VICTORIA UNIVERSITY OF WELLINGTON
TE HERENGA WAKA

WPI

Re-Storying the Indigenous Lizards of Te Arawa

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Presented To
Dr. Sara Belcher

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1 Introduction

Aotearoa New Zealand faces significant challenges in monitoring and protecting its native wildlife. Among the 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 environments where introduced predators and human activity threaten their survival. Therefore, 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 disrupted the animals and ecosystems and required researchers to perform frequent checks on the tracking devices (S. Belcher, personal communication, November 13, 2024). This increased the overall burden of cost and effort for skink research. Furthermore, scientists need strategies that they can deploy and share across varied habitats to map skink populations.

Dr. Sara Belcher, a researcher at Victoria University of Wellington, has worked in the field of ecosystem monitoring for 21 years. Her research is focused on the use of tracking tunnels to follow predator populations to evaluate whether pest-elimination methods achieve their goals. Her team has recently innovated the use of minimally invasive tracking tunnels that may improve tracking outcomes for skinks. They plan to adapt these small tunnels that currently monitor pest populations to offer more targeted conservation efforts.

Belcher's work can boost effective and replicable systems for tracking skink populations. Sharing these methodologies offers opportunities to collaborate with community and citizen science programs. A partnering iwi in the Rotorua region sees this program as a chance to integrate skink conservation measures with local education in the context of Māori storylines. The minimally invasive quality of these devices is crucial to the iwi partners, as their spiritual obligation to care for the land (*kaitiakitanga*) prioritizes minimizing disruptions to the ecosystem (Roberts et al., 1995). Furthermore, the incorporation of *mātauranga Māori* into conservation connects this traditional knowledge to modern science, allowing for a bicultural approach to research. Consequently, a careful assessment of these monitoring devices could help engage communities with conservation.

The goal of this project is to investigate non-disruptive methods of skink monitoring alongside scientific and cultural partners in Aotearoa, both at East Harbour Regional Park (Baring Head) and in Rotorua. To achieve this goal, we have identified three objectives: 1. Investigate tracking approaches through testing bait types; 2. To compare detection rates between tracking tunnels and pitfall monitoring; 3. Collect perceptions and *mātauranga Māor*i indicators of skink health. Through completing these objectives, we will deliver our sponsor an effective methodology to monitor and build awareness for ongoing skink population restoration efforts in the Rotorua region.

2 Literature Review

This chapter provides context and detailed background information for our project. It explores the origin and habitat zones of the skinks that we are monitoring, examines existing methods of lizard monitoring in New Zealand, and delves into the ancestral knowledge and cultural significance of lizards in Māori tradition. Finally, it integrates Māori knowledge with Western science.

2.1 Origin Theories and Habitat Zones

Due to its mountainous geography and dynamic climate, the New Zealand archipelago features a wide range of ecosystems. The country is a small section of the subcontinent of Zealandia, a highly seismic and volcanic region of the world. The country's long narrow shape and mountain ranges capture global weather patterns, creating pronounced climate contrasts that vary from lush, high-rainfall zones to dry, semi-arid regions, resulting in a rich biodiversity (Mackintosh, 2001).

Skinks are thought to have first emerged in this landscape around 16-22 million years ago, with several theories supporting how skinks first arrived in New Zealand. One idea is that they were good swimmers and migrated from a different island. Another belief is that Zealandia was not always submerged. This theory is more probable, as it would explain the extensive skink diversity found in the country. (Smith et al., 2007, p. 480). Due to their early presence, the New Zealand Department of Conservation and Herpetological Society recognizes skinks as a native species.

Baring Head and Rotorua—the two sites designated for this study—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, features geothermal activity, volcanic soils, and unique microclimates in an area with immense Māori cultural heritage (see **Figure 1**) (Leathwick & Mitchell, 1992).

