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SHORT COMMUNICATION

Evaluation of a rat ultrasonic vocalisation as a novel audio-lure in two New Zealand forest settings

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Abstract: Actively attracting rats to trapping and baiting areas would potentially reduce the costs and labour required for controlling rats over large areas of forest. In this pilot study we explored the potential of using an ultrasonic lure to attract rats in two forest study areas: Tuateawa and Te Hoe. Data was collected from the Tuateawa study area over 21 discrete 24 h periods using tracking tunnels and cameras. Results indicated that rats were present more often at sites where a 50 kHz Norway rat ultrasonic vocalisation (USV) was played compared to sites where it was not played, although significance could not be attributed based on the low numbers detected. Interestingly, mice were detected at the Tuateawa study area more often at sites where the USV was played compared to sites where it was not played, with differences approaching a significant level of confidence ($p = 0.059$). At the Te Hoe study area, data was collected over a three-month period using A24 self-resetting traps and cameras. Results indicated that the weekly numbers of rats killed was higher ($p = 0.025$) at sites where USVs were played than at sites where USVs were not played. These findings indicate that rat USVs can attract rats and mice to trapping areas in New Zealand forest settings and support the view that including USVs in trapping methods could potentially enhance the efficiency of trapping and hence reduce the costs associated with current methods.

Keywords: pest control, *Rattus*, ultrasonic lure, USV

Introduction

New Zealand forests are home to a wide range of endemic plant and animal populations, whose survival is threatened by predation from invasive mammalian pests (Atkinson 2006; Russell et al. 2015; Russell & Broome 2016). Of particular concern are three introduced species of rat (*Rattus rattus*, *Rattus norvegicus*, and *Rattus exulans*) that are responsible for declines in native bird, reptile, and invertebrate species (Atkinson 2006). Efforts to reduce the impact of rats have tended to focus on reducing their numbers by trapping and poisoning programs. While such methods can be effective, they are relatively passive in that they require animals to approach close enough to the trap or bait station to detect the associated visual or olfactory lure. This can make trapping and poisoning both costly and laborious because they require the distribution and maintenance of large numbers of traps and bait stations across the areas needed to be controlled (Duron et al. 2017; Lee et al. 2022). Furthermore, intensive baiting programs can generate public disquiet, especially when applied in a perceived non-discriminatory fashion, such as aerially distributing poison pellets, or carrying out control programs close to human habitation and waterways. While complete eradication has been achieved in locations with hard borders, such as offshore and mainland islands, maintaining reduced rat numbers elsewhere to levels that allow native populations to thrive can therefore come at considerable cost in both resources and community relations (Parkes et al. 2017). A potential improvement to current control methods would be to reduce the required intensity of toxic bait and trap placement by moving towards a more active method of attracting rats from wider areas to focused areas of entrapment. This would potentially result in impactful numbers of rats trapped using a reduced density of trap placements for a particular area of pest control.

Rats are known to communicate using ultrasonic vocalisations (USVs). Long duration calls at frequencies between 18 kHz and 32 kHz (typically 22 kHz) have been reported as associated with alarm calls, whereas short duration calls between 35 kHz and 72 kHz (typically 50 kHz) are associated with appetitive calls (Brudzynski 2005). This is explained as vocalisations of the 22 kHz range being generated when a rat's cholinergic system is active, producing negative states in the rat, such as fear and insecurity; whereas 50 kHz signals are generated when the rat's dopaminergic system is active, resulting in positive states, such as a sense of security and well-being (Brudzynski & Chiu 1994; Brudzynski 2007). Lower frequency artificially created ultrasonic signals have been used to repel rats in a range of commercially available products (Shumake 1997). In contrast, emission of 50 kHz USVs has been linked to the promotion of play, exploration, and other social interactions in Norway rats (*R. norvegicus*)

