EXPLORING VALUE SYSTEMS:

MĀORI PERSPECTIVES IN SCHOLARLY LITERATURE ON MICE-INVERTEBRATE INTERACTIONS IN AOTEAROA NEW ZEALAND

By:

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Exploring Value Systems: Māori Perspectives in Scholarly Literature on Mice-Invertebrate Interactions in Aotearoa New Zealand

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by
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ABSTRACT

Introduced species present a threat to the native wildlife of Aotearoa New Zealand which evolved primarily in the absence of mammals. In a review of 57 articles, we explored the role of *mātauranga* (Māori Traditional Knowledge) in introduced mouse management. We found *mātauranga* was misrepresented in ecological literature, and often used to contextualize research methodologies, rather than to inform them. We used the Ecological State Assessment Tool to support inclusion of Māori-informed methods in introduced mouse management.

ACKNOWLEDGEMENTS

We would like to thank our sponsor, Dr. Sara Belcher, for all her guidance throughout this project and her patience as our team learned about a knowledge system that was completely new to us. We also want to express our appreciation to Dr. Belcher for showing our team around the Greater Wellington region and for sharing her humor and music with us along the way.

We would like to thank Alan King-Hunt, our sponsor's research assistant, not only for his exuberant help throughout our project and for being one of our key informants, but also for extending his friendship, guidance, and love of cricket to our team.

We would like to acknowledge our advisors, Professors Ken Stafford and Leslie Dodson, for their support and guidance throughout PQP and the IQP.

Finally, we are grateful for our key informants Piata Hohaia, Janel Hull, and Rawiri Smith, for their contributions to this project and to our understanding of *mātauranga*.

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MEET THE TEAM

RONIT AVADHUTA

Kia ora, my name is **Ronit Avadhuta**, and I am from Shrewsbury, Massachusetts. I am an undergraduate junior pursuing a Mathematical Sciences major. At WPI, I am President of the national Pre-Health Honors Society AEΔ, and I also work in the ER part-time. Last Summer, I worked in a heart failure research lab at MaineHealth, where we worked with human STEM cells and lab mice. I enjoyed my time working with mice, and wanted to explore the practical management of mice in New Zealand. I also entered this IQP with an appreciation of different languages and cultures – involved in Japanese and Italian clubs – but I had never gotten the chance before to fly across the world to learn about and incorporate Māori Traditional Knowledge as part of a national eradication project. From this IQP, I learned conservation is much more than "do no harm." I feel a renewed sense of motivation in taking care of the planet rather than a hands-off attitude.

LAURA ROMANIA

Kia ora, my name is **Laura Romania** and I'm a third year student pursuing a dual degree in Environmental Engineering and Environmental & Sustainability Studies. At WPI, I am involved with Club Water Polo and Green Team, particularly the Community Garden committee. Much of my enthusiasm for environmental work is rooted in an upbringing of hiking, kayaking, and camping in upstate New York. I am particularly interested in the areas of ecological restoration, climate resiliency, green development, as well as the means of achieving environmental justice. I was previously familiar with concepts of Indigenous Traditional Ecological Knowledge, and was genuinely excited by the prospect of learning about Māori culture for our project. My experience on this IQP has further opened my eyes to the idea that humans and nature should take care of one another. I genuinely believe that this lesson of reciprocity will stick with me throughout the remainder of my academic and professional pursuits.

MATT SALUZZI

Kia ora, my name is **Matt Saluzzi**, and I am from Chatham, New Jersey. I am a junior pursuing a Bachelor's in Mechanical Engineering. On campus, I am part of Arnold Air Society, a community service organization, and i5 Space, a space education association where I held the role of squadron commander for a year. I entered this IQP looking to expand my knowledge around environmental conservation and truly immerse myself in nature, gaining a deeper understanding of ways I can help the ecosystem. When starting this project, I was excited about having the opportunity to collaborate with individuals across Aotearoa and gain a deeper understanding of Māori Traditional Knowledge, a subject which I was previously unfamiliar with. After conducting this IQP, I have been able to learn more about how humans and nature are intertwined. With this newfound knowledge, I still intend to continue pursuing my hobbies including space, but also refocus on ways I can help within Earth's atmosphere.

DREMA UTTECHT

Kia ora, my name is **Drema Uttecht** and I'm from Chelmsford, Massachusetts. I'm a third year undergraduate student pursuing a Bachelor's and Master's degree in Biomedical Engineering. At WPI, I am a peer tutor for the Academic Resource Center and Public Relations Officer for the Science Fiction Society. I enjoy playing board games, crocheting, and hiking in my free time. Coming into this IQP, I was really excited to be doing an environmental project with hands-on field work. I was unsure of the Māori Traditional Knowledge component as I haven't encountered indigenous knowledge systems before, but was excited to delve into this unique area of research. After completing this project, I realize I had lost touch with nature during the past few years, but being in Aotearoa has rejuvenated my love of nature. Learning about the Māori culture and their intimate connection with the Earth, though, has truly deepened my appreciation for all that nature gives to us, and how we can best reciprocate these gifts.

EXECUTIVE SUMMARY

MĀORI PERSPECTIVES ON INTRODUCED SPECIES IN AOTEAROA

Introduced species present a threat to the health of native wildlife in Aotearoa New Zealand, where a unique ecosystem evolved primarily in the absence of mammals (*About Predator Free 2050*, n.d.). The management of introduced species is of special concern in Aotearoa, and the Predator Free 2050 initiative (PF2050) was established in 2016 with the goal of protecting native species and increasing biodiversity through the removal of rats, possums, and mustelids (*About Predator Free 2050*, n.d.). The PF2050 initiative excludes the eradication of mice as they are difficult to target. Thus, it is important to consider the implications of not managing the mouse population and its consequences for vulnerable native species.

The implications of harmful non-native species may be considered through cultural and scientific lenses, including the perspective of the indigenous people of Aotearoa: the Māori. Input from Māori peoples can offer insight into the protection of biodiversity which differs from Western science. Their Traditional Knowledge system, or *mātauranga*, is based on generational observations and emphasizes a relationship to ancestors, future generations, and the natural world (Figure 1) (Mahuta, 2019; McAllister et al., 2023). Our project aimed to highlight the value of considering Māori perspectives in the research literature of invasive mammalian predators, and the development of tools to eradicate or manage predator populations.

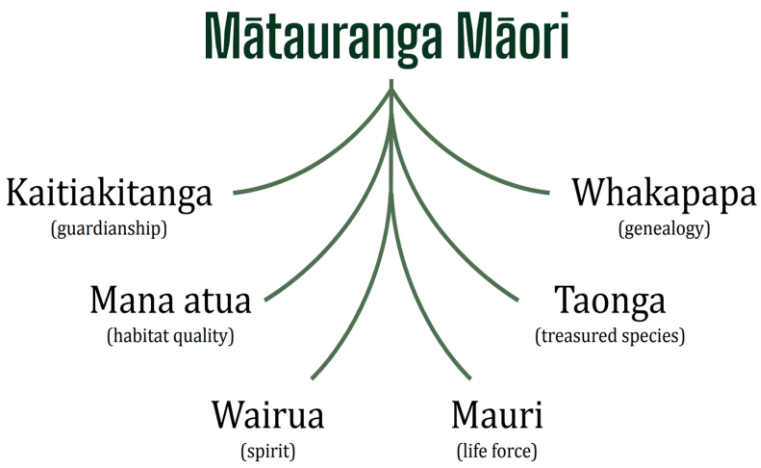

Figure 1. Tree of concepts in mātauranga Māori, central to the theme of our project (Belcher et al., 2021).

LITERATURE ANALYSIS, INTERVIEWS, AND THE ECOLOGICAL STATE ASSESSMENT TOOL

We conducted a literature analysis of 57 scholarly and expert literature using NVivo, a qualitative data analysis tool, to identify how, or whether, *mātauranga* (Māori Traditional Knowledge) is incorporated into ecological literature. We looked at literature discussing *mātauranga* in introduced species management and the effects of mice on the ecosystem in Aotearoa, particularly differences between discussion-style articles (editorials, forums, and reviews) and peer-reviewed research articles. Gathering evidence of research gaps in Māori values and mouse behavior can help inform future Predator Free 2050 actions.

We spoke with four key informants to explore the role of *mātauranga* Māori in environmental management and of mice impacts on conservation: Alan King-Hunt, a Researcher at the School of Māori Studies at Victoria University of Wellington; Piata Hohaia, a Ranger at Zealandia *Te Māra A Tāne* and member of the Ngāti Toa Rangatira *iwi* (tribe); Janel Hull, a Senior Communications Advisor for the Department of Conservation (DOC); and Rawiri Smith, an Environment Manager for Kahungunu *ki* Wairarapa (the Wairarapa *hapu* (sub-tribe) within the Kahungunu *iwi*).

We conducted a short field study in Wrights Hill Reserve, a public park in Karori, to understand the practical application of Māori values in the field. Our team collected rodent and invertebrate activity data using chew cards and leaf litter sampling. Our small set of field data was analyzed using the Ecological State Assessment Tool (ESAT) model, developed by our sponsor Dr. Sara Belcher, a Senior Lecturer in the School of Science in Society at Victoria University of Wellington. The ESAT takes in quantitative population data and qualitative social data, weights them by a variety of Māori values, and outputs a resource management model (Belcher et al., 2021).

