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RESEARCH

Video monitoring finds no bat interactions with resetting traps in Pureora Forest Park

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Abstract: In New Zealand, endemic bat species require conservation management involving suppression of mammalian pest populations to prevent bat population declines. Toxins are frequently used to control mammalian pests; however, lesser short-tailed bats (*Mystacina tuberculata*) are also susceptible to poisoning due to their unique forest floor foraging behaviour and willingness to sample different types of bait. Self-resetting traps may offer a suitable alternative to the use of toxins for control of rats if they do not also present a by-kill risk to bats. To evaluate this risk we video monitored Goodnature A24 TM traps in Pikiariki, Pureora Forest, that had been lured, but not activated, and recorded bat activity using automatic bat monitoring devices. We detected high levels of activity of both New Zealand bat species in the vicinity of traps and captured footage of bats flying past traps on six occasions. However, we found no evidence of bats directly interacting with traps. This is a promising indication that A24 traps may be safe to use in areas with bats. However, next steps should be to experimentally operationalise re-setting traps and monitor bat survival at the population level using mark-recapture techniques. We caution against extrapolating the results of our study to different types of trap, lure, and trap positioning; we also recommend not locating traps close to *Dactylanthus taylorii*, a food source for short-tailed bats, as a precaution.

Key words: *Chalinolobus tuberculatus*, invasive species, *Mystacina tuberculata*, non-target risk, pest control, resetting trap, trail camera

Introduction

Introduced species are a key driver of biodiversity loss worldwide (Clavero & García-Berthou 2005). In New Zealand, an island with few native mammals, introduced mammalian pests have driven extinctions of a range of native taxa including birds (Holdaway 1999), a bat (King & Lloyd 2021), and herpetofauna (Towns & Daugherty 1994), and continue to contribute to the decline of many extant species (Innes et al. 2010; O'Donnell et al. 2017; Hitchmough et al. 2021). Biodiversity conservation in New Zealand is heavily focussed on pest mammal control and eradication (Brown et al. 2015).

Numerous tools exist for controlling and eradicating mammalian pests in New Zealand. For the widespread ship rats (*Rattus rattus*), Norway rats (*R. norvegicus*), and brushtail possums (*Trichosurus vulpecula*), toxins are the primary option for large-scale control or eradication operations (Brown et al. 2015). In some cases, the use of toxins is not favoured because of the risk of poisoning non-target species (Eason et al. 2017). In these cases, trapping might offer an alternative; however traps can also potentially harm non-target species (Brown et al. 2015). The risk that any predator control tool poses should be carefully evaluated by considering the likelihood of harm to individuals and the net impact (positive or negative) on the non-target population (Kemp et al. 2019).

North Island podocarp-hardwood forests host a relatively high abundance of mammalian pests, particularly ship rats (*R. rattus*) year-round (Walker et al. 2019). Pest suppression is necessary for the conservation of many vulnerable native species, including New Zealand's two endemic bats; the long-tailed bat (*Chalinolobus tuberculatus*, hereafter referred to as long-tailed bat) and the lesser short-tailed bat (*Mystacina tuberculata*, hereafter referred to as short-tailed bat). However, because short-tailed bats forage beneath the forest canopy and are capable of feeding on invertebrates on the forest floor, they are at risk from ingesting toxins either directly or through secondary poisoning (Dennis & Gartrell 2015). A pest control operation at Pikiariki, Pureora Forest, in 2009 resulted in the accidental death of at least 115 short-tailed bats from poisoning (Dennis & Gartrell 2015).

Changing how toxins are presented and limiting the time that they are in the environment has prevented further known short-tailed bat deaths at Pikiariki; however, the current pest management approach is still suboptimal for two reasons. Firstly, toxin continues to be detected in guano or tissue samples from dead short-tailed bats, but at sublethal levels, showing that they are still exposed. The long-term effects of sublethal exposure to toxins on the bat population is unknown,

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but of concern (Dennis 2019). Secondly, predator suppression targets required for recovery of the sympatric long-tailed bat population are not consistently reached with restricted toxin use.

