Alex Albright, Sam Dearsly, Andrew Jopson, Daniel Joubert,
Amy van Lindt

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School of Geological Sciences
University of Canterbury
Christchurch
New Zealand

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The time period for this research limited experimental options. Our findings were limited to only the Hogs Back trapline, but were consistent with other literature allowing for extrapolation to other trapping programmes.

Exploration into the efficacy of targeted toxin delivery systems and/or kea-safe possum traps.

Exploration into the use of multi-capture rat and stoat traps.

Exploration into methods for the exclusion of mice from traps.

Introduction

Pest control in New Zealand is an ongoing issue that has been a core focus for ecologists and public conservation groups alike for decades. Since the introduction of mammalian carnivores to New Zealand, many native species, particularly native avifauna, have declined with some being driven to extinction (Byrom, Innes, & Binny, 2016; Holdaway, 1989; Innes, Kelly, Overton, & Gillies, 2010). Numerous community groups across the country undertake trapping operations in an attempt to reduce the dramatic impact mammalian predators are having on New Zealand's native bird populations. The New Zealand Conservation Trust (NZCT) is a charitable, volunteer-based organisation who aim to advocate for New Zealand's native taonga species, and contribute to achieving the national goal of becoming a predator-free nation by 2050. The NZCT operate six traplines in central South Island of New Zealand, five in Craigieburn Forest Park and one in the Carlyle Valley. These areas are representative of the common issues associated with mammalian pest species, and harbor populations of brushtail possums (*Trichosurus vulpecula*), stoats (*Mustela erminea*) and rats (*Rattus exulans, Rattus norvegicus, Rattus rattus*). According to Elliott and Kemp (2016) these introduced mammals are the main cause of population decline in many native avian species.[Int)4(ro)-2(du)4(ction)]TJm0 g0 0.00000912 0 612 792 reW*nBT/F4 12 Tf1 0 0 1 157.82 40

notorious for their inquisitive nature, a trait that can make them susceptible to irresponsible trapping efforts. Ensuring kea friendly mammalian trapping methods are employed is of utmost priority for the NZCT. After reviewing current literature in pest control research in New Zealand, this report takes a mixed methods research approach in an attempt to answer the research question. By deriving pest abundance indices through the use of tracking tunnels we aimed to determine whether population abundances were representative of the NZCT trap catch data. We then combined this with qualitative observations of the NZCT traplines. Results are then summarised and discussed in an ecological context and from this, relevant recommendations for the NZCT are provided.

A review of relevant literature in pest control

Baits and lures

Exploration of literature regarding alternative food-based baits and lures has provided insight into easily accessible, effective and economically viable pest attractants. Rats have been shown to be attracted to baits containing a high fat content, specifically, cheese, milk chocolate, Nutella and walnuts which were statistically more attractive than the peanut butter controls (Jackson, Hartley, & Linklater, 2015). As a lure for stoats, broken and hard boiled eggs were suggested in one study by Dilks, O'Donnell, Elliott, and Phillipson (1996) to be significantly more effective than possum flesh, dead mice, tinned cat food and various synthetic lures. This study was conducted number of captures per unit of volunteer effort. This increase in efficiency is beneficial for volunteer programmes, as it increases the number of captures per volunteer effort.

Long lasting lures are being developed to assist in improved pest control effort. Lure trials by Murphy et al. (2014) found that female Norway rat urine and scats were the most attractive to both male and female Norway rats. It was also found that urine and scats from stoats did not appear to act as a repellent (Murphy et al., 2014). By creating lures that a pest has a high affinity towards, target specific pest control can be improved.

Multiple capture traps and targeted toxin delivery

Recent literature has discussed the use of new pest eradication technology as a means to more efficiently control mammalian pest species in New Zealand (Carter & Peters, 2016; Warburton & Gormley, 2015). The use of multiple-capture and targeted toxin traps have been found to have increased efficiencies over single capture traps, and increased selective targeting in comparison to nationally used aerial 1080 poison (Eason, Shapiro, Ogilvie, King, & Clout, 2017).