FINDINGS

FINDING 1: MĀORI PERSPECTIVES AND VALUES ARE OFTEN MISREPRESENTED IN ECOLOGICAL SCHOLARLY LITERATURE

We found that Māori perspectives and values are often misrepresented in ecological literature. Out of the 57 articles coded in NVivo, 31 discussed **Māori science** concepts either explicitly, defined as the use of ***kaitiakitanga***, ***mana atua***, ***mauri***, ***taonga***, ***wairua***, or ***whakapapa*** in the text, or implicitly, defined as the use of key words or phrases related to a Māori value without use of the term. Of a total of 265 references to **Māori science**, 64% were implicit references. Each mention was then categorized as meaningful, defined as the definition or discussion of a Māori concept being crucial to the meaning of the sentence, or non-meaningful, defined as mention of a Māori value without discussion of the concept and its significance. Of the total mentions of Māori science, 31% were non-meaningful.

Mentions of **Māori science** in discussion-style articles, which includes editorial, forum, and review articles, were relatively evenly split between implicit and explicit, whereas only 9% of mentions of **Māori science** in research articles were explicit. Of meaningful mentions of **Māori science**, 69% came from discussion-style articles and 31% from research articles. This not only highlights the lack of explicit use of Māori values in research, but also a lack of meaningful mentions in scholarly and expert articles. Mentions of Māori values may provide context to research instead of informing research methods, as the majority of **Māori science** references were found in the introduction and discussion of research articles. Furthermore, key informants suggested that Māori values are seldom actualized in invasive species management.

FINDING 2: FIELD INTERVENTIONS COULD BENEFIT FROM A MULTI-CONTEXTUAL APPROACH THAT INCLUDES MĀORI-INFORMED METHODS

We found that current field interventions could benefit from a multi-contextual approach that includes Māori-informed methods. We defined a multi-contextual approach as an overlap between Māori values and multi-method approaches. Multi-method approaches in the context of this literature analysis mean instances where multiple techniques were used, for example baiting and trapping as opposed to only baiting. Multi-method approaches were underrepresented as current interventions in literature, with only 15% of the 207 mentions of **current interventions**

mentioning a **multi-method approach**. In contrast, **baiting** and **trapping** accounted for 73% of mentions, which may imply that there is room for including Māori-informed methods in invasive predator management in Aotearoa. Our key-informant conversations highlighted the potential for this gap to be filled with Māori-informed invasive predator management techniques.

FINDING 3: INCREASED MĀORI ACCEPTANCE AND ENGAGEMENT IN CURRENT PREDATOR ERADICATION TECHNIQUES CAN HELP ACHIEVE MANAGEMENT TARGETS

Modeling the involvement of Māori people in resource management via the Ecological State Assessment Tool (ESAT), we found that Māori acceptance and engagement in current predator eradication techniques can help achieve management targets, as represented by higher Ecological Health (EH). Acceptance is whether a Māori individual or *iwi* would approve of a predator intervention while engagement is whether they themselves would participate in it (Belcher et al., 2021). *Iwi* capacity is how much the *iwi* can put towards conservation efforts (Belcher et al., 2021). After inputting our small set of field data, we manipulated three variables: Māori Cultural Acceptance of current predator eradication techniques, Māori Cultural Engagement in current predator eradication techniques, and Māori Perceived Risk of Mice. Throughout this process, we kept *iwi* Capacity, or the capabilities of *iwi*, constant at 100%. When Māori Cultural Acceptance, Cultural Engagement, and Perceived Risk of Mice were set to 0%, the model did not meet PF2050 management targets.

While increasing any one of these three factors alone did increase the EH, we found that together, when Cultural Acceptance, Cultural Engagement, and Perceived Risk of Mice were all increased to 100%, the model improved and surpassed the PF2050 management target (Figure 2). This indicates that the presence of *iwi* alone is not enough to fulfill the Predator Free 2050 management target – Māori acceptance and engagement in predator eradication may be necessary to reach this goal.

Figure 2. The Ecological Index (EI) outcome when Māori acceptance, engagement, and the perceived risk of mice are high. The red trendline exceeds Predator Free 2050 goals (Credit: Dr. Sara Belcher).

FINDING 4: AREAS FOR FURTHER RESEARCH IN INVASIVE MICE BEHAVIOR

We identified topics to better understand the impacts of mice as an invasive species in Aotearoa using information collected from our literature analysis and key informant interviews. Notably, this included mouse predation on birds and reptiles, as well as the role of nitrogen fixation and climate change on eruptions of mice populations. These subjects, if further researched, could contribute towards the inclusion of mice in Predator Free 2050 eradication efforts.

RECOMMENDATIONS

Although our literature analysis provided valuable insights, we recommend conducting an improved literature analysis. This may include cultivating a more robust set of coding criteria for Māori *ariā* (concepts) considering multiple perspectives, gathering a more extensive set of literature regarding broader topics of predator eradication in Aotearoa, and using a shared collection of coding categories across multiple NVivo projects.

Our literature analysis and key informant interviews were primarily focused on Māori perspectives regarding mice preying on invertebrates in New Zealand. Some important topics arose between our **areas for further research codebook** and informant conversations which were outside the scope of our project but could benefit from further investigation. Examples of these topics included: how collaboration between Māori *iwi* (tribe) and protected conservation areas might limit available resources for invasive mammals, or how recognizing *mana atua* (structural diversity) of the ecosystem could inform solutions incorporating existing predator-prey relationships. These topics may be considered through a longer-term monitoring study, observing the effects of mice on native biota, and investigated using the Ecological State Assessment Tool (ESAT).

CONCLUSION

Our recommendations have presented research topics for future exploration regarding mouse eradication strategies which prioritize Māori views and understanding the role of mice on native biota in Aotearoa. Focusing on the larger mission statement of PF2050, Traditional Knowledge could work with Western practices, to help inform them.

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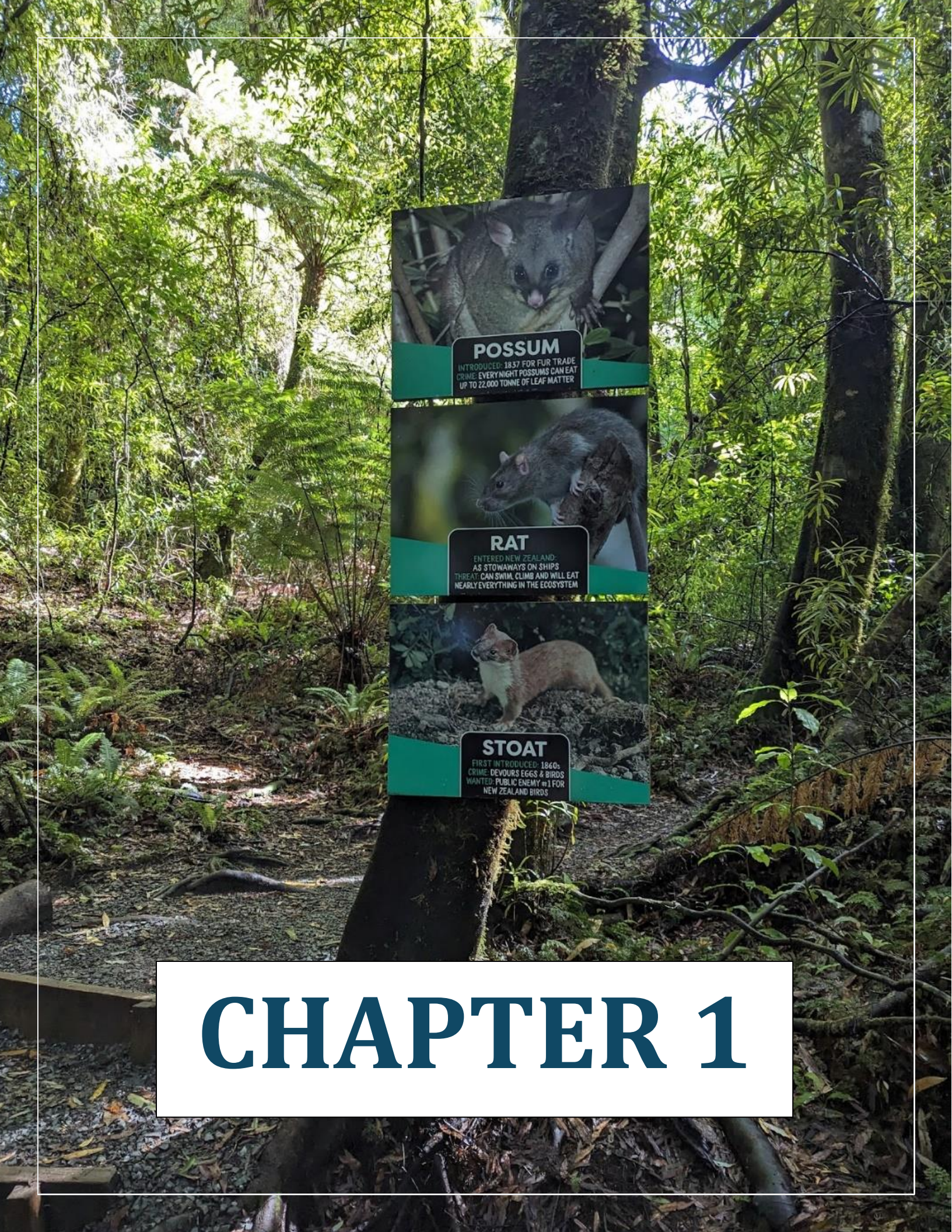
We would like to acknowledge the complexity of *te reo* Māori (the Māori language) as a multidimensional language (Dr. Sara Belcher, Personal Communication, 2024), and recognize that the glossaries and definitions are not all-encompassing. Furthermore, this is not an exhaustive list of all Māori terms related to environmental conservation. Additionally, we recognize that there may be cultural differences between different *iwi* and *hapu* regarding *mātauranga* Māori. These glossaries were compiled using a blend of wisdom from our sponsor, key informants including Alan King-Hunt, a researcher at Victoria University, and Rawiri Smith, Environment Manager for Kahungunu *ki* Wairarapa, and various academic papers discussing *mātauranga* Māori.

