

New Zealand native bird scat (*Apteryx* and *Nestor* spp.) prompts investigation by introduced rats

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Abstract

New Zealand's avifauna is subject to extensive predation by introduced mammals. Of these, rats, with well-developed olfactory senses, are a significant threat to native avifauna, especially nests and chicks. It is, however, still unclear what olfactory cues predators primarily use to locate prey. We sought to determine whether native North Island brown kiwi (*Apteryx mantelli*) and kaka (*Nestor meridionalis*) scat can be used to attract rats to tracking tunnels compared to unscented tracking tunnels. Treatment tunnels were paired with an empty control tunnel or two empty tunnels were placed in the same site in a random ordered design across ten sites. Each pair of tunnels was placed out for a five-night tracking regime. Pooled scat solution from native brown kiwi and kaka significantly increased the rate of tracking by rats compared to control tunnels (adjacent) and control - control tunnel pairs (which received no evidence of rat footprints). We discuss predator utilisation of olfactory signals from avian scat to locate nests and discuss the implications of these results.

Key words: olfaction, predation, prey attraction, tracking, *Rattus*, Kiwi, Kaka

Introduction

Rats (*Rattus* spp.) have well-developed olfactory systems that are used to interpret complex information from their environment; to detect food, avoid predators and to communicate with conspecifics (Dulac and Torello, 2003; Hughes et al., 2010; Yin et al., 2011). Understanding how particular olfactory signals can prompt innate attraction could shed light on the development of novel tools for managing pest species in New Zealand and world-wide (Apfelbach et al., 2005; Campbell-Palmer and Rosell, 2011; Swaisgood, 2007). Compounds that stimulate olfactory senses to attract animals are already used to track and trap rats in the domestic and wild environments, including food-based lures (Clapperton et al., 1994; Cunningham and Moors, 1996; Gillies and Williams, 2001; Gould et al., 2007). However, in the wild it becomes increasingly difficult to detect, and trap, rats at low population densities (Russell et al., 2008). Other more effective olfactory cues might be found and utilised to improve the monitoring and management of rats and other pest mammal species.

Conspecific olfactory cues may improve detection and trapping rates of mammals in ways that are more species-specific than food-based lures. For example, glandular secretions of conspecifics have been used to improve the capture rate of stoats (*Mustela ermine*) and ferrets (*Mustela putorius furo*) in the wild (Clapperton et al., 1999; Spurr et al., 2004). In a similar vein, the olfactory cues of predatory species have been used to suppress the activity of small mammals (Apfelbach et al., 2005). Ward et al. (1997) and Yin et al. (2011) confirmed that the presence

of predatory scents can reduce the foraging activity of hedgehogs (*Erinaceus europeaus*) and Norwegian rats (*Rattus norvegicus*), respectively.

Monitoring rat populations in wild environments largely involves tracking tunnels to estimate densities through an index of activity. Subsequent control is typically landscape-scale poisoning and trapping operations that predominantly use food-based lures to attract and deliver poison to target individuals (e.g. Clapperton et al., 1994; Gillies and Williams, 2001; Gould et al., 2007). However, the efficiency of return from these strategies (i.e. the number of kills) diminishes rapidly as the population size declines. There is also growing public concern for the use of intensive and widespread poison programmes within New Zealand (Eason et al., 2010, 2011). Thus, identifying and developing new olfactory cues are required to improve rat detection and control through kill trapping. This is particularly important in wild habitats where rats are at low and invading densities (Russell et al., 2008).

Another method of control may be to develop a means of manipulating olfactory cues used by predators, to better hide prey that are otherwise highly apparent to rodent olfactory systems (i.e. Price and Banks, 2012). Despite this, techniques that disrupt, or by other means manipulate olfactory systems for conservation are not well developed or widely applied (Campbell-Palmer and Rosell, 2011). The exceptions have been research programmes for flagship, conservation-reliant species in captivity (Swaisgood et al., 2000, 2004) or species subject to intensive *in situ* management (Linklater et al., 2006; Jackson et al.,

2012).

It is well established that New Zealand's avifauna has evolved largely in absence of predatory mammals and as such, is vulnerable to introduced mammalian predators and competitors. Of these, rats have caused significant reductions in avifaunal biodiversity within New Zealand (Holdaway, 1989; Atkinson and Cameron, 1993; Dowding and Murphy, 2001; Moorhouse et al., 2003; Remeš et al., 2012). Strategies that are able to reduce the effect of rats on endemic native species are, therefore, of significant conservation importance (Moorhouse et al., 2003; Pierce and Westbrooke, 2003; Remeš et al., 2012).

We sought to determine whether rats utilise olfactory cues from the faeces of native avian species to locate prey – the first step towards identifying, refining and reproducing an avian faecal olfactory cue that can improve rat detection and trapping. Rats are known to raid kaka (*N. meridionalis*) nests found close to ground-level on Kapiti Island, and reductions in wild rat populations have been shown to improve kaka juvenile recruitment (Wilson et al., 1998; Moorhouse et al., 2003). North Island brown kiwi (*A. mantelli*) are renowned for the strong smelling faecal products, which contain volatile hydrocarbons that are presumably used for intraspecific social communication (Castro et al., 2010).