Trapping presents a possible alternative management approach in Pikiariki to prevent sublethal poisoning of short-tailed bats and provide necessary pest suppression to help protect long-tailed bats. Traps that require manual re-setting following each trigger event are too labour intensive to be used effectively to suppress rats over large areas because conservation projects are generally resource limited and require more cost-effective solutions. Self-resetting traps offer a solution by reducing the number of visits required and therefore the labour needed to service them. The Goodnature Ltd. A24™ self-resetting trap (hereafter referred to as A24) is designed to kill rats and stoats. In field trials, they have successfully suppressed rats to undetectable levels (Gillies et al. 2014). A24 traps are designed to automatically re-set and be triggered up to 24 times before they need to be serviced. A long-life chocolate lure is used when rats are targeted. Captive trials have shown that short-tailed bats are attracted to lures/baits containing sugar compounds (Beath et al. 2004); therefore, bats may be a non-target concern for resetting traps. Even without the lure, bats may be at risk of entering the traps given their willingness to enter cavities for roosting. Because of this concern, Department of Conservation Performance Standards for the A24 included, prior to our study, the compulsory restriction that these traps cannot be used in short-tailed bat habitat unless as part of research to identify impacts.

Our study aimed to evaluate the likelihood of bats interacting with A24 traps by using trail cameras to monitor baited but disarmed traps in areas with high bat activity. This information will help to evaluate whether re-setting traps are an appropriate alternative to toxins for controlling pests in areas where short-tailed bats are present.

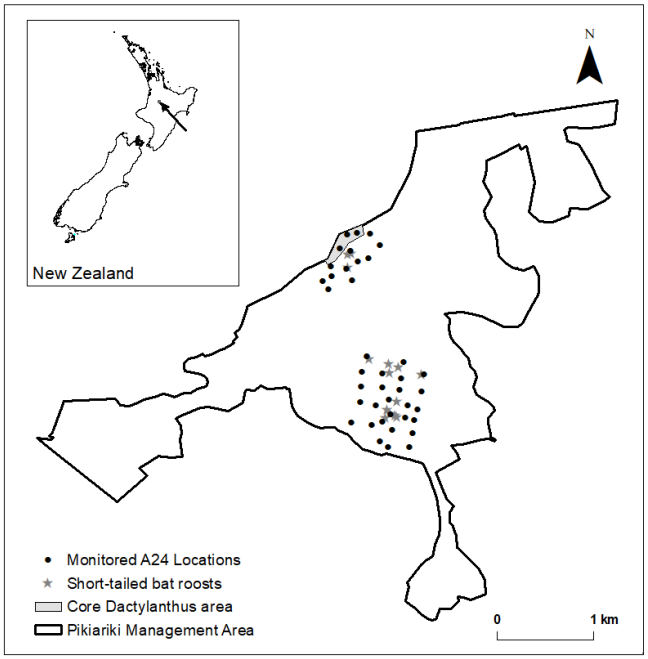

Figure 1. Location of Pikiariki, Pureora Forest Park, in New Zealand, and layout of monitored A24 trap stations in Pikiariki in relation to *Dactylanthus taylorii* and lesser short-tailed bat roosts.

Methods

Study site and timing

The study took place in Pikiariki Ecological Area, Pureora Forest Park in the central North Island (Fig. 1). Pikiariki is an 870 ha area of podocarp-hardwood forest managed by the Department of Conservation.

Both short-tailed and long-tailed bats have known maternity roost locations within Pikiariki and bats are active in the forest interior and edges. Short-tailed bats begin roosting communally in maternity roosts from October in Pikiariki and females give birth to pups in December (T. Thurley, Department of Conservation, pers. comm.). Long-tailed bats roost communally by November and give birth in December (O'Donnell & Borkin 2021).

We carried out two trap monitoring sessions during time periods when we expected bats to be active and motivated to seek food. Session one took place between November 17th and December 14th in 2020. At this time of the year, both species of bats are using maternity roosts, and pregnant females likely have high energy requirements (O'Donnell & Borkin 2021; Parsons & Toth 2021). Session two took place between March 9th and April 19th 2021. At this time of the year, short-tailed bats are mating, and males occupying singing roosts have high energy demands (Czenze & Thurley 2018). This is also when short-tailed bats feed on the nectar of *Dactylanthus taylorii* (hereafter *Dactylanthus*), a flowering plant of the forest floor (Czenze & Thurley 2021), and when young of both bat species are volant (O'Donnell & Borkin 2021; Parsons & Toth 2021).