GLOSSARY OF TE REO MĀORI TERMINOLOGY

Term/Concept	Definition
Ariā	A concept, idea, or feeling that encompasses ecological state indicators or values.
Hapu	A subtribe within an *iwi*.
Iwi	Māori tribe or nation.
Kaitiaki	A guardian or caregiver who takes care of the land they belong to.
Kaitiakitanga	The act of guardianship or responsibility that those who belong to a land (*tangata whenua*) have in taking care of the land. Also describes stewardship and intergenerational sustainability as they relate to caring for the environment.
Mana atua	The sacred spiritual power of an ancestor as embodied in habitat quality and its structural diversity.
Mauri	A life-force or integrity of an animal and its authenticity.
Mātauranga	A knowledge system that describes the origins of the universe, and comprises Māori perspectives, culture, values, and a worldview that embraces ancestors and future generations.
Papatūānuku	The idea or concept of Mother Earth in terms of being the origin of the sky, land, and living things.
Rāhui	A temporary ban on the utilization or harvesting of a certain resource to allow it to replenish.
Ranginui	The idea of the Sky Father, who was once married in an embrace with *Paptūānuku*.
Rawa	Resources or goods.
Tangata whenua	People who belong to the land and have a duty in its care. This applies not only to Māori but also to people who have become one with the land over generations.
Taonga	Natural treasures that include the sky, land, species, and rawa or resources.
Wairua	Relating to the spirit of a land or species via its ecological diversity, distribution, and essence.
Whakapapa	Community composition (richness or abundance), connectedness, and indigenous dominance.
Whānau	A family group within a *hapu* (subtribe).
Belcher et al., 2021; Mahuta, 2019; McAllister et al., 2023; Mercier et al., 2022; New Zealand Ministry for the Environment, 2022; Royal, 2007; Tadaki et al., 2023; Wehi et al., 2023	


POSSUM
INTRODUCED: 1837 FOR FUR TRADE
CRIME: EVERY NIGHT POSSUMS CAN EAT UP TO 22,000 TONNE OF LEAF MATTER
RAT
ENTERED NEW ZEALAND: AS STOWAWAYS ON SHIPS
THREAT: CAN SWIM, CLIMB AND WILL EAT NEARLY EVERYTHING IN THE ECOSYSTEM
STOAT
FIRST INTRODUCED: 1860s
CRIME: DEVOURS EGGS & BIRDS
WANTED: PUBLIC ENEMY no 1 FOR NEW ZEALAND BIRDS

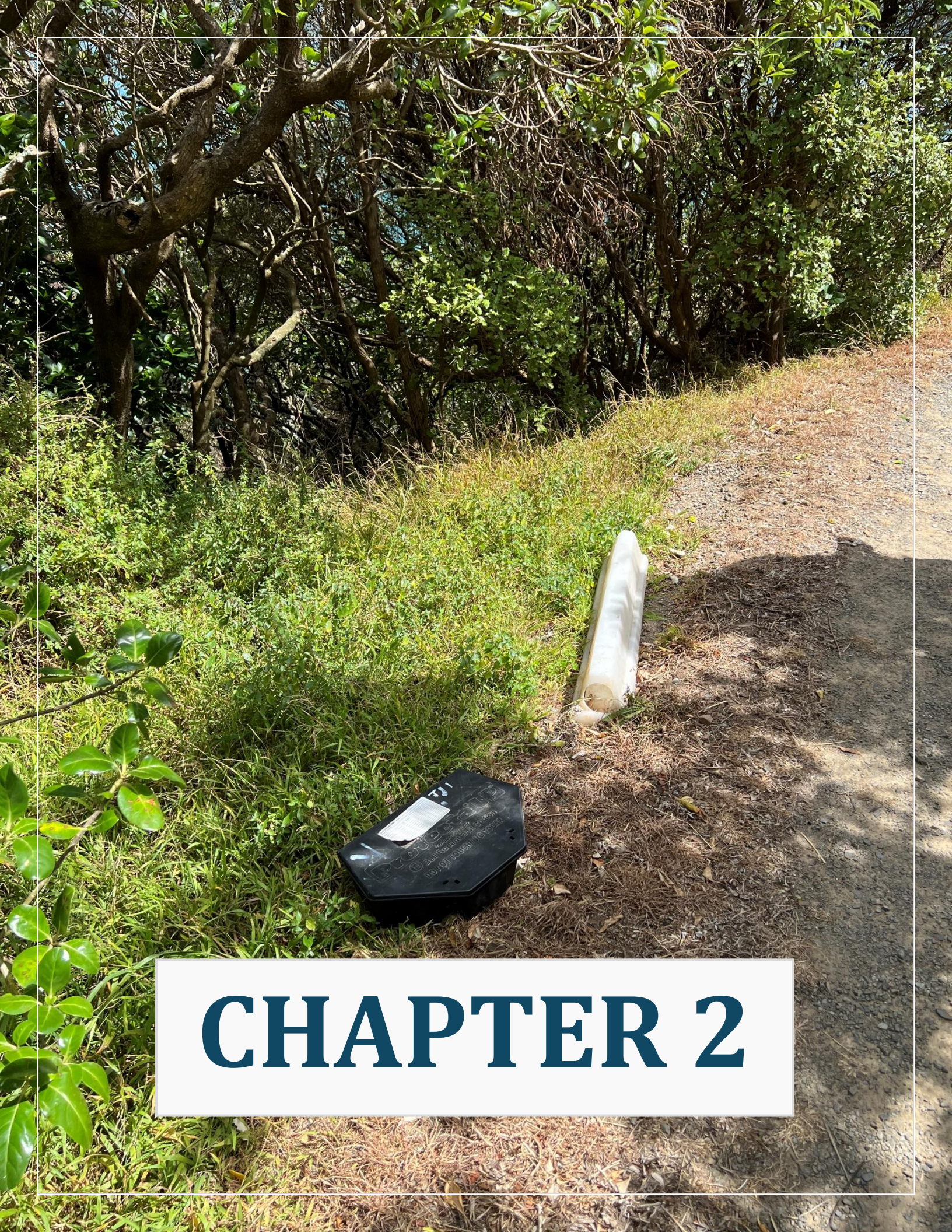
CHAPTER 1

INTRODUCED SPECIES AND CONSERVATION

Over the course of 80 million years, the unique ecosystem of Aotearoa New Zealand evolved in the presence of only one native mammal, the bat, allowing endemic species to thrive in an isolated environment (McGuinness, 2007). Today, many mammal species, including rodents, exist as wild, feral, or domestic populations which arrived in Aotearoa as a result of Pacific exploration, European colonization, as well as commerce and travel (Parkes & Murphy, 2003). These introduced species present a significant threat to the success of native wildlife and plants through predation and competition for resources.

The Predator Free 2050 initiative (PF2050) in New Zealand was established in 2016 with the goal of protecting native species and increasing biodiversity through the removal of five key predator species: rats, stoats, ferrets, weasels, and possums (*About Predator Free 2050*, n.d.). The PF2050 initiative faces the problem that mice are much more difficult to eradicate than rats, which results in mice typically being excluded from eradication efforts. This exclusion leads to uncontrolled mice populations which prey on native species, including invertebrates (Watts et al., 2022). Therefore, it is important to consider the implications of not managing the mouse population and the effect it has on vulnerable species.

The implications of harmful non-native species may be considered through cultural and scientific lenses, including from the perspective of the indigenous people of Aotearoa: the Māori. Input from Māori peoples can offer insight into the protection of biodiversity which differs from Western science. Western science is characterized by "analytical and reductionist methods" (Mazzocchi, 2006, p. 464). *Mātauranga,* or Māori Traditional Knowledge, in Māori culture presents another way of knowing based on generational observations, which emphasizes a relationship to ancestors, future generations, and the natural world (Mahuta, 2019; McAllister et al., 2023). The idea of *kaitiakitanga* (guardianship) for example, stems from the concept of *mātauranga*, and stresses the importance of the responsibility of people for taking care of the land and nature (Royal, 2007). This project aims to employ Māori perspectives to identify research gaps in literature and in the field surrounding what changes in invertebrate populations in Aotearoa's ecosystems are due to mice.



CHAPTER 2

THE ROLE OF MĀORI VALUES IN INTRODUCED MOUSE MANAGEMENT

This chapter discusses the biological, governmental, and social context of invasive mice management in Aotearoa. This includes literature on invasive predator management, mouse impacts on New Zealand's native biodiversity, and Māori Traditional Knowledge.

ENVIRONMENTAL CONSERVATION IN MĀORI CULTURE

Indigenous Traditional Knowledge encompasses a system of wisdom based upon "millennia of observations" by indigenous peoples, as is described in *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants* (Kimmerer, 2013, p. 159). Dr. Robin Kimmerer, a botanist, author on indigenous Traditional Knowledge, and member of the Citizen Potawatomi Nation, explains that concepts in Traditional Knowledge predate Western science and provide a framework for understanding human connection to the land and the "intelligence" of the natural world (Kimmerer, 2013, p. 300).