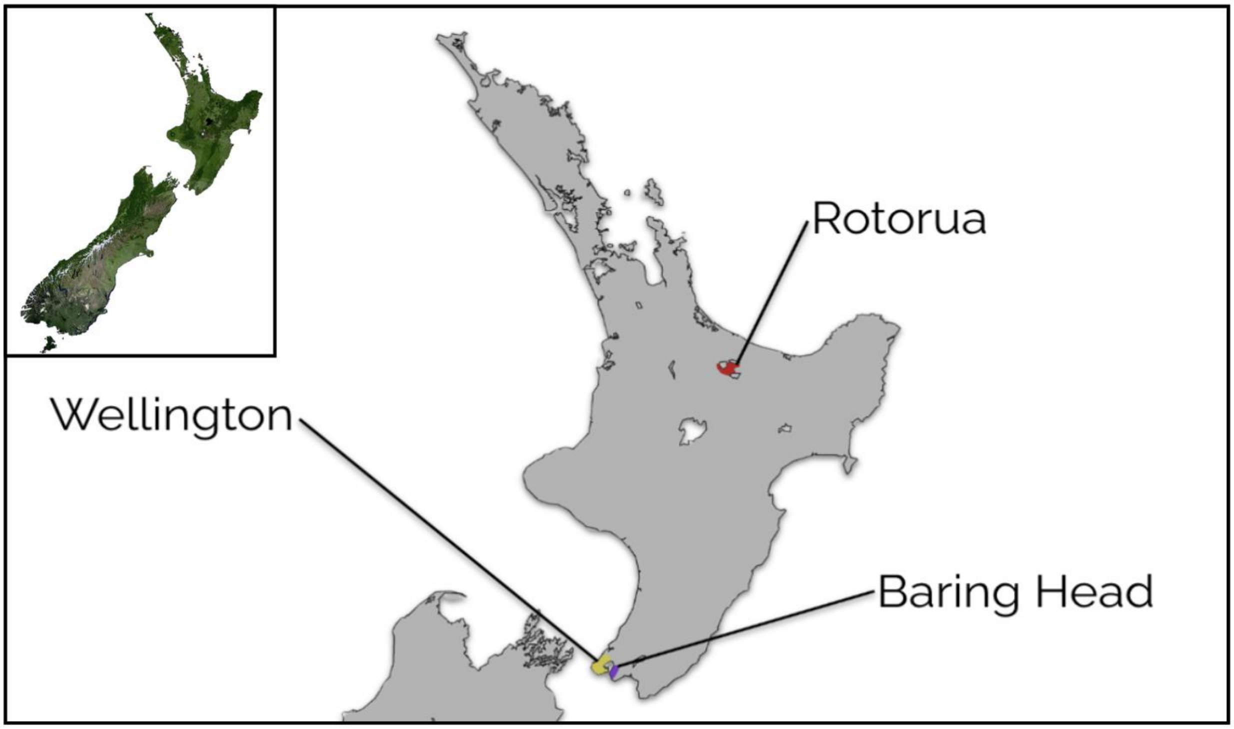

Figure 1 A map showing the locations of Wellington, Baring Head, and Rotorua (New Zealand Maps & Facts, 2024).

Together, these two regions provide valuable insights into New Zealand’s distinct ecological and cultural landscape.

Baring Head

Located on the southern coast of Aotearoa New Zealand’s North Island, facing the Cook Strait and Wellington Harbor, Baring Head is a rich ecological site with habitats across 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 and communities.

The coastal zone, with its dunes and beaches, supports native flora and fauna, especially reptilian species including the common skink (Oligosoma polychroma) and common gecko (Hoplodactylus maculatus), as well as less common reptiles like the spotted skink (Oligosoma lineoocellatum) and copper skink (Oligosoma aeneum). Characterized by steep, vegetated cliffs, the coastal escarpment hosts various native plants such as mingimingi and coastal tree daisies and provides additional habitats for common and copper skinks along with other lizard species.

Adjacent to the coastal escarpment, terraces support resilient native flora and provide nesting sites for bird species. The valley escarpment, with its grey scrub and regenerating forest, creates a rare plant community that is well-adapted to the coastal environment and supports a high population of lizards. The river flats contain critical wetland areas essential for aquatic species and endangered birds (Crisp, 2011).

Rotorua

Rotorua, by contrast, is a city in the north-central portion of the North Island of New Zealand. It lies at the southwestern end of Lake Rotorua, making it part of the northeastern section of the volcanic plateau. This area is known for its geothermal activity, containing 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 region’s soils, generated from the Taupo Pumice eruption around 130 AD, provide fertile ground, supporting a distinctive vegetation pattern across different terrains and soil depths (Leathwick & Mitchell, 1992). The town itself is located on relatively flat terrain that gradually ascends to the south and west. The city is well-connected by roads to major centers such as Auckland and Wellington (Letcher, 2013).

Before 1870, Rotorua was largely unknown by European settlers and remained primarily Māori territory. It was only in 1882 that formal settlement began in what is now the central township. The land around Lake Rotorua was home to descendants of Māori who arrived in New Zealand on the Arawa waka (canoe) around 1350 A.D., establishing a deep-rooted cultural presence that continues to shape the region today (Shelford, 2011). Today, Māori iwi represent a significant portion of the population in the city and its surrounding areas (Letcher, 2013).

Each of these two sites presents its own distinct ecosystem and unique skink habitat, allowing researchers to test and refine skink monitoring methods. By studying population patterns in these contrasting environments, we can shed light on skink behavior, habitat preferences, and adaptive strategies across Aotearoa.

2.2 Lizard Monitoring Methods in New Zealand

There are many surveying and monitoring methods in use for lizards in New Zealand. Local scientists have adapted these strategies from international standards to fit the landscape and speciation of New Zealand (Lettink & Monks, 2016, p. 19). The methods follow either trapping or tracking protocols, with four of the most common trapping approaches featuring visual surveys, pitfall traps, funnel traps, and artificial retreats. Tracking tunnels are a new innovation. Each of these methods is described below in greater detail.

Visual surveys

Visual surveys record skink presence and abundance within a defined region. Researchers observe the area and record any skink sightings. Depending on the requirements of the study, researchers may capture and mark skinks. The species will dictate which time of day to conduct observations as well as the ideal landscape of the survey area. Most visual surveys occur during the initial or peak sun when skinks are often sunning. The “spotlighting” technique uses a spotlight mounted to a pair of binoculars so that observers can see the “eye shine” of any nocturnal skinks (Lettink & Monks, 2016, p. 18). Visual surveys often require significant time and effort, which leads to high costs and increased observer bias, but appropriately implemented surveys can yield highly accurate and applicable data (Sorenson, 2022, p. 85).

Pitfall traps

Pitfall traps are the most common method for capturing skinks due to their simplicity. It 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. 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 of any captured skinks, but they take longer to install and researchers must check them daily. Pitfall traps also have an increased risk of skink mortality in areas with heavy predator presence and can cause habitat disturbance (Lettink & Monks, 2016, p. 22).

Funnel traps

Funnel traps can be made at home or built by modifying fish traps. These traps have a funneled entrance with bait inside. The bait is usually canned fruit or cat food, and this trapping method primarily catches species that hunt aggressively based on scent (Sorenson, 2022, p. 86).

Installing and uninstalling funnel traps is easy, but they require daily maintenance and can be costly (Lettink & Monks, 2016, p. 23).

Artificial retreats

Artificial retreats are a relatively new method for skink tracking in New Zealand. An artificial habitat modeled after the ideal habitat of a given skink species will eventually attract those skinks. There is a significant set-up period to allow skinks to grow accustomed to the habitat and begin to use it. Once in place, artificial retreats are low maintenance and non-disruptive. If left permanently, the habitat may affect skink habits and distribution, which can assist in restoration (Lettink & Monks, 2016 p. 24).

