Enhancing Monitoring Methods for Native Skinks of Aotearoa

A Fusion of Mātauranga Māori and Western Science

By Joshua Caputo, Jose Perez,
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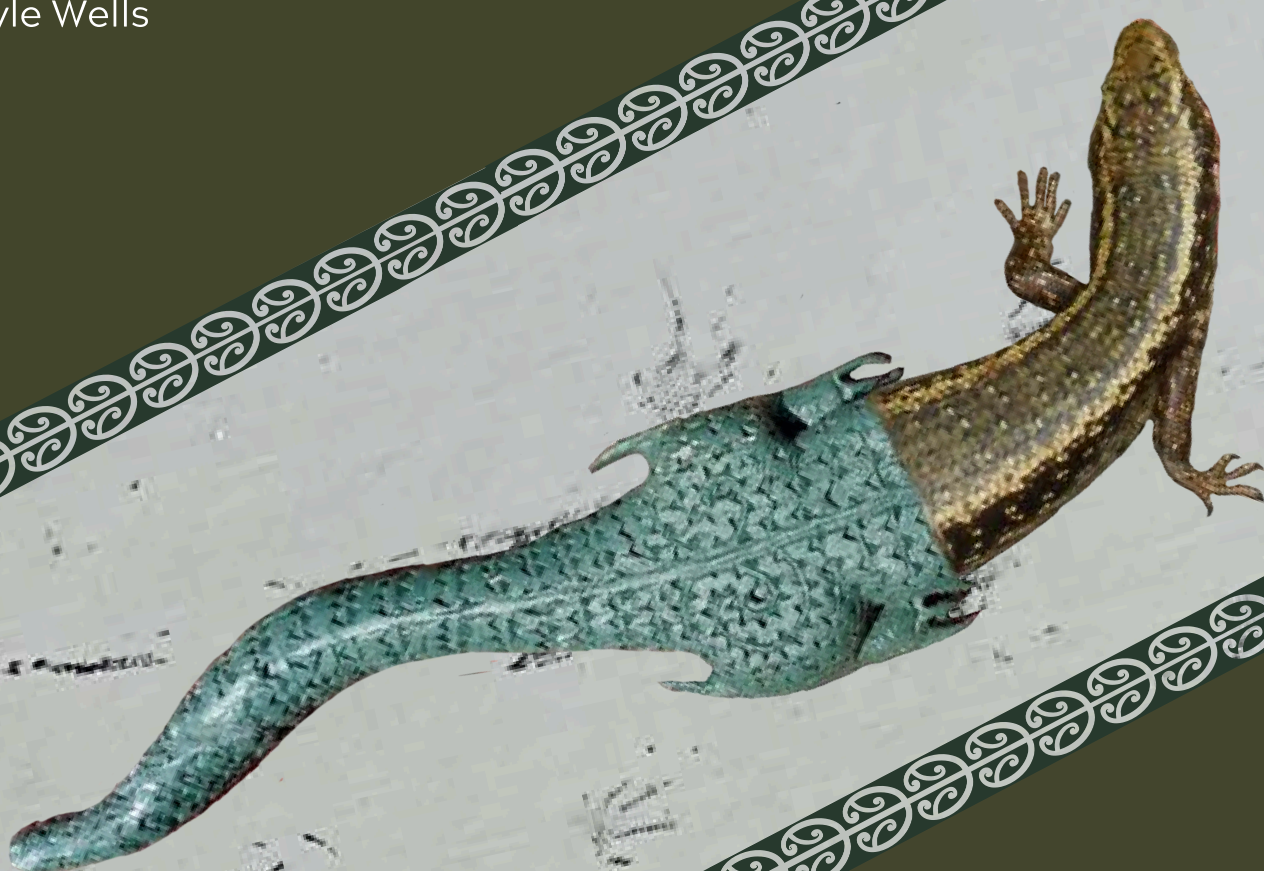
Macayle Wells



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Enhancing Monitoring Methods for Native Skinks of Aotearoa

An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelors of Science
Submitted on March 7th 2025

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Submitted To: Dr. Sara Belcher, The Greater Wellington Regional Council, Te Kura Taiao Collective

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ABSTRACT

This project supports the Predator Free 2050 Goal in Aotearoa New Zealand by analyzing tracking tunnels as part of a conservation initiative for threatened native skink species. We conducted fieldwork to test the outcomes of bait type and other factors that support skink detection. We compared pitfall traps and tracking tunnels using existing data from two local agencies: the GWRC and EcoGecko. To create a strategy that incorporates citizen science and education using a Māori framework, we partnered with the Te Arawa *iwi* near Rotorua, to learn how youth education programming integrates into conservation. Through testing and analysis, we found that bait is not as useful as originally thought. Additionally, we outlined non-invasive tracking methods for use in conservation education.

EXECUTIVE SUMMARY

Background
Aotearoa, New Zealand, faces significant challenges in monitoring and protecting its native wildlife. Skinks, a ground-dwelling lizard, are among these native species and require special attention due to their cultural importance as Māori consider them to be *taonga* (treasured species). The introduction of pest species like rats, mice, hedgehogs, and mustelids to the island nation over the past centuries have decreased native skinks' population, putting several subspecies at risk of extinction. In this context, effective skink monitoring is crucial for conservation efforts.

The current standard method for tracking native skink populations is pitfall traps. These traps involve a buried bucket with its rim flush to the ground and tinned apricots placed inside as bait to attract skinks. Researchers must check the traps daily to collect results and prevent the skinks from dying due to predation or malnutrition. This method requires a costly installation process and is dangerous to the native skink populations, conflicting with Māori ecological values.

Māori conservation values are based on *mātauranga Māori*, a knowledge system that intertwines environmental, cultural, and spiritual dimensions, shaping the way Māori understand and interact with the natural world. *Mātauranga Māori* is rooted in *kaitiakitanga*, or guardianship of the land, which prioritizes minimally invasive and ethically responsible conservation approaches (Mead, 2022). Researchers like Dr. Sara Belcher, a professor at Victoria University of Wellington, are searching for less invasive alternatives for lizard monitoring that reflect Māori perspectives on conservation. They have applied tracking tunnels with replaceable inked cards to capture the footprints of animals that walk through. This generates data on which species are present in an area without directly interfering with the animals, better aligning with *mātauranga Māori* values.

The Te Arawa *iwi* through the Te Kura Taiao Collective in Rotorua is exploring ways to incorporate scientific tools like tracking tunnels into conservation awareness. Their goal is to educate young people about the current health of the ecosystem through a more modern approach. Tracking tunnel monitoring is an avenue to engage their students and reinforce their spiritual obligations to care for the environment in an approachable and exciting way. This would also adapt interactive, citizen science into their kinesthetic learning model (S. Herewini, personal communication, February 2, 2025).

Figure E.1 Team members learning from Stu Herewini, a member of the Te Kura Taiao Collective, about the significance of *iwi* conservation work.

Our partners in the Te Kura Taiao Collective and Dr. Belcher tasked us with identifying ways to improve tracking tunnels' ability to measure native skink abundance. In addition to consideration for the site location of the tunnels, attracting skinks means evaluating proper bait and even possible implications from other variables such as moonlight.

Process
To begin our bicultural approach for skink monitoring, we conducted tracking tunnel trials in Baring Head in East Harbour Regional Park. We performed trials in 20 tunnels and used this data to test bait types. We compared this against two datasets from the same area spanning 2012-2024: tracking tunnel data from the Greater Wellington Regional Council (GWRC) and pitfall trap data from EcoGecko, a herpetology consultancy group. This data supplied us with additional bait trial results, plus 13 years of records to inform our analysis of other factors.

Figure E.2 Team members placing tracking cards in tunnels.

We evaluated our data using the count of tunnels with lizard tracks (tracks) and the rate that lizards were detected in tunnels (detection rate). We compared variables including the detection rates of pitfall traps against those of tracking tunnels and calculated the approximate relationship between the two measures. Using the GWRC data, we retroactively added data about the moon phase and luminosity to data from 2012-2024 to study patterns in skink activity.

We traveled to the Rotorua region of New Zealand to understand the value of this work for environmental education applications at the Te Arawa *iwi*. We visited the *iwi* for two days to learn about the anticipated application for our skink research and the area it hopes to conserve. We discussed the stories that we found and listened to their opinions and perspectives in relation to *mātauranga Māori*.

Findings
This project illuminated the fact that implementing a bicultural approach is substantially more challenging than it appears to an outsider. We began this project believing that we could investigate tracking tunnels from a Western science approach and incorporate Māori aspects afterward. When we arrived in Rotorua to meet with the *iwi*, we were unprepared for how different it was from our expectations. We met with Stu Herewini, who took us under his wing as our *Koro* (grandfather) and taught us through kinesthetic learning about Māori culture. Experiencing this new worldview was eye-opening, as it highlighted a fundamental difference in priorities between Western science and Māori culture. Stu plans to use tracking tunnels in his classes to engage students with the land and the culture simultaneously.

The analysis of methods to improve tracking tunnels for monitoring yielded several findings. We examined three bait type trials: peanut butter, tinned apricots and a control with no bait. The peanut-butter trial yielded a detection rate of 0.55, while the apricots and the control trials both had a rate of 0.5. Each trial consisted of a total of 20 existing tracking tunnels at Baring Head, broken up into two tracking lines (lines m3 and m4) with 10 tunnels in each line. This sample size is too small to make definitive generalizations, but the data does suggest that bait has little to no effect on whether skinks cross through the tunnel. **Figure E.3** plots these bait trials using tracks as the unit.

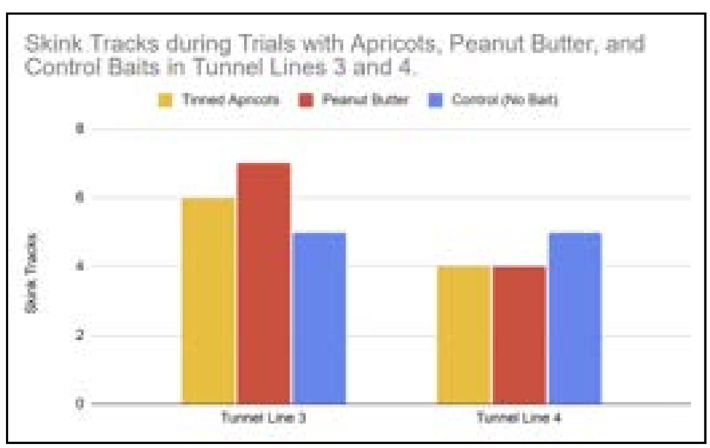


Figure E.3 Skink Tracks during Trials with Apricots, Peanut Butter, and Control Baits in Tunnel Lines 3 and 4.

Our review and analysis of historic GWRC tracking data suggests that moon phase and luminosity appear to have little effect on skink activity. The R2 value of the trendline was 0, indicating that there is likely no correlation between moon luminosity and skink activity in tracking tunnels. When we looked at non-native pests, the data analysis did show significant relationships to skink activity. The clearest correlation was in the comparison of hedgehog tracks and skink tracks over the last 13 years. **Figure E.4** demonstrates the tendency for the skink population to increase when the hedgehog population decreases. Consequently, the recovery of local skink populations in Baring Head is most likely a result of pest-elimination efforts in the area.

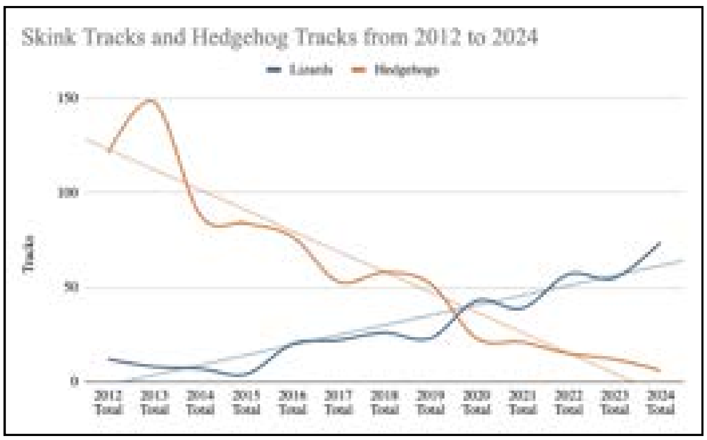


Figure E.4 Skink Tracks and Hedgehog Tracks from 2012 to 2024 using GWRC Baring Head data.

Equation E.1 is a logarithmic equation that demonstrates the relationship between pitfall trap detection rates and tracking tunnel detection rates. This equation roughly converts from tracking tunnel detection rates to pitfall trap population estimates. This means researchers do not need to remake the population estimation models that already exist for pitfall trapping results. This should assist the transition from pitfall traps to tracking tunnels.

$$y = 0.917 + 0.245 ln(x)$$

Equation E.1 The equation to convert from tunnel detection rate (x) to pitfall detection rate (y).

While Western science often focuses on data collection to uncover solutions, it is the elders' commitment to *Papatuanuku* (Earth Mother) and the well-being of all living things that drives much of the *iwi*'s work. The stark contrast in these goals makes it challenging for both sides to fully comprehend the other, even when there is a willingness to engage. Our experience working with both groups in Aotearoa made it clear that true bicultural collaboration requires not only an exchange of knowledge but also a mutual respect for the integration of both Māori wisdom and Western science. We strived to incorporate these two elements at the same time into our investigation by allocating the same weight to both viewpoints within our project framework.

Figure E.5 Skink tracks recorded on a tracking card from tunnel 4-8.

Recommendations

Based on the project findings, we provided our research partners with a set of recommendations to enhance the efficacy of tracking tunnels for skink monitoring. These recommendations aim to improve data quality and strengthen community involvement while reinforcing a bicultural approach that integrates Western scientific methods and *mātauranga Māori*.

Recommendation 1. Remove bait from tracking tunnel operations.

Our data suggests that skinks will go through tunnels at relatively equal rates regardless of bait choice. As our sample sizes were small, we suggest conducting further studies into the efficacy of each bait across various locations. However, until there is further research on this topic, our current recommendation is to forego the use of bait. This reduces tracking costs and simplifies the tracking process which ideally will allow for more testing with equal resources.

Recommendation 2. Connect hedgehog control and skink monitoring.

We observed a clear relationship between decreasing Baring Head hedgehog numbers due to population control measures and increasing skink activity. This suggests that hedgehogs have a direct impact on the native skinks' survival rates. Given these findings, we recommend prioritizing hedgehog population control to facilitate skink population growth. Expanding these targeted trapping efforts will be critical for maintaining and restoring skink populations

Recommendation 3. Prioritize tracking tunnels for skink monitoring.

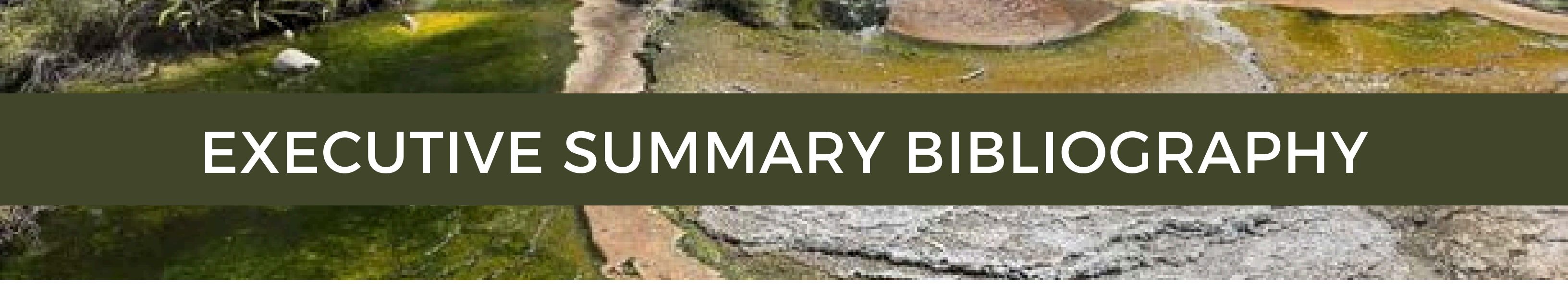
Our project establishes tracking tunnels as a viable method for measuring skink presence in a geographical area. We recommend skink monitoring operations transition from using pitfall trapping to utilizing tracking tunnels. To ease this transition, an equation like **Equation E.1** could allow existing pitfall population estimation models to be used with tracking tunnel data. However, building confidence in this equation requires collecting more tracking tunnel data in a variety of locations.

Recommendation 4. Involve youth in conservation via tracking tunnel projects in a kinesthetic learning environment.

Through communication with the Te Kura Taiao Collective, it became evident that their plan for implementing tracking tunnels into the kinesthetic learning curriculum could provide students with a sense of responsibility for their environment and engage with their culture. Educators should introduce tracking tunnels and conservation topics to students in a collaborative environment. Encourage active participation by giving each student an opportunity to maintain and monitor their own tunnel. Groups of students can synthesize their data to help identify trends and form conclusions about native skink populations.

