Laboratory rats as trap lures for invasive Norway rats: field trial and recommendations

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Abstract: The Norway rat (*Rattus norvegicus*) is a highly destructive invasive species but while rat eradications on islands are effective, detection of survivors or reinvasions is challenging. We tested whether laboratory rats can act as lures for wild rats. We live-trapped rats first by using food baits, followed by live trapping using male and female lure rats vs controls (i.e. the same trapping device but without the lure animal). Norway rats were more frequently attracted to lure rats compared with controls. There was no sex bias in the trapped animals. Numbers of Norway rats caught with food baits compared with lure rats did not differ, but trapping rates were higher when using lure rats. Rat activity was detected only around lure rats. Ship rats (*Rattus rattus*) were not caught with Norway lure rats. We demonstrate the potential for detecting invasive Norway rats using conspecific rats as lures. Further research looking at conspecific attraction in other situations and in direct comparison with food-baited traps is needed to determine the efficacy of this method as a control measure.

Keywords: conspecific; eradication; invasive species management; rat control; *Rattus norvegicus*

Introduction

The Norway rat (*Rattus norvegicus*) is a highly successful and destructive invasive species worldwide (Long 2003; Jones et al. 2008). Norway rats have been eradicated from many offshore islands (Towns & Broome 2003; Howald et al. 2007) and from several predator-proof-fenced inland sites (Speedy et al. 2007). However, because of the species' remarkable swimming abilities (Harper 2005; Russell et al. 2005) and its capacity to survive on small vessels (Harper 2005), reinvasions to rat-free islands remain a threat. Thus, the detection and targeting of new invasions or remaining survivors is a high management priority.

The methods most commonly employed for the detection and control of invasive rats include kill traps, tracking tunnels, and poison stations, all of which are food baited (Dilks & Towns 2002; Howald et al. 2007; Russell et al. 2008a). In New Zealand, the Department of Conservation is also using rat-detecting dogs (Dilks & Towns 2002). However, when populations of pest rats are at low densities, such as during the early stages following reinvasions, these methods often prove ineffective, probably because competition is low and food is abundant (Thorsen et al. 2000; Dilks & Towns 2002; Russell et al. 2005, 2008b). In 2010, for example, the detection system on rat-free Ulva Island (off Stewart Island, New Zealand) failed to detect the presence of invading Norway rats, which subsequently resulted in the establishment of a new population (Masuda & Jamieson in press). In some other recent island incursions, it took 3–4 weeks to capture individual rats after an incursion was detected (F. Buchanan, S. O'Connor, DOC, pers. comm.).

Norway rats are highly sociable, and complex intraspecific interactions are key components in their behaviours (Barnett 1958; Calhoun 1963; Boreman & Price 1972). Therefore, we tested whether caged laboratory rats (*Rattus norvegicus*) could act as lures for wild Norway rats. Previously, the feasibility of intraspecific attraction in an invasive rodent using live conspecifics under field conditions had only been superficially tested. Wace (1986) tried to lure Norway rats with laboratory rats, but in sites that retrospectively were found not to be inhabited by Norway rats. Gsell et al. (unpubl. data) tested the efficacy of lure rats against food, but as they used only tracks, the species and sex of the visiting animals could not be determined. Conspecific odours as attractants are more common, and traps scented with house mouse (*Mus musculus*) odour have been found to enhance the capture rates of this species (Volfova et al. 2011). Other rodent species (*Peromyscus maniculatus, Dipodomys agilis* and *D. merriami*), however, when not in reproductive condition, were more attracted to neutral over scented traps, implying periodic avoidance of social interactions (Daly et al. 1980).

We used live animals because the relative importance of each sense in this species' social interactions is largely unknown, and confining the study to scent alone might limit the power of attraction. Live animals, such as goats (Taylor & Katahira 1988), mynas and crows (Tidemann 2005; Tsachalidis et al. 2006), have been used elsewhere as conspecific decoys, thus providing encouraging examples of the importance of social behaviour in the detection and capture of invasive animals.

