at the intersections of either 2 km, 1 km, or 500 m grids nested within the 4 km grid (Fig. 1). In all cases, sampling stations that fell within 20 m of a forest edge were moved towards the centre of the patch until the nearest forest edge was 20 m away, to ensure that vegetation plots remained within forest habitat.

We used data from the 2009–2014 sampling period of the Terrestrial Biodiversity Monitoring Programme. However, not all sampling stations selected for the programme were included in our analysis. First, some private land owners did not give permission to survey on their land. Second, the programme included sites on several of the Hauraki Gulf islands, which we excluded from our analysis because rats and/or possums typically did not occur on these islands, and because where they do occur their responses to pest control are likely to differ compared with mainland sites because of reduced recolonisation from the surrounding area. Third, rats and possums were not surveyed in the first year of the programme (i.e. only plants and birds were sampled in 2009), so around a quarter of all sampling stations had no rat or possum data and were excluded from our analyses. Fourth, a number of sampling stations fell within two predator free sanctuaries in which rats, possums, and other invasive mammals had been eradicated. We did not use these sites in our analyses, because they provided no useful