Mammalian pest control: An assessment of a trapping programme at Craigieburn Forest Park

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

GEOG309: Research Methods in Geography
School of Geological Sciences
University of Canterbury
Christchurch
New Zealand

Table of Contents

Executive Summary

Research context

Community conservation groups across New Zealand run volunteer based trapping programmes that aim to control mammalian pests in advocation of native bird species. One particular group, The New Zealand Conservation Trust, have some concerns regarding the efficiency of their traplines. An assessment of their trapping programme will provide insight into trapline efficiency and ultimately provide a platform from which improvements can be made.

Research question

Are the current trapping methods implemented at Craigieburn Forest Park operating at their full potential, given resource limitations?

Methodology

- Two separate tracking tunnel lines were installed in forest remnant patches along the Hogs Back Track in Craigieburn Forest Park.
- Four tracking cameras were placed to derive qualitative data on pests.
- Pest abundance indices were determined through the Department of Conservation's tracking tunnel calculator.
- The New Zealand Conservation Trust historical catch data was assessed.

Key findings

- Mice are removing bait from traps, decreasing their effectiveness.
- Alternative pest control methods have the potential to improve New Zealand Conservation Trust's trapping operation.
- Trap maintenance and monitoring is required to ensure programme efficiency.

Major shortcomings and limitations of the research

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.

Future research/efforts

- 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.
- More stringent recording, monitoring and maintenance of traps.
- A more extensive multiple traplines study over a longer time period may produce findings that better represent New Zealand Conservation Trust's trapping efficiency.

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.

The New Zealand Conservation Trust have expressed general concern regarding the efficiency of their trapping operation. More specifically, they suspect mice (*Mus musculus*) are removing bait from traps, rendering them ineffective until they are re-set approximately one month later. In order to provide some insight into the NZCT's concerns, we developed the following research question; Are the current trapping methods implemented at Craigieburn Forest Park operating at their full potential, given resource limitations? It was important to acknowledge the resource limitations of the NZCT, i.e. funding and volunteer hours, to allow recommendations to be practical and employable. One particularly important limitation unique to groups trapping in the subalpine and alpine regions of the Southern Alps is the presence of endemic kea (*Nestor notabilis)* populations. Kea are a nationally endangered South Island parrot species that are 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 in the Hawdon Valley, near the Craigieburn Forest Park, reducing the uncertainty associated with environmental and/or ecological heterogeneity.

Some mammalian predators have been shown to exhibit trap shy behaviour, but by pre-feeding locked-open traps with a non-toxic bait, mammals may become more accustomed to their presence. In a study by King and Scurr (2013), pre-feeding traps significantly increased the 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 capture traps more efficient for both cost and volunteer effort (Carter & Peters, 2016; Warburton & Gormley, 2015). When pest densities are low, studies show that the efficiencies of multiple capture traps tend to decline (Carter & Peters, 2016). Warburton and Gormley (2015) concluded that under simulated low pest densities, single capture traps could continue to be a more cost effective option than multiple capture options. Although, under high densities such as an influx 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). Utilizing this method of application recorded high levels of effectiveness and efficiencies, with Murphy et al. (2014) claiming over 100 applications possible per trap, as well as near 100% kill rate. Currently there are restrictions for the use of toxins such as 1080 that include requisition of a licence. Such restrictions could limit toxin use in volunteer pest control programmes (Murphy et al., 2014) Regardless, both pest management methods could aid in improving the pest management plan used by the NZCT.

Current best practice and monitoring

A study done in New Caledonia targeting the Pacific, Black and Norway rats, as well as house mice found that the sensitivity settings of snap traps used was a significant contributing factor in determining which rodent species was caught (Theuerkauf, Rouys, Jourdan, & Gula, 2011). More sensitive traps caught smaller, lighter individuals in addition to the heavier mice species and rats, but experienced more false triggering events from abiotic factors such as inclement weather and falling sticks.

The negative effects stoats and rats have on indigenous bird populations are undoubtedly significant and trapping programmes have been shown to mitigate these negative effects (Gibbs, 2009; White & King, 2006). Controlling ship rat populations through the use of trapping alone is often ineffective, however, trapping is effective at controlling stoat and possum populations (Brown, Elliott, Innes, & Kemp, 2015). Recommended spacing between traps targeting rats and 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 mainland, although positive results have been shown from trapping operations in forest fragments in Hamilton, where Tui numbers increased eight-fold (Fitzgerald & Innes, 2013) as well as in the Catlins and Dart Valley, where, in combination with aerial application of 1080, trapping operations resulted in increased breeding success for Mohua populations (O'Donnell, Dilks, & Elliott, 1996).

