Herpetofauna survey of geothermal ecosystems in the Waikato region

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ABSTRACT

The indigenous ground dwelling fauna of geothermal ecosystems in the Taupo Volcanic Zone is relatively poorly understood. A tracking tunnel survey was conducted with the aim of identifying the ground-dwelling vertebrates living in geothermal habitats at four sites in the Taupo Volcanic Zone, with the specific intent of locating and identifying native lizard populations at these sites. 162 tracking cards were collected from a total of 60 tracking tunnels over a period of 40 days. The tracks recorded on the tracking cards were identified, and Chi squared (X^2) analysis was performed to identify the strength of the relationships between the type of prints detected, the vegetation type at the tunnel, and the site from which the tunnels were collected. In total, the prints of six different terrestrial vertebrate species and groups of vertebrates were identified. The common brushtail possum *(Trichosurus vulpecula)*, the European hedgehog (*Erinaceus europaeus*), various rat species (*Rattus sp*.), an unidentified mustelid species (*Mustela sp*.), house mice (*Mus musculus*) and an unidentified skink species, likely indigenous, (*Oligosoma sp*.) were detected at these sites. Print detection exhibited a relationship with both site and with vegetation type, though it was unclear whether site related factors or vegetation related factors had the more significant effect on the distribution of terrestrial vertebrates. This study is the first of its kind to find evidence of a lizard association with a geothermal habitat in New Zealand. Additional research will be necessary to identify the species of the lizard detected.

1. INTRODUCTION

The Taupo Volcanic Zone (TVZ) in the northern half of the North Island of New Zealand is home to unique geothermal ecosystems and habitats. These ecosystems are highly localized and are generally defined by geothermally acidified and mineralized soils, centered around one or more geothermal features, such as patches of heated ground, geothermal streams, pools, and fumaroles. The characteristics of these Geothermal Ecosystems are dependent on a range of factors, such as soil and water chemistry, hydrology, local topography, and climate, that combine in ways that make them highly variable compared to other native habitats. This variability can even exist within any given ecosystem, as geothermal ground cools, and geochemical influences diminish with distance from geothermal features. The unique characteristics of these systems allow flora and fauna that would otherwise be unable to survive at lower latitudes to establish themselves in the unusual geothermal habitats of the TVZ. Plants normally confined to warmer climates have established communities here, and endemic species have developed distinct genetic forms giving these habitats special significance (Beadel et al., 2018).

The localized nature of these ecosystems, combined with their small size, variable habitats, and unique flora make them especially vulnerable from a conservation standpoint (Holdaway et al., 2012) as small changes in any number of factors could theoretically result in the destruction of rare and unique geothermal habitats. Threats to these systems include the depletion of geothermal water resources for energy production reducing ground temperatures, intrusions by pest plant species, grazing and destruction of soil structure by domestic livestock, damage caused by geothermal tourism, and intrusion by plantation forestry, among others. Ensuring the sustainable management of these ecosystems is an ongoing task for the Waikato and Bay of Plenty Regional Councils. (Boothroyd, 2009; Beadel et al., 2018).

As part of geothermal monitoring efforts in the region, the vegetation of geothermal ecosystems in the TVZ is reasonably well defined (Smale and Fitzgerald, 2014) (Wildlands Consultants, 2014a, 2021), as is the biota of geothermal waters (Duggan and Boothroyd, 2002, 2003); the terrestrial fauna of these ecosystems, however, is relatively poorly understood. Though some study has been conducted on terrestrial macro-invertebrates in geothermal ecosystems, (Willoughby and Beard, 2013), no studies so far have been done on the distribution of terrestrial vertebrates in geothermal ecosystems of the TVZ.

Of the terrestrial vertebrates with the potential to be endemic to geothermal ecosystems, indigenous lizards are a good candidate for study. They, along with frogs, have short ranges (Hitchmough *et al.*, 2021) so the detection of an individual within a geothermal ecosystem will imply the existence of a permanent population within that ecosystem. These localised populations will have a more intimate relationship with the geothermal ecosystems than far ranging birds or bats. As many indigenous lizards native to the TVZ are also nationally endangered (Hitchmough *et al.*, 2021), determining whether these species have populations in geothermal habitats is an essential step in the protection and management of both geothermal ecosystems, and of indigenous lizard populations.