Recommendation 5. Expand the relationships between *Iwis* and the Department of Conservation.

Local *iwis* consider themselves guardians of the natural ecosystems and are closely engaged with and concerned about preserving them. Creating partnerships between them and the DOC could further empower *iwis* to fulfill their duties as guardians of the land they reside in while increasing the DOC’s pest tracking and control operations. Creating a framework based on the Te Arawa *iwi*’s partnership with the DOC could allow other interested *iwis* to engage in these pest and native species tracking operations. This scheme must give the *iwis* complete authority over the information they choose to share and the DOC could provide them with the necessary training to effectively track these pests. The intent of this recommendation and a desirable impact of our project is to create and foster a bicultural model for skink monitoring in Aotearoa.



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Stu Herewini


Dr. Ingrid Shockey


Dr. Robert Kinicki

We would like to thank our partner Dr. Sara Belcher who has assisted us during our time in Wellington to accomplish all of our research. Without her, we would not have been able to carry out our trials or this project.

We would also like to thank Stu Herewini for taking time to guide us through a cultural immersion experience in Rotorua.

Finally, we would like to thank our advisors Dr. Ingrid Shockey and Dr. Robert Kinicki for their continued support throughout the process of this project.

AUTHORSHIP

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MEET THE TEAM

Joshua Caputo

Kia ora! I'm Josh Caputo from Robbinsville, New Jersey. I am pursuing a dual degree in Mechanical Engineering and Robotics Engineering. I was excited to work on this project because of the opportunity to study native wildlife and ecosystems. Learning about the Māori traditional knowledge of Aotearoa has been a great experience that has broadened my cultural awareness.

Jose Perez

Hello, my name is Jose Perez. I come from Almeria, Spain, and I am studying computer science with a BS/MS in artificial intelligence. I feel like this project was a great opportunity to understand some of Aotearoa's ecological challenges and how a Māori perspective can offer unique and holistic solutions. Learning about the importance of *kaitiakitanga* (guardianship) and the Māori connection to the land has helped me appreciate the role of cultural knowledge in addressing ecological issues.

Leah Uglevich

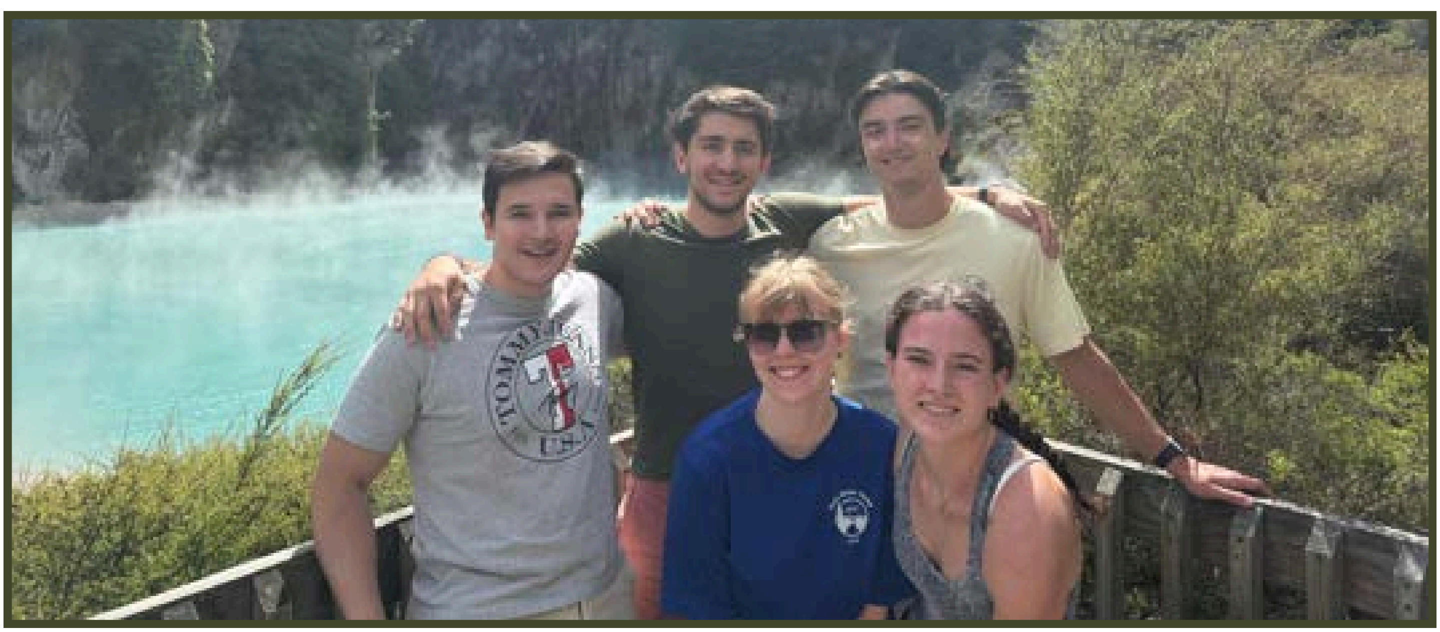
Kia ora, I'm Leah Uglevich from Maynard, Massachusetts, studying biomedical engineering with a focus on biomaterials and tissue engineering. I've really enjoyed working on this project with an interdisciplinary team and seeing how our different perspectives came together. Experiencing Māori culture firsthand through the Te Arawa *iwi* in Rotorua was eye-opening, especially in understanding how their scientific perspectives differ from our own.

Henry Wagg

Kia ora! My name is Henry Wagg. I am a robotics engineering student from Portland, Maine. I have loved getting to explore all the beautiful areas in New Zealand while searching for skinks. This project provided me with the opportunity to immerse myself into Māori culture through the Te Arawa *iwi* in Rotorua which was a fascinating experience that challenged my understanding of our place in the world.

Macayle Wells

Kia Ora! I'm Macayle Wells from Plainville, Connecticut, studying Mathematics with a focus in Actuarial Science. I've really enjoyed my time interacting with a new culture and learning about the native species of skink has been a bridge for me to do so. This project has allowed me the space to truly embrace and appreciate the environement. Interacting with Māori Culture has made me contemplate and revise my own values on how I view and treat the world.



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GLOSSARY OF TE REO MĀORI TERMINOLOGY

All Māori terminology, indicated by italics, throughout this paper is linked back to this glossary page

Term/Concept/Name	Definition
Aotearoa	The Māori name for New Zealand.
Atua	Ancestor with continuing influence, god, demon, supernatural being, or deity.
Hapū	Kinship group, clan, tribe, subtribe.
Hauora	Be fit, well, healthy, vigorous, in good spirits.
Ikatere	The son of Punga and grandchild of the atua, Tangaroa.
Kaitiakitanga	Guardianship, stewardship, trusteeship, trustee.
Kauri	Largest forest tree found only in the northern North Island.
Kānuka	A white tea-tree with white flowers and soft leaves.
Kōrero	Speech, narrative, story, news, account, discussion, conversation, discourse, statement, information.
Koro	Elderly man, grandfather, grandad, grandpa - term of address to an older man.
Mānuka	A common native scrub bush with aromatic, prickly leaves and many small, white, pink or red flowers.
Maramataka	Almanac, Māori lunar calendar, calendar - a planting and fishing monthly almanac.
Mātauranga Māori	Māori knowledge originating from Māori ancestors, including the Māori world view, perspectives, creativity and cultural practices.
Mingimingi	Native shrubs with small, narrow leaves which alternate or are in tufts, prickly to touch. Fruit is red, pink, blue or white and the bark is black.

All definitions found in this glossary have been copied from the Te Aka Māori Dictionary (Te Aka Māori Dictionary, n.d.).

Term/Concept/Name	Definition
Ngārara	Insect, creepy-crawly, reptile.
Papatūānuku	Earth mother and wife of Rangi-nui. All living things originate from them.
Punga	An atua, the son of Tangaroa and ancestor of reptiles and some fish such as sharks and stingrays.
Purakau	Myth, ancient legend, story.
Ranginui	Sky Father.
Tangaroa	The atua of the sea and fish. Sometimes known as Tangaroa-whaiariki.
Tangaroa-ā-roto	Moon on the twenty-third night of the lunar month - for some tribes (e.g. Te Whānau-ā-Apanui) this is the ninth night of the lunar month.
Taonga	Treasure. Anything of value, including socially or culturally significant objects, resources, phenomena, ideas, or techniques.
Tū-te-wanawana	The atua of reptiles.
Tāwhiri-mātea	The atua of the winds, clouds, rain, hail, snow and storms, he was also known as Tāwhiri-rangi and Tāwhiri-mate-a-Rangi.
Waiata	Song, chant, psalm
Waka	Canoe, vehicle, conveyance, spirit medium, medium (of an atua).
Whakapapa	Genealogy, lineage, descent. It is central to all Māori institutions.
Whakatuakī	Māori sayings.
Whānau	Extended family, sometimes used to include friends who may not have any kinship ties to other members.

All definitions found in this glossary have been copied from the Te Aka Māori Dictionary (Te Aka Māori Dictionary, n.d.).

INTRODUCTION

Aotearoa, New Zealand, faces significant challenges in monitoring and protecting its native wildlife. The Department of Conservation has set a national goal of Predator Free 2050, aiming to eliminate all non-native pests. This initiative is critical for protecting endangered and vulnerable native species in Aotearoa. Among these important species, native skinks, a family in the suborder of lizards, play an important role in the ecosystems and hold cultural significance as *taonga* (treasures) in Māori communities. Maintaining stable populations of these creatures is critical for preserving biodiversity in fragile Aotearoa environments. Thus, creating effective population monitoring strategies is integral to these conservation efforts.

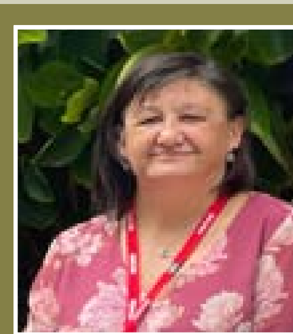
Tracking populations of reclusive species such as skinks can be difficult. Previous efforts to monitor these species were labor-intensive and disruptive to the animals and ecosystems (S. Belcher, personal communication, November 13, 2024). This increases the overall burden of cost and effort for skink research. Dr. Sara Belcher is a scientist at Victoria University of Wellington with decades of experience in ecosystem monitoring and working at the intersection of *mātauranga Māori* and Western science. Her field research focuses on using tracking tunnels to follow predator populations and evaluate whether pest-elimination methods achieve their goals. She is working to adapt these minimally invasive tracking tunnels for skink monitoring by selecting an appropriate bait to attract skinks. Researchers at the Greater Wellington Regional Council (GWRC) commonly use peanut butter in existing tracking tunnel efforts, but they have successfully used fruit in pitfall trapping, which suggests it may effectively attract skinks.

Simple tracking tunnels like these also bring an opportunity for community organizations to engage in citizen science. The Te Arawa *iwi* (tribe) in the Rotorua region seeks to integrate skink conservation measures with local education in the context of Māori stories. The minimally invasive quality of these tracking devices is crucial to the *iwi* partners as part of their spiritual obligation to care for the land (*kaitiakitanga*) (S. Herewini, personal communication, February 2, 2025). Furthermore, the incorporation of *mātauranga Māori* into conservation allows for a bicultural approach in research, connecting traditional knowledge to modern science.

Our team partnered with Dr. Sara Belcher to investigate non-disruptive methods of skink monitoring while integrating scientific and cultural frameworks. To achieve this goal, we conducted skink-tracking experiments in Baring Head and compared our results with existing tracking data from the same location that the GWRC collected. We designed our analysis to uncover skink activity factors and test their preferred bait types. While considering the cultural dimension of the project, we explored the thread of skink narratives within Māori literature and collaborated with the Te Arawa *iwi* in Rotorua in their development of an educational park. Our project provides preliminary results and recommendations in advancing skink monitoring protocols through a fusion of *mātauranga Māori* and western scientific tracking methods. The outcomes of this work include suggestions for collaborations between *iwis* and the New Zealand Department of Conservation, as well as recommendations about modifications to tracking methodologies for native Skinks.

MEET OUR PARTNERS

Dr. Sara Belcher



Dr. Sara Belcher is a professor and researcher at Victoria University of Wellington where she works at the intersection of *mātauranga Māori* and Western Science. Prior to her time at the University, Dr. Belcher worked at the GWRC for 18 years implementing pest mangement practices.

Stu Herewini

Stu Herewini is a member of the Te Arawa *iwi* as well as the Te Kura Taiao Collective in Rotorua. The Te Kura Taiao Collective is an environmental conservation organization working with local school systems on kinesthetic learning models to increase cultural engagement through the use of Western science.

Figure 1.1 A description of the project partners.

BACKGROUND

This chapter provides context and detailed background information about our project. It explores the origin and habitat zones of the skinks that we monitored, examines existing methods for skink monitoring in Aotearoa, and delves into the ancestral knowledge and cultural significance of lizards in Māori tradition. Finally, we describe the potential value of projects that integrate *mātauranga Māori* knowledge with Western science. A Māori Glossary found at the start of this report defines the Māori terms utilized in our study and each italicized Māori term is linked back to this glossary.

2.1 Site Locations for Cultural Research and Skink Monitoring

Due to its mountainous geography and dynamic climate, the archipelago of Aotearoa features a wide range of ecosystems. Baring Head and Rotorua are excellent examples of the biodiversity of Zealandia: Baring Head, on the southern coast of the North Island, offers a unique site for atmospheric monitoring and supports rich coastal ecosystems (Baring Head/ Ōrua-Pauanui Historic Area, 2023). Meanwhile, Rotorua, set on the volcanic plateau of the North Island, features geothermal activity, volcanic soils, and unique microclimates in an area with immense Māori cultural and biological heritage (see **Figure 2.1**) (Leathwick & Mitchell, 1992). Together, these two regions provide valuable insights into Aotearoa's distinct ecological and cultural landscape.

Baring Head

As the field site for our primary tracking testing, Baring Head is located in East Harbor Regional Park on the southern coast of Aotearoa's North Island, facing the Cook Strait and Wellington Harbor. Baring Head was chosen for its rich ecological habitats spanning five distinct zones: the coastal platform, coastal escarpment, marine terraces, valley escarpment, and river flats. This diverse system provides vital habitats for rare and threatened species.

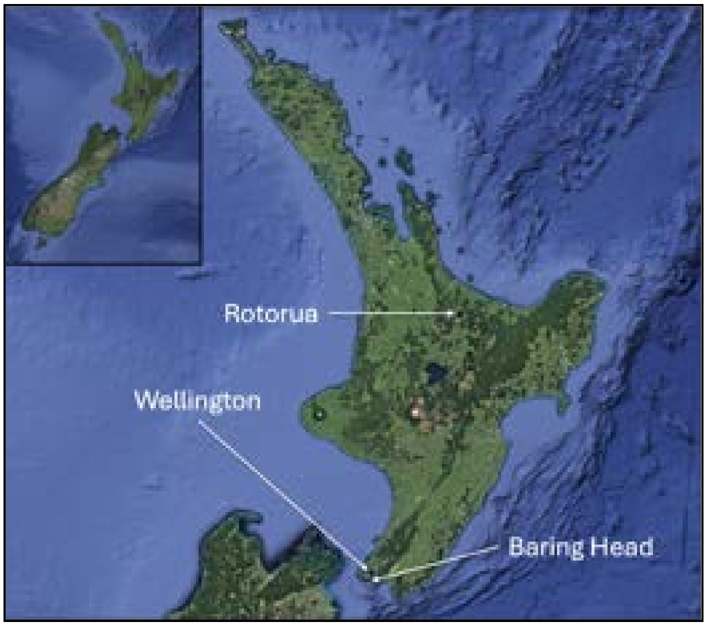


Figure 2.1 A satellite map showing the locations of Wellington, Baring Head, and Rotorua within Aotearoa's North Island (Google, n.d.).

The coastal platform is comprised of dunes and beaches that support many reptilian species such as the common skink (Oligosoma polychroma), common gecko (Hoplodactylus maculatus), and less common reptiles like the spotted skink (Oligosoma lineoocellatum) and copper skink (Oligosoma aeneum). Directly abutting the coastal platform, the coastal escarpment includes steep, vegetated cliffs. Further up and adjacent to the coastal escarpment, marine terraces support resilient native flora and provide nesting sites for bird species (Crisp, 2011). The valley escarpment hosts a diverse array of rare plants and supports many skink species that find their home in the abundant rock piles. The river flats are a wetland area between the toe of the escarpment and the Wainuiomata River, and are essential for threatened plant and invertebrate species, as well as native fish and birds (Crisp, 2011).

Rotorua

Our second project site, the city of Rotorua, is in the north-central portion of the North Island of the country. It lies at the southwestern end of Lake Rotorua and is part of the northeastern section of the volcanic plateau. Teeming with geothermal activity, the region is known for hot springs, boiling mud pools, and spouting geysers. Rotorua's climate is notably cooler and less maritime than other parts of the North Island (Leathwick & Mitchell, 1992). The town itself resides on relatively flat terrain that gradually ascends to the south and west (Letcher, 2013).