Trap set up and placement

Trap stations were set up at 40 locations (Fig. 1) within 500 m of known short-tailed bat colony roosts or *Dactylanthus* and within areas that were part of short-tailed bat home ranges in a previous study (Toth et al. 2015). Long-tailed bats are known to range widely across Pikiariki so we were confident that this species would also be detected at sites chosen to maximise short-tailed bat encounters. Trap locations were selected using a systematic sampling design. We made use of marked lines in the forest used for pest management purposes and we placed trap stations approximately every 100 m.

At each trap station we identified two trees spaced approximately 1 m apart. We attached a disarmed A24 trap to one tree. We followed the manufacturers' recommendations for trap position, with the base 120 mm from ground-level. Each trap was installed with an activated Goodnature chocolate A24 Automatic Lure Pump™ plus an empty CO_2 cannister so that it physically replicated a live trap. We then attached a Bushnell Core DS No Glow Trail Camera® to the second tree and trained its field of view on the trap. Cameras were set to record video for 30 seconds when triggered by movement. Lastly, we hung an automated acoustic bat monitoring unit (ABM; AR4 model, Department of Conservation, Wellington) on a branch approximately 1.5 m above the trap and camera configuration to record bat activity in the vicinity of the trap. ABMs were set to record from one hour before sunset through to one hour after sunrise, which is the time period when both bat species are likely to be active (Sedgeley et al. 2012).

The ABMs had a detection distance of 30–50 m (Smith et al. 2020), so the 100 m spacing of trap stations ensured that detections at individual stations would be independent. In November/December, trap stations were active for four weeks, with a battery and memory card change after two

weeks. In March/April, trap stations were active for up to six weeks with no additional servicing.

Video footage and acoustic data analysis

The acoustic data recorded by ABMs (number of bat echolocation calls) was analysed using BatSearch Version 3.2 software (Department of Conservation, Wellington). AviaNZ version 3.1.1 (Marsland et al. 2019) was used to automate the process of identifying bat echolocation calls on nights with little noise (many false positives were generated on days with heavy rain and had to be resolved manually). Exploratory analysis showed that bat activity was too high at many sites to count individual bat echolocation calls as a measure of bat activity. Instead, we chose to record the presence or absence of bats, identified to species, in each 15-minute time interval.

The video footage recorded by trail cameras at the 40 monitored trap stations was analysed by reviewing the footage on the Microsoft Films & TV app (2022, Microsoft Corp.). Video footage was analysed for the time period matching the ABM setting (between one hour before sunset and one hour after sunrise). To understand non-bat activity around the trap, in each instance of a non-bat vertebrate triggering the camera the species was identified and we recorded whether it interacted with the trap. An interaction was defined as physical contact with the trap. We deemed it unnecessary to distinguish between ship rat (*Rattus rattus*) and Norway rat (*Rattus norvegicus*) for the purpose of the study, so rat interactions were pooled. Where there were multiple species in the video footage or images, this was recorded, but the first animal to trigger the camera was used to generate simple summary statistics. The exception to this was for bats, where all occurrences were summarised because they were our main focus. Bat detections were described as follows: (1) acoustic detection only; (2) video detection, but no interaction with trap; (3) video detection and physical contact with trap, but not trap entrance; (4) video detection and physical contact with trap entrance, but no entry; (5) video detection and trap entered. Simple average detection rates per night were calculated and graphed as a measure of bat activity in the vicinity of each trap.

Results

Acoustic data

In November/December, 34 of 40 ABMs successfully recorded bat echolocation calls. The remaining six devices had technical failures so are not included in analyses. Bat echolocation calls of both species were recorded at all trap stations with functioning ABMs (Fig. 2). The overall mean likelihood of detecting a short-tailed bat pass per 15-minute time interval was 0.34. The overall mean likelihood of detecting a long-tailed bat pass per 15-minute time interval was 0.35. The trap