Our objectives were to (1) detect possible differences in the attractiveness of cages containing lure rats (males and females) vs control cages (which contained the same food as in the lure animal cages), (2) detect possible differences in the attractiveness of male vs female lure rats, and (3) compare the attractiveness of lure rats vs food bait for wild Norway rats.

Methods

We conducted the study during May–June 2010 at Shakespear Regional Park (36°36′23.42″ S, 174°48′38.85″ E), Auckland, New Zealand. Mammalian pest control in the park consisted of trap lines and poison-bait stations. We conducted our experiments in bush and scrub in the western section of the park's wetland.

In order to assess population density and tag as many individual Norway rats as possible, we performed preliminary trapping at the site during 180 trap nights (TN) using double-door live traps (16 × 16 × 70 cm; Neal Blaymires, Te Puke, New Zealand) partly covered with corrugated plastic for weather protection and baited with carrots and peanut butter. Traps were spaced between 30 and 70 m apart, depending on the terrain (Fig. 1b,c). Traps were visited early mornings and re-baited as required (where bait was missing) or every 3 days.

Trapped Norway rats were removed into an anaesthesia chamber (13 × 13 × 30 cm), anaesthetised with isoflurane gas, and had PIT tags (Allflex Australasia, Palmerston North, New Zealand) injected under the skin between the shoulders. Animals were placed in a cotton bag for weighing and recovery, after which they were released at the site of capture. We identified tagged animals with a reader (Allflex RS200-1, France). Ship rats (*Rattus rattus*) were not tagged.

We used four male and four female laboratory rats (cross breeds between albino and hooded races) as lures. The lure rats were housed individually in custom made wooden and metal wire mesh cages (25 × 25 × 50 cm). Each cage incorporated a nest box, an inner food compartment and a water bottle. Grain-based pellets (Rodent chow 86, Massey University, Palmerston North, New Zealand) and fresh water were provided *ad libitum* throughout the experiment. Control cages were set up identically but without the lure rats.

All cages (lure rats and controls) were placed individually inside rectangular enclosures made of white corrugated plastic and metal wire mesh (40 × 60 × 80 cm) on a wooden frame. The top and sides of the enclosures were covered by corrugated plastic and the front, rear and floor were covered with wire mesh. Inside the enclosure, the cage was placed on one side and a double door live trap (as above) was placed on the other side with doors open to the front and the rear of the enclosure (Fig. 1a). This design enabled us to protect the lure animals from the weather while providing the wild rats with a corridor to access the inner cage through the trap. To provide trapped animals with food and at the same time minimise the effect of food bait, we placed inside the traps small sealed plastic bags containing two or three rodent pellets. We distributed the enclosures in four clusters, each with a lure male, a lure female and control, separated by 20 (±5) m. The clusters fall within the minimum home ranges recorded for both male and female Norway rats in natural and farming habitats (85–90 m; Innes 2005b). Control enclosures were always placed between the lure rat enclosures. The orientation of the male and female enclosures was random. Distances between clusters were between 100 and 500 m (Fig. 1a).

We conducted the experiment over 17 consecutive nights (total of 68 trap nights for each type of treatment). Enclosures were visited early mornings (0600–0800 hours) and any trapped Norway rats were processed using the same handling and tagging procedure as in the preliminary trapping. To avoid