Before 1870, Rotorua was largely unknown by European settlers and remained primarily Māori territory. The land around Lake Rotorua was home to descendants of Māori who arrived in Aotearoa on the Arawa *waka* (canoe) around 1350 A.D (Taonui, 2005). It was only in 1882 that formal settlement began in what is now the central township. Today, Māori *iwi* represent a significant portion of the population in the city and its surrounding areas (Letcher, 2013).

Baring Head and Rotorua provide an excellent opportunity for sharing data across ecological biodiversity conservation and cultural bioheritage education with skinks as the common thread. Baring Head offers a distinct range of microhabitats and natural formations, making it a controlled and diverse environment for our tracking work. Meanwhile, Rotorua's deep Māori roots support the cultural exploration necessary to tie the impact of our work to educational initiatives.

2.2 Lizard Population Trapping and Monitoring

Skinks were first thought to have emerged in Aotearoa around 16-22 million years ago, and due to their early presence, the New Zealand Department of Conservation and Herpetological Society recognizes skinks as a native species. Surveying and monitoring skink populations can help guide conservation efforts and assess the impact of both native and non-native predators in the region. Local scientists have adapted strategies from international standards to fit the landscape and speciation of Aotearoa (Lettink & Monks, 2016, p. 19). The next sections detail the commonly applied approaches for monitoring skinks in New Zealand.

Pitfall Traps
Due to their simplicity, pitfall traps are the most common method for tracking skinks. A pitfall trap consists of a bucket sunk into the ground and mostly covered, leaving a thin opening appropriate for skinks to enter. Holes in the bucket prevent flooding, while the cover protects against the sun and most predators. These traps can catch multiple skinks at a time, allowing researchers to track the population of these animals. When not in use, covering the entrance or inserting sticks and foliage as an escape will “shut down” the trap without requiring labor to uninstall the trap (Sorenson, 2022, p. 26). Pitfall traps allow researchers to identify the species, gender, and size of any captured skinks, but they take longer to install, and researchers must check them daily. However, pitfall traps have an increased risk of skink mortality in areas with heavy predator presence and can cause habitat disturbance (Lettink & Monks, 2016, p. 22).

Tracking Tunnels
Tracking tunnels, as an alternative to trapping, allow researchers to monitor small mammal pests. A tracking tunnel is a long, covered tunnel with a removable card placed on paper at its base. Researchers treat the center of the card with weather-resistant ink and typically pair it with peanut butter as bait, leaving either end of the card empty. When an animal goes through the tunnel, they walk through the ink and leave prints on the blank portion of the card (see **Figure 2.2**).

While originally used for mammal studies, tracking tunnels unexpectedly captured invertebrate and skink prints in addition to the expected rodent prints. In response, researchers are evaluating tracking tunnels for use in skink monitoring (Jarvie, & Monks, 2014, p. 213).

Aotearoa features approximately 100 different species of lizard so footprints alone cannot identify which species passes through the tunnel. Due to their design, a single skink can be tracked multiple times by tracking tunnels. These limitations mean that the devices cannot estimate population numbers, but the tracking tunnels can still detect binary skink activity (Lettink, Young, & Monks, 2022, p. 2). In cases of restoration efforts, detecting changes in skink activity can provide information about the success and distribution of the restoration. With further research, tracking tunnels can monitor skink activity to show the effectiveness of invasive pest eradication methods in areas with high populations of rats, mice, and hedgehogs, which are predators of native skinks (Lettink, Young, & Monks, 2022, p. 4).

Previous Comparative Studies of Tracking Methods
A study conducted in Aotearoa in 2022 compared the effectiveness of tracking tunnels against pitfall traps for monitoring skink populations. After setting up pitfall traps and tracking tunnels across an area of known skink activity, researchers tallied total skink detections from each method over 13 days.

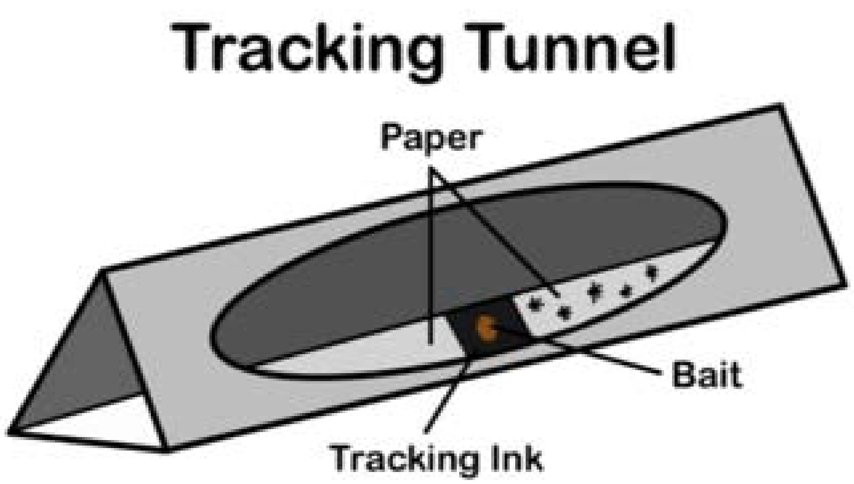


Figure 2.2 A diagram of a typical tracking tunnel setup.

The results showed that tracking tunnels detected skinks roughly twice as often as pitfall traps (Lettink, Young, & Monks, 2022). This suggests that skinks are more likely to run through tracking tunnels than fall into pitfall traps, which would indicate tracking tunnels are a more effective monitoring method.

Peanut butter is the standard bait recommended for use in tracking tunnels because previous studies focused on rats and mice. Although peanut butter worked in attracting some skinks, most skink monitoring methods can utilize pieces of tinned fruit since this is closer to a standard skink diet. There is also a possibility that the skinks enter the tunnel to find shelter, without regard for the bait within (S. Belcher, Personal Communication, 2025).

Tracking tunnels are less disruptive to habitats and require significantly less maintenance than pitfall traps. While tracking tunnels can only determine presence/absence, they are the safest method for skinks and can be the least expensive and most accessible. However, further research is necessary to optimize their use (Jarvie, & Monks, 2014, p. 215).

2.3 Ancestral Knowledge and the Place of Lizards in Māori Culture

Monitoring species health supports traditional Māori values and knowledge as part of a respectful and interwoven approach to ecosystem and community wellbeing. *Mātauranga Māori* intertwines environmental, cultural, and spiritual dimensions as the foundation for knowledge. It represents the collective knowledge of the Māori people, and it draws upon these associated perspectives to understand everything that exists in the universe (Mead, 2022). Māori *iwi* pass this knowledge through generations, in the form of stories incorporating *whakapapa* (genealogies), *whakataukī* (sayings), *kōrero* (prose), and *waiata* (songs and chants) (Kawharu, 2000).

Whakapapa in particular connects all living and non-living things, forming a web of relationships that unite people, animals, plants, and all-natural things as part of a shared ancestry. *Whakapapa* traces the lineage of every element in the natural world back to *Papatūānuku* (Mother Earth) and *Ranginui* (Sky Father) (Roberts, 2013). This concept reinforces the understanding that humans do not separate themselves from nature but embed themselves deeply within it, shaping the basis for *kaitiakitanga* (guardianship), an obligation to care for all beings as family (Te Ahukaramū, 2007). Conservation, therefore, is not merely a practical obligation but a spiritual duty the Māori heritage deeply embeds.

Mātauranga Māori of Lizards

The Māori worldview that all animals are interconnected through *whakapapa*, places all beings within the same extended *whānau* (family), where each has a role and responsibility within the ecosystem (McRae, 2017). Among these beings, lizards (*ngārara*) hold cultural and spiritual significance, embodying unique roles as protectors and guardians in Māori traditions (Haami, 2007).

Whakapapa situates lizards within a broad ancestral lineage that connects them to highly respected deities, emphasizing their status as a *taonga* species within Māori culture. **Figure 2.3** illustrates that the genealogy of lizards traces back to *Tangaroa*, the god of the seas and son of *Papatūānuku* and *Ranginui* (Andersen, 2010). *Tangaroa*'s son, *Punga*, holds the title of God of Unusual or 'ugly' Creatures, a category that includes reptiles, amphibians, and some fish. *Pungas* offspring include two brothers: *Ikatere*, the ancestor of fish, and *Tu-te-wana-wana*, the ancestor of lizards. According to Māori tradition, the children of *Papatūānuku* and *Ranginui* sought to separate their parents to allow light to reach the earth. All but one of their children, *Tāwhiri-mātea*, the god of storms and winds, supported this plan. In opposition, *Tāwhiri-mātea* unleashed powerful storms upon his siblings as punishment, forcing *Tangaroa* to retreat to the sea. This separation led to a conflict between *Tangaroa*'s sons, *Ikatere* and *Tu-te-wana-wana*, over whether they should follow their father into the ocean or remain on land. Ultimately, *Ikatere* chose the sea, while

Tu-te-wana-wana stayed on land, symbolizing the ancestral divide between fish and lizards (Haami, 2007).

Māori celebrate lizards, as descendants of Tu-te-wana-wana (as seen in Figure 2.3), not only for their resilience and adaptability but also for their role as guardians and symbols of caution. Thriving in challenging environments, lizards represent both protective and watchful qualities, acting as spiritual intermediaries that connect the natural and spiritual realms. In Māori cosmology, they serve as caretakers of sacred spaces, embodying caution and vigilance (Haami, 2007). Through kaitiakitanga, the protection of lizards aligns with the Māori commitment to maintaining natural balance and fulfilling their role as guardians of the environment. By protecting these treasured creatures, Māori traditions preserve lizards' legacy as spiritual protectors and symbols of caution, fostering cultural respect and value for them within the ecosystem.

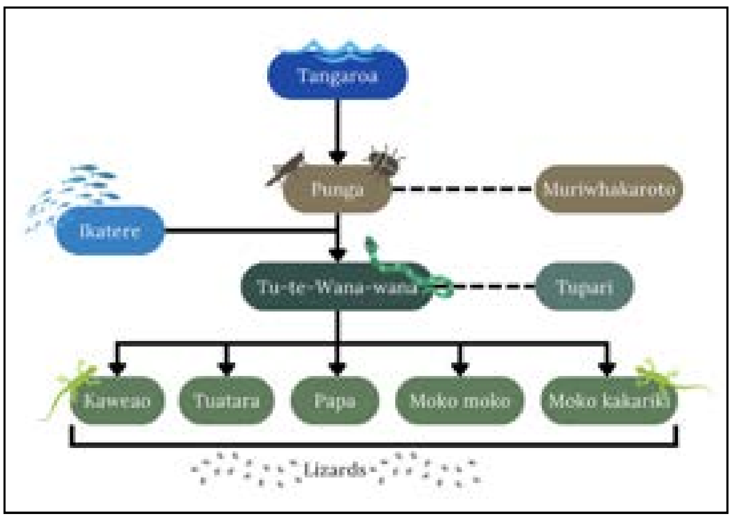


Figure 2.3 A *whakapapa* of fish and reptiles (Andersen, 2010).

2.4 Bicultural Approaches to Conservation: Integrating *Mātauranga Māori* and Western Science

Integrating Māori knowledge systems (*mātauranga Māori*) with Western Science, offers a comprehensive shared framework for addressing Aotearoa's ecological challenges. In 2004 the Nova Scotian Mi'kmaq Elders, Albert and Murdena Marshall developed a method known as Two-Eyed Seeing that emphasizes the potential value of viewing the world in terms of both Western Science and Indigenous worldviews (Bartlett et al., 2012). This method has both "commonalities and differences in the interpretation and application", and therefore researchers should, "aim to clearly reflect on and describe their application of the framework in their publications" and work to incorporate the Two-Eyed Seeing methodology throughout their research process in a meaningful way (Wright et al., 2019). Western Science complements *Mātauranga Māori* by offering a different lens that enriches traditional knowledge and supports conservation efforts (McRae, 2017). This integration fosters conservation practices in Aotearoa that are ecologically effective and culturally aligned with Māori values, fulfilling the responsibilities of *kaitiakitanga* and serving both nature and the community.

Learning from a Case Study in Dunedin

An impactful example of this approach comes from a research project initiated by the Department of Microbiology and Immunology, University of Otago, Dunedin, New Zealand. Researchers collaborated with Māori *iwi* to solve the growing epidemic of *kauri* dieback, a disease caused by Phytophthora agathidicida that has been killing native *kauri* trees by infecting the roots and disrupting nutrient and water absorption. This disease is a severe threat to the biodiversity and cultural heritage of Māori communities in northern Aotearoa (Lawrence et al., 2019). *Kauri* trees (Agathis australis) are among the largest and longest-living trees in Aotearoa. They play an essential role in stabilizing ecosystems and contributing to biodiversity (Hood, 2021). The *kauri* are *taonga*, symbolizing strength and resilience, and embody deep spiritual significance for many *iwi* (Bradshaw et al., 2020). Conserving *kauri* trees thus represents both an ecological and cultural priority.

Lacking a cure, researchers turned to *mātauranga Māori* for potential solutions, focusing on native plants traditionally valued for their medicinal properties. This approach identified *kānuka* (*Kunzea robusta*), a plant highly regarded in Māori culture for its healing properties and later found to have bioactive potential against *Phytophthora agathidicida*. The study ultimately revealed chemical compounds within the *kanuka* that could inhibit spore germination and disrupt mycelial growth (Lawrence et al., 2019). This research underscores how *mātauranga Māori* can direct scientific inquiry toward culturally and ecologically significant species, contributing to both *kauri* preservation and the protection of Māori traditional knowledge.

Maintaining Ethical Research Practices
Ensuring such collaborations are respectful and mutually beneficial requires researchers to acknowledge Māori intellectual property rights and adhere to cultural protocols that uphold Māori sovereignty. Windchief and Cummins (2022) emphasize that bicultural research demands ethical accountability and a commitment to genuine partnership. In the antimicrobial plant study, researchers engaged with local *iwi* and *hapū* (clan) from the beginning, consulting them on the project's objectives and methods, and actively protected and acknowledged their contributions (Lawrence et al., 2019). By fostering trust and prioritizing Māori values, bicultural projects empower Māori communities as stewards of their ancestral lands, supporting their role in environmental management and reinforcing the importance of cultural respect within scientific research.

Aotearoa's Vision Mātauranga, a government science policy framework with the mission to unlock the science and innovation potential of Māori knowledge, resources, and people, supports these bicultural collaborations by promoting partnerships that respect and integrate Māori knowledge alongside scientific research. The Ministry of Research, Science, and Technology developed Vision Mātauranga, which emphasizes building strong, trust-based relationships with *iwi* to align conservation practices with Māori values and experiences (Kaiser & Saunders, 2021). By fostering an environment where environmental stewardship respects both scientific inquiry and cultural heritage, Vision Mātauranga aligns conservation with *kaitiakitanga*, the Māori belief in the protection of the environment, establishing a resilient and inclusive approach to preserving Aotearoa's unique ecosystems for future generations.

2.5 Summary

Skink monitoring is a critical dimension of ecosystem health monitoring. In Aotearoa, a bicultural approach can be challenging to implement, but both cultural and scientific perspectives play a crucial role in developing well-rounded solutions. Cultural knowledge from lived experiences provides practical solutions that emerge from generations of observation, often offering insights that Western science may overlook. When these two perspectives are blended into a bicultural framework, they create opportunities for new and innovative solutions that may not have been possible independently. For this reason, integrating a bicultural approach into skink monitoring and Western science can generate solutions that are not only educational but also culturally inclusive, allowing both knowledge systems to contribute meaningfully to the outcome.

APPROACH

The goal of our project was to investigate non-disruptive methods of skink monitoring using scientific and cultural frameworks in Aotearoa as summarized in **Figure 3.2**. This chapter discusses the methods we used for each of our three objectives:

1. Investigate and test tracking strategies.
2. Compare tracking approach outcomes.
3. Articulate skink tracking significance in the context of *mātauranga Māori*.

We summarize our approach to data collection in **Figure 3.2** and describe our strategies in greater detail below.

3.1 Objective 1: Investigate and test tracking strategies

Partnering with Dr. Belcher, the project team conducted a site assessment at Baring Head. We identified two tracking tunnel lines on the coastal platform and recorded key environmental conditions relevant to the study. We documented this metadata using a standardized table (see **Appendix A**) and used it to compare site conditions between trials.

Figure 3.1 Setting tracking cards in Baring Head.