Tracking Tunnels

Tracking tunnels, as an alternative to trapping monitor small mammal pests in New Zealand. A tracking tunnel is a long, covered tunnel with a card placed as the base. The center of the card is treated with weather-resistant ink and typically paired with bait, leaving either end of the card empty. When an animal goes through the tunnel, they walk through the ink to the bait and leave prints on the blank portion of the card (see **Figure 2**).

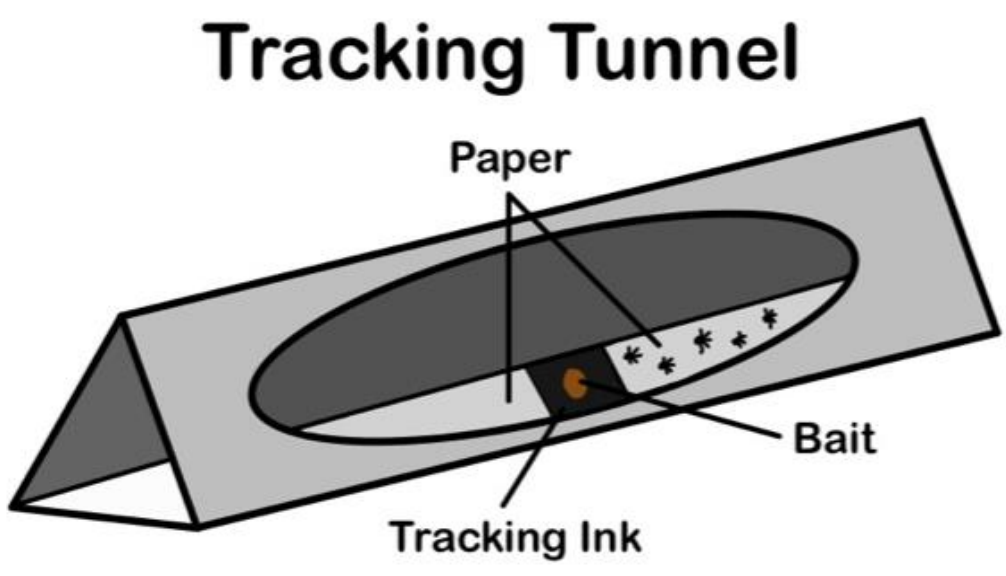

Figure 2 A diagram of a typical tracking tunnel setup.

In the course of mammal studies, researchers observed invertebrate and lizard prints in addition to the expected rodent prints. In response, they tested tracking tunnels for invertebrate monitoring and proved their effectiveness. While testing with lizards, prints were smudged and unclear. Researchers found that skink tracking required a lower viscosity ink and a coarse card texture because the skinks struggled to get traction (Jarvie, & Monks, 2014, p. 211). The initial lizard testing also attempted to identify the species based on the prints. This effort was somewhat effective for geckos, but skink tracks were indistinguishable from one another because their tracks were too similar (Jarvie, & Monks, 2014, p. 213).

A study conducted in 2022 compared the effectiveness of tracking tunnels against pitfall traps for monitoring skink populations. After setting up pitfall traps and tracking tunnels spread across an area of known skink activity, researchers tallied total skink detections from each method over 13 days. The results showed that tracking tunnels detected skinks roughly twice as often as pitfall traps. Due to their design, a tracking tunnel can record a single skink by tracking tunnels multiple times. This means the devices cannot estimate population numbers, but the tracking tunnels can still detect 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 in predator-heavy areas to show the effectiveness of invasive pest eradication methods (Lettink, Young, & Monks, 2022, p. 4).

Compared to other methods of lizard trapping and monitoring, tracking tunnels are less disruptive to habitats than pitfall traps and artificial retreats. Tunnels also require significantly less maintenance than pitfall traps and funnel traps. They are the safest method for skinks and can be the least expensive and labor-intensive. While tracking tunnels can only determine presence/absence, further research can determine the best methods for implementing the tunnels to support monitoring initiatives (Jarvie, & Monks, 2014, p. 215).

2.3 Ancestral Knowledge and the Role of Lizards in Māori Culture

Monitoring species health supports the traditional Māori values and knowledge that underpin a respectful and interwoven approach to monitoring lizard populations in the habitats of Baring Head and Rotorua. *Mātauranga Māori* is a worldview that intertwines environmental, cultural, and spiritual dimensions. It is the foundation for Māori culture, the collective knowledge of the Māori people, and it draws upon these associated perspectives to understand everything that exists in the universe. *Mātauranga Māori* is described as a 'pool of knowledge', as it encompasses the past, present, and future wisdom that Māori communities have gained (Mead, 2022). Māori iwi pass this knowledge through generations, in the form of storylines incorporating *whakapapa* (genealogies), *whakataukī* (sayings), *kōrero* (prose), and *waiata* (songs and chants) (McRae, 2017). Rooted in a deep respect for all life forms, *mātauranga Māori* is the thread that responds to environmental, social, and cultural well-being over time while preserving ancestral values.

Whakapapa (genealogy) 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 the Māori deities *Papatūānuku* (Mother Earth) and *Ranginui* (Sky Father), emphasizing the interconnectedness of all beings and their unique roles within the ecosystem (Roberts, 2013). This concept reinforces the understanding that humans are not separate from nature but are deeply embedded within it, with an obligation to care for all other beings as family. Beyond a record of ancestry, *whakapapa* forms the foundation of Māori identity, instilling a sense of responsibility toward the environment and shapes the basis for *kaitiakitanga* (guardianship), which calls for caring for the natural world with the same respect they show to family members (Roberts et al., 1995). Conservation, therefore, is not merely a practical obligation but a spiritual duty the Māori heritage deeply embeds. By acting as guardians of biodiversity and fostering ecological balance, Māori honor their ancestral commitments, promoting the health and harmony of the environment for future generations (Mahuika, 2019).

Mātauranga Māori of Lizards

The Māori worldview that all animals are interconnected through *whakapapa* (genealogy), 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 (Roberts, 2012). This acknowledgment for lizards underscores the cultural duty of *kaitiakitanga* (guardianship), where protecting lizard populations supports both environmental balance and ancestral connections.