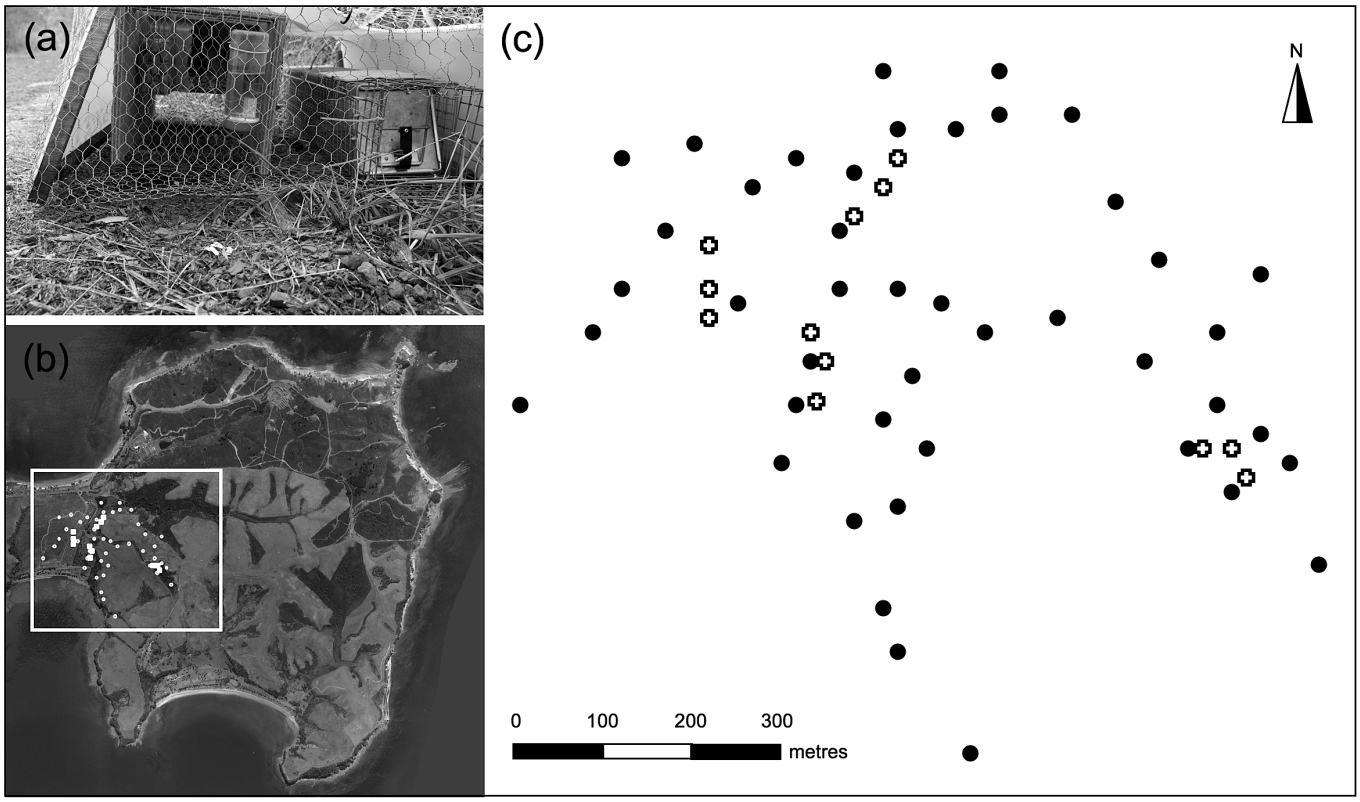

Figure 1. (a) Front view of a live-lure enclosure showing the lure rat's cage (left) and the live trap (right). (b) Shakespear Regional Park with the study site and trap locations. (c) Enlarged scheme showing arrangement of traps. Closed circles represent traps baited with food and open crosses represent a cluster of traps including both male and female lure rats and a control. Aerial map courtesy of Land Information New Zealand. GIS layers by B. Kreigenhofer.

rat habituation to an enclosure, which could prevent other individuals from entering the traps, any Norway rats that were caught three times in the same trap were euthanased with isoflurane and removed from the site. We also recorded signs of rat activity around the enclosure (i.e. faeces and digging) and sprung traps. We used two infrared cameras coupled with a portable digital video recorder (AVerMedia, EB1304 MOB, Taiwan) to verify that the observed signs of activity were due to wild Norway rats.