We hypothesise wild rats will be more attracted to tracking tunnels containing the avian faecal scent than control tunnels adjacent (without any avian scat present). Similarly, we expect rats will be detected in control tunnels paired with avian scat treated tunnels, although the detection

rate is expected to be significantly less. Paired control tunnels are furthermore predicted to provide the lowest rates of tracking, with no incentive present for rats to investigate tunnels (albeit a new object in their environment). By understanding the processes and signals by which rats locate avifaunal prey it may be possible to improve conservation efforts of vulnerable bird species by masking (to reduce predation rates) or developing a lure (to improve capture rates) thereby reducing the effect of mammalian predators in the New Zealand landscape.

Methods

To track rats, tracking tunnels were constructed using corrugated plastic sheets to dimensions 10 x 11 x 60 cm (width x height x length). Within each tunnel, an extra sheet of plastic (10 x 60 cm width x length) was made to house a sponge (soaked in Indian ink) in the centre of the tunnel. Two 168 cm² sheets of blotting paper were placed either side of the sponge, covering both entrances, to record footprints from the inked sponge (Figure 1).

For the treatment, fresh kiwi and kaka scat was obtained pooled together from Wellington Zoo and frozen at -18 degrees Celsius at Victoria University of Wellington Ecology lab until needed for experiments (< one month). For treatment tunnels, scat was thawed and sufficient distilled water was added to the scat sample to enable us to dispense it from a 50 ml syringe (≤ 10 ml water). This solution was added to cotton wool balls and fixed to the center of tracking tunnel ceiling using a paper clip. Control tunnels did not contain any scent, nor

cotton wool as we were interested in determining whether bird scat would provide a means of detection, and not directly at comparing its efficiency to food-based lures.

Experiments were conducted between July–August 2011 in areas of regenerating native bush in Wellington City. We selected five areas, each containing two sites ≥ 1 km apart, within three suburbs (Karori, Kelburn and Northland; $n = 10$) which had not received any pest management before or during the analysis. At each site we conducted two 5-day tracking experiments in a randomised design: tracking tunnels were placed in pairs ≤ 5 m apart and consisted of either one tunnel containing scent (pooled kiwi and kaka scat), and the other a control tunnel (hereafter T-C), or both were control tunnels (hereafter C-C). The order was randomised to remove a treatment order bias. Tunnels were checked on days one three and five, and scat solution was topped up in treatment tunnels on day 3.

Statistical analyses

To analyse the response (tracking), the blotting paper from each tunnel was overlaid with a grid of 1 cm² squares.

The number of grid squares containing footprints were counted across both blotting sheets per tunnel, and the mean proportion of grid squares with footprints present calculated for each tunnel to provide an index of rat activity for treatment and control tunnels. Rat activity amongst tunnels was not normally distributed and its variance was not homogeneous. Thus, we conducted a permutation analysis of variance with 1000 replicates to test for treatment effects (Quinn and Keough, 2002). We compared the response (the proportion of blotting paper occupied by footprints) in T-C vs. C-C tunnel pairs as well as within the T-C pairs to determine whether rats tracking was greater in scented tunnels. To reduce the likelihood of type I errors, a sequential Bonferroni correction for multiple tests was applied to the significance values of the two tests; T-C vs. C-C, between treatments and T vs. C, within treatment tests (S. Pledger, pers comm.). Statistical analyses were conducted in R statistical environment version 2.15.1 (R Core Team, 2012).

Results

No rat footprints were observed in C-C treatment tunnel pairs but the T-C pairs were tracked by rats (proportion of



Figure 1. View of tracking tunnel inset with two sheets of blotting paper paper (168 cm² each) showing tracked footprints of *Rattus* species with Indian ink soaked sponge (center).

Table 1. Summary table of values obtained of rat footprints found in tracking tunnels pairs Treatment-Control (T-C) and Control-Control (C-C). Noticeably, no C-C conditioned tunnels produced tracking evidence.

Site	Treatment	Proportion area occupied	Treatment	Scent lure present	Percentage area occupied
1	C-C	0	T-C	Yes	23
		0		No	0
2	C-C	0	T-C	Yes	0
		0		No	0
3	C-C	0	T-C	Yes	0
		0		No	0
4	C-C	0	T-C	Yes	0.8
		0		No	0.3
5	C-C	0	T-C	Yes	0
		0		No	0
6	C-C	0	T-C	Yes	0.9
		0		No	0
7	C-C	0	T-C	Yes	0
		0		No	0
8	C-C	0	T-C	Yes	10
		0		No	0
9	C-C	0	T-C	Yes	0
		0		No	0
10	C-C	0	T-C	Yes	18.1
		0		No	7.14

blotting paper with footprints range in T-C pairs 0 - 23%; Table 1). Scat treated tunnels (T-C) had the greatest activity recorded with lower rates in the adjacent control station (C) (Figure 2). Notably the treatment C-C had no area occupied as these stations recorded no footprints.