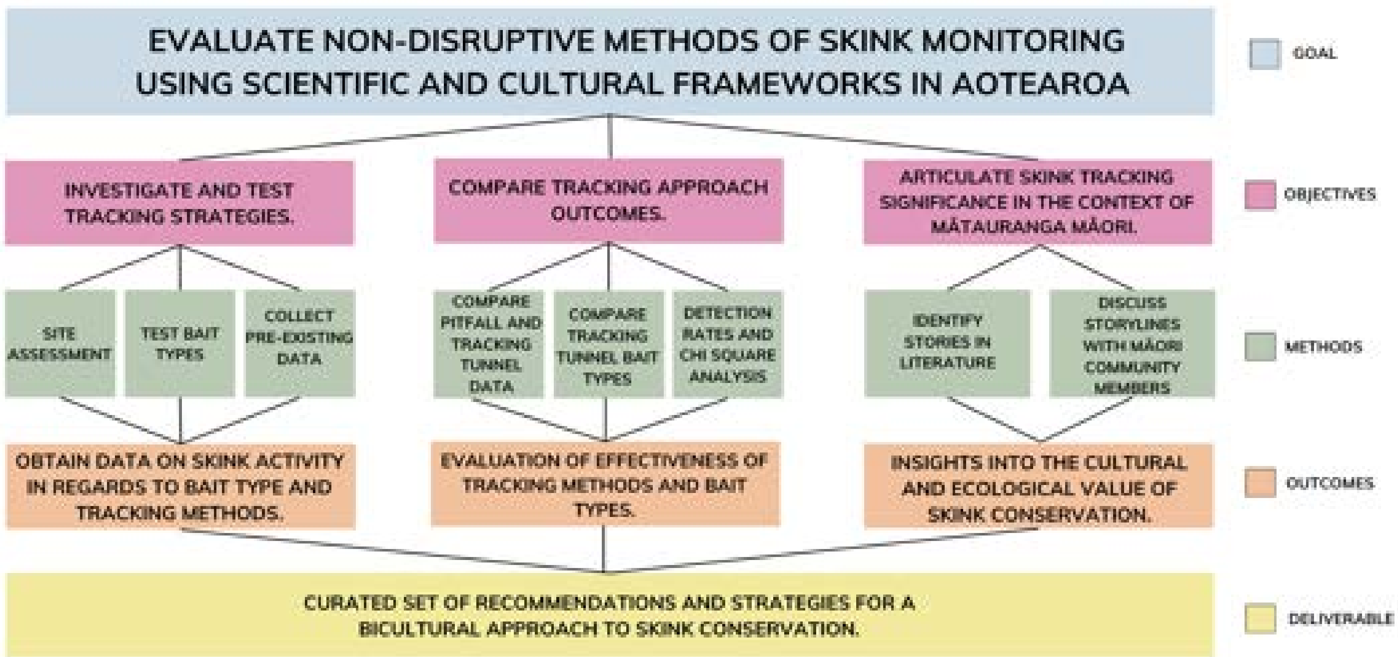


Figure 3.2 A flow diagram depicting project methods and their outcomes.

To evaluate the effectiveness of fruit as bait, we conducted two trials. Each took place over a 24-hour period using the tunnel lines, one with bait and one without any bait. For each tunnel, our team used a Black Trakka card from Gotcha Traps LTD, which consists of two blank sections with an ink pad in the center. During the baited trial, we added tinned apricot to the center of the ink. At the end of each trial, the team removed all twenty cards and checked for skink footprints on the tracking cards (see **Appendix B** for examples of animal prints on tracking cards). We recorded the results and tracking dates, along with the corresponding tunnel ID number (see **Appendix C**).

To gain more context on the effectiveness of past and current tracking methods, the GWRC provided us with records of monitoring efforts done in Baring Head over the last 13 years. We obtained records of previous tracking tunnel trials using peanut butter as bait completed by the GWRC. In addition, EcoGecko, a herpetology consultancy group that runs lizard population surveying and monitoring programs, provided us data for pitfall trap trials with fruit as bait. Researchers collected both datasets in Baring Head, the same area where we conducted our tracking tunnel trials.

3.2 Objective 2: Compare tracking approach outcomes

Our analysis evaluated findings from existing data obtained from the GWRC and EcoGecko, along with our own experiments based on the detection rate, which is the value of mean detection per trap-night. The total number of trap-nights is the product of the number of traps and the nights they were active. From this value, we calculated the detection rate for each line using **Equation D.1** in **Appendix D**. We calculated the standard error for each trial with **Equation D.2** in **Appendix D**. We utilized this process for our own tunnel trials and to analyze the summarized findings of the tunnel trials provided by the GWRC. For the pitfall trap data, we followed the same process, treating each catch as a successful track.

Tracking tunnels can only detect presence or absence and cannot create population models. To determine whether this could be an effective population monitoring method, we compared pitfall and tunnel data over the last 13 years. We compared the average detection rates found each summer to determine the mathematical relationship between pitfall and tunnel data.

To improve tracking tunnels efficacy, assessing the different baits was our primary focus. We employed the data from our trial and the GWRC's monitoring for this investigation. We calculated the detection rate of each tunnel line with each bait type. Based on conversations with Dr. Belcher, we identified other potential variables that could influence skink presence. First, we went back to the GWRC tracking tunnel data and added the moon phase for each trial to determine if there was a correlation between the moon and animal activity. Second, we used the GWRC data to correlate pest and skink activity to identify primary skink predators.

3.3 Objective 3: Articulate skink tracking significance in the context of *Mātauranga Māori*

To meet this objective, we primarily conducted research in the Victoria University library to uncover cultural references to lizards in Aotearoa. We assembled a selection of narratives that showcase the critical role that lizards hold in Aotearoa. Much of the available literature on this topic was dated and often presented cultural descriptions with a colonial lens.

In Rotorua, we were fortunate to conduct interviews with *iwi* members and cultural historians using the discussion prompts found in **Appendix E.** We recorded these discussions to allow us to have accurate notes. At the beginning of each recording, we obtained verbal consent based on the consent form found in **Appendix F**. We visited with and experienced a meaningful interaction with members of the Te Arawa *iwi* for three days to learn about the projected application of our skink research and the area it hopes to conserve. We discussed the stories that we initially found and listened to their perspectives in relation to *mātauranga Māori.*

We reviewed our discussion recordings and created notes with photographs of the trip upon our return. We incorporated Māori cultural narratives about skinks into the archive of

Figure 3.3 Skink carving in front of the Te Paparere-a-Ratoroua Marae in Rotorua.

stories we gathered from our research at Victoria University found in **Appendix G**. This added considerable depth to our preliminary research and informed a bicultural framework for exploring how Māori values for skink conservation can contribute to public conservation education and citizen science.

RESULTS AND DISCUSSION

This project aimed to adopt a bicultural approach to conservation by integrating data from both Western and Māori knowledge frameworks. We conducted most of our data analysis using Western approaches but drew from opportunities to apply cultural knowledge such as lunar phase analysis, weaving it into elements of our results and recommendations. During our time in Rotorua, we engaged in an immersive cultural experience shaped by community guidance and conversation. This environment allowed us to more carefully explore culture, values, and stories alongside science and conservation metrics. By blending these perspectives, we aimed to create a more holistic understanding of skink populations and their environment in Aotearoa.

4.1 Investigate and test tracking strategies

The team completed the tracking trials in Baring Head on February 12, 13, and 14, 2025. Our team completed all three trials on fair weather days, in tracking tunnels along the beach. We recorded all the site assessment data in our Tracking Trial Conditions Table in **Appendix A**. Many of the tunnels in line 3 were surrounded by low brush and shrubs, providing ample coverage for skinks (see **Figure 4.1**). Most tunnels in line 4 were out in the open, with nearly half of them being the only cover within 10 meters (see **Figure 4.2**).

Figure 4.1 Tunnel 1 on line 3.

Figure 4.2 Tunnel 2 on line 4.

After collecting the tunnel tracking cards, we analyzed them for inked footprints of skinks and other species. We had many combinations of animal tracks on our cards. Several cards showed just skink tracks as seen in **Figure 4.3**, some cards showed only pest species such as the card shown in **Figure 4.4**, and others had a combination of pest and skink tracks as is depicted in **Figure 4.5**. Only 13 of the 40 cards had no visible tracks. In total, we recorded 20 cards with skink tracks over 40 trap-nights. We recorded all of the data in our Tracking Cards Results Table (see **Appendix C**). **Appendix B** contains the images of all the types of tracks we encountered over the two tracking nights.

4.2 Compare tracking approach outcomes

Our team standardized the data from our Baring Head trials as skink detection rates, which we averaged per trap-night. In tunnels with no bait, we recorded 10 skinks over 20 trap nights, resulting in a detection rate of 0.50. Similarly, the tunnels baited with apricots also saw 10 skinks over 20 trap-nights, leading to the same detection rate of 0.50. To compare these results with peanut butter as bait we used existing GWRC skink monitoring data on the same two tunnel lines from February 9, 2025. This trial recorded 11 skink detections over 20 trap-nights, yielding a detection rate of 0.55. While the sample size is too small to draw definitive conclusions, the data suggests that bait type or the absence of bait has little impact on whether skinks cross through the tunnel. **Figure 4.6** compares the results of the three bait trials. **Appendix H** provides further breakdowns of our comparison with more detailed data.

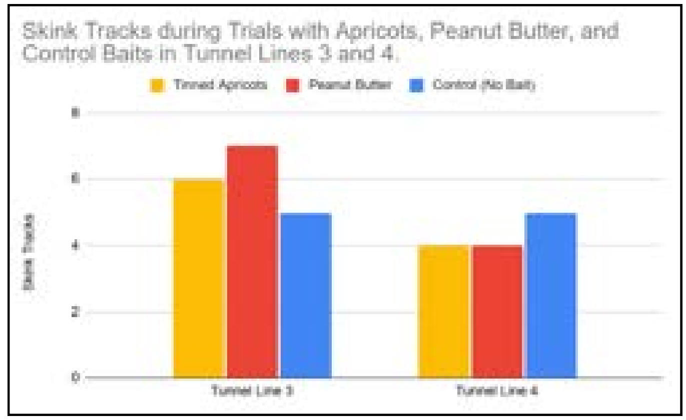


Figure 4.6 Skink tracks during Trials with Apricots, Peanut Butter, and Control Baits in Tunnel Lines 3 and 4.

Additionally, our team used GWRC data to evaluate the possible impacts of the *maramataka* moon phases (found in **Figure 4.7)** and moon luminosity against skink behavior and other animal activity. After retroactively adding data about the phase and luminosity of the moon for every night of trials performed from 2019 to 2024, we determined the skink detection rates during each moon phase and plotted this in **Figure 4.8**. There is a 0.1 increase in skink detection rates during the waxing gibbous phase. There is only one trial that feeds this data point. This is from second highest tracked skink population spike in record which is likely causing this apparent spike on the graph. Although there may be a correlation with the *maramataka* moon calendar, more directed

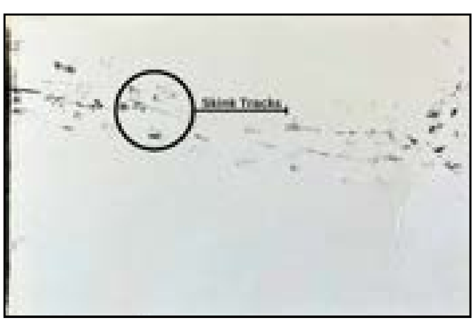


Figure 4.3 Tracking card from tunnel 4-8 with skink prints.

Figure 4.4 Tracking card from tunnel 3-1 with hedgehog and mouse prints.

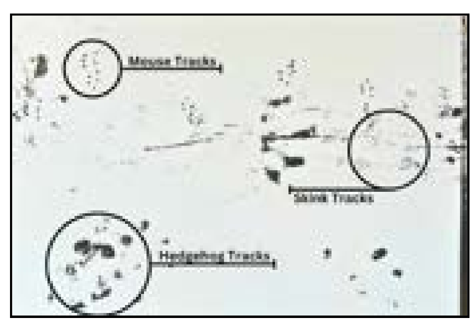


Figure 4.5 Tracking card from tunnel 3-6 with skink, mouse, and hedgehog prints.

research is needed before definitive conclusions can be made. To attempt to draw more conclusive results, we also identified the moon luminosity for each of the GWRC trials and plotted them in a similar manner in **Figure 4.9**. A trendline was added and the R2 was calculated. This R2 value was 0.01, indicating that there was no practical correlation found through this method. To prevent unnecessary outliers, we exclusively used data from summer trials for both **Figure 4.8** and **Figure 4.9**. **Appendix I** contains additional graphs and charts. The

***Figure* 4.7** *Maramataka* Moon Phase Calendar.

results in **Figure 4.9** do not indicate that the moon luminosity affects the activity of skinks.

Our third level of data analysis explored the relationships between the activity of skinks and non-native pests. We used GWRC data over the last 13 years to create a timeline of detection rates for skinks, hedgehogs, rats, mice, and possums. **Figure 4.10** graphs the total count of pest tracks against skink tracks each year since 2012. **Appendix J** contains detailed graphs for each pest. The analysis suggests there is a slight inverse relationship between the two populations. **Figure 4.11** illustrates the tendency for the skink population to increase as the hedgehog population decreases. These results also suggest that over time local conservation and pest-elimination efforts have had a clear effect on populations within the area. These programs have rehabilitated skink populations and effectively reduced many pest populations.

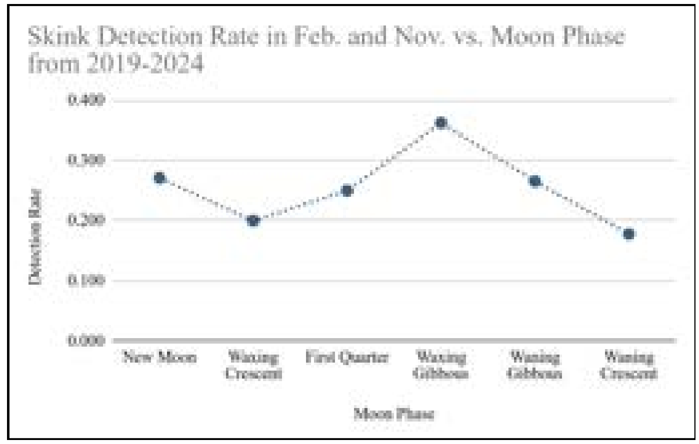


***Figure* 4.8** Skink Detection Rate in February and November over the Lunar Cycle from 2019 to 2024.

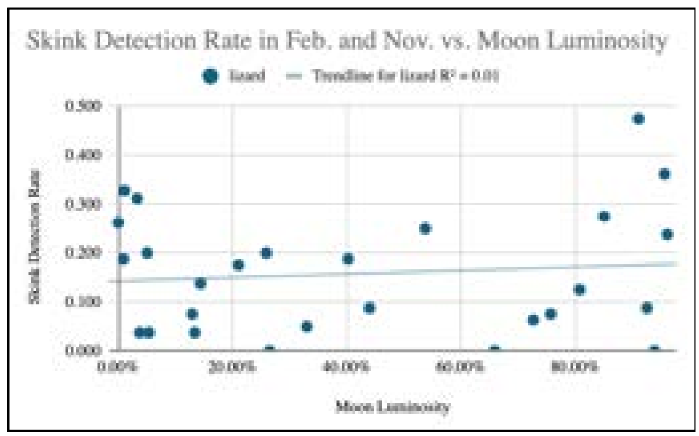


***Figure* 4.9** Skink Detection Rate in February and November vs. Moon Luminosity.

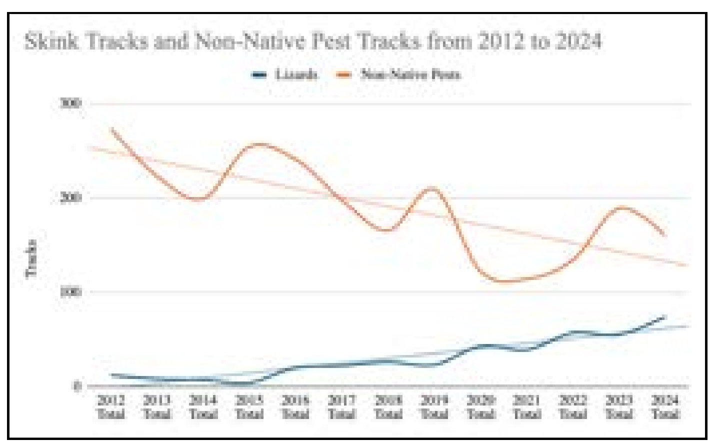


***Figure* 4.10** Skink Tracks and Non-Native Pest Tracks from 2012 to 2024.

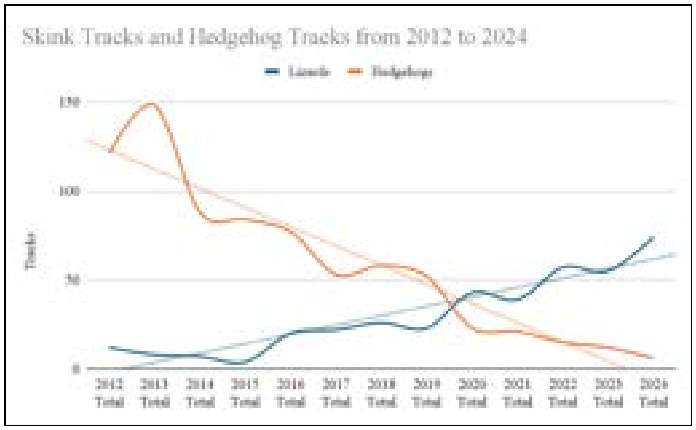


Figure 4.11 Skink Tracks and Hedgehog Tracks from 2012 to 2024.