Data analysis

Conservative estimation of Norway rat densities was made by dividing the number of unique animals caught (during both bait and live-lure trappings) by the total area they were caught in. We considered 200 m beyond the clusters to be the area borders. We calculated corrected trap-night (CTN) values by subtracting half the number of trapping events and trap setoffs from the total number of trapping nights (Cunningham & Moors 1996). We compared trapping rates of Norway rats (not including recaptures) as a function of treatment (conspecifics vs controls), cluster (fixed factor), and CTN (variate), using ANCOVA. We also used ANCOVA to compare trapping rates of Norway rats as a function of treatment (male vs female lures), cluster and CTN. We used chi-square tests to compare gender distributions of trapped Norway rats for each treatment, as well as gender distributions of trapped Norway rats between lure males and lure females.

To evaluate trap efficiency, we compared the number of unique Norway rats caught per trap between food bait preliminary trapping, lure rats, and controls using one-way ANOVA and Bonferroni *post hoc* correction. We calculated rates of non-trapping activity made by Norway rats near the traps. Signs of activity (digging and scats) were marked as 1 for each night if present and 0 if not present. We then calculated the mean activity for each treatment.

Results

Total trappings of unique Norway rats (food-bait and live-lure trappings combined) yielded an estimation of five rats per hectare. Trapping rates of Norway rats were higher with lure rats than with control cages (ANCOVA; $F = 248.18$, d.f. = 1, $P = 0.004$; Table 1). Cluster, but not CTN, had an effect on trapping rates (ANCOVA; $F = 30.02$, d.f. = 3, $P = 0.032$; and $F = 0.062$, d.f. = 1, $P = 0.825$; respectively). There were no differences in trapping rates between male and female lures (ANCOVA; $F < 0.000$, d.f. = 1, $P = 1$). Corrected trap nights (CTN), but not cluster, had an effect on trapping rates (ANCOVA; $F = 19.6$, d.f. = 1, $P = 0.047$; and $F = 12$, d.f. = 3, $P = 0.077$; respectively). We found no differences in gender distribution among Norway rats caught using food bait, lure rats and controls (chi-square test; $\chi^2 = 0.6$, p = 0.98). There was no evidence that the gender of the lure rats had an effect on the gender of the trapped animals (chi-square test; $\chi^2 = 0.62$, p = 0.89).

Trapping rates (captures per trap laid) were higher using lure rats than either controls or food baits (one-way ANOVA and Bonferroni *post hoc*; $F = 6.25$, d.f. = 2, $P = 0.004$; Fig. 2). Signs of activity (in the form of digging and faeces) were recorded near six of the eight lure-rat enclosures (on up to 13 nights out of the total 17 per enclosure). Four of those had major digging under the enclosures and they were re-excavated by the wild rats every night after we blocked the tunnels each morning. Rodent activity of this nature was never observed near control enclosures or near food-baited traps. Video footage verified that Norway rats were responsible for these signs of