Tracking tunnels are a cost effective method for monitoring rodent and mustelid abundance (King & Edgar, 1977). In summation, tracking tunnels are a 'run through' tunnel containing two pieces of paper either side with a tracking medium (black ink) and bait in the middle. The Animal footprints are left on the tracking paper as it moves through the tunnel (Gillies & Williams, 2013). Tracking tunnels are often not target specific, and can provide information on a variety of species cheaply and efficiently. Tracking tunnels are not a direct measure of population density, just a measure of activity, and so is best suited for comparisons to other locations which have also undergone tracking tunnel operations. For each tunnel line, each tunnel is recommended to be spaced 50 metres apart for rodent tracking, and 100 metres for mustelid tracking. Tracking tunnels should be placed across the environmental range in order to successfully generate measure for the entire location (Gillies & Williams, 2013).

As well as tracking tunnels, many pest control programmes use capture rates from kill traps as an indication of operative success. However, other techniques may be more successful in deriving animal abundances, particularly when abundances are low. King et al. (2007) highlights the importance of having effective monitoring in place, particularly when pest control efforts are costly and require time and effort. Glen, Warburton, Cruz, and Coleman (2014) compared trail cameras with kill traps to determine capture rates. They found that in areas with pest control operations that targeted stoats, feral cats (*Felis catus*) and hedgehogs (*Erinaceus europaeus occidentalis*), capture rates of cats and hedgehogs were higher with cameras than with kill traps. A similar study by Anton, Hartley, and Wittmer (2018) found cameras to be more efficient at 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 indicators of possums density, indices for this species were not calculated. However, density 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 detected by the cameras were noted to have bait missing but not have been triggered. This is an indication that mice are removing bait from traps without triggering the trap mechanism. Possums were recorded investigating the scent of the lure and attempting to enter the trap (Fig. 2). One possum was recorded interacting with a trap for approximately two hours before moving away. One rabbit, one chaffinch (*Fringilla coelebs*), and one blackbird (*Turdus merula*) were the only other species recorded by trail cameras.

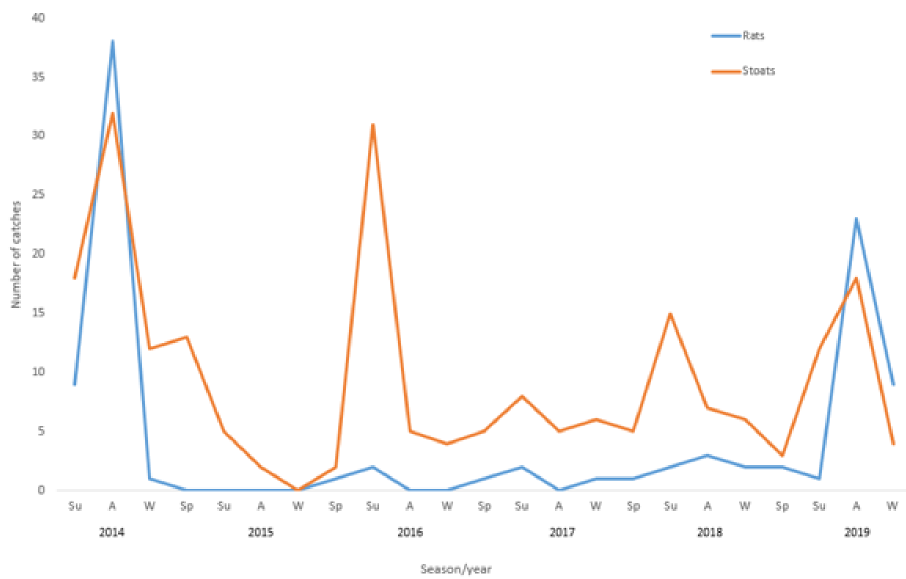


Figure 1. Seasonal trends in rat and stoat catches across five traplines in at Craigieburn Forest Park from 2014 - 2019. Su = summer, A = autumn, W = winter, Sp = spring. Data source: NZCT.

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.

Figure 2. Top: A mouse standing on the trap trigger plate of trap 253 as outlined by the black circle. Bottom: A possum standing on trap 256.

Discussion

A key finding of our research was the presence of rats in Craigieburn Forest Park. King (1983) and Kelly et al. (2005) both recorded the absence of rats during their studies in the area. Cold temperatures currently limit rats from extending into New Zealand's high altitude and more southern habitats (Walker, Kemp, Elliott, Mosen, & Innes, 2019). A study conducted between 1974 and 1999 showed that rats were not caught above ~1030m above sea level on Mt Misery, Nelson Lakes National Park, New Zealand (Christie, Wilson, Taylor, & Elliott, 2017). Mean annual air temperature across New Zealand between 1941 and 2010 have been recorded to be increasing ~0.1 °C per decade (Sturman & Quénol, 2013). The trend of an increasing climatic temperature poses an escalating threat to New Zealand's native birds as rat range and population expansion continues (Walker et al., 2019). Resource availability is also a key factor limiting rat population expansion, often mediated by plant productivity (Clapperton, Maddigan, Chinn, & Murphy, 2019).