In an island study completed by Carter et al. (2015) significant decreases in rat (73% to 7%) and possum (30% to 0%) indices were recorded after the installation of Goodnature® A12 and A24 traps. The use of spatial simulation models has also reported similar efficiencies when modelling the use of multiple capture traps (Warburton & Gormley, 2015). Both studies consider the cost versus effectiveness aspect of implementing multiple capture traps. Under high rat densities the ability to eradicate multiple pests over one trapping iteration (one month) proved multiple of mammalian pests post masting events, or in areas of high reinvasion risk, multiple capture traps were proven to be very successful in reducing pest numbers (Carter & Peters, 2016; Warburton & Gormley, 2015).

Targeted toxin delivery methods have been proposed as an alternative to aerial drops of sodium fluoroacetate (1080) (Murphy et al., 2014). The spit fire trap acts as an applicator, depositing 1080 paste on the underside of rats who then ingest it when grooming (Murphy et al., 2014) stoats is 100 – 200 meters (Department of Conservation, 2019). Eradicating or suppressing pest populations to levels where native bird populations can thrive has long been a major issue on the detecting invasive mammals than tracking tunnels. In both studies, cameras were baited with lures. It is possible that on-going camera monitoring could be utilized in conjunction with tracking tunnels to provide an indication of predator abundance before, during and after control efforts for the New Zealand Conservation Trust, particularly because it is practical and Kea friendly.

Methodology

Quantitative

Our quantitative research was conducted along the Hogs Back Track trapline, located in Craigieburn Forest Park, South Island, New Zealand (See Appendix A). The Hogs Back Track runs through patches of beech (*Nothofagus solandri*) forest remnants separated by alpine grasslands (King, 1983). Adhering to New Zealand's Department of Conservation best practice, we placed two tracking tunnel lines (See Appendix B). The first tunnel was placed 500m from the start of the track at Texas flat and subsequent tunnels were placed at 100m intervals for 2.2km. The second line began 100m from the start of the track at Castle Hill Village, and subsequent tunnels were placed every 100m over a 1.1km distance. Each tunnel was placed approximately 10m off the main track on alternating sides, and baited with peanut butter to attract rodents. In total, 33 tunnels were placed. Tunnels were left out for one track night, however, they were not able to be checked for two nights due to weather. After card collection, tunnels were re-baited using chicken mince to attract mustelids and left out for three track nights.

We assessed trends the NZCT's historical catch data in Craigieburn Forest Park only using Microsoft Excel. Footprints and markings on the tracking cards were compared against images provided in H. Ratz's (1997) paper 'Identification of footprints of some small mammals' and expert help was sought from University of Canterbury Professor, Dave Kelly. Using the

Department of Conservation's tracking tunnel calculator excel spreadsheet we calculated the mean tracking rates and overall proportion of tunnels tracked for both rodents and mustelids.

Qualitative

Four trail cameras were installed on trees across the traplines to monitor pest activity around the traps. Two cameras were placed overlooking high performing traps (trap nos. 256 & 253) and two were placed on low performing traps (trap nos. 270 & 250). Trap performance was determined according to trap catch summary data (See Appendix C). Trail cameras were set up using the video motion sensor which recorded for 15 seconds after each activation. These were left out for five trap nights in total. Additionally, general observations of the NZCT's trapping methods were made and recorded during a trap resetting day.