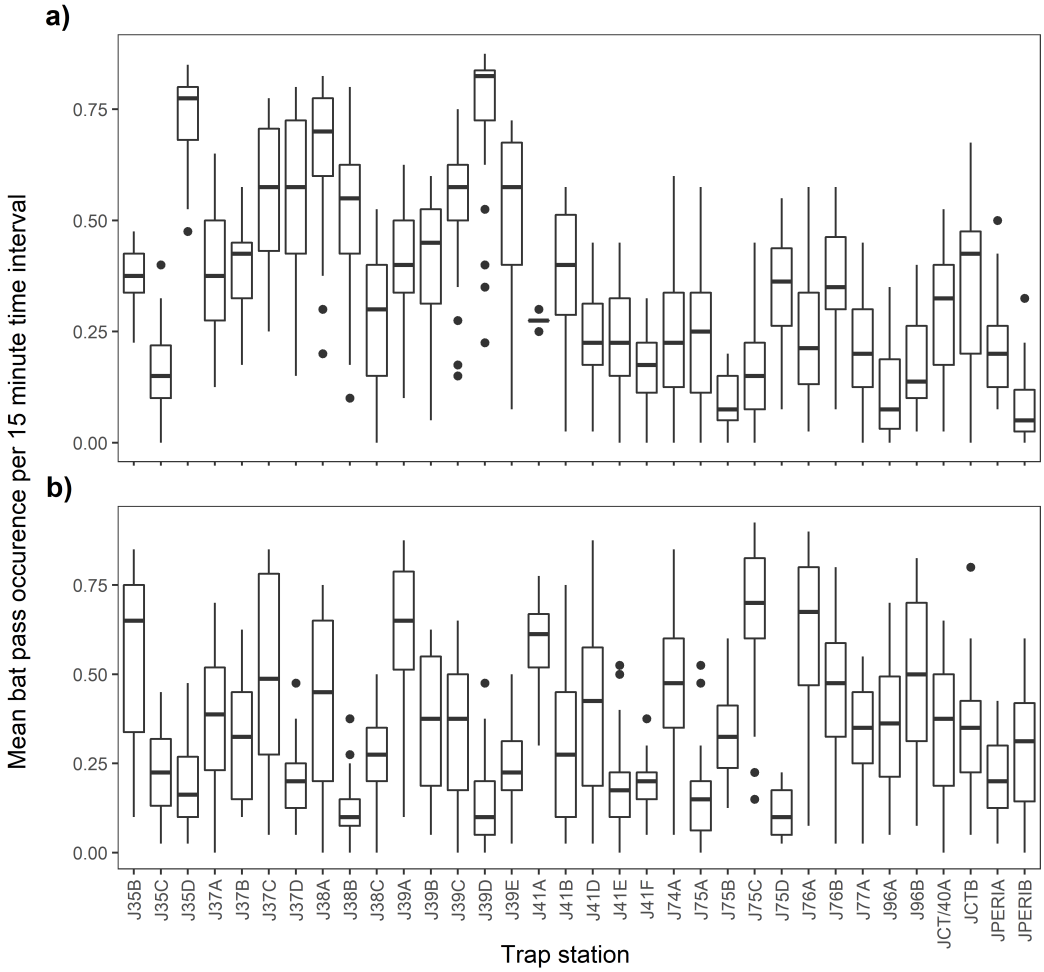

Figure 2. Mean occurrence of a) lesser short-tailed and b) long-tailed bat echolocation calls per 15 minute time interval, recorded across 34 trap stations in Pikiariki, Pureora Forest Park, in November/December 2020.

station with the greatest likelihood of detecting a short-tailed bat pass was J39D (0.74 per 15-minute time interval), which was located within 10 m of an active short-tailed bat roost. The trap station with the highest likelihood of detecting a long-tailed bat was J75C (0.68 per 15-minute time interval).

In March/April, 39 of 40 ABMs successfully recorded bat echolocation calls, with one device failing to record properly. Bat echolocation calls of both species were recorded at all trap stations with functioning ABMs (Fig. 3). The overall mean likelihood of detecting a short-tailed bat pass per 15-minute time interval was 0.44. The overall mean likelihood of detecting a long-tailed bat pass per 15-minute time interval was 0.30. The trap station with the greatest likelihood of detecting a short-tailed bat pass was again J39D (0.90 per 15-minute time interval), which was located within 10 m of an active short-tailed bat roost. The trap station with the highest likelihood of detecting a long-tailed bat was J76A (0.71 per 15-minute time interval).