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(Burke et al. 2017, 2021; Davidson & Hurst 2019; Inagaki & Ushida 2021). For example, after 50 kHz calls from female rats were played to males for durations of 15 min it was observed that male rats displayed approach behaviours and increased their exploration and time in the open (Inagaki & Ushida 2021). It therefore seems reasonable that 50 kHz signals played in an outdoor setting could attract local rats to the source of the signal. Success has been reported in the use of subsonic audio lures for attracting possums (*Trichosurus vulpecula*) and stoats (*Mustela erminea*) in New Zealand (Kavermann 2013; Williams 2021; Graham 2024). However, the use of USVs to attract rats in forest settings has not previously been reported. Internationally, USVs have been used to attract bats, many of which are attracted to frequencies around 50 kHz, and there are several digital acoustic lures available for these types of studies (see reviews by Aylen 2020 and Aylen et al. 2022). In particular, the Apodemus BatLure (Apodemus Field Equipment, Westerhoven, The Netherlands) presents as a potentially robust device useful for transmitting USVs in the 20–100 kHz range in forest setting for long periods.

In this study, we report our findings for a pilot investigation that examined the potential of using a 50 kHz Norway rat USV to attract rats to areas of detection and entrapment in two New Zealand forest settings. We hypothesised that rat numbers and entrapments would be higher in areas where the USV attractant was applied.

Methods

Study areas

Two study areas were used for this work, Tuateawa and Te Hoe, and a different detection method was used at each site. At Tuateawa, tracking tunnels and cameras were used to record rat presence/absence, whereas at Te Hoe, A24 traps (Goodnature, Wellington) combined with cameras footage were used.

Tuateawa

The Tuateawa study area was located approximately 3 km north of the settlement of Tuateawa on the Coromandel Peninsula, New Zealand (175.56 °E, 36.63 °S) and adjacent to Tuateawa Rd within the north-eastern extension of the Department of Conservation (DOC) managed Kennedy Bay Forest Park (Fig. 1). Tuateawa Road connects Little Bay with Kennedy Bay on the north-eastern coast of the peninsular and the area was chosen for its accessible location, conservation importance, and history of rat activity. The area contains remnant populations of kaka (*Nestor meridionalis*) and brown kiwi (*Apteryx mantelli*), as well as regenerating forests of coastal broadleaf and kauri (*Agathis australis*). Two sites within the area were chosen for the study. The first site was located approximately 100 m inland on the seaward side of the road, where the land descends eastward towards the headwaters of the Taiharuru Stream. The second site was approximately 200 m from the