Results

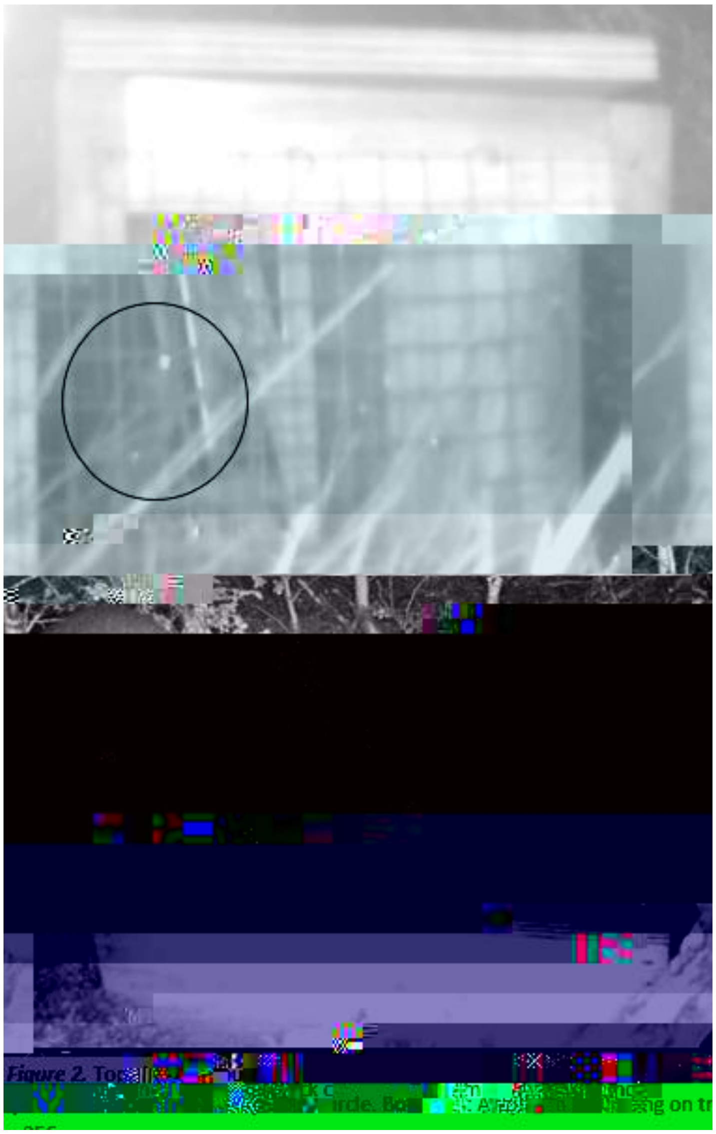
Quantitative

Mammalian predators caught by the NZCT between 2014 and 2019 included large numbers of stoats, rats, mice and hedgehogs, as well as low numbers of cats, weasels (*Mustela nivalis*), ferrets (*Mustela putorius*), possums and rabbits (Lagomorpha species). General population trends in rat and stoat populations were also observed in the data. Inconsistencies relating to the recording of the data challenge the reliability of these trends, however some inferences can be made. In summer and autumn rat and stoat numbers increase substantially and reduce over winter (Fig. 1). Large increases in rat catches occurred in the summers of 2014 and 2019 and are likely correlated with mass mast seeding events. We identified two types of footprints on the tracking cards, indicating mice and possums. Considering tracking tunnels are not designed to be indices for mice were calculated to be 38% (±12%). No other footprints were found on the tracking cards.

Qualitative

Trail cameras revealed mice and possum interactions with the traps. Mice can be observed entering traps and, on one particular occasion, a mouse was captured walking over trap trigger plates without setting them off (Fig 2). In the process of camera recollection, traps with cameras were checked to see if bait had been interfered with. Traps that had mice interference as

An observation of the Hogs Back trapline revealed mould growth underneath the bait container in many of the traps, thought to be due to remnants of old bait or animal biomass that had not been adequately removed prior to trap re-setting. Subsequently traps with mould were noted to not have captured a mammalian predator over this particular trapping period. It was also noticed that hedgehogs had been caught in traps during the observation day as well as their presence recorded in the NZCT historical catch data. One aspect of the trapping programme that stood out in particular was the significant amount of time and effort required to maintain a trapline, this also includes volunteer training and maintenance of traps. Volunteer effort could potentially be wasted if traps are not operating efficiently.



dramatic population reduction as rats are better adapted for the exploitation of alternative food sources (Parlato, Armstrong, & Innes, 2015). Following the stoat population explosion and due to density-dependent processes. It has been shown by (Farnworth, Innes, & Waas, 2016) that mice demonstrate avoidance behaviour in response to artificial illumination. Although this type of avoidance behaviour is likely to be common in rats and stoats it is possible that a light sensor device could be fitted into the center of a trap that is only sensitive to the presence of individuals who reach the center of the trap, i.e. mice. However, there is very little research on the use of this technique to prevent mice from removing bait. Another technique that could be employed by the NZCT to prevent mice stealing bait is it permanently secure bait to the trap and to cover the bait so that it cannot be removed, however there is no research that can support this as a solution to mice stealing bait.