Video footage

In November/December 39 trail cameras successfully captured video footage. One camera was accidentally set to record still images. Cameras were triggered on average 12 times per night (range: 0 to 223, number of trap nights: 1036). All cameras were triggered at least once during the study period, so were considered working and suitable for use. Eighty-nine hours of video footage were captured and reviewed along with 1266 still images. It was possible to review still images to identify visitors to trap stations. The first image of each individual animal was recorded for still images.

No bats were observed in video footage from the November/December study period. There were 3868 camera trigger events by non-bat vertebrates (Table 1). Of these, the majority were mice (1473) followed by rats (1299) and possums (1068).

In March/April 36 trail cameras successfully captured video footage. A further two were accidentally set to record still images, one camera failed to record/operate, and another was stolen. The number of nights that cameras were active ranged from 18 to 42 before batteries ran out of charge or memory cards were filled. One camera was moved by a possum after five nights so that the trap could no longer be viewed. The total number of available camera trap nights was 1395. Cameras were triggered on average 14 times per night (range: 0 to 165, number of trap nights: 1395). Eighty-two hours of video footage were captured and reviewed along with 3352 still images.

Bats triggered cameras on six occasions in total (Table 1). Five of these bat trigger events were at a single trap station located within 3 m of *Dactylanthus*. Bats did not interact with the traps in any of the footage. All video clips showed a bat flying past (Fig. 4a), except on one occasion when a