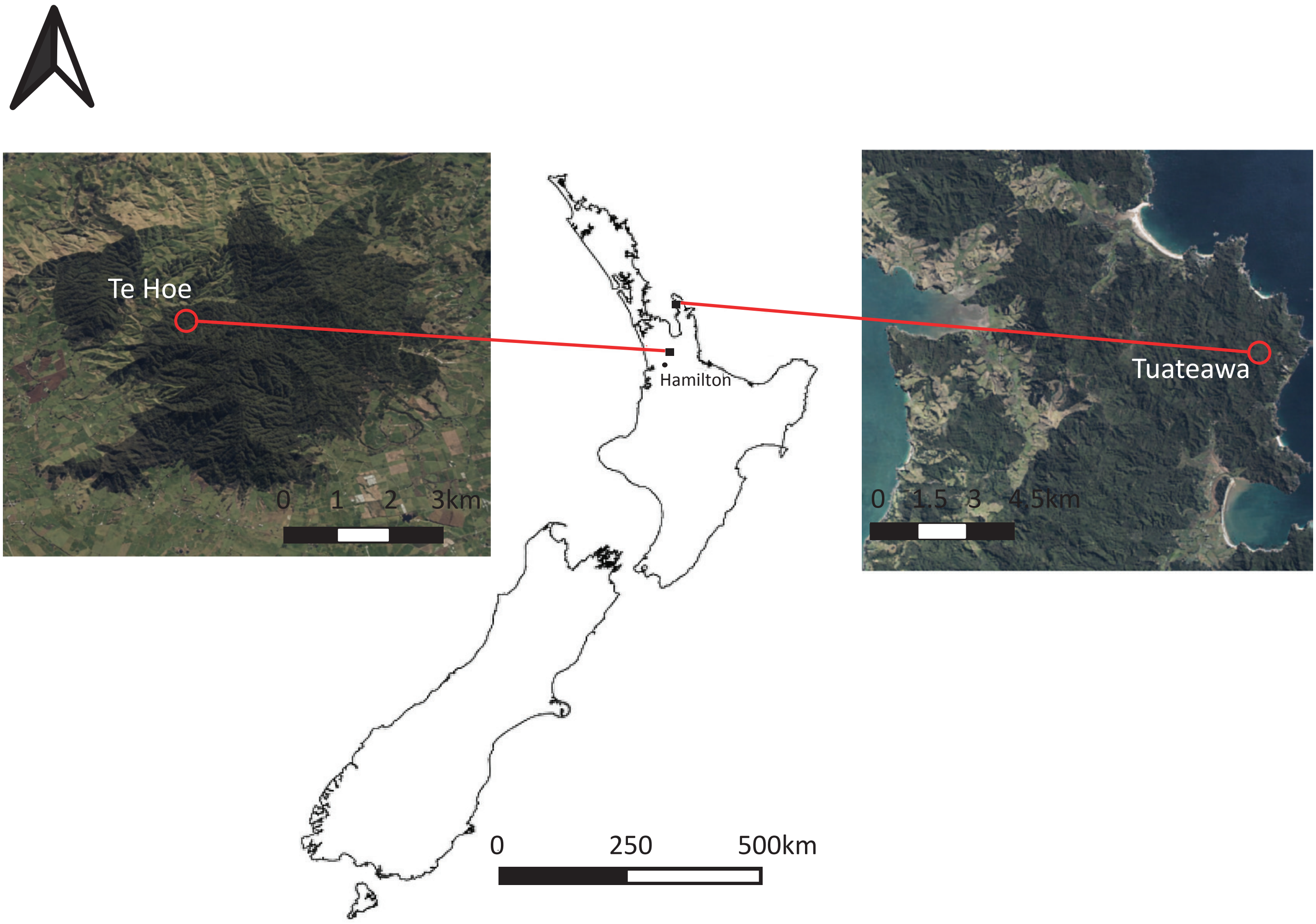

Figure 1. Location of the two areas used to examine rat ultrasonic vocalisations as potential audio-lures. The right inset shows the Tuateawa study area, and the left inset shows the Te Hoe study area.

first site, on the inland side of the road at a point where the land slopes westward toward the headwaters of the Tuateawa Stream. Rats were known to be active at both sites from annual monitoring data supplied by Habitat Tuateawa (HT) - a local pest control group. At the time of the study, rat and possum control was being applied to adjacent areas by both HT and Moehau Environmental Group (MEG) using trapping, however the two sites chosen for study had not received previous rat control as they had formed part of a previously used negative control area for monitoring.

Te Hoe

The Te Hoe study area was in a large block of remnant and regenerating broadleaf and kauri forest approximately 5 km north of the township of Te Hoe in the northern Waikato (175.35 °E, 37.48 °S; Fig. 1). The area was chosen for its accessible location, potential conservation value, and anecdotal information suggesting it may contain a high level of rat activity. The area was on private land adjacent to the Mangatea Stream amongst areas of mixed sheep and beef farming (Fig. 1). At the time of the study the forest block was not actively pest controlled, and the landowner had observed a paucity of birdsong in the block as well as noticing that rats were being caught around farm buildings nearby the study area (Ross Baker, landowner, pers. comm.). As with the Tuateawa study, two sites were selected within the Te Hoe study area that were approximately 200 m apart. Both sites were in steep wooded forest, approximately 60 m above the Mangatea Stream on its southern bank. Each site bordered a gully area where tributary creeks fed the Mangatea Stream. The presence of rats at the two sites within the Te Hoe study area had been confirmed two months earlier by Wintec project students using tracking tunnels and cameras placed at each site for three consecutive periods of seven days.

Methods

Tuateawa study area

The Tuateawa study was conducted between December 2023 and August 2024. The study examined whether rats were more attracted to sites within the area when social USVs were present compared to when social USVs were absent.