Rat populations are particularly difficult to control (Campbell et al., 2015) although self-resetting traps have been shown to significantly reduce tracking indices of rats in areas of high re-invasion risk. Self-resetting traps can be left for several months without requiring maintenance, whilst education to reduce mould, and employing continuous monitoring of traplines in the future will benefit the NZCT.

Limitations

Our experiment options, and ability to reach Craigieburn Forest Park from Christchurch, were limited by time. According to the DOC tracking tunnel guide v2.5.2 (Gillies & Williams, 2013), tunnels should be left for at least 3 weeks (ideally even longer if you plan to survey mustelids) prior to the first survey session to ensure any resident animals are conditioned to the presence of the tunnels. Due to a limited time period to collect res

Recommendations

Suggested measures for the NZCT to implement to ensure their trapping programme is operating at full potential:

Mice

- Prevent bait being removed by securing it to the traps, i.e. mesh covering, metal container.

Rats and stoats

- Pre-feeding traps to maximise captures per volunteer effort.
- Use of multi-capture traps. Goodnature® A24 with the kea excluder, increases capture rates and decreases volunteer effort.
- Targeted toxin delivery system, i.e. bait stations on trees.

Hedgehogs

- Raise traps to prevent hedgehogs entering, increase chances for rat and stoat catches.

Trap maintenance and monitoring

- Clean mould out of traps.
- Start monitoring traplines using tracking tunnels and cameras to determine their effectiveness.
- Ensure volunteers are skilled on best trapping practices.