New Zealand lizard species tend to be highly elusive (Bell, 2009) so detecting and monitoring New Zealand geckos and skinks visually is difficult. Nonvisual methods like pitfall traps, g-minnow traps and tracking tunnels must be employed to identify and categorise skink and gecko populations. Of these methods, tracking tunnels are cheap, low maintenance, are quick to install and uninstall, and can be left in the field for extended periods of time without needing to be retrieved. In addition, they do not involve the same risks to animals as trapping or handling. This makes tunnels the ideal method for detecting and locating populations, as they can be quickly deployed over a large area, where they can collect data over a long period of time without having to be checked on more than once a fortnight. In most cases, it is difficult to distinguish between the tracks recorded on a tracking card of species within the same family. Tracking cards can distinguish between families of animals (mouse and rat tracks for example) however, with reasonable accuracy. To identify the species of a given population, more intensive monitoring methods like g-minnow and pitfall traps for lizards, or camera traps and, mechanical traps and bait stations for mammals, must be employed. As tracking tunnels cannot easily select for any given species, data on exotic vertebrate populations, including stoats, ferrets, weasels, rats, mice and possums, and even on terrestrial invertebrate populations is also collected in studies that use them. Tracking tunnels can also struggle in that they do not detect all animals in the area around the tunnel. Because of this, reports on studies that use tunnels can typically only discuss species distribution in terms of likelihood of detection (MacKenzie *et al*., 2002).

This survey aims to use tracking tunnels to determine the existence and distribution of any populations of native lizards, and potentially of mammalian pest species at four geothermal systems within the Taupo Volcanic Zone. Tracking card data was cross-referenced with vegetation data, (Wildlands Consulting 2014a, 2021), to identify any relationships between vegetation type and vertebrate detection.

2. EXPERIMENTAL

2.1 Site Selection

Four geothermal ecosystems in the Waikato region were selected based on geographical spread, the ease by which they could be accessed, and on the diversity of their geothermal vegetation. They were monitored for a period of 40 days between 9 December 2021 and 21 January 2022. These ecosystems were Waikite geothermal ecosystem, the Longview Road geothermal ecosystem in the Reporoa Geothermal System, the Ōrakei-kōrako geothermal ecosystem and the Craters of the Moon geothermal ecosystem in the Wairākei-Tauhara Geothermal System

A total of 60 tracking tunnels with inked tracking cards were installed in geothermal vegetation over this period, in a range of sites selected in the field to represent a range of vegetation types and degrees of geothermal influence. In total 162 tracking cards were collected from the four sites.

2.2 Data Collection

Tracking cards were collected from the tunnels thrice during the 40-day monitoring period, and precise location (±5 metres) was recorded for each tunnel.

Vegetation class at each tracking tunnel was described in the field, and cross referenced with data from Wildlands Consulting technical reports (2014a, 2021). Where there was discrepancy between the 2014 Wildlands report vegetation class and the observed vegetation, vegetation class was redefined based on field observations, using classes described by Wildlands, 2014. Occasionally vegetation at a tunnel location was part of a unique microhabitat that was localised to a single site. After data collection, these vegetation classes were re-categorised into one of six broad categories based on similarities in vegetation, and on proximity to sites with well-defined vegetation.

In total, six main vegetation classes were sampled in this study: Indigenous fernland, Indigenous treeland, manuka-dominant scrub mingimingi-dominant scrub, kānuka-dominant scrub, and Loamfield.

2.3 Data Analysis

The tracks of rat species, mice (*Mus musculus*), the common brushtail possum (*Trichosurus vulpecula)* mustelids, European hedgehogs (*Erinaceus europaeus)*, *Oligosoma* skink species and gecko species can all be easily distinguished on inked tracking cards. (Agnew, 2009) For each tracking card, presence and absence of each of these groups were recorded.

For each tracking card and each tunnel, the vegetation class, broad vegetation description, tunnel location and the animals detected were described qualitatively. The number of cards from each site, the number of cards collected from each vegetation type, and the number of cards on which a given species was detected were recorded as discrete variables.

Chi Squared (X^2) tests were used to determine the significance of the association between the site and vegetation class of a given card, and the detection of the various species identified in this study.

$$X^2 = \sum \frac{(Observed\ detection - Expected\ detection)^2}{Expected\ detection}$$

The following notation is used in this report to describe the conditions behind statements of significance. (X^2 (*degrees of freedom*, N = *number of samples total*) = *Chi squared for these parameters*, p = *selected confidence level*.)