On the first day of the study, one tracking tunnel (Traps.co.nz, Christchurch, NZ) was placed on a flat area of ground at each of the two sites that had been selected within the Tuateawa study area. Each tracking tunnel was fitted with an inked tracking card, and smooth cinnamon lure (Connovation, Auckland, NZ) was applied to each end of the tracking card. A Minox DTC450 motion-detecting trail camera (Minox GmbH, Isny im Allgäu, Germany) was mounted on a tree approximately 3 m from each tracking tunnel, oriented so that the tunnel and immediate surrounding area could be monitored. The camera was fitted with a 32 GB SD card (130 MB s^{-1} write speed) and programmed to take 10 s video bursts with a 5 s delay between bursts. At each site, a weatherproof housing (illustrated in Fig. 2a) was mounted approximately 1.7 m above ground level on a tree adjacent to the tracking tunnel. At the first site, a BatLure digital acoustic lure (Apodemus Field Equipment, Westerhoven, The Netherlands) was installed in the housing, as illustrated in Fig. 2b. The acoustic lure was connected to a Remco 9 A/h 12 V sealed lead-acid battery (PBTech, Hamilton,

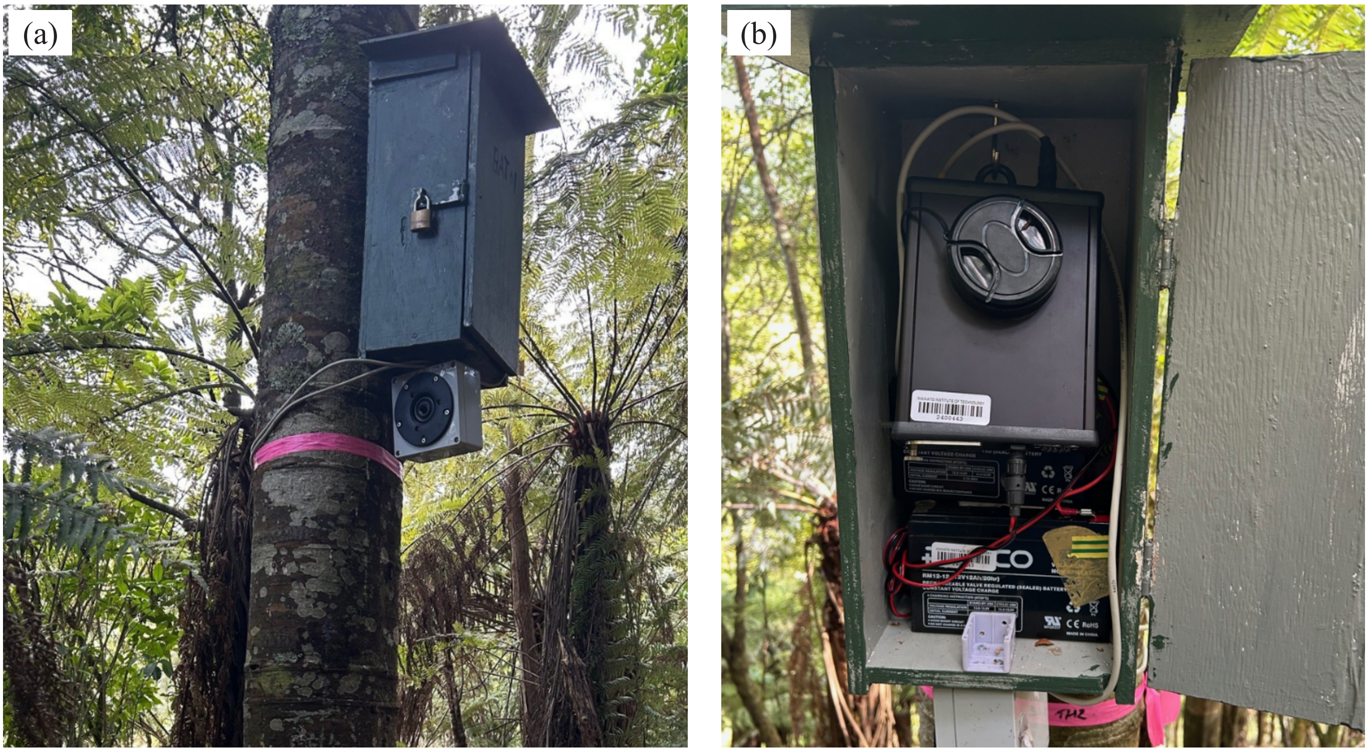

Figure 2. Weatherproof bio-acoustic lure housing mounted approximately 1.7 m above ground level on a Tanekaha tree at the Te Hoe study area. The weatherproof external speaker was suspended beneath the housing (a) and the Apodemus BatLure bio-acoustic lure installed inside the housing (b), connected to either one 9 A/h deep cycle gel-cell battery (Tuateawa 24 h study periods), or two batteries connected in parallel (33 A/h total) as shown for the longer Te Hoe study periods.

NZ), and a BatLure External Speaker BG60 (Apodemus Field Equipment, Westerhoven, The Netherlands) suspended underneath the base of the housing, as illustrated in Fig. 2.