The summer of 2018/2019 experienced the largest mast seeding event in more than 40 years (Department of Conservation, 2019), producing a dramatic increase in the food availability for rats and mice. Seed fall from this masting event occurred in the months of autumn, inducing a sudden and immense population explosion of rodents, as reflected in Figure 1. Following breeding in winter (Blackwell, Potter, & Minot, 2001). In New Zealand's southern beech forests, mice are the main prey choice of stoats (Smith & Jamieson, 2003). The population explosion of mice dramatically increases the carrying capacity of stoats within Craigieburn's Forest Park. This relationship was demonstrated in Veale, McMurtrie, Edge, and Clout (2015), where stoat populations did not experience a significant increase in recruitment following a mast year on islands void of rodents, whereas the contrary has been recorded on islands containing a rodent population. Stoats born following a masting event have also been shown to have a larger weight than years prior. This is of concern as larger individuals require more food, however, the mortality rate of stoats increases with size when food availability is low (King & Moody, 1982). In spring, seed rot and germination alongside seed predation drastically reduces the food availability for rodents. Following this reduction in food availability, mice in particular, will experience a 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 increase in body weight, this crash in mice population will be exacerbated by an increase in stoat predation. Scarcity of mice will ultimately cause stoats to search for an alternative prey source, imposing severe predation pressure on the native bird population. Stoats are the primary killer of kea (Innes et al., 2010), the Craigieburn Forest Park kea population is hence of particular concern. Stoats typically breed in the summer, and their young are often easier to catch due to reduced neophobic tendencies (Domigan & Hughey, 2008). This highlights the potential benefits of a targeted summer trapping operation, although, trapping throughout the year is most effective at reducing stoat populations (King & Powell, 2011).

Rats typically breed in the spring/summer in temperate forest habitats, they have the ability to produce four litters per breeding season, each containing on average 5-6 pups (Clapperton et al., 2019). However, a high resource abundance can allow rats to breed throughout the year, an expected response to a mast seed year. The rat population explosion requires attention, as rats have played a large role in the decline of many small endemic bird species (Parlato et al., 2015). Small, endemic, tree cavity nesting birds, such as the rifleman (*Acanthisitta chloris*), tomtit (*Petroica macrocephala*) and the South Island robin (*Petroica australis*) should be of particular concern in the Craigieburn Forest Park as their populations are declining nation-wide. Rats are said to be contributing to this decline, as they are able to enter small tree cavity openings, nesting sites of small bird species (Parlato et al., 2015). The hedgehog is also considered a predator to native birds, however, their main prey choices consist of a variety of large insects (Jones, Moss, & Sanders, 2005). Hedgehogs are a major predator of ground-nesting and riverbed breeding birds, such as the banded dotterel. However, in the case of the Craigieburn Forest Park, ground nesting birds are not prevalent (Kelly et al., 2005)

Another key finding was mice interference with bait. By removing bait from traps mice are rendering the traps useless for the duration of the trapping period. Additionally, active control of mice is of lesser importance than that of rats and stoats as mice populations are likely to decline 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 being able to successfully capture pests. This is important for the NZCT's trapping programme considering it is volunteer based, there may be times where the current traps cannot be maintained. Pre-feeding existing traps could also be an option to increase rat trap efficiency. King & Scurr (2013) pre-fed traps with non-toxic PRO cereal pellets and had successful results in trap efficiency. Pre-fed traps have been shown to increase the captures per volunteer effort, a key finding for future work by the NZCT.

From camera observations, possums have been detected in the area. Currently there are no control methods in place for possums in Craigieburn Forest Park due to the risk posed to kea, and the absence of kea-approved traps. Possums are omnivorous and prey on eggs and chicks of a variety of forest birds species (Brown, Innes, & Shorten, 1993). In general, possum populations can be easily reduced by establishing traps or poison stations (D. Kelly, personal communication September 21, 2019), in the absence of kea-approved traps targeted poison stations could be an option for possum control for the NZCT. Finally, improving trap maintenance through volunteer 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 results we could not adhere to this thus compromising the quality of our tracking results. Additionally, seasonality may have affected our quantitative results by reduced detection rates (Jackson et al., 2015), as well as bad weather preventing rat tracking cards from being collected after two nights instead of the recommended one night.