MĀTAURANGA MĀORI

In Aotearoa, regional Traditional Knowledge can best be recognized through the Māori concept of *mātauranga*. *Mātauranga* is a knowledge system which describes the origins of the universe, and comprises Māori perspectives, culture, values, and a worldview that embraces ancestors and future generations (Mahuta, 2019; McAllister et al., 2023). According to Mahuta (2019), the former Minister for Māori Development, *mātauranga* emphasizes the interconnected relationship between humans and the natural world. *Kaitiakitanga*, an element of the Māori worldview, is characterized by guardianship, stewardship, intergenerational sustainability, and caring for the environment (Royal, 2007). Likewise, the Māori concept of *whakapapa* emphasizes the relationship between humans and the land and seas which sustain them (Wehi et al., 2023). *Mauri* is the concept of a "life-force," or keeping the original spirit of a species and the land true to itself (Royal, 2007).

Traditional practices in many Māori *iwi* (tribes) have included *rāhui* (temporary ban) on the harvesting of *rawa* (resources), hunting and fishing only as needed for food, and considering breeding seasons for hunting activities (Royal, 2007). *Taonga* is the concept of a treasured *rawa* (resource) or species (Figure 3) (Belcher et al., 2021). *Rāhui* may be used to improve the *mana*, or the spiritual power, of an area, thereby accounting for the health of that environment (Royal, 2007). These practices reinforce Māori values for maintaining a "reciprocal and balanced relationship with *Papatūānuku*," the Earth Mother (McAllister et al., 2023, p. 3).

Figure 3. Carving of a Tuatara, a *taonga* (treasured) species of Aotearoa.

MĀORI RELATIONSHIP TO INTRODUCED SPECIES

Polynesian peoples have a history of voyaging and transporting crop and animal species for food, and this was true for the 13th century Māori settlers who brought the *kiore*, or Polynesian rat, with them to Aotearoa (Hewitt, 2021; Peek, 2022; Wehi et al., 2023). *Kiore* have presented a point of contention as they pressure birdlife through predation and competition for resources, but *kiore* have been a historically valued food by Māori peoples and are a *taonga* (treasured) species (Wehi et al., 2023). In 2004 for instance, controversy sparked between the New Zealand Department of Conservation (DOC) and the Ngatiwai *iwi* (tribe), over proposed eradication of the *kiore* from *Hauturu-O-Toi* Little Barrier Island, which is north of Auckland (Russell & Broome, 2016). According to Wehi et al. (2023), these conflicts reveal the need for a multidimensional framework for introduced species policies which "[aligns] management approaches with Indigenous community needs" (p. 1410).

INTRODUCED SPECIES TO AOTEAROA

In the last several centuries, an abundance of mammals have been introduced by settlers. Following the introduction of the *kiore* by 13th century Māori settlers, 18th century European colonists unintentionally brought an influx of stowaway mammals including mice and three species of rats (King, 2023; Hewitt, 2021). To combat the irruption of rodents, mustelids, and possums, hedgehogs were introduced intentionally but had unintended consequences on native species (King, 2023). Introduced mammalian predators devastated the native biota of Aotearoa, leading to the decline of many species, including the wētā, a species of invertebrate, and kiwi bird, and extinction of some, such as the laughing owl (Broome, 2009; King, 2023; Ruscoe et al., 2013).

PREDATOR FREE 2050

The Predator Free 2050 mission (PF2050) was established by the New Zealand government in 2016 with the goal of protecting native species and increasing biodiversity through the removal of five mammalian predator species in Aotearoa: rats, stoats, ferrets, weasels and possums (*About Predator Free 2050*, n.d.).

Rats are directly affected by the eradication efforts of PF2050, while mice are indirectly targeted (*About Predator Free 2050*, n.d.). The eradication of rats and other mammal species has a collateral effect on the mouse population, as mice thrive in environments free of other mammals; this phenomenon is known as mesopredator release (Angel et al., 2009). Mice can affect a greater range of native biota when they are the sole introduced mammal, achieving increased population density in rat-free environments (Hewitt, 2021). This was seen most notably on Buck Island, an island off the coast of St. Croix, where the eradication of one rat species led to an acute surge in house mice numbers (Witmer et al., 2007). In the absence of rats, mice will exhibit rat-like behavior, which can include increased targeting of large invertebrates, such as the tree wētā (Appendix A) (Parkes et al., 2016).

MĀORI VALUES IN CURRENT PREDATOR MANAGEMENT INTERVENTIONS

Currently, the two major Western strategies for managing predator species, which could pose a threat to the *mauri* (life-force) and proper *kaitiakitanga* (guardianship) of local ecosystems in Aotearoa, are trapping and baiting (Owens, 2017). Baiting is most commonly accomplished with sodium fluoroacetate, or 1080, a poisoned cereal bait pellet, spread aerially or in bait stations (Figure 4) (Eason et al., 2011). 1080 effectively targets mammalian predators, however it is contested over fears of environmental contamination in rivers and soil, thereby altering the integrity of *mauri* of the forest (Owens, 2017; Tadaki et al., 2022). Trapping utilizes standalone systems that lure in animals via non-lethal bait and kill the animal quickly (Figure 4). Traps have their drawbacks though, with the risk of unintentionally killing native fauna which could be seen as not properly preserving biodiversity, a core tenet of *kaitiakitanga* (Mercier et al., 2017; Owens, 2017).

Figure 4. Rodent trapping and monitoring on Matiu/Somes Island: Top: black box rodent bait station; middle: rodent tracking tunnel; bottom: wooden box baited trap.

Invasive species management has historically prioritized Western science, while precluding indigenous participation in conservation (Wehi et al., 2023). Understanding indigenous perspectives on issues of the environment may equip decision-makers to synthesize Western and Traditional Knowledge and create policies that reflect Aotearoa's cultural makeup. Mercier et al. (2022) identified the potential for Māori Traditional Knowledge to inform baiting through traditional means, such as the use of *īnanga* 'whitebait' (juvenile fry of fish) and wētā as baits.

OUR SPONSOR: DR. SARA BELCHER

Our project sponsor, Dr. Sara Belcher, a Senior Lecturer at Victoria University of Wellington, and developer of the Ecological State Assessment Tool (ESAT), supports the incorporation of Māori values in eradication measures in Aotearoa (Figure 5) (Belcher, 2020). Current methods of eradication employ Western scientific ideals, which often do not acknowledge human interference and cultural ideas and emphasize objective or quantitative results. The ESAT "enables quantitative ecological data to be viewed through a Māori perspective," which Dr. Belcher has used to model the outcomes of biotechnology on endemic bat protection (Belcher et al., 2021, p. 1).

Figure 5. Dr. Sara Belcher is a Senior Lecturer at the School of Science at Victoria University, before which she worked at Greater Wellington Regional Council.

THE ECOLOGICAL STATE ASSESSMENT TOOL

The Ecological State Assessment Tool (ESAT) "assess[es] quantitative scientific data using Māori ecological indicators" based on population and social data (Belcher et. al, 2021, p. 1). This tool is intended for scientific researchers and decision makers to improve their eradication plan "to facilitate genuine comanagement" (Belcher et. al, 2021, p. 1). ESAT combines quantitative and qualitative data as inputs, weighing them according to different Māori perspectives to create a resource management model representing where efforts and materials are currently being spent (Belcher et al., 2017). This model can then identify possible areas of improvement in ecological management by offering suggestions, such as recommending more social engagement (Figure 6). Ultimately, ESAT may help "the Crown to meet their resource management obligations to Māori under the Treaty of Waitangi" (Belcher et al., 2021, p. 1).

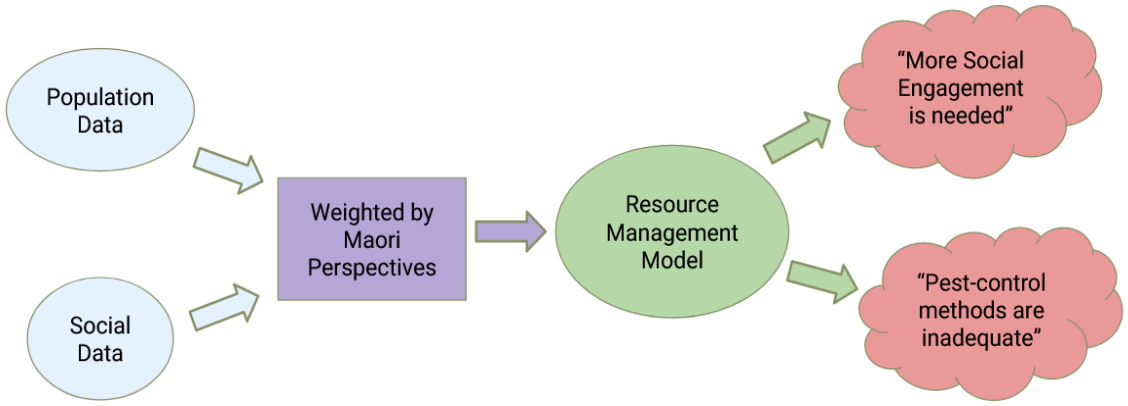


Figure 6. Flowchart of data processing in the Ecological State Assessment Tool (Belcher et al., 2021).

The ESAT comes prebuilt with different Māori indigenous perspectives that can be selected via drop-down menus. Each grouping of Māori *ariā* (concepts) comes with a brief definition and allows a weighting of that *ariā* to be applied to the population and social data. Adjusting the weighting of an *ariā* will thus change the output in the predictive model. Examples of these *ariā* include *wairua* (soul), *mauri* (life-force), *whakapapa* (connectedness), and *kaitiakitanga* (guardianship) (Belcher et al., 2021).

An important statistical tool relevant to ESAT is the Shannon Wiener Diversity Index (DI), which is used to quantify diversity in an ecosystem using population data (Appendix B). The DI is used to inform the Ecological Index (EI), which is a measure calculated by ESAT to holistically represent the health of the ecosystem. Optimizing the ESAT model consists of maximizing this Ecological Index to surpass Predator Free 2050 project targets.