The BatLure device was programmed to play a 16 bit wav file containing five repeats of a 50 kHz USV recorded from an oestrus female Norway (Fischer) rat (F344). The recording had been provided by Dr Hideaki Inagaki of Aichi Medical University, Japan (see Inagaki & Ushida (2021) for details), and the device was programmed to play the file in a continuous loop with a 5 s delay between repeats. The file was saved to a 32 GB SD card contained within the BatLure device. The volume was set at approximately two thirds maximum to prevent distortion at 50 kHz, as advised by the manufacturer. Successful broadcasting of the USV was confirmed by examining the waveform recorded by an Audiomoth v1.2.0 ultrasound recorder (LabMaker GmbH, Berlin, Germany) placed approximately 3 m from the external speaker during running.

The programmed BatLure device and camera were both switched on and left to run for 24 h. At the second site, the tracking tunnel and camera only were set up as described above and left to run for 24 h. After run completion, tracking cards were collected from both sites, and fresh cards and lure applied. Video files were downloaded from each camera and the cameras re-set. The BatLure device was then moved to the second site and installed, with freshly charged batteries, in the weatherproof housing that had previously been placed at that site. The BatLure device and cameras were then switched on, as described above, and left to run for a further 24 h study period, after which the data was collected as described above.

The above procedure was repeated for a total of 21 study periods between December 2023 and August 2024, with the BatLure device being moved between sites after each 24 h run. Rat presence was determined using both video and tracking card data. The presence of other animals was also recorded when detected. The study used two permanent sites in order to minimise site-variability and neophobia in the target species.

Te Hoe study area

The Te Hoe study was conducted between June and August 2025. This study examined whether more rats were killed when social USVs were present than when they were absent. Probable rat kills were determined to have occurred when A24 self-setting rat traps (Goodnature, Wellington) were triggered at a study site.