Tracking tunnel results and ground observations are only representative of the Hogs back Track trapline, thus our findings may not be reflective of other NZCT traplines. Kea are present in the area, limiting what can be done with pest control. There is uncertainty if kea are at risk of bycatch or poisoning when certain traps or toxin delivery methods are utilized. Due to the proximity of the Hogsback to Castle hill village, and because the track is often accessed by the public, pest eradication methods need to take these factors into account.

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 additional resources. Moderate densities of mice were found along the Hogs Back track, we expect this population to diminish following resource depletion and predation by stoats. However, we have found that mice are removing bait from traps, decreasing the effectiveness of the traps.

Exploitation of the 2018/2019 mast seeding event will dramatically increase the threat to New Zealand's native bird population. The recent detection of rats within the alpine environment introduces challenges for conservation efforts in these areas. Effective control of rats and stoats will require the use of multi-capture traps and/or targeted poison delivery systems. Implementation of these methods will optimise volunteer efforts. To ensure targeting control of rats and stoats, hedgehog catch could be reduced by raising the traps off the ground. Exploration into alternative baits and lures may also help to improve future trapping efforts, increasing target affinity and capture rate.

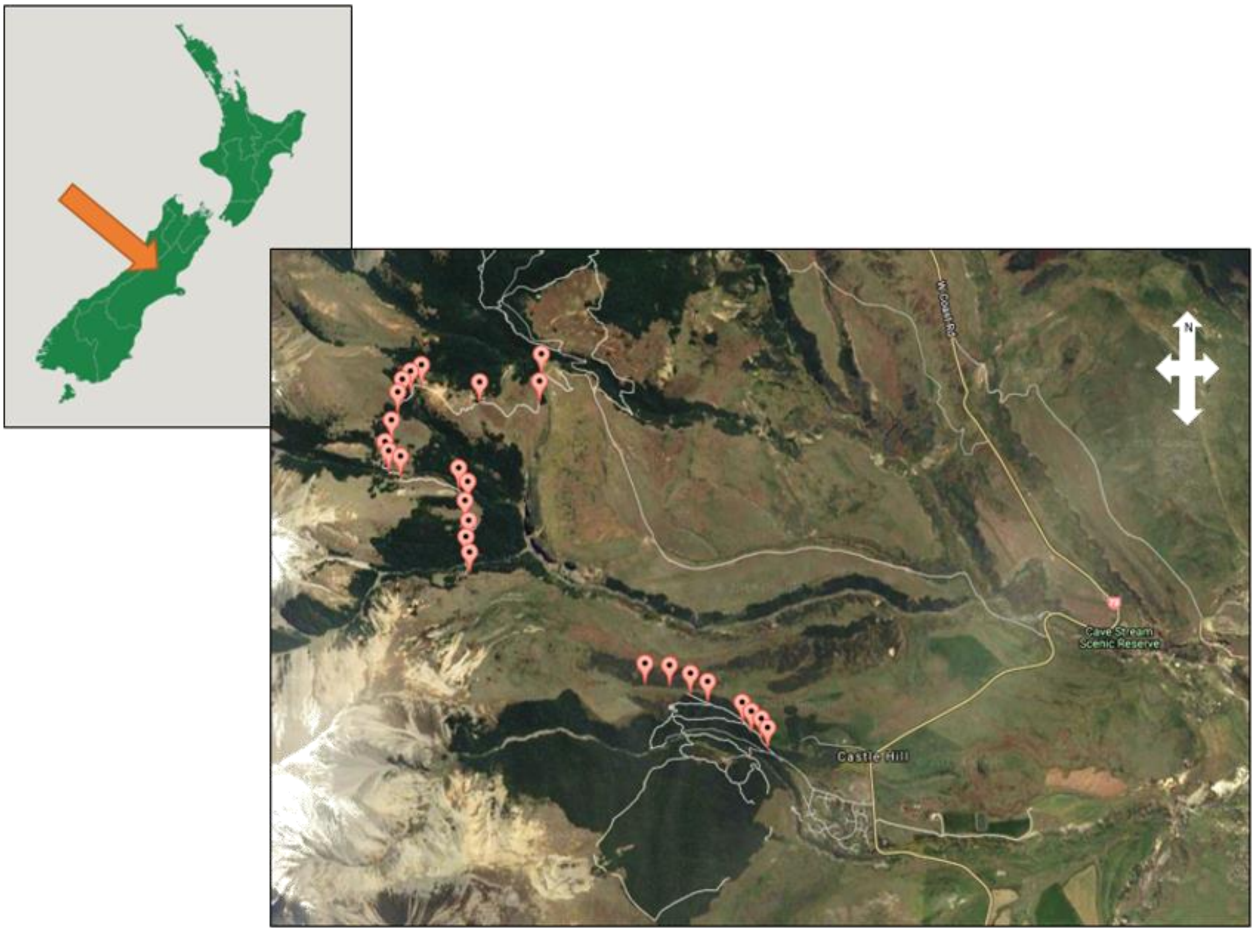
Acknowledgements

We would like to thank Dave Kelly, for his help and recommendations on the direction of our research and the project in general, Hadee Thompson-Morrison for keeping us on track and for her advice on how to tackle the project as a group. Daniel Leadbeater, our community partner, for his enthusiasm and understanding, and without his involvement the project would not have happened in the first place, and for this we thank him greatly. We would like to extend this thanks to The New Zealand Conservation Trust also, for approaching us with the project and for their overall contributions to conservation in New Zealand.

Appendices

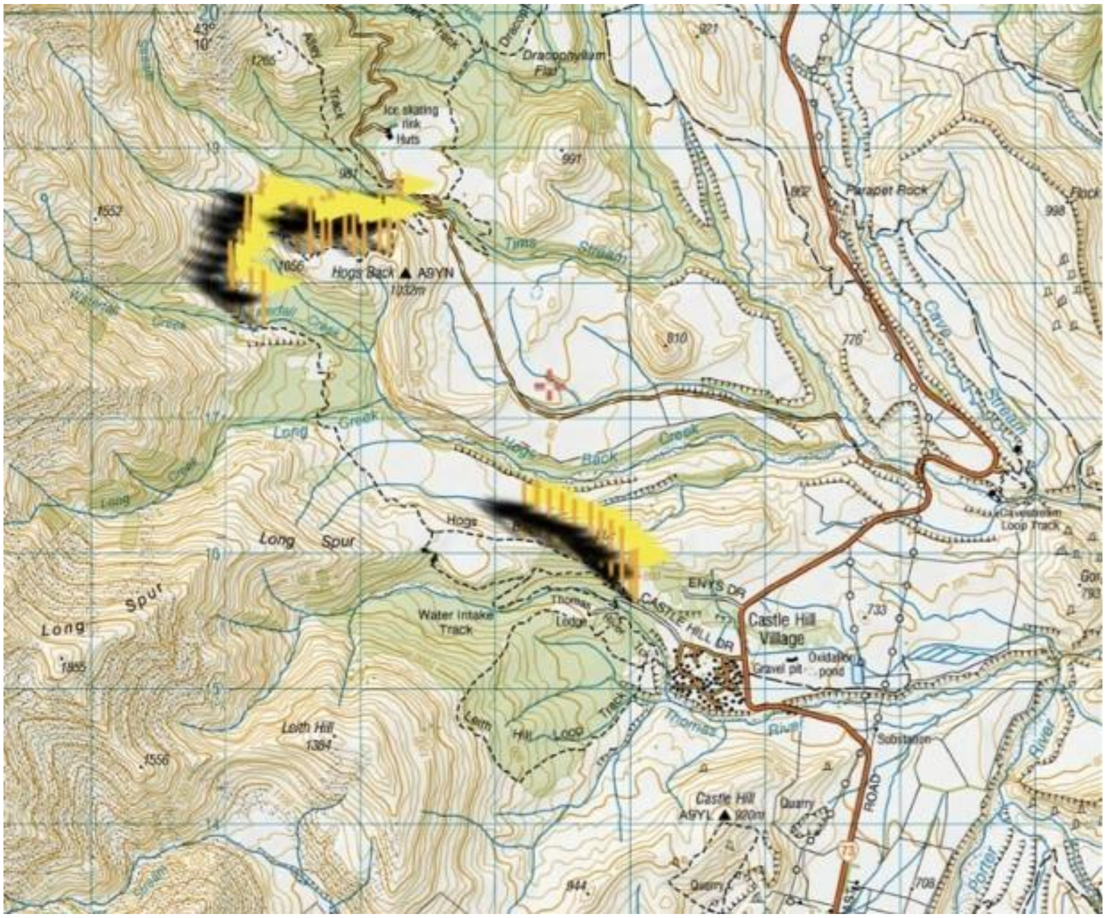
Appendix A.