3. RESULTS

3.1 Data

A total of 162 tracking cards were gathered from sites at Waikite, Longview Rd, Ōrakei-kōrako, and Craters of the Moon (Figure 1). Of these cards, 20 were taken from Waikite, 28 from Longview Rd, 38 from Ōrakei-kōrako, and 76 from Craters of the Moon. Prints on these cards were identified.

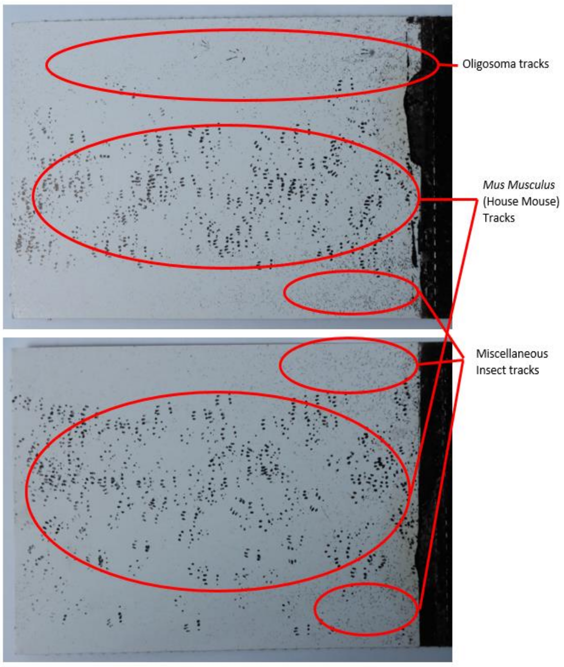

Figure 1: Example tracking card with skink and mouse tracks from Craters of the Moon.

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Of the groups identified in this study, Mice were present at all sites, and detected frequently at all sites other than Waikite. Rats were detected at all sites in moderate numbers other than at Longview Road, where they were not detected at all, the brushtail possum was detected at all sites, though it was uncommon at Ōrakei-kōrako and Craters of The Moon. The European hedgehog, and an unspecified mustelid were detected at Waikite only, and in low numbers. Geckos were not detected at any sites, and skinks were detected only once, at Craters of the Moon.

Table 1: Number of cards with tracks belonging to *M musculus (M.m), Rattus sp. (R.sp.), T vulpecula (T.v.), Oligosoma sp (O.sp.).*, and *E europaeus (E.e.)* collected from the Craters of the Moon (CTM), Longview Rd (LVR), Ōrakei-kōrako (ORK) and Waikite (WKT) geothermal ecosystems.

Site	*M.m.*	*R.sp.*	*T.v*	*E.e.*	M.sp.	O.sp.	Cards
CTM	28	29	2	0	1	1	76
LVR	15	0	4	0	0	0	28
ORK	13	15	2	0	0	0	38
WKT	1	5	12	4	0	0	20
Total	**57**	**49**	**20**	**4**	**1**	**1**	**162**

Of the vegetation classes sampled in this study, Mingimingi-dominant and kānuka-dominant scrub were the most common, followed by Mānuka-dominant scrub. Loamfield and indigenous fernland were the least sampled of the vegetation types in this study and sampled slightly more frequently were Indigenous treeland and manuka dominant scrub in that order.

The tracking card data from each of the sites can be cross-referenced with vegetation class data to compare the abundance of the four different groups detected under different types of plant coverage.

Table 2: Number of cards with tracks belonging to *M musculus (M.m), Rattus sp. (R.sp.), T vulpecula (T.v.), Oligosoma sp (O.sp.).*, and *E europaeus (E.e.)* collected from vegetation classes indigenous fernland (IF), indigenous treeland (IT), loamfield (LO), manuka dominant scrub (MaS), mingimingi dominant scrub (MiS) and kanuka dominant scrub at Craters of the moon, Longview Road, Ōrakei-kōrako and Waikite geothermal ecosystems.

Class	*M.m.*	*R.sp.*	*T.v.*	*E.e.*	*M.sp.*	*O.sp*	Cards
IF	0	3	0	0	0	0	10
IT	2	10	8	4	1	0	18
LO	7	2	0	0	0	0	9
MaS	13	7	2	0	0	0	22
MiS	17	14	3	0	0	0	42
KS	18	13	7	0	0	1	61
Total	**57**	**49**	**20**	**4**	**1**	**1**	**162**

The Skink at Craters of the Moon was detected in Geothermal kānuka-dominant scrub. As only one individual was identified, no comment may be made on the variation of detection for this species.