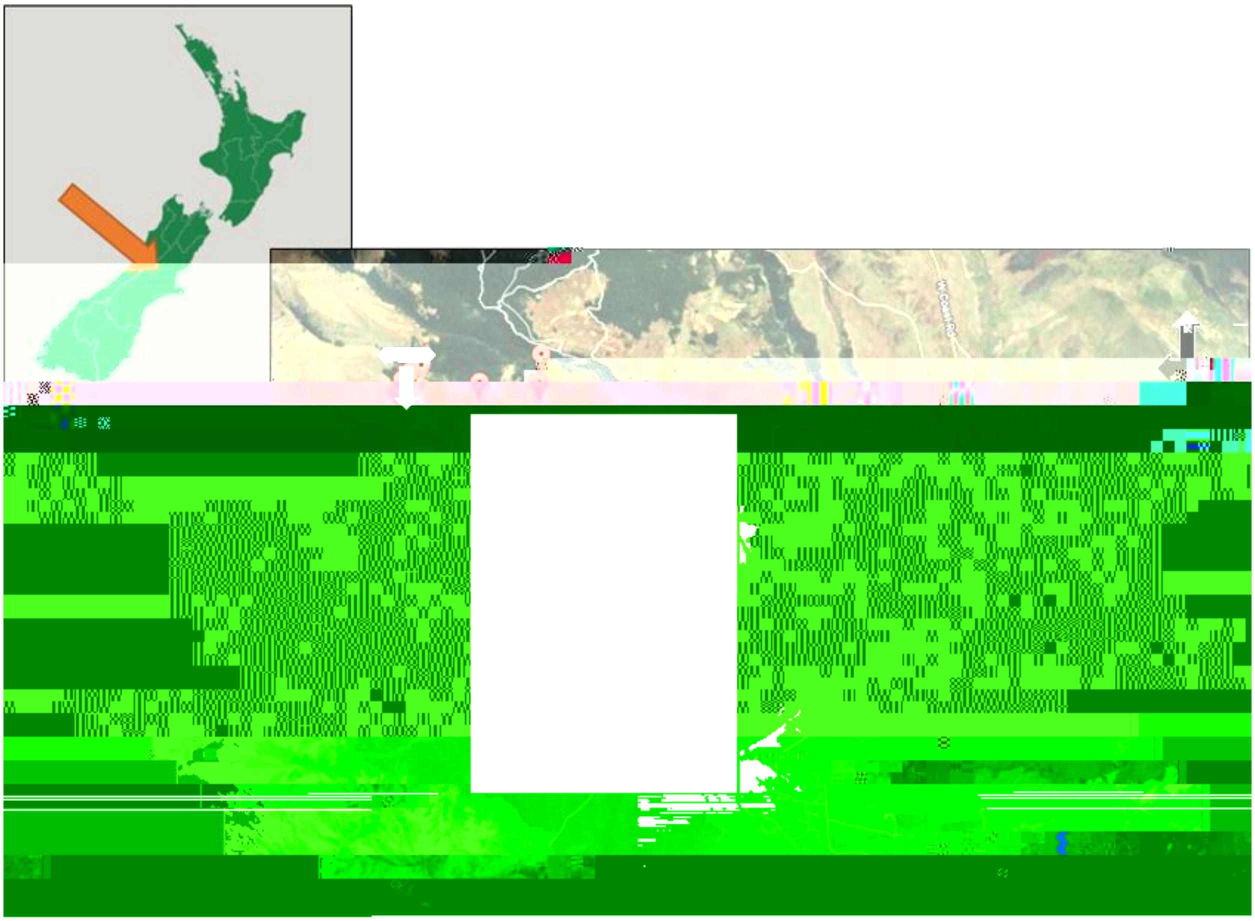
Conclusion

Given resource limitations, the potential for improvement of the current trapping methods implemented at Craigieburn Forest Park by the NZCT is evident. Improved monitoring and maintenance of the traps can initially improve the efficiency of NZCT operations with little

Appendices

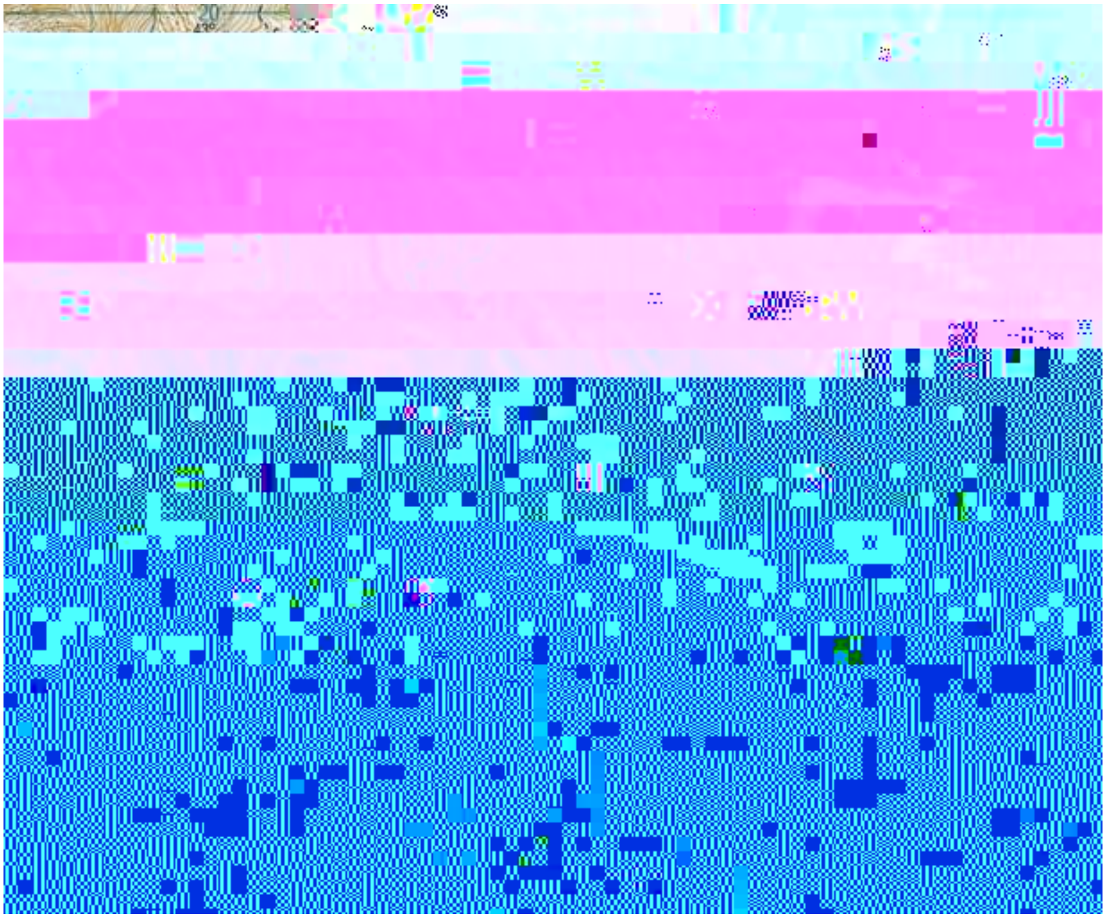
Appendix A.