THE VALUE OF MĀTAURANGA IN RESEARCH AND ENVIRONMENTAL STEWARDSHIP

The incorporation of *mātauranga* (Māori Traditional Knowledge) into policy can help prioritize the perspectives of Māori *iwi* in natural resource management and biodiversity protection, however the values of *mātauranga* are often oversimplified, misunderstood, or appropriated without credit (Mahuta, 2019; Tadaki et al., 2023). While explaining the applications of *mātauranga* in conservation, Dr. Belcher explained how some Māori *iwi* might evaluate environmental health using *mauri* (life-force), and the associated challenges of realizing that knowledge through policy:

> *When you ask an elder what the* mauri *is of the forest, they will not use facts and figures. They will tell you how it's not good because of this and this and this, but they won't actually provide you with something that scientists can take to politicians and say, 'here's the figures and this is how much it's improved or decreased.'*
>
> (Dr. Sara Belcher, Personal Communication, 2023)

TE TIRITI O WAITANGI

Article Two of *Te Tiriti o Waitangi* (Treaty of Waitangi) guarantees *whānau* (families), *hapu* (subtribes), and *iwi* (tribes) the right to manage and interact with the environment (McAllister et al., 2023). According to McAllister et al. (2023), this article is meant to ensure that Māori perspectives and values are recognized in environmental management, however some legislation has actively prevented Māori from exercising this right. As research can inform policy and management, it is important that ecological research acknowledges the role of Māori perspectives and values, although this subject is seldom realized in academia (Dr. Sara Belcher, Personal Communication, 2024).

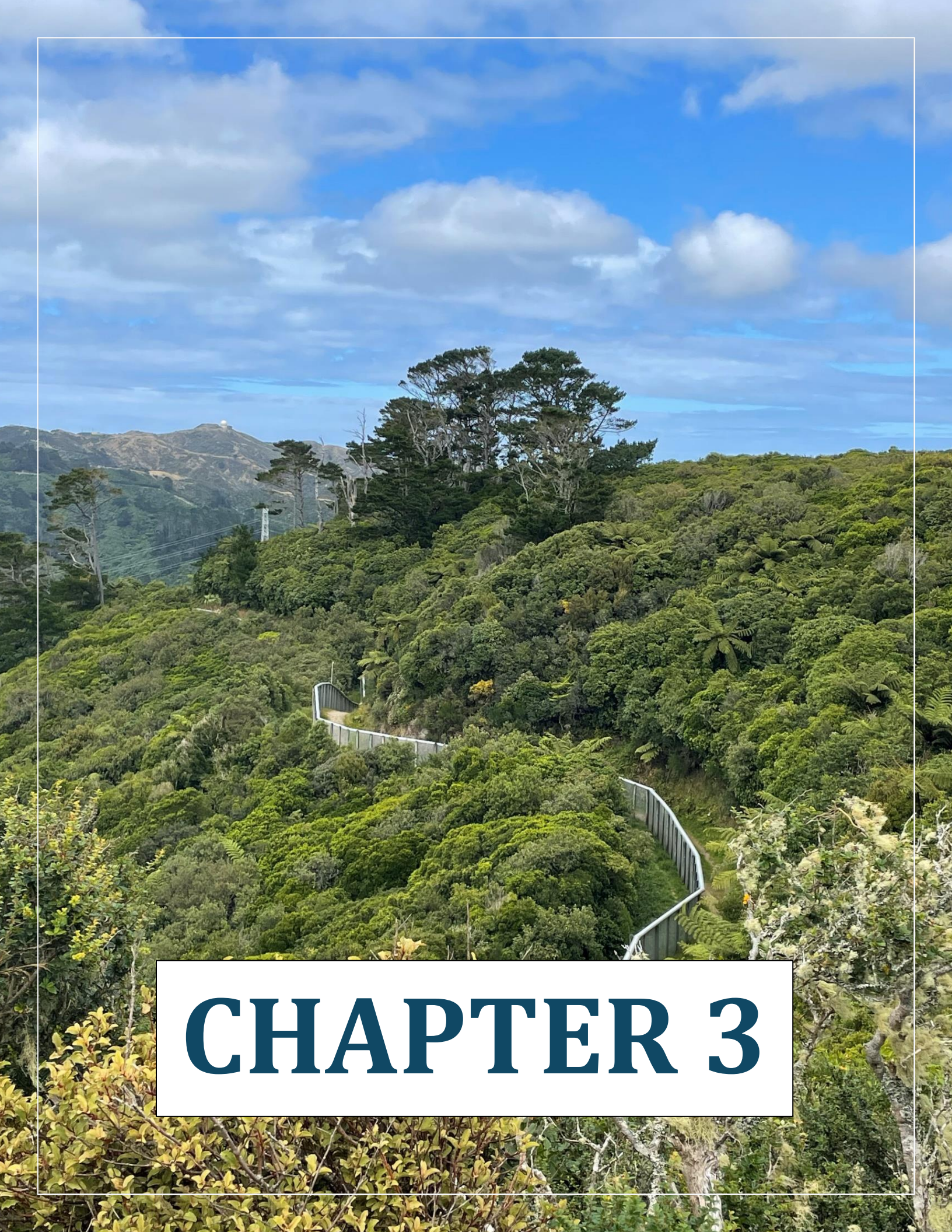
IDENTIFYING MĀORI PERSPECTIVES IN SCHOLARLY LITERATURE

Understanding the use of *te reo* Māori (the Māori language) and incorporation of Māori values in scholarly literature and bodies of research presents an opportunity to assess how authors and scientists acknowledge *mātauranga* in their work. Identifying commonalities in the use of Māori perspectives in peer-reviewed research articles and discussion-based literature, like Department of Conservation informational documents, could inform the inclusion of Māori perspectives in future research. A literature analysis is an effective method for identifying such commonalities. Literature analysis is a method in which a selection of literary works is extensively reviewed and annotated to evaluate the presence of themes, perspectives, and sentiments. The application of *mātauranga* Māori (Māori Traditional Knowledge) in literature may differ among different types of publication, such as research articles, forum articles, review articles, editorials, and white papers.

A literature analysis focused on the effects of invasive rodents on native species, especially invertebrates, could be useful to understand the overlap of rodent management with *mātauranga* Māori. An article from Hewitt (2021), for example, focuses on the impacts of mice and hedgehogs on beetles in New Zealand forests, while an article from Watts et al. (2011) focuses on the boom in wētā populations after rodent eradication. Another research article from the Department of Conservation incorporates the idea of *mauri* as Ecological Health as part of their Biodiversity Assessment Framework to keep track of conservation progress with rats, stoats, and possums (McGlone et al., 2020). More than rodents though, meta-analyses of an extensive collection of articles could contribute to the identification of areas of invasive predator management which could benefit from the inclusion of Māori-informed techniques.

OUR PROJECT

Our project aimed to employ Māori perspectives to identify research gaps surrounding the change in ecological health due to mice on Aotearoa's ecosystems. A research gap is a topic identified as requiring further investigation by an author or key-informant. Collecting evidence of research gaps is useful in justifying PF2050 funding towards specific initiatives. Our team identified several objectives to address our project goal: identify gaps in literature on mice-invertebrate interactions through Māori-informed perspectives; understand expert perspectives of mice impacts in conservation and the value of *mātauranga* in environmental management; understand the practical application of Māori values through sample field data on mice-invertebrate interactions.



CHAPTER 3

EVALUATING VALUES AND INSIGHTS ACROSS LITERATURE, EXPERT OPINIONS, AND FIELD DATA

This chapter discusses the strategies our team implemented to accomplish our three objectives. We used a literature analysis to assess gaps in research regarding the incorporation of Māori Traditional Knowledge that could benefit from further exploration by academic and government researchers, collected expert perspectives on the value of Māori knowledge in environmental management, and gained a preliminary understanding on the practical application of Māori values in the field by recording the impacts of mice on native invertebrates.

LITERATURE ANALYSIS

The literature analysis focused on evaluating the use of Māori Traditional Knowledge in research as well as the identification of research gaps, particularly to determine predominating forms of predator eradication, overlap with Māori values, and areas for future research across journal articles. We utilized NVivo, a qualitative data analysis software tool, to compile, organize, and analyze 57 journal articles and discussion pieces relating to mouse diet, mouse-rat interactions, mouse-invertebrate interactions, and current interventions for introduced species management (Figure 7). The sampling strategy includes papers provided by Dr. Sara Belcher and Alan King-Hunt, literature that deals specifically with the topic of rats and mice as invasive species in Aotearoa, and articles discussing the role of *mātauranga* in introduced species management. The latter were gathered from searches in the WPI and Victoria University online library databases (Appendix C).