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



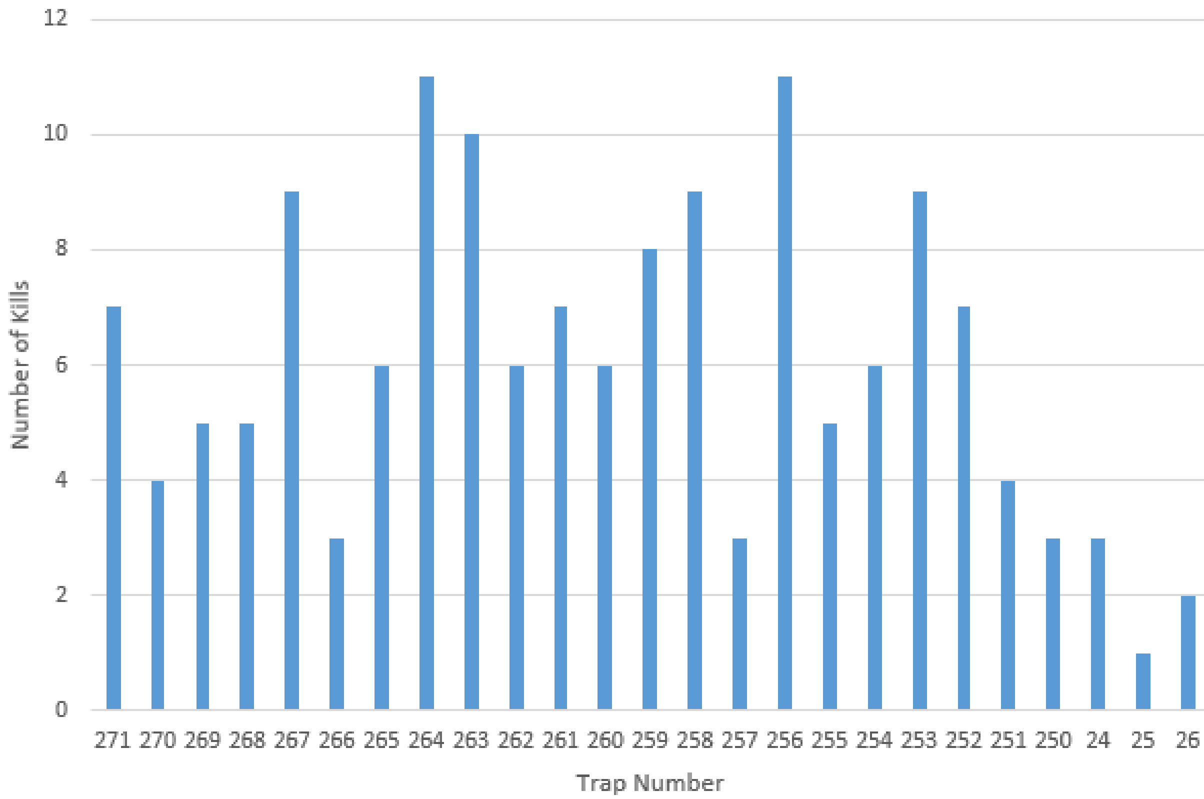
Appendix B.

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.



References

Anton, V., Hartley, S., & Wittmer, H. U. (2018). Evaluation of remote cameras for monitoring multiple invasive mammals in New Zealand. *New Zealand Journal of Ecology, 42*, 74-79. doi:10.20417/nzjecol.42.3

Blackwell, G. L., Potter, M. A., & Minot, E. O. (2001). Rodent and predator population dynamics in an eruptive system. *Ecological Modelling., 142*(3). doi:10.1016/S0304-3800(01)00327-1

Brown, K., Elliott, G., Innes, J., & Kemp, J. (2015). Ship rat, stoat and possum control on mainland New Zealand. An overview of techniques, successes and challenges. Retrieved from https://www.doc.govt.nz/about-us/science-publications/conservation-publications/threats-and-impacts/animal-pests/ship-rat-stoat-and-possum-control-on-mainland-new-zealand/

Brown, K., Innes, J., & Shorten, R. (1993). Evidence that possums prey on and scavenge birds' eggs, birds and mammals. *Notornis., 40*(3), 169-177. Retrieved from https://notornis.osnz.org.nz/publications

Byrom, A. E., Innes, J., & Binny, R. N. (2016). A review of biodiversity outcomes from possum-focused pest control in New Zealand. *Wildlife Research, 43*(3), 228-253. doi:10.1071/WR15132

Campbell, K. J., Beek, J., Eason, C. T., Glen, A. S., Godwin, J., Gould, F., & Threadgill, D. W. (2015). The next generation of rodent eradications: Innovative technologies and tools to improve species specificity and increase their feasibility on islands. *Biological conservation, 185*, 47-58. doi:10.1016/j.biocon.2014.10.016

Carter, A., Barr, S., Bond, C., Paske, G., Peters, D., & van Dam, R. (2015). Controlling sympatric pest mammal populations in New Zealand with self-resetting, toxicant-free traps: A promising tool for invasive species management. *Biological Invasions, 18*(6), 1723-1736. doi:10.1007/s10530-016-1115-4