Two weeks prior to the study, one un-activated A24 trap was attached to a tree at each of the two Te Hoe sites. The traps were mounted approximately 15 cm above the ground. The weatherproof BatLure housings were attached to the same trees approximately 1.7 m above the ground, in the same manner as described for the Tuateawa study. The traps and weatherproof housings were then left in place for two weeks, so that local animals could become familiar with their presence. The Goodnature A24 monitoring application (app) was then downloaded (Apple App Store) and installed on a mobile phone. On the first day of the study, at each site, the A24 trap was activated according to the manufacturer's instructions. Briefly, the Bluetooth chirp was connected to the mobile phone app and the traps were each loaded with a nut-butter lure refill (Goodnature, Wellington). Each trap was then primed by installing a CO_2 gas cannister that had been supplied with the trap. Installation involved screwing the cannister into the trap socket so that pressure from the gas released into the trap forced the internal striker into a primed position behind a launch spring. Each cannister contained enough CO_2 gas to reset the trap 24 times after the striker was released by movement of a trigger set in front of the lure (the trap works by a rat, as it attempts to reach the lure, triggering release of the striker behind its spring, causing instant death through blunt trauma). A test strike was conducted by inserting a piece of card into the trap to trigger the trap at each site to ensure the trap worked (i.e. the spring-loaded striker was released and then re-set by the gas cannister) and the Bluetooth chirp recorded the strike to the downloaded mobile phone app. We had observed that data from the Bluetooth chirp did not always download automatically when the mobile phone was brought near the A24 trap. When this occurred, a gentle tap on the side of the chirp was sufficient to effect the connection, however we noticed that a harder tap could be incorrectly registered by the trap as a strike (i.e. a false positive), so video surveillance using the Minox cameras, which recorded time of video, was used to detect events where larger animals may engage with traps at the same time as strikes were recorded, so that they could be later discounted in the analyses. At each site a Minox camera (described earlier) was attached to a tree approximately 3 m from the trap so that the trap and its immediate surroundings could be monitored. Cameras were set to record 10 s intervals of video, with a 5 s delay between video captures as described earlier. At the first site, the BatLure device was installed in the weatherproof housing and connected to the BatLure external speaker as described earlier. The BatLure device was connected to a 9 A/h battery connected in parallel to a 24 A/h battery of the same type (33 A/h total). The BatLure device was then switched on and the 50 kHz Norway rat file, described earlier, played over a seven-day period through the external speaker (earlier tests had shown that the BatLure device would play continuously for at least 6 days under these conditions). The external speaker was oriented to play across a level area of terrain toward a nearby gully in the opposite direction to where the second site was located. The cameras at both sites were then switched on and the areas left for seven days, after which time trap activity data at both sites was collected using the phone app. Video records were downloaded from the cameras. The BatLure device was then moved to the second site, where it was installed in the weatherproof housing and connected to freshly charged batteries and the external speaker, which was oriented in the opposite direction to the first site. The downloaded trap data contained the number of strikes recorded and the day and time of each strike. These data were compared to downloaded video footage to confirm which strikes correlated with rat activity at the time of the strike. Strikes that occurred at the same time as rat activity was recorded on video were regarded as presumptive rat kills.

The above process was repeated each week, from the end of May 2025 to the end of August 2025 (12 weeks total). As with the Tuateawa study, the Te Hoe trial used two permanent sites to minimise site-variability and neophobia in target species. The risk of the areas being trapped out was considered minimal due to the likelihood that removed rats would be quickly replaced from overlapping home ranges.

Statistical analysis

Bar graphs were used to give a visual summary of rat and mouse presence or absence across the study areas under different treatment conditions. These descriptive figures allow for a comparison of the frequencies and proportions between groups, showing patterns in detection rates when ultrasonic vocalisations were present or absent. McNemar's test, which has a chi-squared distribution that takes into account the paired nature of responses (Watson & Petrie 2010), was performed using an Excel spreadsheet (Microsoft Corporation 2025) to compare the difference in the number of discordant pairs: comparing the number of weeks where there were more detections (Tuateawa study) or kills (Te Hoe study) with USVs, compared to the number of weeks where there were more detections or kills without USVs (α = 0.05).

Results

Tuateawa study area

At sites where USVs were not present, rats were detected by camera and/or tracking tunnels during five of the 21 study periods. This represents a percentage detection of 24%. At sites where USVs were present, rats were detected during eight of the 21 study periods, representing a percentage detection of 38% (Fig. 3).

During six of the 21 periods, rats were present at sites with USVs, and none were present at sites without USVs, compared to three periods when rats were present at sites without USVs but not present at sites with USVs. McNemar's test did not indicate a relationship between rat detection and USV presence ($p = 0.32$). In contrast, tracking tunnel and video records for other animals revealed that mice (*Mus musculus*) were detected during 20 out of 21 study periods (95%) when audio was present, compared to 15 out of 21 periods (71%) when audio was not present (Fig. 3). Mice were detected at both sites during fourteen study periods, at only the site with USVs during six periods, and at only the site without USVs in one period. McNemar's test approached significance for a relationship between a higher frequency of mice detection and USV presence ($p = 0.059$).

Te Hoe study area

The A24 traps used for the Te Hoe study registered a total of 23 strikes during the three-month trial, comprising between zero and five strikes per week for each trap. Video records revealed that, for seven strikes, possums were interfering with a trap, either by biting, scratching, or climbing on the Bluetooth chirp at the same time as the strike was recorded. The 16 remaining strikes were recorded as presumptive rat kills and their distribution during the trial is presented in Fig. 4.