The T-C treatment tunnel pairs were significantly more tracked than C-C tunnels (1000 permutations, $n = 40$, $P < 0.05$; Figure 2). Furthermore, the difference in rat activity between treatment T (0 – 23%) and control C (0 – 7.4%) tunnels in T-C tunnel pairs could be attributed to the influence of avian faecal scent in treated tunnels (1000 permutations, $n = 20$, $P < 0.0005$).

Discussion

The kiwi and kaka faecal scent lure significantly increased rat activity in tracking tunnels in suburban Wellington City. The ability to detect rats by tracking tunnels may increase if more rats are motivated to visit a tracking tunnel. The scent may also have prompted an individual rat to investigate the same tunnel repeatedly where it would not typically do so in the absence of the avian scent. Regardless of which of these possibilities is most true, rats appear motivated to investigate tracking tunnels by the olfactory cues from avian faeces.

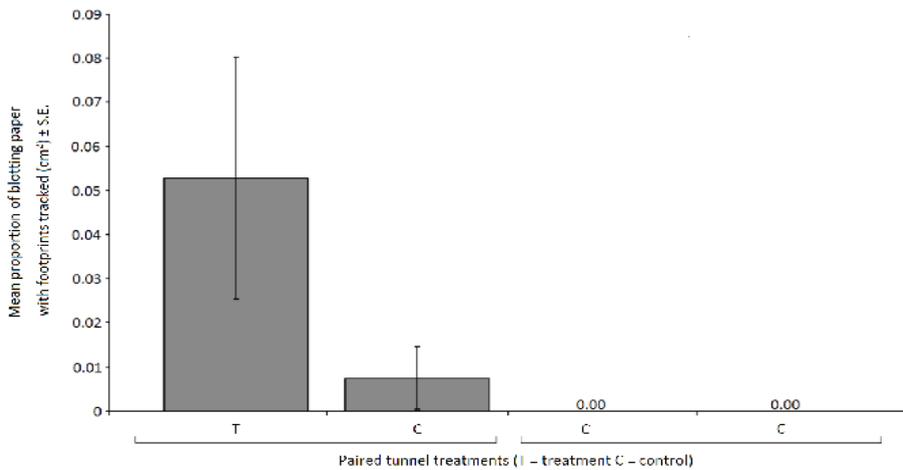


Figure 2. Bar graph of the mean proportion of blotting paper occupied by footprints (to index activity) within tracking tunnels of treatment pairs Treatment-Control (T-C) and Control-Control (C-C).

The notable absence of footprints in all C-C tunnel pairs is of interest as it appears control tunnels (which would only provide shelter) were not themselves sufficient to motivate rats to enter and cross inked sponges and blotting paper, at least in suburban Wellington. The result is particularly surprising because live-trapping of rats around Wellington City indicates that both ship and Norway rats are common in the recreational and revegetating city green space areas adjacent to residential environments (W. Linklater, unpublished data). This is especially true for the latter species which is more commonly caught, as they are more likely to use tunnels, whereas ship rats are more arboreal (Innes, 2005a,b).

The absence of rat tracks in tunnel pairs without a scent lure illustrates the importance of a lure in tracking tunnels when they are used for the detection and estimation of wild populations using activity indices. Tracking tunnels without lures are thus unlikely to be sensitive rodent population detection tools. Having a

scent present in one tunnel allowed for residual detection of rats in paired control tunnels, although the effect of avian faecal scent is shown to be a significant attractant in our analysis.

Since the control tunnels did not contain cotton wool, it is possible that rats may have been attracted to the cotton wool in the treatment tunnels alone. Although this is unlikely, we suggest further work investigating the role of prey scent in tracking and trapping of small mammals. For example, in intensive breeding programmes of *Apteryx* spp. and *Nestor meridionalis*, both conservation-reliant taxa, it may be prudent to mask or remove faecal scents where rodent predation risk cannot be entirely removed. The threat to nest boxes, in particular, may be minimised if they are routinely cleaned of avian faeces. Price and Banks (2012) have shown that introducing a quail scent to artificial nests before the introduction of quails minimised the likelihood of predation by rats and attributed this to the signal (i.e. scent) becoming less significant for

rats to investigate as the signal did not pertain to a reward (prey). By identifying key signal compounds in conservation reliant bird taxa, it may be possible to mask the location of nests by providing a blanket of scent which is unrewarding to predatory mammals.

Improving our understanding of the olfactory cues rats use to locate prey may lead to improvements in rat monitoring and control, or reductions in the risks to avian breeding success through improved scent lures or scent management. The next stage of this research is to evaluate whether faecal scent can act as a greater attractant than standard food-based lures (Clapperton et al., 1999; Gould et al., 2007) and evaluate the degree to which faeces alone contribute to avian nest detection where several cues may be used by rats. Research to identify what volatile chemicals found in faeces contribute most to rat attraction is still required. Nonetheless, studies of olfaction hold considerable promise for novel conservation tools.

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