Finally, our team evaluated the effectiveness of tracking tunnels against pitfall traps in the same areas by comparing existing GWRC tracking tunnel monitoring in Baring Head against EcoGecko's pitfall trapping results. We compared tunnel detections rate with pitfall catches per trap-night for the available years. **Figure 4.12** plots the pitfall catch per unit on the y-axis, and the total tunnel detection rate on the x-axis.

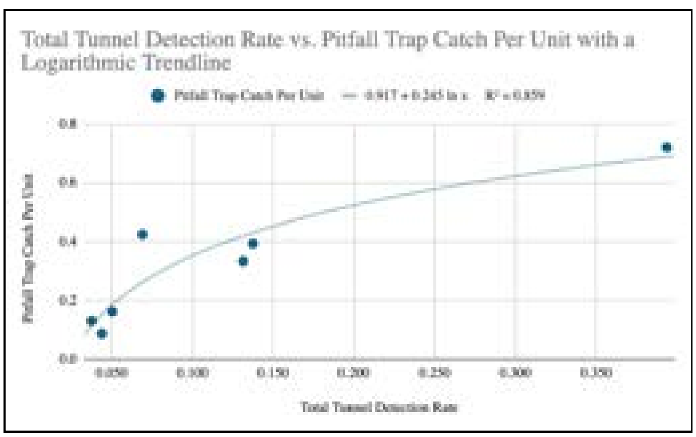


Figure 4.12 Total Tunnel Detection Rate vs. Pitfall Trap Catch Per Unit with a Logarithmic Trendline.

We tried many different trendline styles when determining which one to use for this graph. Through conversations with Dr Belcher, we decided that a logarithmic trendline fits the data most accurately. **Appendix K** includes the other trendlines we investigated. This provided us with **Equation 4.1** that roughly converts tracking tunnel detection rates into pitfall trap catch per unit. This provides researchers with a more standard value that they can plug into their population estimation models to roughly estimate the skink population. An issue that we faced when deciding on trendlines was the point at (0.069, 0.425). We believe that this point is an outlier as it does not closely match the other data points. We did not remove this due to the limited total number of data points, as it is possible that with more data this point would not be an outlier.

$$\boxed{y = 0.917 + 0.245 ln(x)}$$

Equation 4.1 The equation to convert from detection rate (x) to traps per unit (y)

In all, these analyses assess the efficacy of tracking tunnels as they are currently used and establish a baseline for how scientists can improve them going forward. The data here is based on relatively small sample sizes, so further testing is necessary to support our findings, but we believe similar patterns are probable in further studies.

4.3 Articulate skink tracking significance in the context of *Mātauranga Māori*

During our time in Rotorua, we worked with Stu Herewini, a representative of the Te Kura Taiao Collective and a member of the Te Arawa *iwi*. Our conversations with him revealed that we had a fundamental misunderstanding of the cultural value of our project. Stu did not want to focus on discussing old stories about why lizards are special to the Māori. Instead, he focused on sharing his culture with us while emphasizing the importance of conservation education to Te Arawa.

Since 2016, the Te Kura Taiao Collective has worked with Māori schoolchildren aged 11 to 16 in the Rotorua area to teach them to connect with their culture and the environment. Stu uses "kinesthetic learning" to form a relationship with students that encourages curiosity and participation outside of a structured school environment. By using the Te Arawa land as his classroom, his approach is to help young people become aware of the deep cultural importance that the land holds. His goal is to bridge the gap between generations by sharing knowledge and experiences. Stu wanted our experience in Rotorua to mimic that of his students as we learned about Māori culture and the uniqueness of the Rotorua landscape. Our prior archival research served as background knowledge and a foundation for Stu's teachings.

When we arrived in Rotorua, we met Stu at the Fenton Street McDonalds. His lessons began with a showing of carvings from Māori stories across the walls of the restaurant (see **Figure 4.13**). He had a role in installing these wooden panels in the 1980s and it was his friends that carved these Māori pieces of art. In front of these carvings, he taught us about *hauora* which is your total health and well-being. Stu used the rest of the evening to facilitate us getting to know each other and forming a *whānau*. This was an important step of Stu's process because he wanted everyone to feel comfortable sharing opinions and asking questions.

Over the next two days, we met separately with Stu and Neil Watson, an instructor with the Te Kura Taiao Collective and local field hockey coach. We walked around the Whaka Geothermal Trails that the Te Arawa *iwi* maintains. Stu encouraged us to use all five senses to interact with the land and the foliage and to take our time and ask questions. Additionally, he challenged us to treat the walk as a cultural experience as opposed to an educational program. During our walk, Stu told us about the *manuka* plant which is endemic to Aotearoa. To learn kinesthetically like the students, Stu had us all touch *manuka* and get up close to look at it. He explained how to distinguish it from the similar *mingimingi* and *kanuka*, which requires feeling or smelling these plants. Our conversations with Stu focused largely on the Māori culture, while Neil discussed Western science more in depth. While we were walking around the park Stu expounded the respect that the Te Arawa have for lizards as *taonga*. An ancient *pūrākau* (legend) tells how his *iwi* departed from Hawaiki on the *waka* and arrived on the sandy beaches on the east coast of Aotearoa's north island after a long journey across the Pacific Ocean. According to this legend, upon landing, a giant lizard jumped off the bow of the *waka* and guided the *iwi* through the forest to Rotorua. Ever since, the Māori have considered lizards as "advisors" or "navigators" and if you see one and it does not run away, it wants to guide you and you should follow.

Figure 4.13 Wooden Carving depicting Māori stories in the Fenton Street McDonalds.

The Te Arawa *iwi* has a unique relationship with conservation. Stu and many other members are deeply involved in local efforts. Stu and his conservation-trained dog Whenua help to locate and mark pest plants for removal by the Department of Conservation (DOC). Stu also often helps to maintain and monitor local forests and streams. The Te Kura Taiao Collective has led multiple campaigns targeting pest species around the geothermal park in Rotorua. In 2023, Stu and his class of 11-year-olds put in 8.2 kilometers of pest traps at the Whaka Geothermal Trails to target mice populations. This year, he is working to get the *iwi* fully certified to conduct conservation monitoring and trapping on their own. Te Arawa would be the first *iwi* to become certified. Stu believes this will be a groundbreaking and hopefully long-lasting collaboration.

Tracking tunnels are the next step for Stu and his students. He hopes to have his students create their own tunnels and select a placement location in the forest. Each student will be responsible for maintaining their tunnel and checking it for tracks. Stu is using the tunnels to connect his students with the land in a personal and private manner. In addition, the data collected through these trials will inform elders to make decisions about the land. The *iwi* may share some data with the DOC, but only at their discretion.

4.4 Discussion

Reflecting on everything we have learned over the past five weeks, we realized how unprepared we were to grasp *mātauranga Māori* through literary research and study alone. During our fieldwork phase, a bicultural approach was more challenging than we expected. For example, when we arrived in Rotorua to meet with the *iwi*, we were struck by the differences in our approach to environmental learning. Stu Herewini took us under his wing as our *Koro* (grandfather) and the first lesson he taught us was the principle of *hauora* (health), which encompasses four pillars focusing on social, spiritual, mental, and physical well-being. Experiencing this new worldview was eye-opening, as it highlighted a fundamental difference in priorities between Western science and Māori culture. Western science often focuses on data collection within highly itemized and often individualized subjects to uncover solutions. Much of the work the *iwis* do is based on a commitment to *Papatuanuku* and the well-being of all living things. The stark contrast in these values can be difficult for both sides to comprehend, even when there is a willingness to engage and share perspectives. Although we believed we had equipped ourselves to learn about Māori culture, we found ourselves struggling with a worldview that felt unfamiliar and, at times, uncomfortable. It challenged our ingrained Western approach to science, forcing us to rethink not just our methods, but also the underlying purpose behind them. Ultimately, we learned that true bicultural collaboration requires not only an exchange of knowledge but also a mutual respect for the integration of both Māori frameworks and Western science.

Figure 4.14 Neil Watson showing our team native flora.

We also recognized the parameters of our project, and the need for more information to strengthen our skink tracking analysis. Our tests with different bait types and skinks yielded interesting results despite the limited data available to us. There was no clear correlation between any bait or lack thereof. This means that the presence of skinks in these tunnels is likely not linked to bait, strongly suggesting that skinks are using tracking tunnels for protection, rather than for the bait inside. However, we drew this conclusion from a relatively small sample size of 20 tracking tunnels and 3 trials. We present this limitation as an opportunity for broader collaboration and further research. If *iwi* partnered with regional councils, a comprehensive citizen science effort that includes *mātauranga Māori* teaching and learning could strengthen the link between communities and researchers. There is much to learn in environmental conservation through the appreciation of lived experience. Regional councils and researchers could utilize a larger, more representative dataset. Our findings highlight how blending diverse narratives and perspectives can lead to a more comprehensive understanding of the world around us. By weaving these approaches together, science can become a tool for meaningful progress, creating a bicultural framework that respects Māori knowledge and advances scientific practices.

4.5 Limitations

One limitation of our project was the relatively short timeframe we were in Aotearoa. With only seven weeks to conduct our research, several constraints emerged. We consequently worked with less data for drawing valuable conclusions. We found virtually no difference between any bait choice, given more time we could have conducted additional trials, accounted for more variables, and potentially observed clearer patterns and provided more detailed results.

Secondly, our study only took place in Baring Head, meaning that all of our data originated from a single location. Baring Head has a unique coastal environment, which differs from conditions found in other areas of Aotearoa. Different skink species in other regions may react differently to tracking tunnels and bait types. As a result, our conclusions may not be as applicable to places with different climates, habitats, or skink subspecies. Nevertheless, our findings do present a snapshot of potential trends.

Finally, we regretted the distance between Wellington and the Te Kura Taiao Collective located in Rotorua. This made it difficult to collaborate as closely as we had hoped. We were only able to visit Rotorua once for a three-day time period, even though the original plan was to spend two weeks there. While our three days still changed our whole perspective and provided great insight into the project, this reduced the amount of time we were able to spend working directly with the Te Kura Taiao Collective and gathering their perspective on this project.

RECOMMENDATIONS

Through our own experimentation and data analysis, we developed a set of recommendations to enhance the efficacy of tracking tunnels for skink monitoring. These recommendations aim to improve data quality, tunnel reliability, and strengthen community involvement while reinforcing a bicultural approach that integrates Western scientific methods and *mātauranga Māori*.

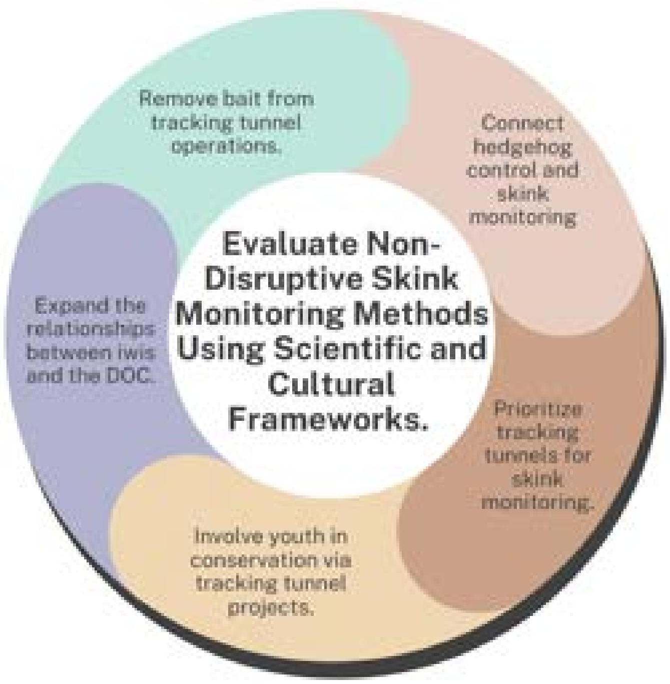


***Figure* 5.1** Our recommendations support the overall goal of the project .

Recommendation 1:
Remove Bait from Tracking Tunnel Operations

Our data suggests that skinks will go through tunnels at relatively equal rates regardless of what is placed inside. We used tinned apricots and compared them against trials of zero bait and trials of peanut butter. Each trial showed roughly equal tracking rates. Our sample sizes were very small and restricted, so we would highly suggest further studies into the efficacy of each bait. However, until that research is complete, our current recommendation is to forego the use of bait. This will reduce costs and simplify the tracking process, ideally allowing for doing more testing with equal resources.

Figure 5.2 Tinned apricots for use as bait.

Figure 5.3 Tracking tunnel set without bait.

To better support our finding, we would encourage another trial of our experiment, on as large a scale as the testing team can handle. Our limited time and resources prevented us from collecting more expansive trials. Even a replication of our bait trials done on a small scale such as ours would strengthen the conclusion that bait is inconsequential. Our research and conversations with experts revealed only fruit and peanut butter as potential baits, but if there is reason to suspect another possibility, testing would be well warranted given our findings.

<u>Procedure:</u>
Continue the current tunnel tracking procedures in place, bypassing the baiting process. We recommend using The Black Trakka from Gotcha Traps LTD for the tracking card. Begin by labeling the card with the precise location and date of tracking. Unfold the card and insert it into the tracking tunnel. Place it down, ensuring to flatten the entirety of the card against the ground, with special care not to place your fingers in the ink section of the card. Return the following day to remove the card. Once again be sure to avoid contacting the ink pad as you slide the card out of the tunnel. Store the tracking cards for analysis after you complete the fieldwork. Inspect each card in a well-lit room and record each type of print found for the tunnel line, number, and date.

Recommendation 2:
Connect Hedgehog Control and Skink Monitoring

Using the tracking tunnel data provided by the GWRC, we observed a direct inverse relationship between skink and hedgehog populations. As hedgehog numbers declined due to recent population control efforts, skink activity in tracking tunnels increased at a directly proportional rate. This trend strongly suggests that hedgehogs, as invasive pests, significantly impact native skink abundance by preying on skink eggs and small skinks. **Appendix I** illustrates a visual representation of this relationship. This is especially important to focus on as despite many years of relatively consistent hedgehog population decline, data from early 2025 monitoring operations suggests that their population may be rebounding.

Given these findings, we recommend prioritizing hedgehog population control to increase skink populations, as they appear to have the most significant impact. Pest traps that are effective in decreasing hedgehog populations are already widely used in parks and reserves to support broader pest management efforts. Expanding these targeted trapping efforts will be critical for maintaining and restoring skink populations. Additionally, while declining hedgehog numbers appear to have the strongest correlation with increasing skink numbers, other invasive pests such as rats, mice, mustelids, and possums may play a larger role in other areas of Aotearoa. Incorporating control measures for these species alongside hedgehog management will further strengthen conservation efforts. Future research should continue monitoring skink population changes following sustained hedgehog elimination efforts while also exploring the broader ecological benefits of reducing multiple pest species to ensure a long-term ecological balance.

<u>Procedure:</u>
The GWRC includes hedgehogs, as well as rats, possums, and mustelids, in site-led management programs. This means that the exact control plan changes based on the extent of the pest invasion (Greater Wellington, 2023). Check with the local regional council for details about how they classify these pests. Predator Free NZ provides approved pest traps under the Animal Welfare Act of 1999, meaning that these traps humanely kill the pests. Select a trap appropriate for the target pest, placement location and available budget. Most traps require emptying and resetting after each kill. Auto-resetting traps are available, but they generally cost significantly more. Place the traps in accessible locations to allow for regular service, but near or in foliage to increase potential pest traffic. When setting traps, use meat, fish, or eggs as bait. Check traps regularly and safely dispose of any pests caught. Form extensive site-specific trapping plans before beginning. Important factors to consider when planning to install traps are: pedestrians, especially children, domestic animals, cost, labor, and landscape.

<u>Helpful Guides and Further Details:</u>
- The GWRC trapping information for each pest
- Trap predators in your backyard
- Predator Free NZ traps

Recommendation 3:
Prioritize Tracking Tunnels for Skink Monitoring

After comparing the EcoGecko pitfall trap data with the tracking tunnel data provided by the GWRC, we were able to establish tracking tunnels as a viable method for measuring skink presence in a geographical area. Tracking tunnels provide a less labor-intensive and cost-effective approach for monitoring skink activity and presence. Unlike pitfall traps which require continuous monitoring to count and release skinks, tracking tunnels allow for researchers to set up the bait, ink card, and tracking cards in one day and collect the tracking cards within a few days with minimal maintenance during that time.