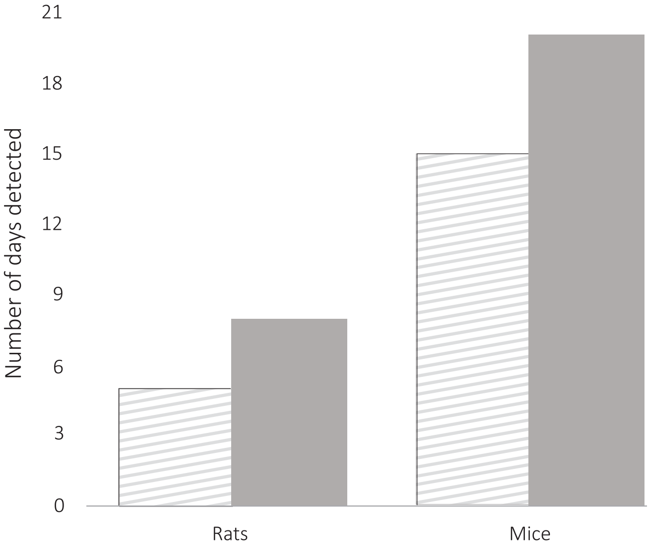

Figure 3. Frequency of 24 h periods (out of 21 total) that rats and mice were detected at the Tuateawa study sites when ultrasonic vocalisations (USVs) were absent (hatched bars) or present (grey bars).

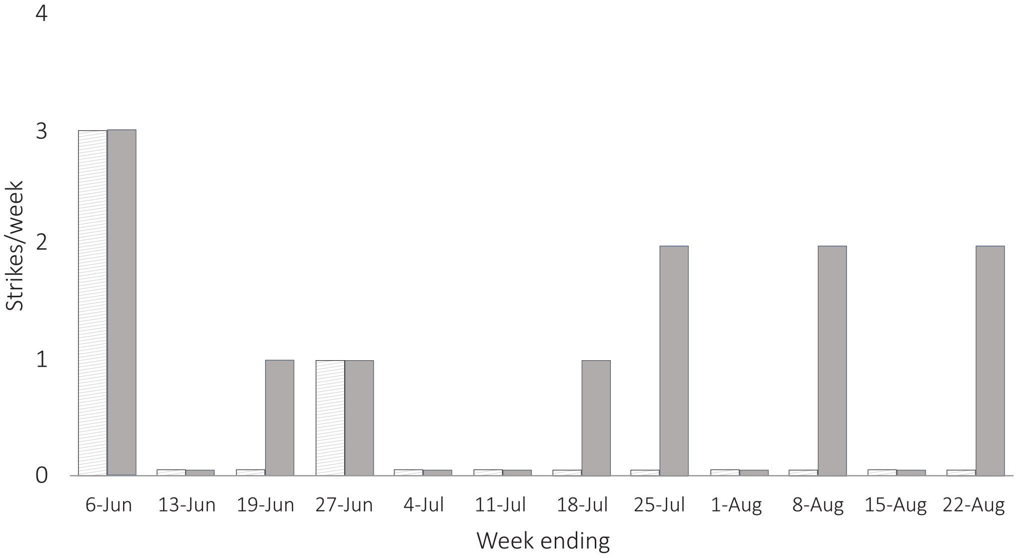

Figure 4. Presumptive rat kills recorded at Te Hoe study area for each week between 30 May and 22 Aug 2025. Presumptive kill numbers are indicated for sites when ultrasonic vocalisations (USVs) were absent (hatched bars) or present (grey bars).

Twelve of the 16 presumptive rat kills occurred at sites where USVs were present, compared with four presumptive kills at sites where USVs were not present (Fig. 4). During the first week there were three rat kills at each site and during the fourth week there was one rat kill at each site. During five one-week periods there were no rat kills at either site. However, during the remaining five weeks, more rat kills occurred at sites where USVs were present, compared to no weeks having higher numbers of rat kills at sites when USVs were not present (Fig. 4). McNemar's test compares this difference in the discordant pairs (5 versus 0) and shows significantly more rat kills when USVs were present ($p = 0.025$).