Whakapapa situates lizards within a broad ancestral lineage that connects them to highly respected deities, emphasizing their status as a *taonga* (treasured) species within Māori culture. **Figure 3** illustrates that the genealogy of lizards traces back to *Tangaroa*, the god of the seas and son of *Papatūānuku* (Mother Earth) and *Ranginui* (Sky Father) (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 (Roberts, 2012).

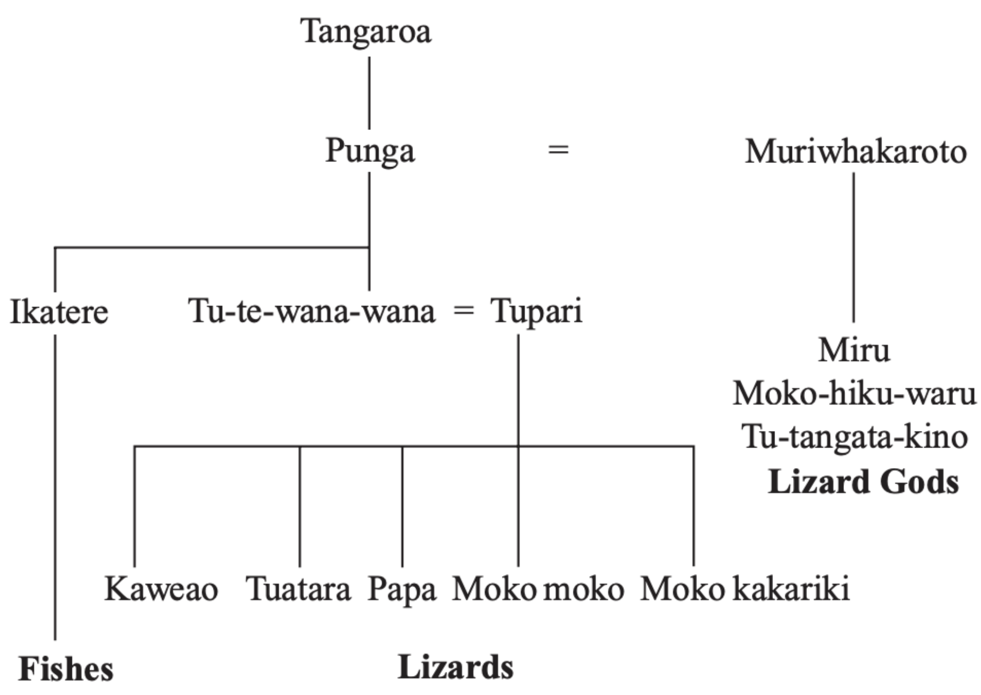

Figure 3 A whakapapa of fish and reptiles (Andersen, 2010).

Māori celebrate lizards, as descendants of *Tu-te-wana-wana*, 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 (Downes, 1937). Caring for lizard populations is more than an ecological responsibility; it is a cultural duty that honors their status as *taonga*, preserving ancestral connections and reinforcing the values embedded in Māori heritage. 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.

2.4 Bicultural Approaches to Conservation: Integrating Māori Knowledge and Western Science

A bicultural approach to conservation, integrating Māori knowledge systems (*mātauranga Māori*) with Western Science, offers a comprehensive framework for addressing Aotearoa's ecological challenges. A method known as Two-Eyed Seeing, developed by Nova Scotian Mi'kmaq Elders, Albert and Murdena Marshall in 2004, 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). Founded in centuries of lived experience and a worldview emphasizing interconnectedness, *mātauranga Māori* complements Western Science by offering unique insights into the relationships among people, animals, plants, and the land (McRae, 2017). This integration fosters conservation practices in New Zealand that are ecologically effective and culturally aligned with Māori values, fulfilling the responsibilities of *kaitiakitanga* (guardianship) and supporting a holistic approach that serves 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 dying native Kauri trees (Lawrence et al., 2019). Kauri trees face a significant threat from kauri dieback, a disease caused by *Phytophthora agathidicida* that infects the roots, disrupts nutrient and water absorption and ultimately kills the tree. This disease has spread rapidly across northern New Zealand, posing a severe threat to the biodiversity and cultural heritage of Māori communities (Lawrence et al., 2019). Kauri trees (*Agathis australis*) are among the largest and longest-living trees in Aotearoa New Zealand. They play an essential role in stabilizing ecosystems and contributing to biodiversity (Hood, 2021). The kauri are *taonga* (treasures), 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. In this study, *mātauranga Māori* practices guided scientists in identifying plant compounds with antimicrobial properties to combat the ongoing kauri dieback epidemic (Lawrence et al., 2019). The 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 three novel flavonoids in kānuka that demonstrated promising antimicrobial activity, inhibiting spore germination and disrupting 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. This case study illustrates the power of bicultural collaboration in conservation science. The partnership not only accelerated scientific discovery but also delineated the importance of protecting native species as both practical and spiritual resources for Māori communities. By integrating Māori perspectives, the research achieved outcomes that support biodiversity conservation while respecting and preserving 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 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.

New Zealand'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 and hapū 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

The literature review revealed several points that will inform our project. First, the contextual and climatic disparities between Rotorua and Baring Head may present some challenges for our study but also offer an opportunity to compare the efficacy of the tracking tunnels. These variations could attract different skink species and alter their behavior in unpredictable ways, making it harder to refine a single tracking method. We will need to verify that the same methods work effectively in both locations. Second, the methodologies used for tracking rodent populations benefit from testing to align with the findings from Jarvie and Monks’ 2014 study. This study shows native skink populations prefer rougher tracking cards and lower-viscosity ink. Implementing these changes will require specialized resources to align the tracking methods with the most up-to-date practices. Finally, Māori knowledge systems can support effective ecosystem management. Lived experience is linked to the land and provides insights that can augment the scope of data for lasting impacts.