3.2 Statistical Analysis

Using chi squared (X^2) tests, the statistical significance of the variation of one discrete variable with another can be determined. This method determines the probability of an observed distribution occurring if there is no relationship between variables, and the true distribution is random. This probability can be used as a measure of significance. Analysing the data from all sites and vegetation classes together, detection of *Mus musculus*, *Rattus* sp., hedgehogs (*Erinaceus europaeus)*, and of possums (*Trichosurus vulpecula)* varied significantly both with site, (X^2 (3, N = 168) = 7.15, p<0.05), and with vegetation (X^2 (7, N = 168) = 11.07, p<0.05).

Tracking tunnels were successfully able to detect the presence of native lizards in a geothermal habitat at Craters of the Moon in the Taupo Volcanic Zone. Only one lizard was detected, so there is no way to draw any conclusions about the size or distribution of any lizard populations in the ecosystem. Pest species, (hedgehogs, rats, mice, mustelids, and possums), were also detected in geothermal ecosystems. Hedgehogs and mustelids were detected exclusively at Waikite. The proportion of cards that detected possums was highest at Waikite, with 60% of the cards collected from that site having possum print. Mouse detection at Waikite was the lowest of all four sites, though this may be because possum damage to the cards prevented mice from being detected. Mice were detected on the highest proportion of cards from Longview Road, with just over 54% of all cards from that site showing signs of mice. At Longview Road possums were detected on the second highest proportion of cards, with 14% of Longview Road sites showing possum sign. Rats were not detected at Longview Road. At the two tourist sites, Ōrakei-kōrako and Craters of the Moon, there was no significant variation in detection of any species with site, (X^2 (2, N = 114) = 3.841 p>0.05.) At Ōrakei-kōrako, 39% of cards detected rats, 31% of cards detected mice and 5% detected possums, at Craters of the Moon 38% of cards detected rats, 36% detected mice, and 3% detected possums.

While detection of mammalian pests varied significantly when data from all four sites was compiled, at individual sites, correlation between detection and vegetation was inconsistent. At Longview Road, there was no clear relationship between detection and vegetation for any vertebrates, (X^2 (2, N = 28) = 5.99, p<0.05). At Waikite there was no significant variation in detection with vegetation for all pests other than *Erinaceus europaeus* (X^2 (2, N = 20) = 5.99, p<0.05), with twice as many hedgehogs detected in indigenous treeland than would be expected given a random distribution. There was statistically significant variation in mouse species *(Mus musculus)* detection with vegetation at Ōrakei-kōrako, X^2 (3, N = 38) = 7.81, p<0.05. With mice detected in fernland and on Loamfield far more commonly than they would have been if detection had been completely random. In contrast, at Craters of the Moon only *Rattus sp.* detection varied significantly with vegetation, X^2 (3, N = 76) = 7.81, p<0.05. Rats were found more frequently in diverse mingimingi scrub and Indigenous treeland than would be expected given a random distribution.

Similarly, variation in detection of groups of vertebrates with site was only statistically significant (p<0.05) under certain vegetation classes. For example, in mingimingi-dominant scrub, *Mus musculus*, *Trichosurus Vulpecula*, and *Erinaceus europaeus*, detection showed no significant variation with site, (X^2 (2, N = 42) = 3.84, p<0.05) but *Rattus* sp. detection did. In kānuka-dominant scrub, *Mus musculus* and *Trichosurus vulpecula* detection varied significantly between sites, (X^2 (3, N = 61) = 5.99, p<0.05), while *Rattus* sp. and *Erinaceus europaeus* detection did not, as Craters of the Moon was the only site where mice were detected in kānuka dominant scrub, and Waikite and Ōrakei-kōrako were the only sites where *Trichosurus* was detected in the vegetation class.