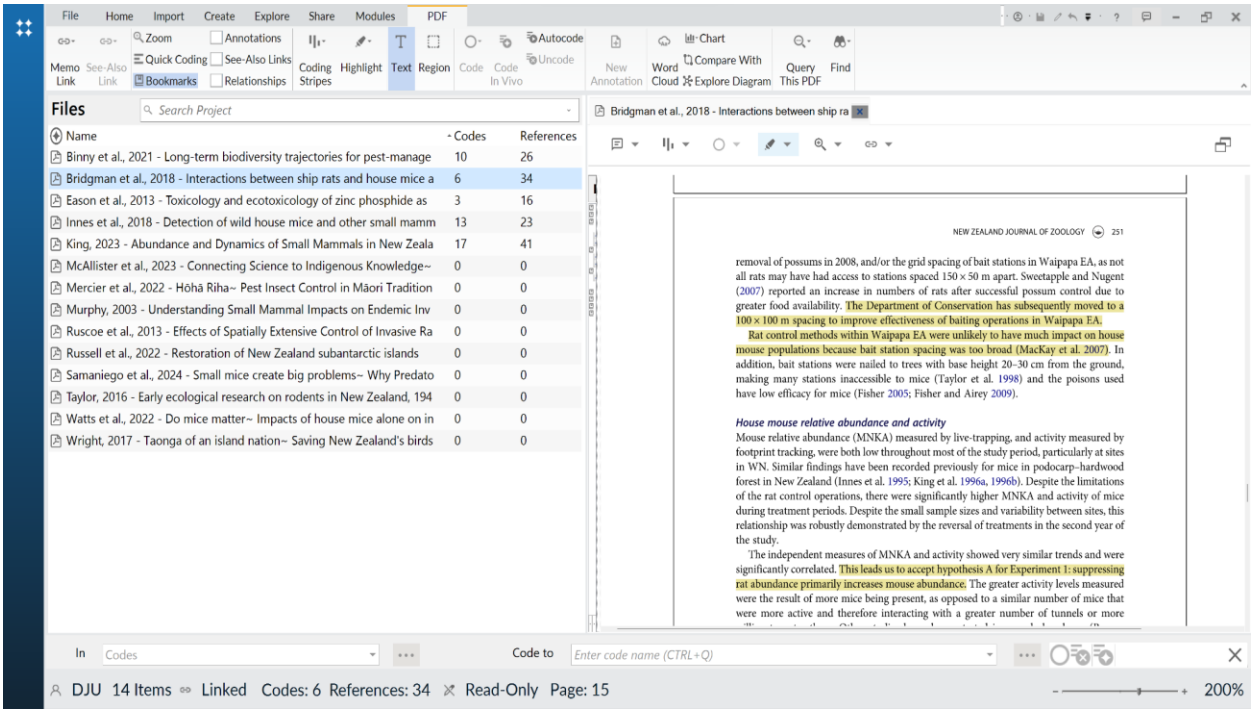


Figure 7. Screenshot of the NVivo program, supplied with a variety of literature to analyze (left) and displaying an example coded paper (right).

NVivo is a useful tool for this project as it can store annotations on multiple research papers, organize annotations under different codes, and aid in identifying certain topics, values, or sentiments that consistently use few references. A reference in this context refers to a section of text highlighted and assigned to a specific code(s). These codes are referenced in our report in bolded text (i.e. ***whakapapa***). Dr. Sara Belcher provided a list of six primary coding categories, or "parent" codes, that were applicable to our research: **mouse diet**, **invertebrate interactions**, **rat and mice interactions**, **current interventions**, **Māori science**, and **areas for further research**. We created "child" codes to further categorize annotations within each "parent," such as **baiting** and **trapping** under **current interventions**. Each code is accompanied by a definition or criteria we followed when annotating (Table 1). Appendix D contains the full list of coding categories that we used.

TABLE 1.

LITERATURE ANALYSIS CODING CATEGORIES.

"Parent" and "Child" Coding Categories	Category Guidelines
Māori Science	Keywords, phrases, or sentences which mention Māori *ariā* (concepts)/values, topics in Māori traditional ecological knowledge, or Māori perceptions of mammalian predator management. If not stated explicitly, this may also include keywords, phases, or sentence(s) whose topics align closely with concepts in Māori knowledge systems, as informed by Belcher et al. (2021).
➔ Whakapapa	Explicitly mentions "*whakapapa*," or mentions "community composition (richness or abundance)," connectedness, and "indigenous dominance" (Belcher et al., 2021, p. 471).
➔ Mauri	Explicitly mentions "*mauri*," or mentions the concept of a life-force or integrity of an animal and its authenticity (Belcher et al., 2021, p. 471).
➔ Taonga	Explicitly mentions "*taonga*," or mentions natural treasures that include the sky, land, species, and *rawa* or resources (Belcher et al., 2021, p. 471).
➔ Wairua	Explicitly mentions "*wairua*," or mentions the spirit of a land or species via its "ecological diversity," distribution, and essence (Belcher et al., 2021, p. 471).
➔ Kaitiakitanga	Explicitly mentions "*kaitiakitanga*," or mentions the act of guardianship or responsibility that those who belong to a land (*tangata whenua*) have in taking care of the land (Belcher et al., 2021, p. 471).
➔ Mana atua	Explicitly mentions "*mana atua*," or mentions "habitat quality," "ecosystem functions," or "structural diversity" (Belcher et al., 2021, p. 471).
Mouse Diet	Keywords, phrases, or sentences which mention foods consumed by mice. Items mentioning mouse predation on plant life, bird life, or invertebrates.
➔ Plant Life	Mentions plant or seed life in relation to the diet, activity, or populations of mice, rats, or other predators.
➔ Impacts on Birdlife	Mentions mouse diet in relation to predation on bird eggs, chicks, or youth. May also mention mouse impacts on birdlife due to competition for resources; if this is the case in relation to competition for invertebrates, also code for **Mouse and Invertebrate Interactions**.

➔ Invertebrates	Mentions mouse diet in relation to predation on invertebrate species. Does not expand upon how this predation impacts invertebrate populations/behavior as a whole, or how invertebrate populations/ behavior impact mice activity.
Invertebrate Interactions	Keywords, phrases, or sentences which mention mammalian predator behaviors in the presence of invertebrates and/or their impact on invertebrate populations.
➔ Mouse and Invertebrate Interactions	Mentions mouse predation on invertebrates and/or impacts of mice on invertebrate populations. This may also include the influence of invertebrate populations/behavior on mice activity.
➔ Rat and Invertebrate Interactions	Mentions rat predation on invertebrates and/or impacts of rats on invertebrate populations.
➔ Other Mammal and Invertebrate Interactions	Mentions other mammalian (stoat, weasel, possum, cat, etc.) predation on invertebrates and/or impacts of that mammal on invertebrate populations.
Rat and Mice Interactions	Keywords, phrases, or sentences which mention the impacts of the presence/absence of mice or rats on the behaviors and populations of one another.
Current Interventions	Keywords, phrases, or sentences which mention eradication or management strategies for invasive mice.
➔ Baiting	Mentions poisons, baits, or anticoagulants utilized to manage or reduce mice populations.
➔ Trapping	Mentions the use of trapping technologies to manage or reduce mice populations.
➔ Genetic Modification	Mentions the potential of genetic modification (Single Sex Offspring Selection, etc.) as a method of managing or reducing mice populations.
➔ Eradication Difficulties	Mentions the challenges of eradicating mice, or reasons why mice are targeted less frequently as a mammalian predator of concern.
➔ Multi-method Approach	Mentions the use or benefit of using multiple management practices simultaneously.
Areas for Further Research	Typically found in the Results/Findings or Discussion sections of journal articles, this category includes keywords, phrases, or sentences which mention research topics which have not yet been explored but should be in the future. This may also include information about limitations or gaps in the author(s) research process.

	This category might overlap with **Eradication Difficulties**.
➔ 1080	Mentions a problem or unexplored suggestion regarding the design of or use of 1080 or Sodium Fluoroacetate.
➔ Animals	Mentions a problem or unexplored suggestion regarding one of the following subcategories.
➔ Biotech	Mentions a problem or unexplored suggestion regarding biotechnology.
➔ Climate Change	Mentions a problem or unexplored suggestion regarding climate change.
➔ Māori Questions	Mentions a problem or unexplored suggestion regarding the execution of Māori values in interventions.
➔ Nitrogen	Mentions a problem or unexplored suggestion regarding nitrogen fixation and effects on population booms.
➔ Sanctuaries	Mentions a problem or unexplored suggestion regarding sanctuaries.

We identified research gaps in literature, defined as topics with consistently few references across all coded literature, by analyzing similarities across groupings of "child" codes within "parents." Determination of **Māori science** concepts in this analysis was completed through incorporation of topics in Traditional Knowledge by Māori authors, as well as insights from key informants.

We discovered that one publication, *Diet of house mice (Mus musculus L.) on coastal sand dunes, Otago, New Zealand* (Miller & Webb, 2001), was duplicated under two different names in NVivo and coded twice. As this article had relatively few codes in it, mostly pertaining to mouse diet, we left the duplicate in, as it would be too difficult to redo all our analysis with the files merged.

KEY INFORMANT CONVERSATIONS

To develop an understanding of Māori values in invasive species management, we met with four key informants to explore the social perceptions of the impacts of mice on conservation efforts. We spoke with Alan King-Hunt, a Researcher at the School of Māori Studies at Victoria University of Wellington, Piata Hohaia, a Ranger at Zealandia *Te Māra A Tāne* and member of the Ngāti Toa Rangatira *iwi* (tribe), Janel Hull, a Senior Communications Advisor for the Department of Conservation (DOC), and Rawiri Smith, an Environment Manager for Kahungunu *ki* Wairarapa (the Wairarapa *hapu* (sub-tribe) in the Kahungunu *iwi*) (Figure 8). Each meeting was conducted using a semi-structured interview format, which Ward (2014) defines as "an interview schedule with prompts of one sort or another" (p. 68). This format allowed for depth of conversation and meaning through a structured but open-ended approach. We tailored prompts to our interviewees, depending on their area of expertise (Appendix E).

Alan King-Hunt

Researcher at Victoria University of Wellington, Te Kawa a Māui (School of Māori Studies)

Piata Hohaia

Ranger at Zealandia Te Māra A Tāne in Wellington

Janel Hull

Senior Communications Advisor for Predator Free 2050 at the Department of Conservation

Rawiri Smith

Environment Manager for Kahungunu ki Wairarapa

Figure 8. Names and titles of our key informants.