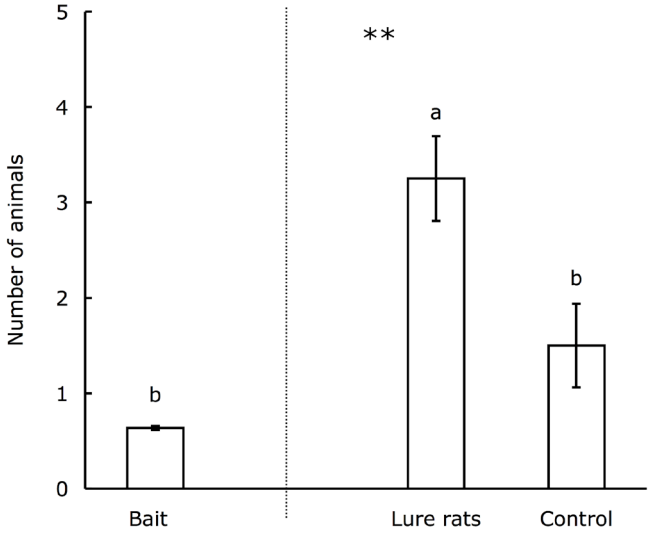

Figure 2. Unique captures (mean ± SE) of Norway rats (*Rattus norvegicus*) per trap. Dashed line indicates separation in time of trapping. ** corresponds with $P < 0.01$. Letters above columns represent significant *a posteriori* comparisons.

Table 1. Number of unique Norway rats (*Rattus norvegicus*) caught with lure rats (males and females combined) and controls (without lure rats) in four clusters (traps in a cluster were 20–25 m apart with the control always in the middle between the lures).

Cluster	Treatment	Trap nights (TN)	Corrected TN	Trappings
A	Lures	34	30	7
A	Control	17	14.5	2
C	Lures	34	31.5	4
C	Control	17	17	0
E	Lures	34	31.5	5
E	Control	17	16	0
F	Lures	34	29	8
F	Control	17	15.5	3

activity (no other species were recorded) and revealed that on eight occasions there were multiple wild rats at the enclosures simultaneously (six occasions of two rats and two occasions of three rats) and multiple cases of rats investigating the trap entrance but not entering the trap.

Ship rats were caught during the preliminary trapping and in the control cages but never in the lure-rat cages. The infrared cameras detected ship rats near a lure-rat enclosure only after the lure animal was removed.

Discussion

All strains of laboratory rats are derived from wild Norway rats. Norway rats are highly social animals, exhibiting complex interactions including inter- and intra-sexual and within and between familiar and unfamiliar individuals (Barnett 1958; Calhoun 1963; Boreman & Price 1972; Alberts & Galef 1973; Robitaille & Bovet 1976; Galef & Allen 1995). We report here for the first time on the manipulation of the Norway rats' social traits, successfully using laboratory rats as lures for invasive wild Norway rats.

Norway rat density at the study site was estimated at five per hectare. This is probably an underestimate, however, as trapping usually underestimates actual rat numbers (Innes 2005b). Moreover, at least half of the area used as the denominator for calculating density was formed of grazing paddocks (a very poor habitat) and therefore the realistic rat density in the experimental area was probably higher. It is therefore safe to assume that rat density at the time of the study was relatively high (2.6–4.2 rats ha^{-1}, but up to 13 rats ha^{-1} in similar habitats; Innes 2005b).

Norway rats were more attracted to lure rats than to the control cages containing the same food and water as supplied to the lure animals. Norway rats are mobile foragers, but their home ranges can vary widely depending on population densities and food availability (Innes 2005b). Chance and Mead (1955) found that investigative behaviour in Norway rats was the dominant trait in an unfamiliar environment, but it did not conflict with other behaviours (i.e. feeding) once the animal was familiar with the environment. Our results suggest, therefore, that the higher trapping rate with the lure-rat cages, and the rat activity observed near the lure rats' enclosures compared with the controls, were not random. Significant differences in trapping rates between the clusters were probably due to Norway rats' uneven spatial distribution, which is habitat dependent, as demonstrated by Innes et al. (2001).

There was no difference between the absolute numbers of rats caught with lure rats and by food baiting. However, trapping rates (average number of animals caught per trap laid) were higher when lure rats were used (i.e. the same number of unique trappings using many fewer traps). Moreover, detection of rat activity, in the form of faeces and digging, was observed only near lure rats. The observations from the video footage suggest that lure rats have the potential to attract more than one animal at a time, and that rats were visiting the lure rats without going into the traps. This suggests that our trapping rates with the lure rats are underestimating the true potential of this luring method.