4. DISCUSSION

Wildlands Consultants (2014b) identified key sites which it deemed were under significant threat from pest animals, including possums, which were identified in this study. Although this document focused primarily on larger terrestrial mammals, such as pigs and deer, interesting comparisons can be drawn between its risk assessment at the four sites and the detection of mammalian pests in tracking tunnels. Waikite and Ōrakei-kōrako were both classified as under "medium" threat from pest animals and Longview Rd and Craters of the Moon were classified as under low risk. In this study, the detection of possums at Waikite was significantly higher than at any of the other sites (X^2 (3, N = 168) = 7.15, p<0.05), including Ōrakei-kōrako, which was under a similar level of threat in Wildlands (2014b). There was no significant variation between possum detection at Ōrakei-kōrako and Craters of the Moon, (X^2 (2, N = 114) = 3.841 p>0.05), despite threat at the two sites being different in 2014. Assuming detection is directly correlated to population of a mammal species, threat at Ōrakei-kōrako may have dropped to low since 2014, as wilding pine removal and pest control have provided greater protection to native geothermal habitats, but threat at Waikite seems to have remained high.

It is very likely that factors related to both site location and management and to vegetation coverage influence the population distributions and thereby the detection rates of pest species in the Taupo Volcanic Zone, though this cannot be confirmed given the lack of stratification in the sampling method employed by this study. Studies on the factors controlling pest species distribution in New Zealand bush suggest that distribution of a species can be related to any number of factors simultaneously. Watkins (2007) determined that in native ecosystems around Pureora, mouse, stoat, and rat detection were affected by habitat. The same study also found that detection of pest species varied not only between habitats, but also spatially within habitats at both Pureora and in Fiordland. Breedt (2017), and Breedt and King (2021) in their studies of pest species distributions in the Waikato Region, estimated that pest species populations varied significantly between locations, land use classes, and vegetation types. They found that pest populations varied spatially within blocks of similar vegetation at the same site. Innes *et al*. (2010) found that management of pasture adjacent indigenous ecosystems and ecosystem fragments, like the one at Waikite, can have a significant effect on mammalian pest population distribution. They found that rats were far more common in fenced, pasture adjacent, forest fragments like the Waikite site, rather than in unfenced fragments, or in large stands of indigenous forest.

Elsewhere in the world, Madden *et al*. (2019) used a tracking tunnel study to find any associations between vegetation coverage and rodent populations on St Eustatius Island in the Caribbean Netherlands. They found correlation between vegetation diversity and rodent population, with rodents preferring denser rainforest to sparse scrub. Our study recorded a similar trend in *Rattus* species detection, both overall, and specifically within the Craters of the Moon ecosystem, where Rattus species were detected more frequently in diverse, mingimingi-dominant scrub than would be expected if their distribution within the ecosystem was random.

As the sampling methods employed in this study were not truly random and samples were not stratified for either site or for vegetation type, it is impossible to determine whether factors relating to site, or factors relating to vegetation type had the more significant effect on detection rates for the of mammalian pests. Nor is it within the scope of this study to identify the nature of any interdependency between vegetation type and site which may be affecting the relationships observed. Expanding the scope of the sampling, including some sort of stratification based on vegetation class and site, and increasing the randomness of the method by which tracking tunnel sites are selected could be potential avenues for further study. Another potential avenue of investigation could involve using the probabilistic model developed by Mackenzie. (2002) to convert detection data into population distributions of the pest species detected.

5. CONCLUSION

The primary goal of this study was to determine the existence of any populations of indigenous lizards in geothermal ecosystems at Waikite, Ōrakei-kōrako, Longview Road, and Craters of the Moon in the Taupo Volcanic Zone. In this, it was successful, identifying a potential for a population of skinks, which are likely to be native in geothermal kānuka scrub at Craters of the Moon. Large skink tracks were recorded in low geothermal kanuka scrub on 11 January 2022 at Craters of the Moon, Taupo. No evidence was found of indigenous lizards at any of the other sites investigated in this study. This is the first lizard sighting associated with a geothermal sight recorded in New Zealand.

The secondary goal of this study was to monitor any exotic vertebrates at the sites investigated. Exotic species were detected at all four of the sites investigated in this study. Mice (*Mus musculus*), and rats (*Rattus* sp.) were the most common species detected, while *Trichosurus vulpecula* (Brush tailed possums) were detected infrequently at all sites except Waikite, where they were detected often, and the European hedgehog (*Erinaceus europaeus*) was detected at Waikite. Detection of these species varied inconsistently with both site and vegetation type both at individual sites and across all four sites. More intensive sampling with a higher degree of rigour in randomisation will be necessary to establish population distributions for these species within and between geothermal ecosystems.

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