Pitfall traps are the current standard for skink population monitoring. This means that many analyses and evaluations rely on pitfall trap data to make conclusions. While both methods acquire accurate and useful data, the values are on a different scale, effectively measured by a different unit. Through our data analysis, we developed **Equation 5.1** to approximate pitfall trap results from tracking tunnel presence data. Using this equation, we can directly compare and combine pitfall and tunnel data. We believe that this can facilitate a smooth transition to prioritizing tracking tunnels as the dominant skink monitoring method. The only caveat is if researchers require detailed data such as subspecies, gender, or size, they would need to utilize pitfall traps. To further improve this equation, we recommend scheduling future pitfall trap operations around the tracking tunnel tracking operations employing the same method that we used. Increasing the data points with more trials will decrease the overall effect of outliers, refining the equation.

$$\boxed{y = 0.754x^2 - 0.0479x + 0.0256}$$

***Equation* 5.1** The equation to convert from tunnel detection rate (x) to pitfall detection rate (y)

***Figure* 5.4** Tracking card with skink tracks.

<u>Procedure:</u>
Identify areas of interest for skink activity to place tracking tunnel lines. Each tunnel should contain a tracking card flat along the ground. After being active for at least one night, collect the tracking card. Inspect the tracking card for footprints (see **Appendix B**), to identify the animals detected. Calculate the skink detection rate. Plug this value into the equation above to determine the approximate corresponding traps per unit (pitfall detection rate), providing a standardized method to roughly equate tracking tunnel data and pitfall trap data.

Recommendation 4:
Involve Youth in Conservation via Tracking Tunnel Projects in a Kinesthetic Learning Environment

Through communication with the Te Kura Taiao Collective, it became evident that their plan for implementing tracking tunnels into the kinesthetic learning curriculum could provide students with a sense of responsibility for their environment and native species. This hands-on approach would not only produce ecological awareness but empower students to actively engage with Māori culture by serving as *kaitiakitanga* of the land. Integrating tracking tunnels into their education provides a modern way to connect students to their cultural heritage while simultaneously introducing them to the Western scientific method.

Procedure:
Introduce students to the role and importance of Aotearoa's native species. Discuss active conservation efforts to protect these species, focusing on local issues that students can see for themselves and get involved in. Acquire tracking tunnels for the school or program, tunnels, cards, and more are available to purchase from Predator Free NZ. Plastic tracking tunnels are generally under $15 NZD each. Constructing the tracking tunnels from scratch is also an option. DIY tunnels can range from easy plastic recyclable crafts to long-lasting wooden constructions. Plan for the budget available, the only requirements are for the tunnel to be wide enough to fit a tracking card and provide cover with two exits, the rest is up to the builder. This process of constructing the tunnel engages the student significantly more and enables them to personalize their tunnel.

After construction, guide students in selecting a suitable location for their tunnel. Have the students identify potential skink habitats among shrubs and rocks and place the tunnels nearby. Be sure to place each tunnel in an independent location, common practice is to space them at least 50m. Baiting the tunnels is optional (see Recommendation 1 in **5.2**) but we do not discourage this choice. Feel free to allow students to experiment with the bait they want to try. Fruits, and peanut butter should be successful for skinks while meats will attract other pests. The data collected is just as important as the process of monitoring. Have the students compile their data and encourage them to form hypotheses and draw conclusions. Continue to monitor to keep track of the local fauna. If there are active conservation efforts in the area, you should see their effects over time.

Helpful Guides and Further Details:
- Predator Free NZ's Schools Toolkit
- DOC Guide to Backyard Monitoring
- Predator Free NZ monitoring equipment

Recommendation 5:
Expand the Relationships between Iwis and the Department of Conservation

Local *iwis* consider themselves guardians of the natural ecosystems and are closely engaged with and concerned about preserving them. This means that they often have a better sense of what is happening in their local area than the DOC. The quality of information collected will improve with further partnerships between the DOC and *iwis*. This partnership will reduce the load on the DOC while empowering *iwis* to fulfill their duties as guardians of the land where they reside. Training *iwi* members on DOC tracking procedures will allow the *iwis* to choose to share and fit any data into existing DOC datasheets.

Procedure:
Develop a framework based on the Te Arawa *iwi*'s partnership with the DOC to allow other interested *iwis* to engage in these pest and native species tracking operations. This should allow the *iwis* to have complete authority over the information they choose to share and should provide them with the necessary training to effectively use the standard DOC methodologies for tracking.

***Figure* 5.5** Our team with Sara and Stu.

CONCLUSION

This project provided an opportunity to experience the preservation of nature from scientific and cultural perspectives and to combine the two. We initially sought to assist researchers at Victoria University in improving tracking tunnels for formal monitoring purposes with attention to cultural priorities. When exploring the cultural side, our partners in Rotorua invited us to explore how to promote academic research in a learning space that honors *mātauranga Māori* and brings young members of the community new modes of cultural education and participation.

Through both paths, we determined that to continue improving the conservation of native skinks, efforts should shift away from pitfall trapping and towards tracking tunnel usage. While pitfall traps can provide detailed species identification and demographics, they require frequent monitoring and site visits. In contrast, tracking tunnels offer a reliable, low-maintenance, non-invasive alternative for measuring skink activity which makes them more sustainable for long-term monitoring and community-driven conservation efforts.

Rather than existing separately, Western science and *mātauranga Māori* have the power and opportunity to complement each other, supporting an inclusive and bicultural approach to learning and conservation. The Te Kura Taiao Collective can utilize citizen science projects such as tracking tunnels and refine their kinesthetic learning models to enable students to actively engage with their culture and the land through a combination of scientific and lived experience to gain and promote ecological knowledge.

Figure C.1 Our team.

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APPENDIX A: Tracking Tunnels' Conditions Checklist

This appendix contains the table we used to complete our daily site and conditions assessment during our bait testing trials.

Tunnel Lines	Date (m/d/y)	Moon Phase	Moon Luminosity	Day Temp (C)	Night Temp (C)	Cloud Cover	Precipitation (mm/h)	Max Wind speed (kph)
3, 4	2/12/2025	Waxing gibbous	98.67	19	12	Clear	0	28
3, 4	2/13/2025	Full Moon	99.99	20	11	Clear	0	24
3, 4	2/14/2025	Waxing gibbous	99.13	24	14	Clear	0	22

Table A.1 The table that was filled out each day during tracking operations which documented the weather and moon phase.

APPENDIX B: Baring Head Tracking Tunnel Tracks

This appendix contains examples of the various tracks we identified during our tracking operations in Baring Head on February 12, 13, and 14, 2025.

Figure B.1 Mouse tracks (ID#4.10.2)

Figure B.2 Gecko Tracks (ID#4.9.2)

Figure B.3 Skink Tracks (ID#4.6.2)

Figure B.4 Weta Tracks (ID#4.1.2)


***Figure* B.5** Hedgehog tracks (ID#3-10-2)


***Figure* B.6** Skink and Mouse Tracks (ID#4-8-2)

APPENDIX C: Baring Head Tracking Card Results

This Appendix contains the data table that we used during our Baring Head bait testing trials.

Tunnel ID (line #, tunnel #)	Date placed (mm/dd/yyyy)	Date Collected (mm/dd/yyyy)	Bait Type	Card Lost?	Skink?	Other Species?
4, 1	2/12/2025	2/13/2025	Control	0	0	0
4, 2	2/12/2025	2/13/2025	Control	0	0	0
4, 3	2/12/2025	2/13/2025	Control	0	1	0
4, 4	2/12/2025	2/13/2025	Control	0	0	0
4, 5	2/12/2025	2/13/2025	Control	0	1	0
4, 6	2/12/2025	2/13/2025	Control	0	1	0
4, 7	2/12/2025	2/13/2025	Control	0	0	0
4, 8	2/12/2025	2/13/2025	Control	0	1	1
4, 9	2/12/2025	2/13/2025	Control	0	1	0
4, 10	2/12/2025	2/13/2025	Control	0	0	1
3, 1	2/12/2025	2/13/2025	Fruit	0	0	1
3, 2	2/12/2025	2/13/2025	Fruit	0	1	1
3, 3	2/12/2025	2/13/2025	Fruit	0	1	1
3, 4	2/12/2025	2/13/2025	Fruit	0	0	0
3, 5	2/12/2025	2/13/2025	Fruit	0	1	0
3, 6	2/12/2025	2/13/2025	Fruit	0	1	1
3, 7	2/12/2025	2/13/2025	Fruit	0	1	0
3, 8	2/12/2025	2/13/2025	Fruit	0	0	0
3, 9	2/12/2025	2/13/2025	Fruit	0	0	0
3, 10	2/12/2025	2/13/2025	Fruit	0	1	0
4, 1	2/13/2025	2/14/2025	Fruit	0	0	1
4, 2	2/13/2025	2/14/2025	Fruit	0	0	0
4, 3	2/13/2025	2/14/2025	Fruit	0	0	0
4, 4	2/13/2025	2/14/2025	Fruit	0	0	0
4, 5	2/13/2025	2/14/2025	Fruit	0	1	0
4, 6	2/13/2025	2/14/2025	Fruit	0	1	0
4, 7	2/13/2025	2/14/2025	Fruit	0	0	0
4, 8	2/13/2025	2/14/2025	Fruit	0	1	1
4, 9	2/13/2025	2/14/2025	Fruit	0	1	1
4, 10	2/13/2025	2/14/2025	Fruit	0	0	1

Tunnel ID (line #, tunnel #)	Date placed (mm/dd/yyyy)	Date Collected (mm/dd/yyyy)	Bait Type	Card Lost?	Skink?	Other Species?
3, 1	2/13/2025	2/14/2025	Control	0	0	1
3, 2	2/13/2025	2/14/2025	Control	0	0	1
3, 3	2/13/2025	2/14/2025	Control	0	1	1
3, 4	2/13/2025	2/14/2025	Control	0	1	1
3, 5	2/13/2025	2/14/2025	Control	0	1	0
3, 6	2/13/2025	2/14/2025	Control	0	0	1
3, 7	2/13/2025	2/14/2025	Control	0	0	0
3, 8	2/13/2025	2/14/2025	Control	0	1	0
3, 9	2/13/2025	2/14/2025	Control	0	0	0
3, 10	2/13/2025	2/14/2025	Control	0	1	1

Table C.1: A table that documents the findings from each of our tracking tunnels during bait type testing.

APPENDIX D: Equations

$$\boxed{\textit{Detection Rate} = \frac{\textit{Tunnels with Positive Detection}}{\textit{Total trap\textasciitilde nights}}}$$

Equation D.1 The Detection Rate Equation.

$$\boxed{\textit{Standard Error} = \frac{\textit{std dev (Sum of Mean detection per trap\textasciitilde nights)}}{\sqrt{\textit{Number of Lines}}} \times 100}$$

Equation D.2 The Standard Error Equation.

$$\boxed{y = 0.917 + 0.245 ln(x)}$$

Equation D.3 The equation to convert from detection rate (x) to traps per unit (y)

APPENDIX E: Consent Form

The following is the consent form used to preface each interview, with verbal consent recorded. We outlined the discussion prompts in Appendices F and H.

WPI

We are a team of undergraduate students from Worcester Polytechnic Institute (WPI) in the United States. We are participating in a project to explore monitoring and restoration efforts for skinks in Aotearoa. If you are willing to participate in this project, please read and note your preferences on this form. Any information shared is purely for our team's understanding, concepts and patterns may be referenced in our report, but personal information will not be reported, shared, or recorded long-term. We will publish our final report, which can be found at the following link:

Do we have your permission to audio record an interview?

Yes ☐ | No ☐

Do we have your permission to video record an interview?

Yes ☐ | No ☐

Will you allow us to use your words and image for use on public website platforms?

Yes ☐ | No ☐

I understand that these interviews will be published at WPI for educational purposes and made available to the public. Images and film clips may also be shared to social media platforms including Instagram and other outlets designed to amplify the experiences of climate change.

APPENDIX F: Discussion Prompts for the Rotorua Iwi

The team developed discussion prompts for members of the Rotorua iwi to learn more about the place of lizards in local storytelling and bioheritage. Appendix D provides information on interviewee consent, and participants completed consent forms before the discussions. Before beginning discussions, the team introduced themselves and gave a brief overview of the project, as well as expressed that our goal for the discussion was to gain insight into mātauranga Māori of skinks.

F1. Could you share how lizards are part of local stories and storytelling?
F2. What work do you do with conservation?
F3. How does the conservation work done by the Te Arawa Iwi connect with the work done by the Department of Conservation?
F4. What students or youth do you work with?
F5. What is the role of this park in the community?
F6. What is your plan for using tracking tunnels?
F7. How do you feel about the way in which Māori culture is being preserved and passed down?

Appendix G: Archive of Collected Māori Stories

Below are the related written Māori stories we researched in the Victoria University of Wellington Library. The title of the story, book we found it in, and brief summary of the story will be included.

The Wellington Harbor Taniwha

Wellington Harbor (*Te Whanganui-a-Tara*) used to be a lake at the head of the fish of Māui (*Te Ika-a-Māui*). Ngake and Whātaitai were *taniwha* (supernatural beings) who lived in the lake that is now Wellington Harbor. Ngake had a lot of energy and used to chase eels, and fish and leap after birds that got too close. Whātaitai, on the other hand, was very laid back and enjoyed sunbathing on the lake's shores. One day, Ngake and Whātaitai went to the southern shores of the lake; they could hear the ocean on the other side of the land, and would often communicate with the seabirds asking what was so special about the sea on the other side. The birds would tell them that the sea was deep and wide and home to many creatures and taniwha. Ngake and Whātaitai dreamed of what the sea would be like. As the years passed, they began to outgrow the lake and felt trapped. One day, Ngake decided to escape to the sea. He coiled his tail into a massive spring and ran into the cliff faces of the shore, smashing through them, creating a pathway through to Cook Straight (*Te Moana o Raukawa*). Whātaitai knew he would have to follow his brother and escape to the sea. However, he was not as strong as his brother and failed to take into account how the tides had shifted. When he went to release his coiled tail he did not have enough power and got stuck between the sea and the lake. Whātaitai hoped that when the tide came in he would be able to swim out to sea.

Unfortunately, the tide only dampened his scales and provided enough fish to him so that he would not get hungry. Whātaitai became good friends with many birds as he lay stranded. One day, when a large earthquake launched his body onto land, Whātaitai made peace with dying among his bird friends. As he died, Whātaitai's spirit transformed into a bird (*Te Keo*) and flew to the top of Mount Victoria (*Matairangi*). This spirit looked down on the *taniwha* body below and finally accepted the sadness that Whātaitai would never make it to the freedom of the sea and joined the *taniwha* spirit world. Over the years, Whātaitais body has turned to stone, earth, and rock and is known to this day as Haitaitai. Matairangi (Mount Victoria) still looks over the body of Whātaitai, and the very top of Matairangi is still known as Tangi te Keo.

When Ngake had let his spring tail loose he created so much force that he created a gash in the earth where the Hutt River was formed (*Teawakairangi*). The remnants of rock from Ngake's escape are visible today as Steeple Rock (*Te Aroaro o Kupe*) and Barrett's Reef (*Te Tangihanga o Kupe*) and are well known by mariners as dangerous rock formations entering Wellington Harbor. When the sea is calm in the Harbor, Ngake is exploring the Pacific Ocean (Te Moana Nui a Kiwa) and when the sea is turbulent in the Harbor, Ngake is at home chasing sea life in his energetic spirit. Adapted from (Grace, n.d.)

The Waitepuru Stream Taniwha
The Waitepuru stream is a taniwha that takes the form of a lizard. The headwaters that feed the rest of the stream are the head of this *taniwha*, the body is made by the main channel, legs are formed by tributaries, and finally, the tail is created when the stream reaches plains at the end of its course. The *taniwha* is believed to be restless and its tail frequently flicks from side to side. This is visible in large flood events that result in the river changing course in the plains. This story was used to warn and remind the local Māori people to never build on that land as the *taniwha* is too unpredictable and would likely destroy their structure the next time it becomes restless. Adapted from (Evans, 2020)

Rotorua Geothermal Activity
Ngatoroirangi was exploring the Taupo region and climbed the Tongariro mountain to search for land for his people. When climbing up the mountain, Ngatoroirangi encountered extreme ice and snow from the *Tawhirimatea*, the god of the winds. Ngatoroirangi realized he was going to die from the cold so to survive, he called to his sisters, Kuiwai and Haungaroa, who were in *Hawaiiki* to bring him fire.

His sisters frantically filled six baskets with embers (the children of *Ruaumoko* the god of volcanic energy). The demi-god siblings of the sisters *Te Hoata* and *Te Pupu* were tasked with bringing these embers to Ngatoroirangi. During their journey, they stopped at many locations, each time getting more frustrated. Each time, they sent embers down into the ground which created Whakaari (White Island), Moutohora (Whale Island), Rotoiti, Tarawera, Rotorua, Orakei Korako, Wairakei, Tokaanu and finally Ketetahi at Tongariro. When they finally reached Ngatoroirangi, they only had one basket of embers. Ngatoroirangi was very angry that he only received one basket of embers and in his rage, he stomped his feet two times shaking the earth, and plunged his paddle deep into the earth. This caused the raw power of *Ruaumoko* to be released and warmed Ngatoroirangi. The pathway that *Te Hoata* and *Te Pupu* took is evident by the geothermal features that now exist there, causing volcanoes and geothermal areas still visible to this day. Adapted from (Ngati Tuwharetoa Kaumatua, n.d.)