We failed to detect significant differences in attractiveness based on the gender of the lure rats. Studies of social behaviour in the Norway rat have shown that when a new male (but not female) was introduced to a colony, it was attacked by the alpha male and to a lesser extent by the alpha female (Barnett 1958; Takahashi & Blanchard 1982). Calhoun (1963) found aggressive interactions within a colony to be inter- and intra-sexual, but male–male interactions were more common. The high trapping rates observed in this study suggest that it was not only dominant individuals that approached the cages. However, the apparently calm behaviour of the wild rats near the enclosure revealed by the video footage suggests that aggressiveness toward lure rats at these densities is probably not common and that attraction seems not to be based on aggression.

Our results also support findings by Shapira et al. (unpubl. data) suggesting that ship rats avoid laboratory rats when the latter are used as lures in the field. Findings by Wace (1986) suggesting some degree of trappability of invasive ship rats with lure laboratory rats might be the result of the former's naïveté to Norway rats at the study site. These rat species often share the same environment (Yom-Tov et al. 1999; Innes 2005a, b), where they compete for food and space. Dominance trends in the interactions of these species are apparently strongly influenced by habitat use (Harper et al. 2005; Harper 2006; King et al. 2011). However, the actual mechanisms of competition and competitive exclusion (i.e. direct or indirect) are poorly understood. Our trapping results, together with the video footage (showing that ship rats were visiting the enclosure only after the lure animal was removed), suggest that this species avoids physical contact with Norway rats.

Species' behavioural traits are important considerations for understanding biological invasions (Holway & Suarez 1999), but despite their potential as a powerful tool for conservation management (Buchholz 2007), the manipulation of invasive species' behaviour for pest control has been mostly limited to food baiting. Live animals are employed as lures for invasive heterospecifics, as in the case of the brown tree snake *Boiga irregularis* in Guam, which is attracted into traps by live mice (Vice et al. 2005), and invasive conspecifics such as radio-tagged wild goats are used to locate otherwise hidden aggregations of animals (Taylor & Katahira 1988). Examples of live luring, especially using conspecifics, are very limited however. Our results demonstrate for the first time that conspecific attraction in an invasive rodent is feasible as a detection and capture tool.

Our lure system does not discriminate between the means of attraction and the relative importance of each sense. Both olfactory communication (Cheal 1975) and vocalisations are crucial aspects of Norway rat social behaviour (Barfield et al. 1979). Our video footage hints that the presence of the actual animal can have considerable appeal, in which event a multi-modal form of signalling is probably the most effective method for luring conspecifics. Conspecific chemical attraction in the form of pheromones is regularly used to enhance pest-insect trapping rates (Burkholder & Ma 1985; Copping & Menn 2000) and attracting birds with conspecific playbacks is common as a conservation tool (Ward & Schlossberg 2004; Hahn & Silverman 2007). Rat beddings as well as playbacks will probably attract wild rats as well and we suggest that the effectiveness of rodent bedding and vocalisation should be tested as alternatives to live animals.

The live-lure-rat method discussed here is novel. Our results demonstrate that there is a potential for its employment as a detecting tool. Although Lawrence (1999) concluded that live lures had no practical place in a stoat management operation and added considerably to the time it takes to check a trap line, from our experience, apart from the need to visit the traps daily, the maintanance of the lure animals was reasonable for

a limited period and is in our opinion worth the extra effort. Because maintenance of caged live animals in the field is impractical for long periods, we suggest that the potential to use this method as a part of a management strategy should be for specific events where food bait might fail (i.e. incursions, reinvasions) or for enforcement of existing control measures during sensitive periods (i.e. native birds' breeding seasons). In addition, by-products of signs of activity around lure traps (i.e. faeces, fur) might be useful for analysis of species present and individual recognition through DNA sampling. Further direct comparisons with other trapping methods are still required in these scenarios in order to determine this method's efficacy. Given the severe effects that invasive Norway rats pose on the environment, we believe this to be a promising line of research.

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