Carter, A., & Peters, D. (2016). Self-resetting traps provide sustained, landscape-scale control of a rat plague in New Zealand. *In Proceedings of the Vertebrate Pest Conference, 27*. doi:10.5070/V427110527

Christie, J. E., Wilson, P. R., Taylor, R. H., & Elliott, G. (2017). How elevation affects ship rat (*Rattus rattus*) capture patterns, Mt Misery, New Zealand. *New Zealand Journal of Ecology, 41*(1). doi:10.20417/nzjecol.41.16

Clapperton, B. K., Maddigan, F., Chinn, W., & Murphy, E. C. (2019). Diet, population structure and breeding of *Rattus rattus* L. in South Island beech forest. *New Zealand Journal of Ecology., 43*(2), 1-8. doi:10.20417/nzjecol.43.22

Department of Conservation. (2019). Where to put trap and bait lines. Retrieved from https://www.doc.govt.nz/nature/pests-and-threats/predator-free-2050/toolkit-predator-free-2050/trapping-and-poisoning/where-to-put-trap-and-bait-lines/

Dilks, P. J., O'Donnell, C. F. J., Elliott, G. P., & Phillipson, S. M. (1996). The effect of bait type, tunnel design, and trap position on stoat control operations for conservation management. *New Zealand Journal of Zoology, 23*(3), 295-306. doi:10.1080/03014223.1996.9518088

Domigan, I. R., & Hughey, K. F. D. (2008). Trapping tunnel design incorporating behavioural preferences of stoats. *New Zealand Journal of Zoology, 35*(3), 243-250. doi:10.1080/03014220809510120

Eason, C. T., Shapiro, L., Ogilvie, S., King, C., & Clout, M. (2017). Trends in the development of mammalian pest control technology in New Zealand. *New Zealand Journal of Zoology, 44*(4), 267-304. doi:10.1080/03014223.2017.1337645

Elliott, G., & Kemp, J. (2016). Large-scale pest control in new zealand beech forests. *Ecological Management & Restoration, 17*(3). doi:10.1111/emr.12227

Farnworth, B., Innes, J., & Waas, J. R. (2016). Converting predation cues into conservation tools: The effect of light on mouse foraging behaviour. *Plos One, 11*(1). doi:10.1371/journal.pone.0145432

Fitzgerald, N., & Innes, J. (2013). *Hamilton City biennial bird counts: 2004–2012*. Retrieved from http://www.hamilton.govt.nz/

Gibbs, G. W. (2009). The end of an 80-million year experiment: a review of evidence describing the impact of introduced rodents on New Zealand's 'mammal-free' invertebrate fauna. *Biological Invasions, 11*, 1587–1593. doi:10.1007/s10530-008-9408-x

Gillies, C. A., & Williams, D. (2013). *DOC tracking tunnel guide v2. 5.2: Using tracking tunnels to monitor rodents and mustelids.* Retrieved from https://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-animal-pests-using-tracking-tunnels-to-monitor-rodents-and-mustelids.pdf

Glen, A., Warburton, B., Cruz, J., & Coleman, M. (2014). Comparison of camera traps and kill traps for detecting mammalian predators: A field trial. *New Zealand Journal of Zoology, 41*(3), 155-160. doi:10.1080/03014223.2014.898667

Holdaway, R. N. (1989). New Zealand's pre-human avifauna and its vulnerability. *New Zealand Journal of Ecology, 12*, 11-25. Retrieved from https://newzealandecology.org/nzje

Innes, J., Kelly, D., Overton, J. M., & Gillies, C. (2010). Predation and other factors currently limiting new zealand forest birds. *New Zealand Journal of Ecology, 34*(1), 86-114. Retrieved from https://newzealandecology.org/nzje

Jackson, M., Hartley, S., & Linklater, W. (2015). Better food-based baits and lures for invasive rats *Rattus* spp. and the brushtail possum *Trichosurus vulpecula*: A bioassay on wild, free-ranging animals. *Journal of pest science, 89*(2), 479-488. doi:10.1007/s10340-015-0693-8

Jones, C., Moss, K., & Sanders, M. (2005). Diet of hedgehogs (*Erinaceus europaeus*) in the Upper Waitaki basin, New Zealand: Implications for conservation. *New Zealand Journal of Ecology, 29*(1), 29-35. Retrieved from https://newzealandecology.org/nzje