APPENDIX H: Bait Type Analysis Graph

This appendix contains an additional graph that breaks down the bait types by animal.

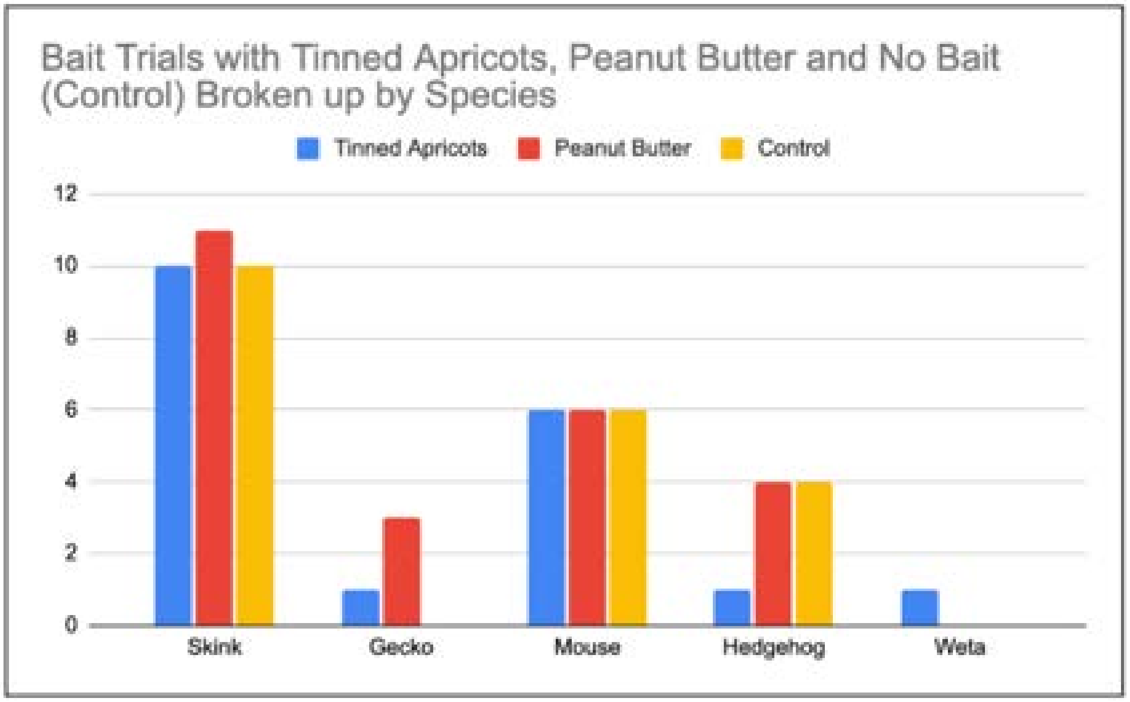

Figure H.1 Bait trials with tinned apricots, peanut butter, and no bait (control) broken up by species.

APPENDIX I: Moon Luminosity Graphs

This appendix contains graphs that plot the skink detection rate against the moon phase or luminosity during the trial. Figures J.1 and J.2 are from data only taken during summer months (February and November), while J.3 and J.4 are similar graphs that used data for the entire year.

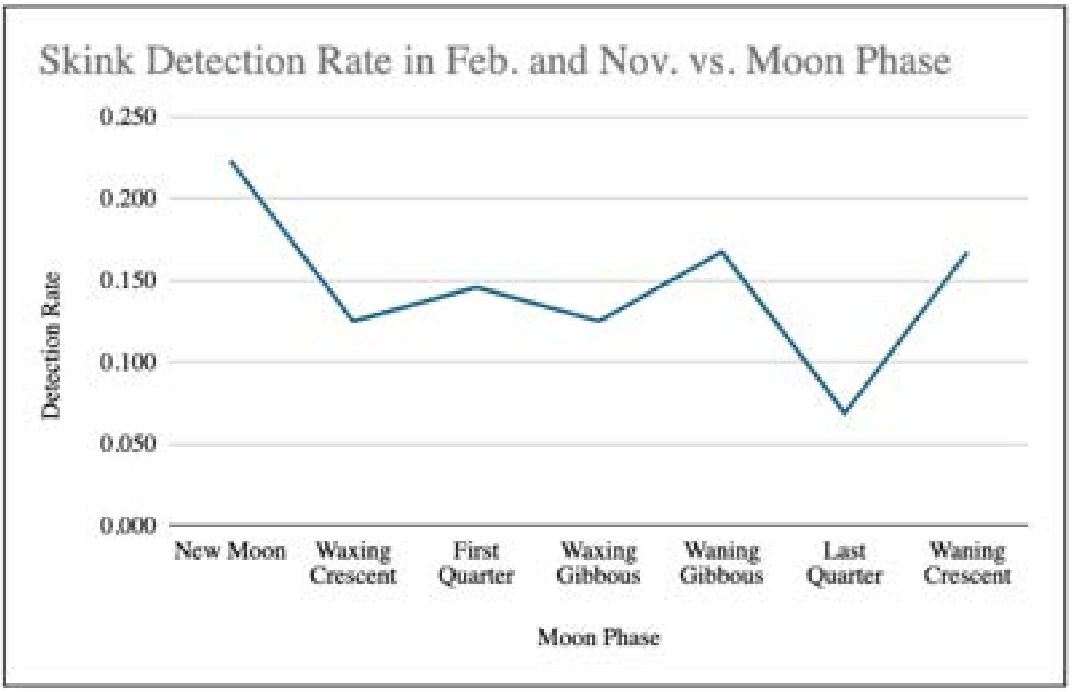

Figure I.1 Skink Detection Rate in February and November vs. Moon Phase.

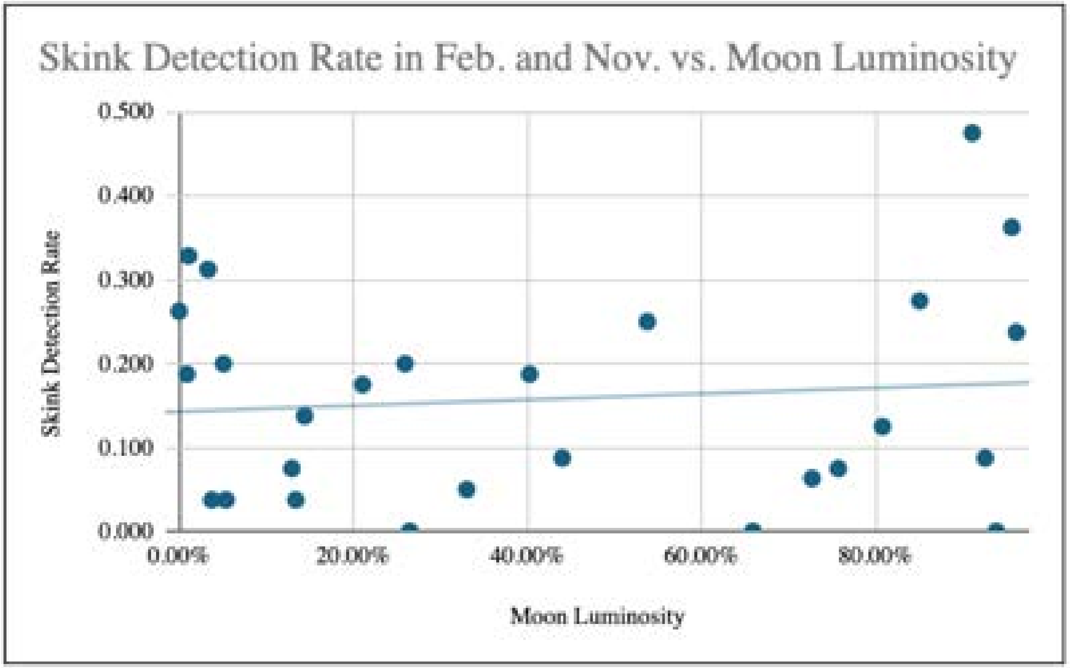

Figure I.2 Skink Detection Rate in February and November vs. Moon Luminosity.

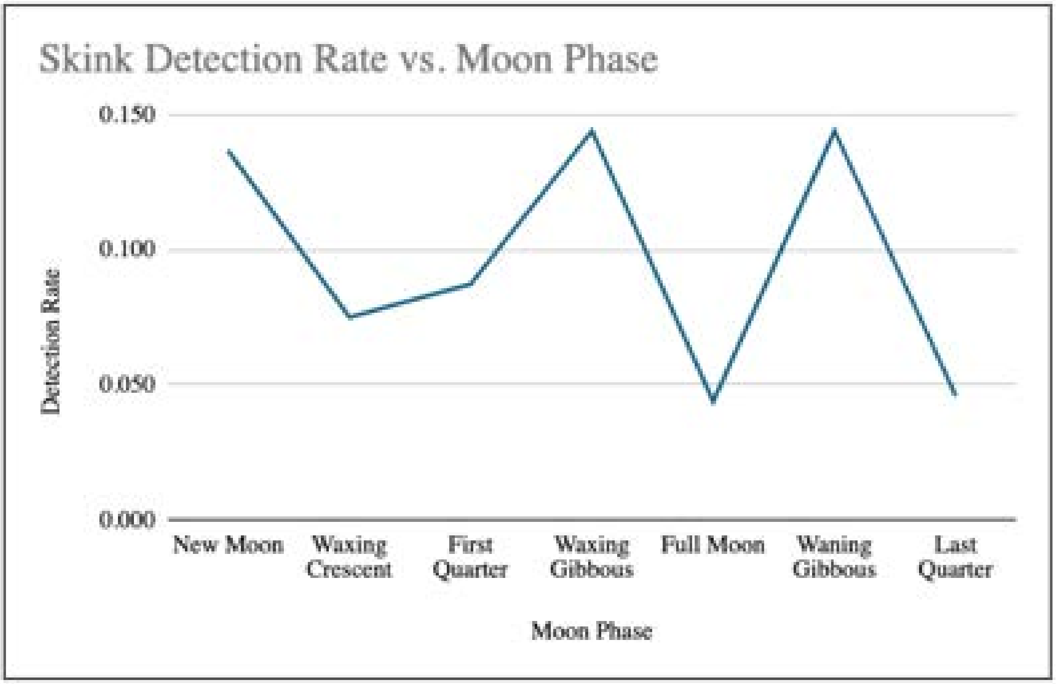

Figure I.3 Skink Detection Rate vs. Moon Phase.

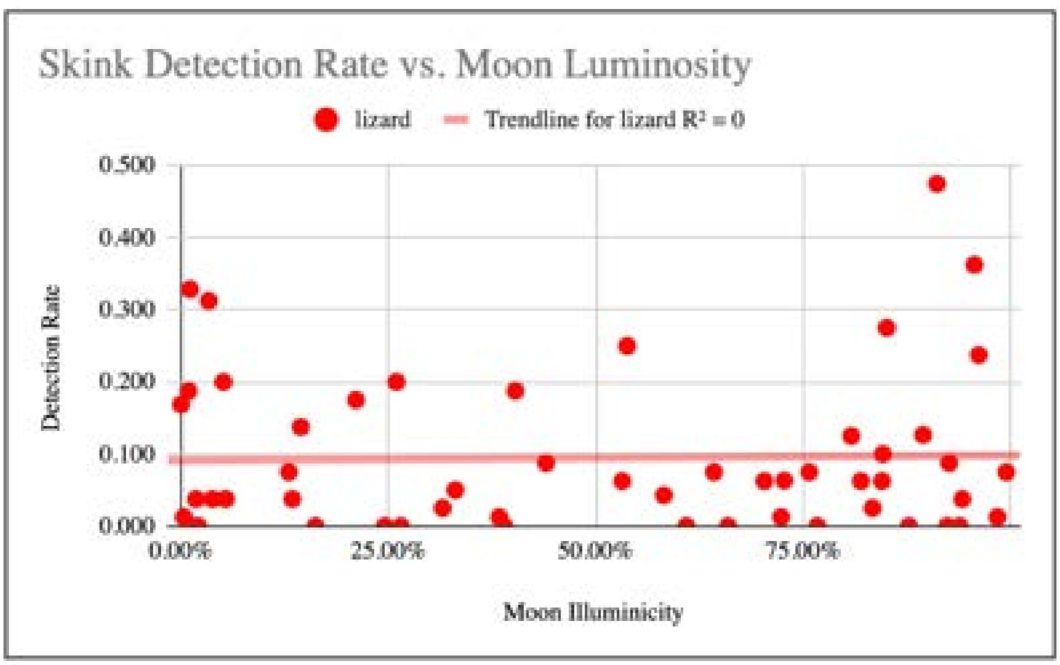

Figure I.4 Skink Detection Rate vs. Moon Luminosity.

APPENDIX J: Graphs for Each Pest Species

This appendix contains graphs that plot the skink tracks and the tracks for each of the pest species actively tracked in Baring Head since 2012.

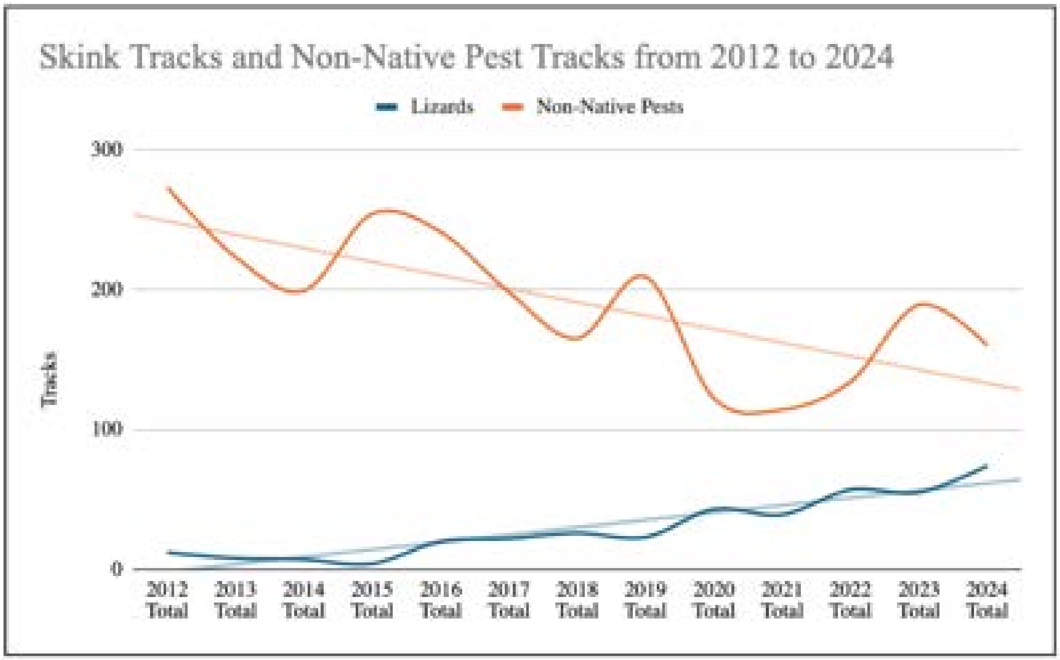

Figure J.1 Skink Tracks and Non-Native Pest Tracks from 2012 to 2024.

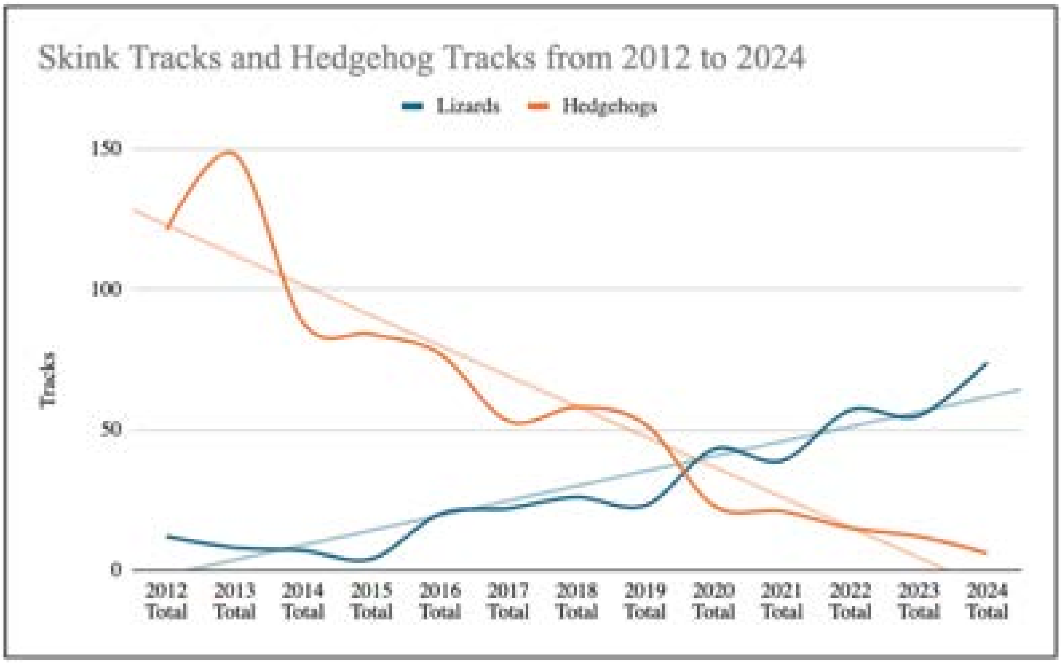

Figure J.2 Skink Tracks and Hedgehog Tracks from 2012 to 2024.