3 Methodology

The goal of our project is to investigate non-disruptive methods of skink monitoring alongside scientific and cultural partners in Aotearoa. This chapter discusses the methods we will use to meet our objectives. The three project objectives are:

1. Investigate tracking approaches through testing bait types
2. Compare tracking tunnel and pitfall trap data.
3. Collect perceptions and *mātauranga Māori* of skinks.

Our team aims to complete each objective with corresponding methodologies relating to our overall purpose of uncovering non-disruptive skink monitoring methods as shown in **Figure 4**.

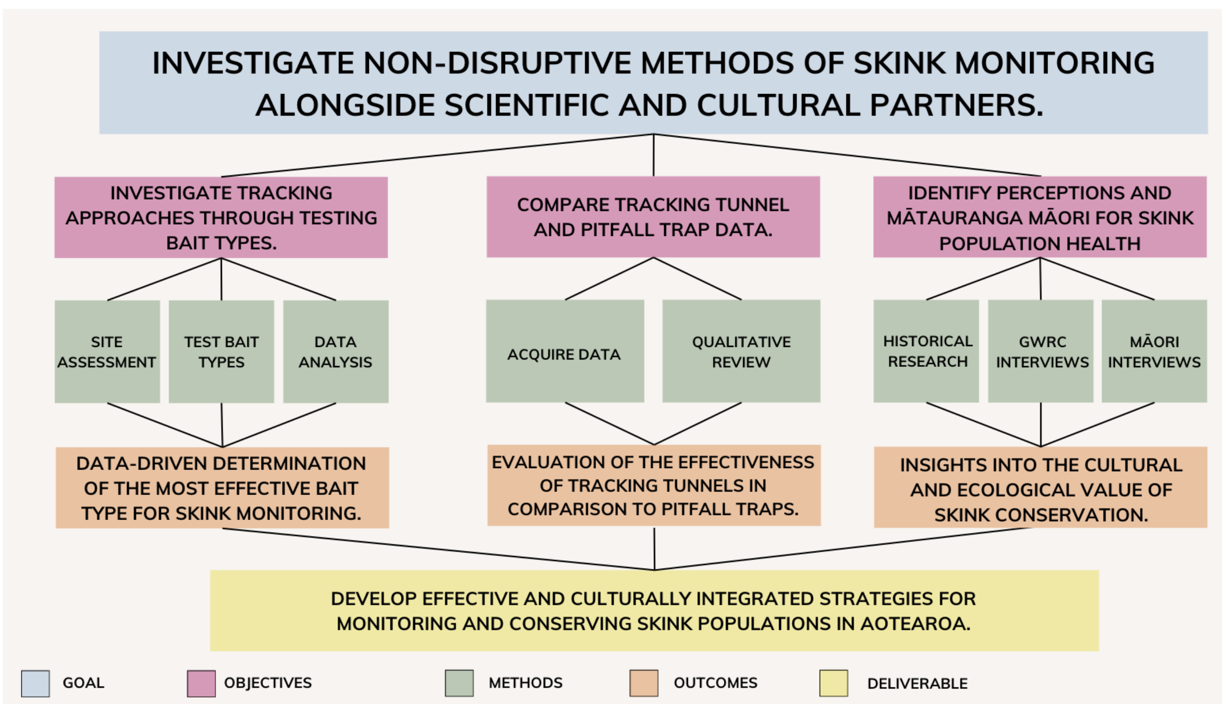

Figure 4 A flow diagram depicting proposed methods and their expected outcomes.

3.1 Objective 1:

Investigating Tracking Approaches Through Testing Bait Types

The project team, alongside Dr. Belcher, will execute a site assessment in East Harbour Regional Park (Baring Head), to gather detailed information about the locations of the tunnel lines and their surrounding habitats. This will involve locating the eight existing tunnel lines and identifying key environmental conditions within Baring Head. We will document items such as sunlight exposure for basking, the presence of native vegetation and rocks for shelter, proximity to roads or grazing areas, and other features that might limit skink presence. Understanding how long the tunnels have been in place will also be important, as skinks may associate older tunnels with bait, potentially influencing their natural behavior (Herbert et al., 2013). Testing will take place in three of the tracking lines, as they are in areas with known skink populations (S. Belcher, personal communication, November 13, 2024). Each tunnel in these three lines will be documented with photos and will also have a specific identification number assigned to it based on which line (A-C) they came from and which tunnel (1-10) they were in. To ensure safety during the assessment, we will avoid hazardous areas such as cliffs, in consultation with our sponsor.

To allow for comparison of these two baits, we will conduct three trials: one for each of the baits, and one control trial without bait. Each trial will take place over two consecutive fair-weather days. On the first day of each trial, our team will place a tracking card in each tunnel with fresh tracking ink in the center. Depending on the trial, we will add bait to the center of the inked card as well. We will repeat this process with the same bait parameter at each tunnel in the line of all three lines of interest. These tunnels will collect data for 24 hours. The next day, the team will remove the bait and ink cards and collect the tracking cards. Our group will examine the cards for skink footprints. We will enter a binary yes/no into a spreadsheet for the presence of skinks to allow for future data analysis.

We will use several data analysis methods when examining the results of the tracking tunnel bait trials. The first is calculating the mean percent tracking rate with **Equation 1**.

$$\frac{Tunnels\ with\ Positive\ Detection}{Total\ Tunnels} \times 100 = Mean\ tracking\ rate$$

Equation 1 The mean tracking rate equation.

Repeating this for each trial will allow for a direct comparison of the percentages. Additionally, a chi-squared test will help determine the significance that bait has on the presence of skinks in tracking tunnels. This test uses **Equation 2**, with O being the tunnels with evidence of skinks during a bait trial, E being the tunnels with evidence of skinks during the control trial, and x^2 being the chi-squared value.

$$x^2 = \Sigma \frac{(O-E)^2}{E}$$

Equation 2 The Chi-Squared Formula

We will then compare the chi-squared test value to a distribution table to determine the p-value, a numerical value used to show the correlation between observed and expected outcomes. This will indicate whether that bait type has a significant impact on skink attraction, allowing us to determine the bait's effectiveness.