Kelly, D., Brindle, C., Ladley, J. J., Robertson, A. W., Maddigan, F. W., Butler, J., . . . Sessions, L. A. (2005). Can stoat (*Mustela erminea*) trapping increase bellbird (*Anthornis melanura*) populations and benefit mistletoe (*Peraxilla tetrapetala*) pollination? *New Zealand Journal of Ecology, 29*(1), 69-82. Retrieved from https://newzealandecology.org/nzje

King, C. M. (1983). The relationships between beech (*Nothofagus sp*.) seedfall and populations of mice (*Mus musculus*), and the demographic and dietary responses of stoats (*Mustela erminea*), in three Zew Zealand forests. *Journal of Animal Ecology, 52*(1), 141-166. doi:10.2307/4593

King, C. M., & Edgar, R. L. (1977). Techniques for trapping and tracking stoats (*Mustela erminea*): A review, and a new system. *New Zealand Journal of Zoology, 4*, 193–212. doi:10.1080/03014223.1977.9517953

King, C. M., McDonald, R. M., Martin, R. D., MacKenzie, D. I., Tempero, G. W., & Holmes, S. J. (2007). Continuous monitoring of predator control operations at landscape scale. *Ecological Management and Restoration*, 133-139. doi:10.1111/j.1442-8903.2007.00350.x

King, C. M., & Moody, J. E. (1982). The biology of the stoat (*Mustela erminea*) in the national parks of New Zealand III: Morphometric variation in relation to growth, geographical distribution, and colonisation. *New Zealand Journal of Zoology, 9*(1), 81-102. doi:10.1080/03014223.1982.10423839

King, C. M., & Powell, R. A. (2011). Managing an invasive predator pre-adapted to a pulsed resource: A model of stoat (*Mustela erminea*) irruptions in New Zealand beech forests. *Biological Invasions, 13*(12), 3039-3055. doi:10.1007/s10530-011-9993-y

King, C. M., & Scurr, D. (2013). Optimizing the ratio of captures to trapping effort in a black rat *Rattus rattus* control programme in New Zealand. *Conservation Evidence, 10*, 95-97. Retrieved from https://www.researchgate.net/journal/1758-2067_Conservation_Evidence

Murphy, E., Sjoberg, T., Barun, A., Aylett, P., MacMorran, D., & Eason, C. (2014). Development of re-setting toxin delivery devices and long-life lures for rats. *In Proceedings of the Vertebrate Pest Conference, 26*(26). doi:10.1080/03014223.2018.1461118

O'Donnell, C. F. J., Dilks, P. J., & Elliott, G. P. (1996). Control of a stoat Mustela erminea population irruption to enhance mohua (yellowhead) Mohoua ochrocephala breeding success in New Zealand. *New Zealand Journal of Zoology, 23*, 279-286. doi:10.1080/03014223.1996.9518086

Parlato, E. H., Armstrong, D. P., & Innes, J. G. (2015). Traits influencing range contraction in new zealand's endemic forest birds. *Oecologia, 179*(2), 319-328. doi:10.1007/s00442-015-3330-6

Smith, D. H. V., & Jamieson, I. G. (2003). *Movement, diet, and relative abundance of stoats in an alpine habitat* (DOC science internal series 107). Retrieved from https://www.doc.govt.nz/globalassets/documents/science-and-technical/DSIS107.pdf

Sturman, A., & Quénol, H. (2013). Changes in atmospheric circulation and temperature trends in major vineyard regions of New Zealand. *International Journal of Climatology, 33*(12), 2609-2621. doi:10.1002/joc.3608

Theuerkauf, J., Rouys, S., Jourdan, H., & Gula, R. (2011). Efficiency of a new reverse-bait trigger snap trap for invasive rats and a new standardised abundance index. *Annales Zoologici Fennici, 48*(5), 308-318. doi:10.5735/086.048.0505

Veale, A. J., McMurtrie, P., Edge, K., & Clout, M. N. (2015). The effects of mice on stoats in southern beech forests. . *Austral Ecology, 40*(1), 32-39. doi:10.1111/aec.12161

Walker, S., Kemp, J. R., Elliott, G. P., Mosen, C. C., & Innes, J. G. (2019). Spatial patterns and drivers of invasive rodent dynamics in New Zealand forests. *Biological Invasions, 21*(5), 1627-1642. doi:10.1007/s10530-019-01922-0

Warburton, B., & Gormley, A. M. (2015). Optimising the application of multiple-capture traps for invasive species management using spatial simulation. *Plos One, 10*(3). doi:10.1371/journal.pone.0120373

White, P. C. L., & King, C. M. (2006). Predation on native birds in New Zealand beech forests: the role of functional relationships between stoats *Mustela erminea* and rodents. *Ibis, 148*, 765–771. doi:10.1111/j.1474-919X.2006.00579.x