Video recordings revealed ship rats (*R. rattus*) exploring traps around the time of most strikes and, on three occasions, being killed by traps. When video was not captured near the time of a strike, rat carcasses were sometimes observed on the ground in videos captured by a later triggering event, indicating that rat activity was not always sufficient to be captured by the cameras, or that kills had occurred during the 5 s lag between video captures. Rat carcasses were also observed on the ground near traps at the end of a study period when traps and audio equipment were serviced. Video records also revealed rat carcasses being eaten by feral cats and, in one case, a possum was recorded eating a large part of a rat carcass over several days.

Discussion

As hypothesised in this study, rats were detected more often at the Tuateawa study area when USVs were present than when not present (8/21 runs vs. 5/21 runs). Although the numbers detected were too low to attribute statistical significance, the observed trend may still be ecologically meaningful. The low level of rat activity observed may have been influenced by ongoing pest control undertaken in adjacent areas. Nevertheless, the results of the Tuateawa trial are revealing in that mice were detected more often when USVs were present. While it may seem counter-intuitive for mice to be attracted to rat vocalisations (rats prey on mice), it is known that mice also emit and are attracted to USVs in the 30–100 kHz range (von Merten et al. 2014; Portfors & Perkel 2014). These findings were unexpected and, while they do not relate directly to the aim of the study, they are nevertheless of interest because, as noted by Samaniego et al. (2023), mice are of ecological concern in New Zealand, so the Tuateawa study findings highlight an opportunity to also consider USV lures as a future method for mouse control.

Significantly more presumptive rat kills were recorded at the Te Hoe study area when USVs were present compared to when they were not present ($p = 0.025$). Interestingly, more rats were killed during the first week of the study (three at each of the two test sites; Fig. 4), than during any of the remaining 11 weeks. As speculated earlier, this may reflect local rats being removed from their home-ranges, followed by migration of replacement animals into the vacated areas over following weeks, suggesting an active role in USVs attracting additional rats into the area.

These findings support the hypothesis that the presence of USVs attracts rats to the areas of entrapment (or at least causes rats to behave in ways more likely to result in them being killed by traps). A future study will likely aim to amplify the numbers of rats attracted to the site of entrapment. One improvement could be to widen the angle of area that the USV signal is broadcast, as ultrasonic speakers tend to have a relatively narrow angle of delivery (Gallardo et al. 2017). In earlier tests, we appraised the Apodemus BatSpinner speaker (Apodemus Field Equipment, Westerhoven, The Netherlands), which uses a spinning mirror to provide a 360° spread of signal, however we found that this device was not robust enough to survive multiple weeks of continuous outdoor use. Another improvement may lie in programming the audio-lure with 50 kHz USVs recorded from local rat populations, particularly ship rats, which were the species most frequently captured in our video recordings and are of particular concern in forests because of their ability to climb trees. Ship rat and domestic Norway rat USVs were not available at the time of the current study. Nevertheless, we have shown that a USV from a laboratory Norway rat appears to attract wild ship rats. Shapira et al. (2013) had earlier reported that captive laboratory Norway rats could attract wild Norway rats, but not wild ship rats. It therefore seems reasonable that wild ship rat USVs may enhance the numbers of wild ship rats attracted to areas of entrapment. Additional refinements may also be achieved by further refining the quality of the signal as received by the rat.

An additional finding of this study was that A24 traps appeared to be triggered by possums interfering with the Bluetooth cap of the trap. Future studies using A24 traps will aim to reduce this possibility by setting up the traps in ways that animals cannot easily access the cap.

In conclusion, the results of this pilot study, based on this dataset, support the hypothesis that rats are attracted to areas where USVs are applied, indicating that rat USVs have potential applications in methods for attracting rats and mice to areas of entrapment in New Zealand forest settings.

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Author contributions: RJ: conceptualisation, methodology, data collection and analysis, field work, writing original draft, and editing. NS: methodology, data analysis, editing.

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