RODENT AND INVERTEBRATE TRACKING

To understand the practical application of Māori values in the field and comprehend the impacts of mice on native invertebrates, our team collected sample field data in Wrights Hill Reserve, a public park in the Karori suburb of Wellington, which borders the Zealandia mainland island. We deployed ten chew cards and conducted two leaf litter samples to monitor the activity of mice and invertebrates (*Possum Population Monitoring*, 2015). Chew cards are rectangular cardboard pieces that are baited to measure rodent activity through bite marks (Figure 9). To set up a chew card, an individual spreads peanut butter on the sides and between layers of the card, folds the card in half, and nails it through the fold to the trunk of a tree at a height of approximately 30 centimeters from the ground. This height prevents interference from unwanted animals (i.e. hedgehogs), isolating its use to rodents or larger mammalian predators.

Figure 9. A chew card in the field.

To deploy chew cards, we established one 10-trap monitoring line along a wooded path in Wrights Hill. Our trapline ran approximately 100 meters, with chew cards placed roughly 10m apart. After deploying a chew card, an ID number was assigned to the site, the approximate

Cartesian coordinate was recorded, and relevant details about card location and placement were recorded. We collected chew cards after seven days and recorded the presence of rat or mouse chew marks.

Invertebrate activity was measured using samples of leaf litter from the forest floor. We gathered two samples along the chew card line: one at the site of the first chew card and one at the site of the final chew card, in areas of undisturbed litter. We filled an approximately four-liter bucket with leaf litter, then poured it into a tray. We categorized the bugs we encountered into broad categories (i.e. isopods, spiders, etc.), and recorded counts for each.

We utilized ArcGIS Pro, a Geographic Information System, to design a detailed layout of our field site for documentation purposes. We created a project with a base layer of satellite imagery of Wrights Hill Reserve, which was overlaid with our monitoring and sampling points (Figure 10).

Figure 10. ArcGIS layout of chew card sites in Wrights Hill Reserve (Credit: Laura Romania).

UNDERSTANDING CULTURAL PERSPECTIVES THROUGH THE ECOLOGICAL STATE ASSESSMENT TOOL (ESAT)

To analyze our limited set of field data through a perspective that incorporates *mātauranga* Māori (Māori Traditional Knowledge), we used the Ecological State Assessment Tool (ESAT) model to better understand how Māori values might be applied in field research (Figure 11). Our field data consisted of one line of ten chew cards and two leaf litter samples.

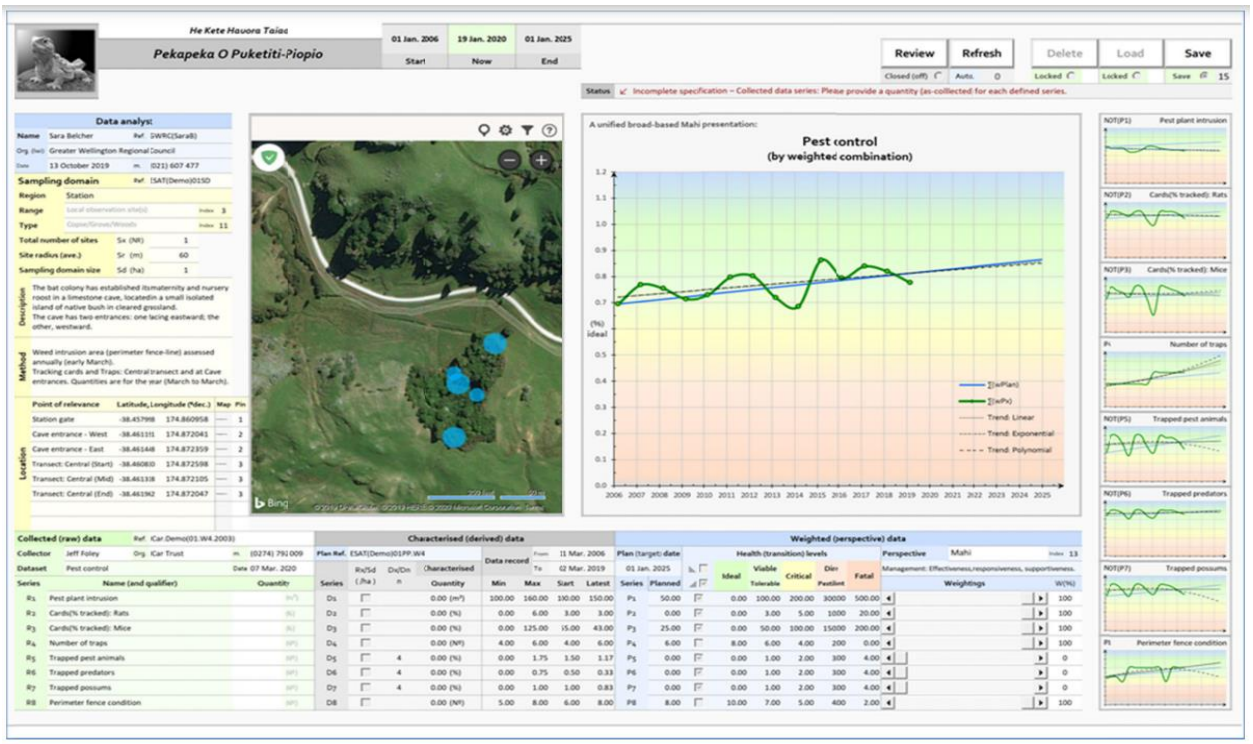
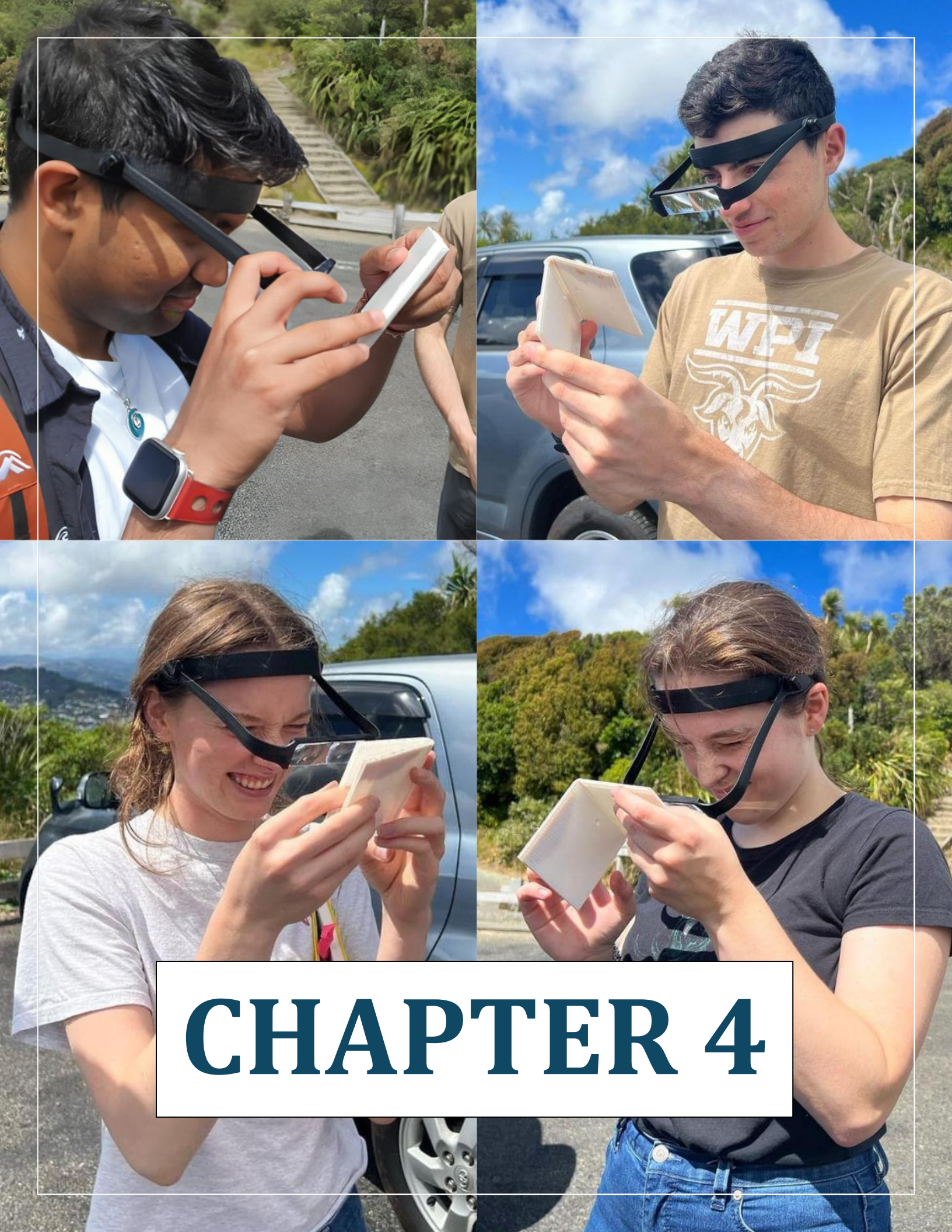


Figure 11. An example Working page in ESAT (Belcher et al., 2021).

Dr. Belcher guided our team in entering our sample field data into ESAT and extrapolating data. Field data on invertebrate counts and mouse activity in combination with existing weightings of terms was input into a new table in ESAT. Dr. Belcher contributed to populating this model via configuring the targets (desired outcomes from the model), background (the definitions of what defines a good or bad outcome), and weightings (whether certain datasets, such as the rodent population, should weigh into the outcome more than others) which are defined by choosing a Māori Perspective from the dropdown.