3.2 Objective 2: Comparing Tracking Tunnel and Pitfall Trap Data

The nature of the seven-week program will limit substantial experimentation to compare tracking tunnels against existing practices. Therefore, we will obtain records of previous tracking efforts conducted by the Greater Wellington Regional Council. According to Dr. Belcher, the GWRC conducts pitfall trapping every three years and tracking tunnel monitoring four times per year. These data will contain the total sum of lizards observed for each site, along with descriptions and measurements of the conditions of each trap. Using these resources, along with any data we collect, we will establish the suitability of tracking tunnels as a formal lizard monitoring method.

We will evaluate the tracking tunnel's ability to detect presence/absence, not its ability to create population models. Using the data from the pitfall traps, we can create a heatmap of the approximate distribution of lizards at each site. We will then map the lizard presence based on the tracking tunnel data. If the site location and conditions match the pitfall data, we can directly compare the two data maps we create. The precise strategies of our data analysis will depend on the reports we currently do not have access to, so the proposed schedule provides us time to craft an appropriate procedure.

We will also develop a qualitative review of tracking tunnels and pitfall traps. We plan to work with Dr. Belcher to learn more about her specialty of tracking tunnels. With access to GWRC reports, we will assess the benefits and drawbacks of tracking tunnels in multiple categories. Based on the comments and conclusions drawn by the researchers, we will use each study to gauge the monitoring method. Our analysis will focus on six categories: Cost, Labor Intensity, Longevity and Repeatability, Habitat Disturbance, Potential Bias/Error, and Confidence. A summary of these evaluations will reflect the reliability of tracking tunnels for widespread use.

3.3 Objective 3: Identify Perceptions and *Mātauranga Māori* for Skink Population Health

The project team proposes three methods for identifying *mātauranga Māor*i skink population health. We will first conduct research to uncover historical texts not easily accessed remotely. Digital research will bridge gaps in our understanding.

We will conduct interviews with iwi members, cultural historians or archivists, and scientists at GWRC. To understand perspectives in Rotorua, we will visit the iwi for several days to learn local insight into mātauranga Māori that features skinks. We will conduct in-depth interviews with individuals with expert knowledge of mātauranga Māori. The purpose of these interviews is to provide our team with appropriate cultural awareness. We will also interview researchers at GWRC about their knowledge of skink storylines to highlight the views of the scientific community. The interviews will inform a bicultural approach, unite the GWRC research and Māori culture to integrate skinks' environmental and personal importance into proposed tracking methods. Appendices B and C include an overview of potential interview questions.

3.4 Proposed Timeline

Our proposed timeline (shown in **Figure 5**) involves getting the majority of our data collection in Baring Head completed by the end of week six, with members of the team planning to travel to the Iwi in Rotorua during weeks two and six. This, coupled with data analysis, interviews, and archival research, will provide us with the necessary time and understanding to create our final deliverable of an effective methodology for monitoring skink restoration efforts and our final paper.