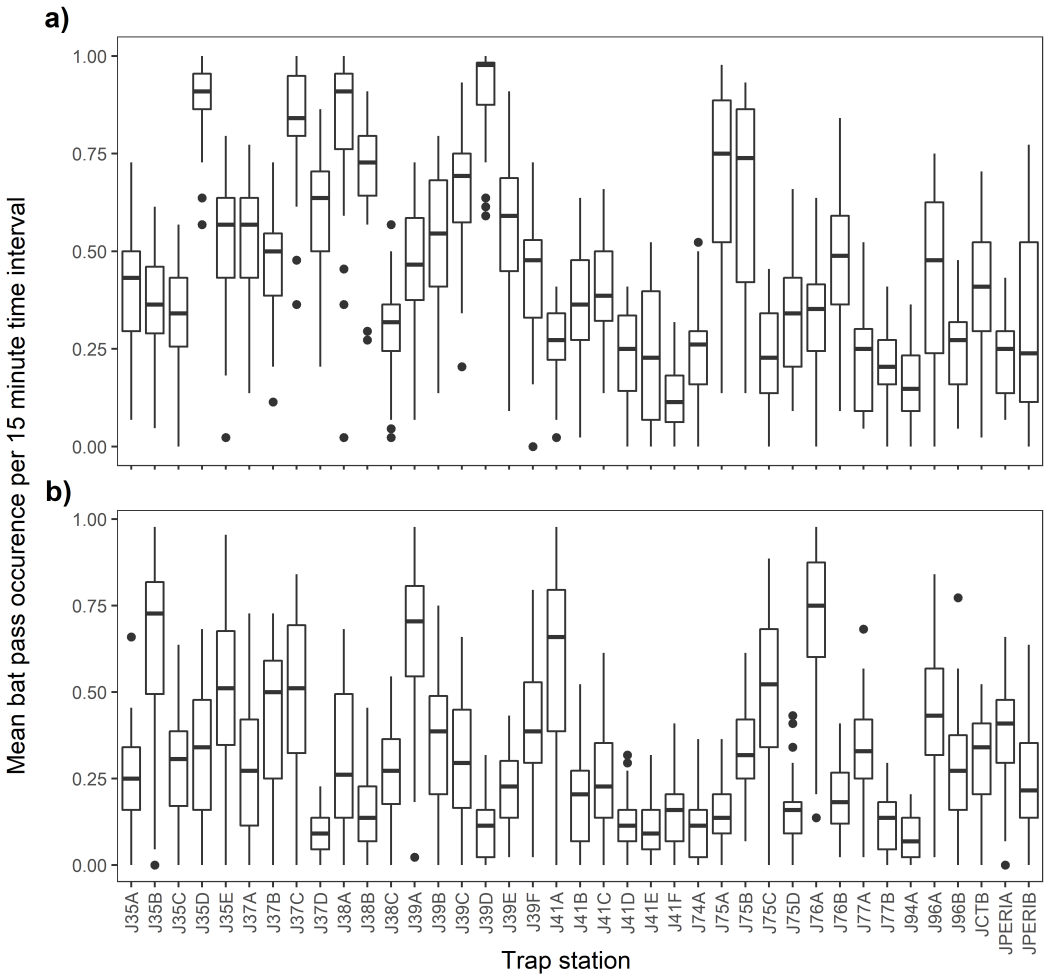

Figure 3. Mean occurrence of a) lesser short-tailed and b) long-tailed bat echolocation calls per 15 minute time interval, recorded across 34 trap stations in Pikiariki, Pureora Forest Park, in March/April 2021.

Table 1. Total counts and average detection rates of different vertebrate taxa captured in trail camera footage from monitoring lured, but disarmed Goodnature A24 resetting traps in November/December 2020 and March/April 2021 at Pureora Forest Park.

Taxa	Total count of camera detections	Mean detection per trap station per night	Were interactions with the trap observed?
November/December 2020			
Bat (*Mystacina tuberculata)**	**0**	**0**	**NA**
Deer (*Cervus elaphus*)	3	0.01	No
Hedgehog (*Erinaceus europaeus occidentalis*)	20	0.09	Yes
Mouse (*Mus musculus*)	1473	1.39	Yes
Possum (*Trichosurus vulpecula*)	1068	0.99	Yes
Rat (*Rattus rattus/R. norvegicus*)	1299	1.20	Yes
Robin (*Petroica longipes*)	2	0.002	No
Stoat (*Mustela erminea*)	3	0.003	No
March/April 2021			
Bat (*Mystacina tuberculata*)	**6**	**0.004**	**No**
Deer (*Cervus elaphus*)	9	0.006	No
Hedgehog (*Erinaceus europaeus occidentalis*)	29	0.02	Yes
Mouse (*Mus musculus*)	6640	5.40	Yes
Pig (*Sus scrofa*)	12	0.01	No
Possum (*Trichosurus vulpecula*)	1800	1.28	Yes
Rat (*Rattus rattus/R. norvegicus*)	2601	1.96	Yes
Stoat (*Mustela erminea*)	7	0.01	Yes
Weasel (*Mustela nivalis vulgaris*)	5	0.003	Yes

*One *Mystacina tuberculata* bat detection was confirmed, but other bat detections could not be determined to species. *Mystacina tuberculata* is most likely, but *Chalinolobus tuberculatus* cannot be ruled out.

Figure 4. Still images taken from camera trap footage of lured, but disarmed, Goodnature A24 resetting traps in Pikiariki, Pureora Forest Park March 2021. Image a) is a bat flyby. Image b) appears to show a lesser short-tailed bat observing a mouse before flying away.

mouse was visiting the trap as the bat flew into shot. The bat appeared to take note of the mouse for a moment and then flew on (Fig. 4b). In the clip with the mouse, the size of the bat's ears distinguish it as a short-tailed bat, but in other video clips we could not confidently identify the bat to species. Non-bat vertebrates triggered cameras 11 109 times. Of these, the majority were again mice (6640) followed by rats (2601) and possums (1800).

Discussion

Acoustic monitoring confirmed that bats of both species were regularly present within the 30─50 m ABM detection radius of traps during November/December and March/April monitoring sessions. This means that there should have been opportunity for bats to encounter traps. Variability between trap sites means that it is difficult to establish a standard detection range for the cameras, but it is likely that at most sites, bats would have had to pass within 3 m of a trap to be captured in video footage. This only occurred on six occasions, all in March/April, and in all these cases bats were recorded flying past the traps with no observations of physical interaction with traps during the 2431 total trap nights.

Trail cameras are regularly used to study small mammals (e.g. Rendall et al. 2014; Samaniego et al. 2022), however, they do not always detect them perfectly (Anton et al. 2018), so it is possible that our cameras failed to be triggered by bats. However, our cameras captured thousands of instances of mice (similar size to a bat) interacting with traps, and six instances of bats flying past traps. To interact with a trap in a way that could be lethal were the trap activated, a bat would need to land and position itself to crawl inside the trap. We consider that if the cameras were readily triggered by mice interacting with traps, and were capable of being triggered by bats in flight, the chances of missing a bat interacting with a trap are low.