Hogs Back Track trapline layout in the Craigieburn Forest Park. Red points indicate individual traps.



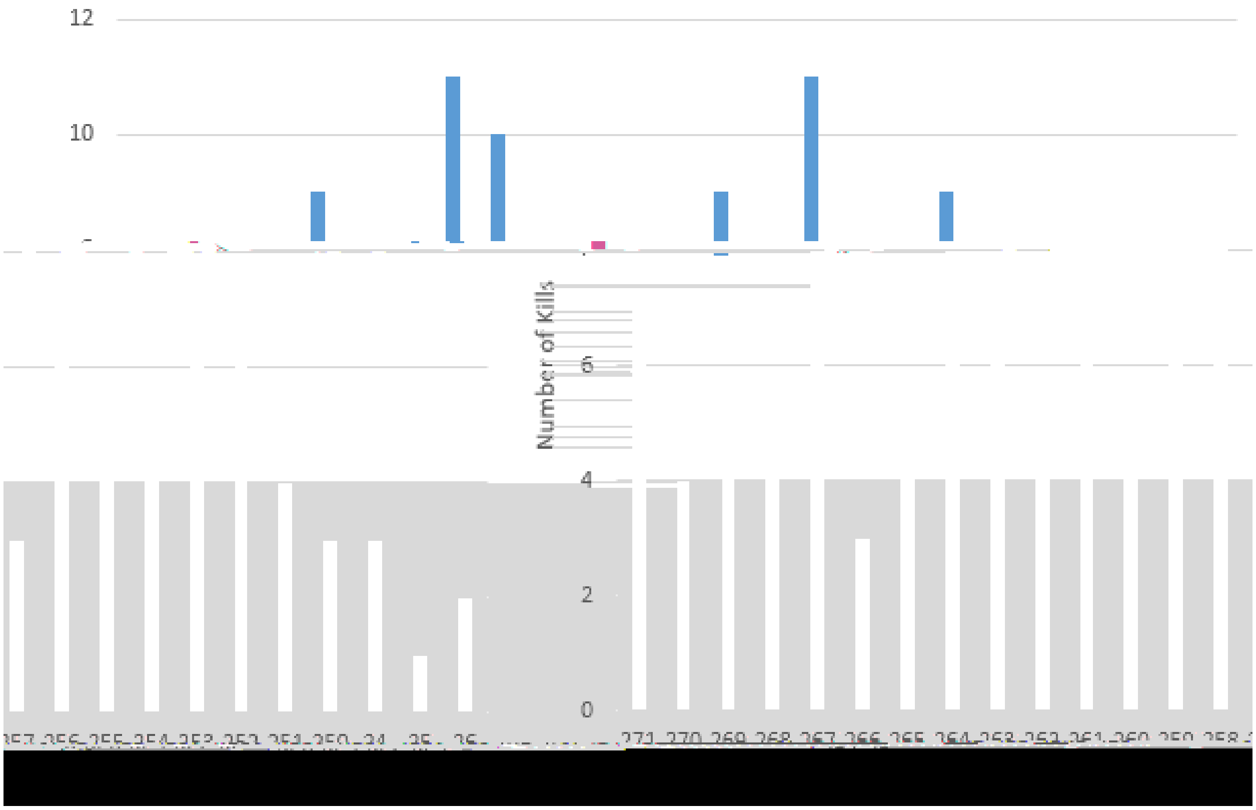
Appendix B.

Tracking tunnel layout on Hogs Back Track. Yellow flags indicate individual tracking tunnels.



Appendix C.

Histogram displaying the number of overall catches per trap on the Hogs Back trapline.



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