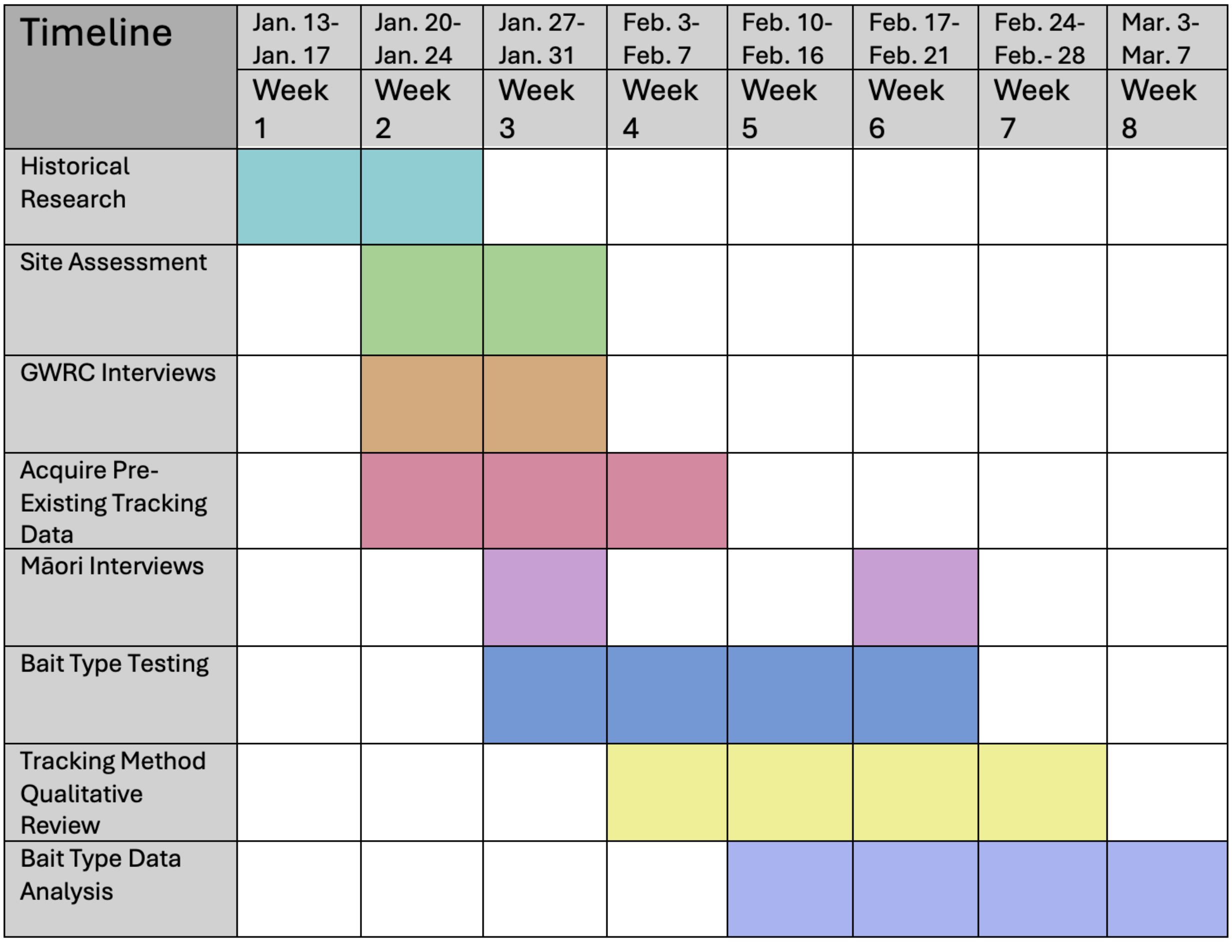

Figure 5 A Gantt chart illustrating the proposed timeline for each methodology.

4 Conclusion

This proposal addresses a clear need to monitor restoration efforts for skinks in Aotearoa. Our focus is to craft a process that is effective and comprehensive, in the hopes that monitoring agencies and researchers can better monitor skink activity for the preservation of native biodiversity. Furthermore, this project aligns with the United Nations Sustainable Development Goal (SDG) 15 of supporting "Life on Land" (UN DESA, 2024).

Figure 6 Goal 15 Logo: Life on Land (UN DESA, 2024).

This proposal introduces an approach that includes the Māori genealogy framework, connecting nature and human activity, and emphasizing the value of skinks in Aotearoa. We will form our conclusions based on data we collect in our experimentation, as well as the comparison of pitfall traps and tracking tunnels. Interviews in Rotorua and with the GWRC throughout the term serve as educational opportunities to provide our team with context to the social value of Maori culture. The combination of data-driven conclusions and an understanding of the cultural background will improve our team's ability to deliver actionable, culturally informed, and evidence-based recommendations to the local iwi of Rotorua. We look forward to working with you and we will present our proposal for discussion upon arrival.

Bibliography

Andersen, J. (2010). *Māori Life in Ao-Tea* (1st ed.). Ams Pr Inc. https://www.abebooks.com/9780404144005/Māori -Life-Ao-Tea-Andersen-Johannes-0404144004/plp

Baring Head Atmospheric Research Station, NIWA. (2022). Retrieved November 16, 2024, fromhttps://niwa.co.nz/atmosphere/baring-head-atmospheric-research-station

Baring Head/Ōrua-pouanui Historic Area. (2023). Heritage New Zealand Pouhere Taonga. https://www.heritage.org.nz/list-details/9621/Baring-Head-%C5%8Crua-pouanui-Historic-Area

Bartlett, C., Marshall, M., & Marshall, A. (2012). Two-Eyed Seeing and other lessons learned within a co-learning journey of bringing together indigenous and mainstream knowledges and ways of knowing. *Journal of Environmental Studies and Sciences*, *2*(4), 331–340. https://doi.org/10.1007/s13412-012-0086-8

Bradshaw, R. E., Bellgard, S. E., Black, A., Burns, B. R., Gerth, M. L., McDougal, R. L., Scott, P. M., Waipara, N. W., Weir, B. S., Williams, N. M., Winkworth, R. C., Ashcroft, T., Bradley, E. L., Dijkwel, P. P., Guo, Y., Lacey, R. F., Mesarich, C. H., Panda, P., & Horner, I. J. (2020). Phytophthora agathidicida: Research progress, cultural perspectives and knowledge gaps in the control and management of kauri dieback in New Zealand. *Plant Pathology*, *69*(1), 3–16. https://doi.org/10.1111/ppa.13104

Crisp, P. (2011). Baring Head ecological values. Greater Wellington. https://www.gw.govt.nz/assets/Documents/2022/03/Baring-Head-Ecological-Values-Report.pdf

Downes, T. W. (1937). Māori Mentality Regarding the Lizard and Taniwha in the Whanganui River Area. *The Journal of the Polynesian Society*, *46*(4(184)), 206–224.

Duncan, R., & Robson-Williams, M. (2024). Co-designing a research programme for impact: Lessons learned from practice by Aotearoa New Zealand's Biological Heritage National Science Challenge Ngā Koiora Tuku Iho. *Kōtuitui*, *19*(2), 164–189. https://doi.org/10.1080/1177083X.2023.2227675

Hood, I. (2021). Kauri dieback. *Plant Pathology*, *70*(4), 764–766. https://doi.org/10.1111/ppa.13356

Jarvie, S., & Monks, J. (2014). Step on it: Can footprints from tracking tunnels be used to identify lizard species? *New Zealand Journal of Zoology*, 41(3), 210–217. https://doi.org/10.1080/03014223.2014.911753

Kaiser, L. H., & Saunders, W. S. A. (2021). Vision mātauranga research directions: Opportunities for iwi and hapū management plans. *Kōtuitui*, *16*(2), 371–383. https://doi.org/10.1080/1177083X.2021.1884099

Lawrence, S. A., Burgess, E. J., Pairama, C., Black, A., Patrick, W. M., Mitchell, I., Perry, N. B., & Gerth, M. L. (2019). mātauranga-guided screening of New Zealand native plants reveals flavonoids from kānuka (Kunzea robusta) with anti-Phytophthora activity. *Journal of the Royal Society of New Zealand*, *49*(sup1), 137–154. https://doi.org/10.1080/03036758.2019.1648303

Leathwick, J. R., & Mitchell, N. D. (1992). Forest Pattern, Climate and Vulcanism in Central North Island, *New Zealand Journal of Vegetation Science*, 3(5), 603–616. https://doi.org/10.2307/3235827