The contrast between ABM and camera detections indicates that although there was regular bat activity in the vicinity of traps, the traps were not regularly approached by bats. Together with the lack of recorded direct interactions with traps, this indicates the traps were not highly attractive to either bat species, despite the sweet chocolate lure. We tried to maximise the likelihood of bats encountering traps by positioning a trap less than 10 m from an active short-tailed bat roost and close to *Dactylanthus* plants flowering on the forest floor, but we still found no signs that bats were attracted to traps.

Traps were disarmed in our study, so the abundance of mammalian pests was not being reduced as it would have been if traps were operational. It is possible that bats might be more tempted to investigate traps when mammalian pest levels are reduced. However, whilst we cannot rule this out, we consider it unlikely. This is because the mean number of trigger events, from all species, per trap per night was 12 in November/December and 14 in March/April. As each trigger event recorded 30 seconds of video footage, this amounts to just six and seven minutes respectively out of the night, leaving many hours when traps were undisturbed by pests; this suggests that bats would have had plenty of opportunities to visit traps in the absence of predators had they wanted to do so.

We timed our trap monitoring sessions to coincide with times when we considered bats were most likely to be active and motivated to investigate baited traps as a possible food source. However, it is possible that there are other times of the year when bats could be more driven to enter traps. For example, during winter and early spring when food may be scarce. There is no evidence that bat foraging behaviour changes at other times of the year in a way that would increase their likelihood of interacting with a trap, but seasonal variation in diet is an unstudied area of bat ecology.

In our trial, we monitored traps baited with the most commonly used Goodnature lure for rats, which is chocolate based. It is possible that other lures could be more attractive to bats. For example, Beath et al. (2004) found that short-tailed bats were willing to approach and sample a variety of different baits, scented lures, and pastes under captive conditions, and peanut and apple flavours were preferred over others including chocolate (though chocolate was accepted). Care should be taken not to extrapolate the results of our study to conditions where other lures are used.

Beath et al. (2004) found that bats rapidly learn to make associations based on food sources. Although we did not find bats to be attracted to traps even when located very close to *Dactylanthus*, a sensible precaution would be to keep traps away from *Dactylanthus* outside of research conditions. In addition, our traps were placed low to the ground at the recommended height of 12 cm from ground level to base. The results of our study should not be extrapolated to such conditions where traps are raised above the manufacturer's recommended height, in case this alters bats' perception of traps and their attractiveness as a food source or as a cavity for roosting. In addition, our results should not be extrapolated to the use of different types of re-setting trap.

Using re-setting traps to control mammalian pests in forest inhabited by short-tailed bats will be beneficial to bat populations if trap networks suppress pests to the levels required to allow them to grow. The results of our study indicate that neither short-tailed nor long-tailed bats are highly attracted to the A24 re-setting traps when positioned as recommended by the manufacturer and baited with chocolate-based rat lure. Given the potential benefits these traps offer, and the lack of evidence of bat by-catch observed in our study, we recommend that the next step is to experimentally operationalise A24 traps for rat control and study bat populations using mark-recapture approaches to determine effects on survival rates. Pikiariki would be an ideal location for this as there is already a baseline dataset of long-tailed and short-tailed bat annual survival rates.

In conclusion, video monitoring of A24 re-setting traps in Pikiariki found no evidence of bat interactions, despite bats being active in their vicinity. This is a promising early indication that these traps may be safe to use in areas with bats. However, we caution against deviating from the trap type, lure type, and positioning used in this study and recommend not locating traps close to *Dactylanthus*, a key food for short-tailed bats, as a precaution. Next steps could be to operationalise re-setting traps in Pikiariki and monitor bat survival at the population level using mark-recapture techniques.

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Author contributions: LB and NG designed the study; LB, JW and NG carried out the field work; LB and JW analysed the data; LB wrote the original manuscript draft; all three authors contributed to review and editing.

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Data and code availability: Data and code are available from the authors.

Ethics: This project involved monitoring deactivated, legal traps set out following standard practice and therefore did not require animal ethics approval.

Conflicts of interest: No conflict of interest is known.

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