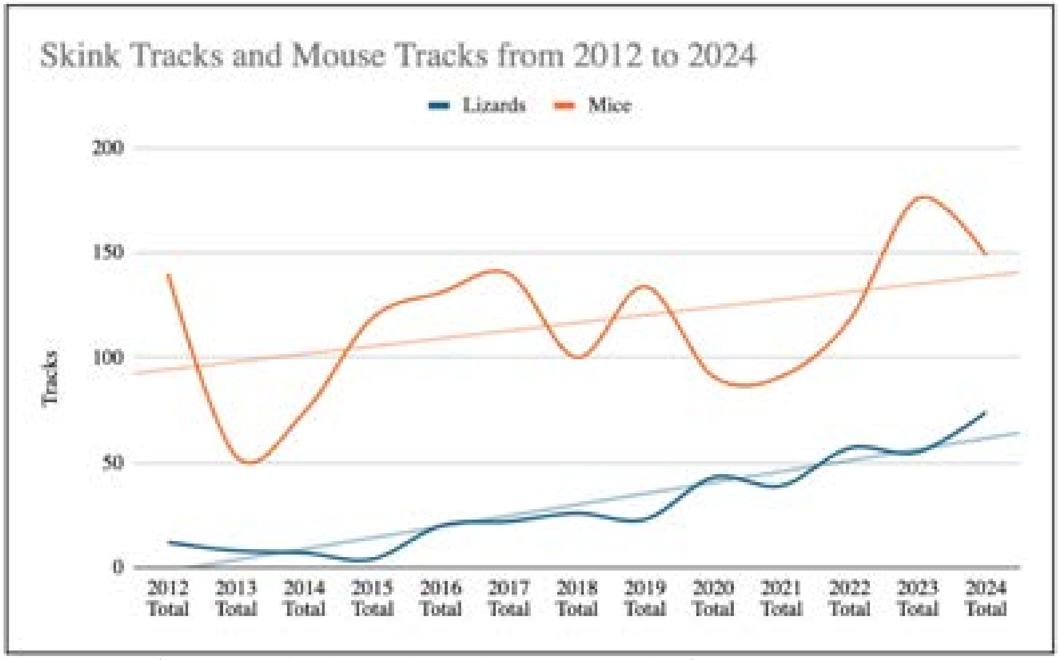

Figure J.3 Skink Tracks and Mouse Tracks from 2012 to 2024.

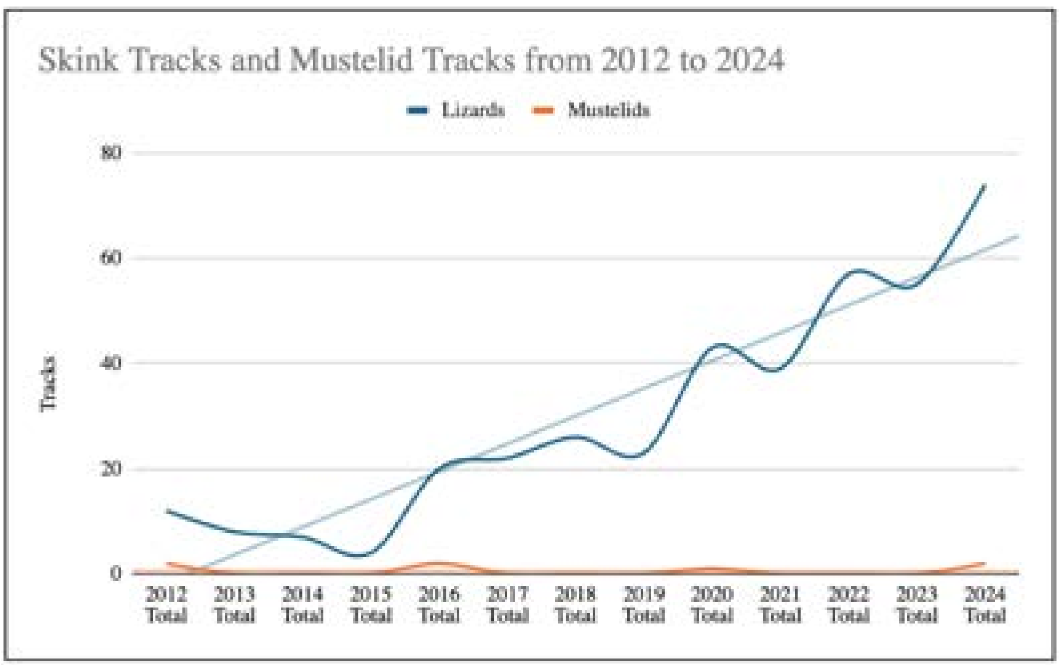

Figure J.4 Skink Tracks and Mustelid Tracks from 2012 to 2024.

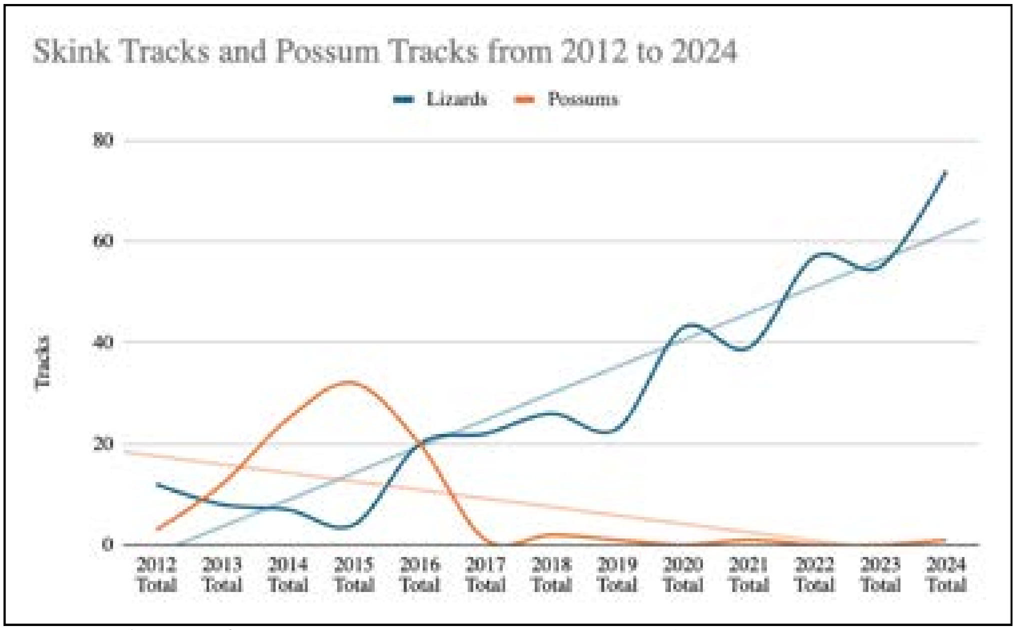

Figure I.5 Skink Tracks and Possum Tracks from 2012 to 2024.

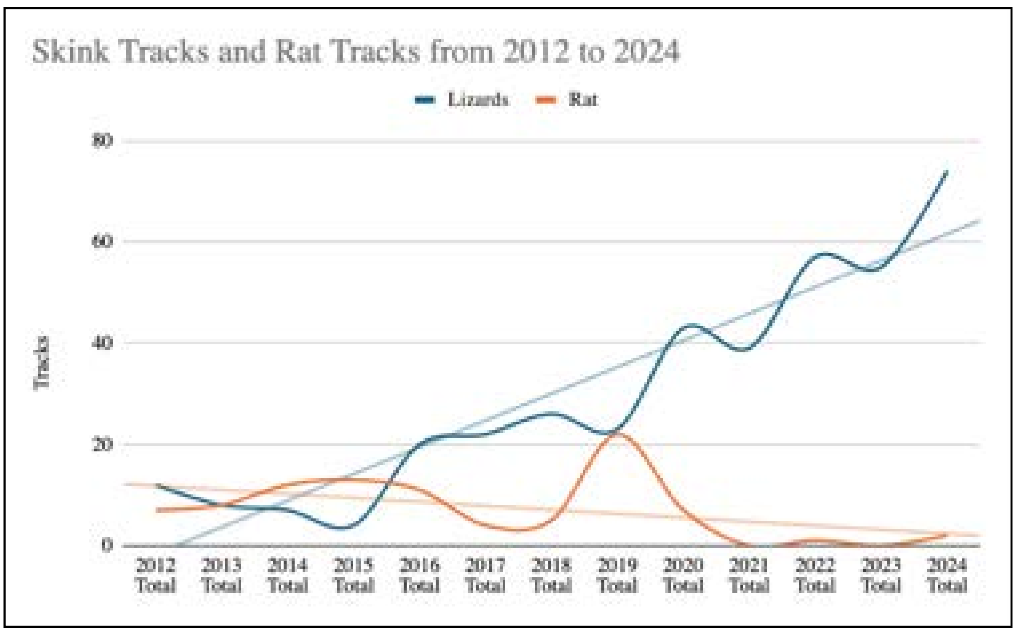

Figure I.6 Skink Tracks and Rat Tracks from 2012 to 2024.

APPENDIX K: Pitfall Trap and Tracking Tunnel Comparison Graphs

This appendix contains figures generated when determining the best fitting trendline to generate a conversion equation between pitfall trap catch per units and tracking tunnel detection rates.

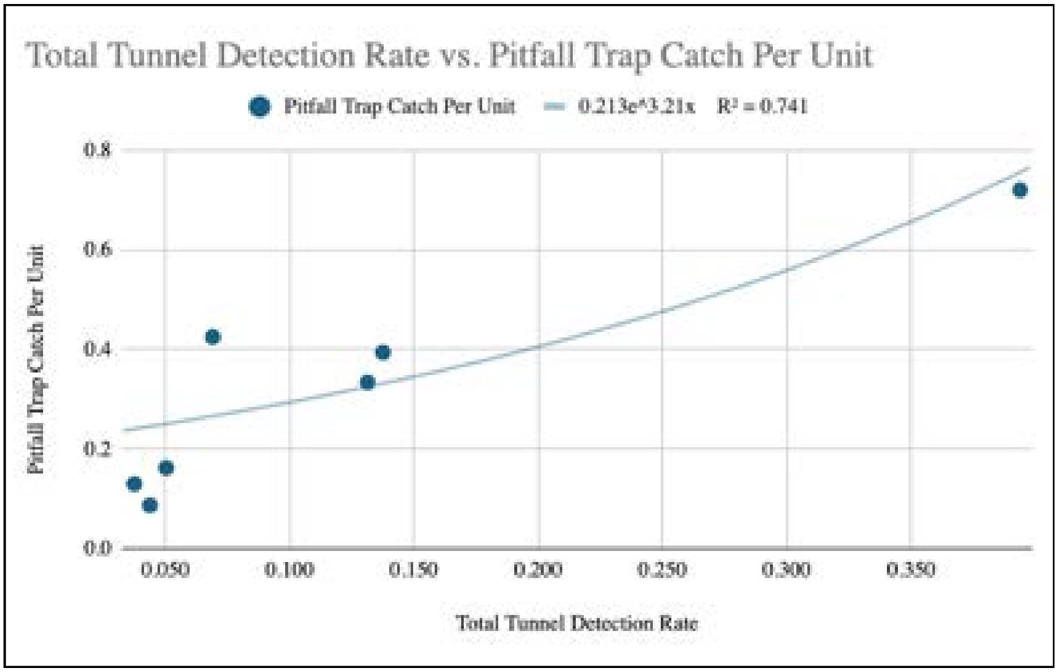

Figure K.1 Total Tunnel Detection Rate vs. Pitfall Trap Catch Per Unit using a linear trendline.

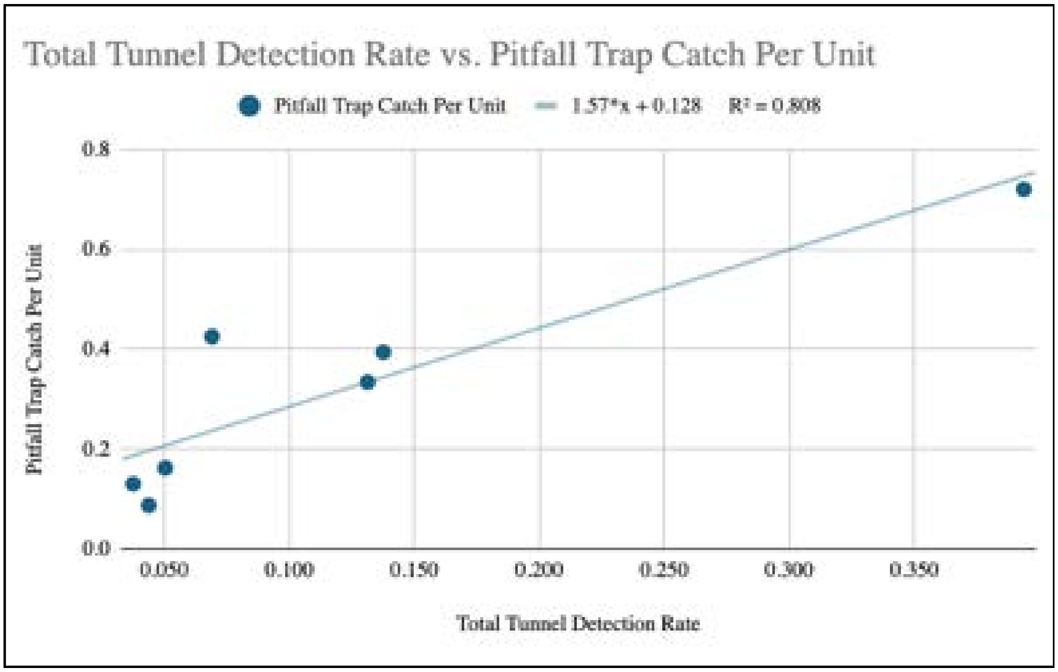

Figure K.2 Total Tunnel Detection Rate vs. Pitfall Trap Catch Per Unit using a polynomial trendline.

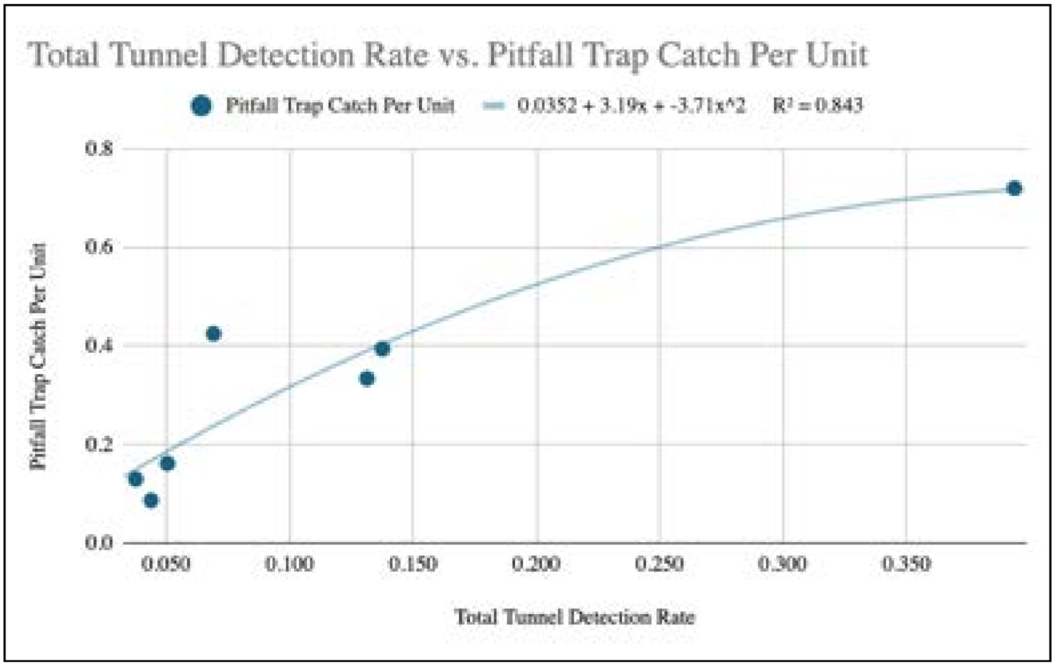

Figure K.3 Total Tunnel Detection Rate vs. Pitfall Trap Catch Per Unit using an exponential trendline.