Letcher, K. (2013, February 8). Rotorua. Britannica. https://school.eb.com/levels/high/article/Rotorua/64198

Lettink, M., & Monks, J. (2016). Survey and monitoring methods for New Zealand lizards. *Journal of the Royal Society of New Zealand*, 46(1), 16–28. https://doi.org/10.1080/03036758.2015.1108343

Lettink, M., Young, J., & Monks, J. M. (2022). Comparison of footprint tracking and pitfall trapping for detecting skinks. *New Zealand Journal of Ecology*, 46(2), 1-5. https://doi.org/10.20417/nzjecol.46.24

Mackintosh, L. (2001). Overview of New Zealand's climate, NIWA. MIWA, Taihoro Nukurangi. https://niwa.co.nz/climate-and-weather/overview-new-zealands-climate

McLintock, A. H., Susan Bailey, B. A., & Taonga, N. Z. M. for C. and H. T. M. (1966). ROTORUA [Web page]. An Encyclopaedia of New Zealand, Edited by A. H. McLintock, 1966.; Ministry for Culture and Heritage Te Manatu Taonga. https://teara.govt.nz/en/1966/rotorua

McRae, J. (2017). *Māori oral tradition: He kōrero nō te ao tawhito / Jane McRae.* Auckland, New Zealand : Auckland University Press, 2017. https://natlib.govt.nz/records/38185126

Mead, H. M. (2022, June 18). Understanding mātauranga Māori. *E-Tangata*. https://e-tangata.co.nz/comment-and-analysis/understanding-mātauranga-Māori /

MetService, New Zealand Climate. (n.d.). Retrieved November 15, 2024, from https://about.metservice.com/our-company/learning-centre/new-zealand-climate/

New Zealand Maps & Facts. (2024, January 8). WorldAtlas. https://www.worldatlas.com/maps/new-zealand

Roberts, M. (2012). Genealogy of the sacred: Māori beliefs concerning lizards. In D. Hooke, G. Pungetti, & G. Oviedo (Eds.), Sacred Species and Sites: Advances in Biocultural Conservation (pp. 249–264). Cambridge University Press. https://doi.org/10.1017/CBO9781139030717.025

Roberts, M., Norman, W., Minhinnick, N., Wihongi, D., & Kirkwood, C. (1995). Kaitiakitanga: Māori perspectives on conservation. *Pacific Conservation Biology*, *2*(1), 7–20. https://doi.org/10.1071/PC950007

Roberts, M. (2013). *WAYS OF SEEING: WHAKAPAPA | Sites: A Journal of Social Anthropology and Cultural Studies*. *10*, 93–120.

Smith, S. A., Sadlier, R. A., Bauer, A. M., Austin, C. C., & Jackman, T. (2007). Molecular phylogeny of the scincid lizards of New Caledonia and adjacent areas: Evidence for a single origin of the endemic skinks of Tasmantis. *Molecular Phylogenetics and Evolution*, *43*(3), 1151–1166. https://doi.org/10.1016/j.ympev.2007.02.007

Sorensen, T. (2022). Species Interactions Between the Plague Skink, Indigenous Skinks, and Invasive Mammals [Thesis, ResearchSpace@Auckland]. https://researchspace.auckland.ac.nz/handle/2292/60997

United Nations Department of Economic and Social Affairs. (2024). The Sustainable Development Goals Report 2024. https://doi.org/10.18356/9789213589755

Windchief, S., & Cummins, J. (2022). Considering Indigenous Research Methodologies: Bicultural Accountability and the Protection of Community Held Knowledge. *Qualitative Inquiry*, *28*(2), 151–163. https://doi.org/10.1177/10778004211021803

Wright, A. L., Gabel, C., Ballantyne, M., Jack, S. M., & Wahoush, O. (2019). Using Two-Eyed Seeing in Research with Indigenous People: An Integrative Review. *International Journal of Qualitative Methods*, 1609406919869695. https://doi.org/10.1177/1609406919869695

Appendix A - Consent Form

The following is a consent form that the team will use to preface each interview. The interviews are outlined in appendices B and C.The team will uphold the individual wishes of each interviewee based on their consent form responses.

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.

Sign: Print: Date:

Appendix B: Interview Questions for the GWRC

The following are sample interview questions for members of the Greater Wellington Regional Council (GWRC), scientific experts, and historians. Information on interviewee consent is found in Appendix A. Before beginning each interview, the team will first introduce themselves and give a brief overview of the project.

1. What is your name?
2. What is your role at the Greater Wellington Regional Council?
3. Do you have any experience with skink monitoring?
4. When did you begin working in this area of focus?
5. What is your perception of the current state of the native skinks in the region?
6. Have you integrated the bioheritage science challenge into any of your skink monitoring practices?
7. Have you thought of incorporating Mātauranga Māori into conservation?
8. Do you have any specific experiences with tracking tunnels as a monitoring method?
    a. Follow up questions:
        i. What were you hoping to learn by using tracking tunnels?
        ii. What unexpected discoveries or interesting patterns have you experienced?

Appendix C: Interview Questions for the Rotorua Iwi

The following are sample interview questions for members of the Rotorua Iwi. Information on interviewee consent is found in Appendix A. Before beginning interviews, the team will first introduce themselves and give a brief overview of the project, as well as express that our goal for the interview is to gain insight into Mātauranga Māori of skinks.

1. What is your name?
2. What is your role within your iwi?
3. From your perspective, what would support the health and well-being of the skinks in the area?
4. In what ways could mātauranga Māori enhance general awareness of skink monitoring?
5. Could you share some stories, legends, or whakapapa that connect your family or friends to skinks and lizards?
6. How are these narratives passed down through generations and what wisdom do they hold?
7. How have lizards and skinks been part of your lived experience?
8. What is the cultural significance of skinks to you?
9. What deeper meanings or connections do lizards represent?
10. What is the general sentiment within your community towards skinks and what lessons can they offer?