CHAPTER 4

ANALYSIS AND FINDINGS

Literature analysis was the primary focus of this project, informing our use of Māori cultural values in research, and aiding in the postulation of research questions for future exploration. Information from key informants and the Ecological State Assessment Tool (ESAT) further supported the value of *mātauranga* (Māori Traditional Knowledge) in conservation as well as the application of Māori-informed invasive species management methods. It is important to clarify the terms "mention," "reference," and "annotation," are used interchangeably. For our literature analysis in NVivo, these terms refer to a section of text in an article which was highlighted/selected and assigned to one or more coding categories, which are marked in bold (i.e. ***whakapapa***).

FINDING 1: MĀORI PERSPECTIVES AND VALUES ARE OFTEN MISREPRESENTED IN ECOLOGICAL LITERATURE

DEFINING MENTIONS OF MĀORI SCIENCE IN LITERATURE

The literature analysis explored the language and intentions behind each reference of **Māori science** to determine whether Māori concepts were utilized in a meaningful way. We categorized each mention of a Māori concept into an explicit or implicit mention. An explicit mention of a Māori value was defined as the use of one of ***kaitiakitanga***, ***mana atua***, ***mauri***, ***taonga***, ***wairua***, or ***whakapapa*****,** referred to as the six key *ariā* (concepts) in the text. An implicit mention of a Māori value was defined as the use of key words or phrases related to a key *ariā*, without explicit mention of the term. Each mention, either implicit or explicit, was categorized as meaningful or non-meaningful, and then into one or more of six codes: ***kaitiakitanga***, ***mana atua***, ***mauri***, ***taonga***, ***wairua***, and ***whakapapa***. A meaningful mention of a Māori value was one where the definition or discussion of the concept was crucial to understanding the meaning of the sentence or offered information that built on the established definition. A non-meaningful mention was one where the Māori value was mentioned without discussion of the concept and its significance. Coding criteria for the six key *ariā* may be found in Appendix D.

An explicit mention of a Māori value was defined as the use of one of the six key *ariā* in the text. For example, Mercier et al. (2022) mention ***taonga*** and ***kaitiakitanga*** in the text: "This *taonga* has been under *kaitiakitanga* 'guardianship' by Māori, who for generations have ensured its prosperity and protection" (p. 279). For the Māori values of ***mauri*** and ***wairua***, McGlone et al. (2020) wrote "*mauri* provides life and energy to all living things, and is the binding force that links

the physical to the spiritual world (e.g. *wairua*)" (p. 2). As seen with the Māori value of ***taonga*** (treasured species), Wright (2017) wrote "our birds are a great treasure – they are a *taonga* of this island nation" (p. 5).

An implicit mention of a Māori value was defined as the use of key words or phrases related to a key *ariā*, without explicit mention of the term. For example, King et al. (2023) wrote "the structure of a local community is determined by the interactions among the resident species past and present, modified by geography" (p. 1), which discusses the idea of connectedness without referencing ***whakapapa***, the related Māori value. Likewise, Wright (2017) writes "our natural heritage is not confined to the conservation estate," which references the idea of inheritance or interconnected genealogy of ***whakapapa*** without a direct use of the word (p. 98).

A meaningful mention of a Māori value was one where the definition or discussion of the concept was crucial to understanding the meaning of the sentence or offers information that builds on the established definition. For example, Watts et al. (2011) mention the idea of using wētā as indicators of ***mauri***: "Hemideina species are large common insects that are easily identified by non-experts and so they are being used as indicator species for monitoring both the 'health' of forest ecosystems" (p. 270). Because the mention builds upon the definition of ***mauri*** to provide new insights, it is coded as a meaningful mention. Meaningful mentions can also take the form of explicit questions to prompt deeper thinking of the Māori concepts at play, as in Mercier et al. (2017): "as *kaitiaki* of Aotearoa's *wao nui a Tāne whakapapa*/biological diversity, how do and can we exercise *kaitiakitanga*?" (p. 76).

A non-meaningful mention was one where the Māori value was mentioned without discussion of the concept and its significance. An example of a non-meaningful explicit mention is "together these introduced animals degrade the *mauri* of the forest," (Wright, 2017, p. 14) where ***mauri*** is used in the sentence without regard or discussion about its contribution. Likewise, there can be an implicit mention of the term without meaning behind it. An example of this is "one of our most treasured birds is the kākāpō," (Wright, 2017, p. 7) which neither needs the reader to understand the definition of the word ***taonga*** nor is the Māori concept discussed further.

It is important to note that an implicit mention of a Māori *ariā* is not necessarily an intentional one. Each *ariā* has associated English terms and concepts, so when one of these terms or concepts was discussed, the passage would be coded as an implicit mention. For example, some terms related to ***whakapapa*** include community and connection, so references to these terms

would be coded for ***whakapapa***, even if the author did not have the *ariā* in mind. Implicit mentions might be examples of how Western and Māori science can sometimes arrive at the same conclusion. Implicit mentions being common may indicate that concepts related to each *ariā* are being discussed somewhat frequently in literature.

A SUBSTANTIAL AMOUNT OF MĀORI SCIENCE REFERENCES ARE NON-MEANINGFUL

Out of the 57 articles coded in NVivo, 31 (54%) discussed **Māori science** concepts either explicitly or implicitly. There were a total of 265 references falling under at least one of ***kaitiakitanga***, ***mana atua***, ***mauri***, ***taonga***, ***wairua***, or ***whakapapa***. Of this total, 64% were implicit mentions (Table 2). Once references of **Māori science** had been coded for either implicitness or explicitness, they were further distinguished into meaningful and non-meaningful mentions. Of the total mentions of Māori science, 31% were non-meaningful. Although meaningful mentions were more common than non-meaningful ones, nearly one third of all mentions of *ariā* being non-meaningful is significant.

TABLE 2.

IMPLICIT AND EXPLICIT MEANINGFUL AND NON-MEANINGFUL MENTIONS OF MĀORI SCIENCE.

	Implicit	Explicit	Total
Meaningful	111	73	184
Non-meaningful	58	23	81
Total	169	96	265

MĀORI SCIENCE CONCEPTS ARE DISCUSSED MORE MEANINGFULLY IN DISCUSSION-STYLE ARTICLES

When classifying by type of article (research article or editorial, forum, and review articles) under implicit, explicit, meaningful, and non-meaningful, the total mentions of Māori science was 222. This difference can be accounted for by the fact that articles mentioning Māori science that did not fall under one of research, editorial, forum, or review articles were ultimately excluded from this analysis. The distinction between meaningful implicit, non-meaningful implicit, meaningful explicit, and non-meaningful explicit was isolated for discussion-style articles (Table 3).

TABLE 3.

IMPLICIT, EXPLICIT, MEANINGFUL AND NON-MEANINGFUL MENTIONS OF MĀORI SCIENCE IN DISCUSSION-STYLE ARTICLES.

	Implicit	Explicit	Total
Meaningful	49	57	106
Non-meaningful	21	15	36
Total	70	72	142

The distinction between meaningful implicit, non-meaningful implicit, meaningful explicit, and non-meaningful explicit was further isolated for research articles (Table 4). Additional information on the use of journal and article types for this analysis may be found in Appendix F.

TABLE 4.

IMPLICIT, EXPLICIT, MEANINGFUL AND NON-MEANINGFUL MENTIONS OF MĀORI SCIENCE IN RESEARCH ARTICLES.

	Implicit	Explicit	Total
Meaningful	43	5	48
Non-meaningful	30	2	32
Total	73	7	80

Mentions of **Māori science** in discussion-style articles were relatively evenly split between implicit and explicit, whereas only 9% of mentions in research articles were explicit. Non-meaningful mentions were split relatively evenly between article types, with discussion-style articles accounting for 53% and research articles 47%. In contrast, of meaningful mentions of **Māori science**, 69% came from discussion-style articles and 31% from research articles. This not only highlights the lack of explicit use of Māori values in research, but also a deficiency in meaningful mentions in these articles.

MĀORI SCIENCE MAY BE USED TO CONTEXTUALIZE RESEARCH, INSTEAD OF INFORMING RESEARCH METHODS

Between the two article groupings (research articles and editorial, forum, and review articles), there were a total 267 references of **Māori science**. Of these, 79% came from discussion-style articles, while 21% references came solely from research articles. The difference between the 267 mentions of **Māori science** for this analysis and other findings is because this dataset included all **Māori science** references – both general mentions and references to specific values (***kaitiakitanga***, ***mana atua***, ***mauri***, ***taonga***, ***wairua***, or ***whakapapa***).

With an understanding of the distinction between references of **Māori science** by article-type, we further sought to understand how researchers and authors employed Māori concepts in their work. If mentions of **Māori science** only appeared in abstracts, keywords, introductions, and discussions, rather than in methods, results, and conclusions, it might be inferred that Māori values were being used to contextualize work rather than contributing directly to the research. For discussion-style articles, most references fell within the **general body** category, indicating that **Māori science** likely contributed comprehensively to the methods of that research (Table 5).

TABLE 5.

MĀORI SCIENCE REFERENCE COUNT BY SECTION FOR EDITORIALS, FORUMS, AND REVIEW ARTICLES (INCLUDED ABSTRACT, INTRODUCTION, AND CONCLUSION).

Total Article Count: 20 | Total Reference Count: 212	
Section	**# of References**
Abstract	14
Keywords	6
Introduction	43
General Body*	137
Methods	1
Results	2
Discussion	20
Conclusion	12
Total	212

**General Body encompasses mentions in between the introduction and conclusion if there were no sections for Methods, Results, or sometimes Discussion*

For research articles, most references fell within the **introduction** and **discussion**, while the minority lied in the **methods**, **results**, and **conclusion** (Table 6). This reveals that **Māori science** was likely used only to provide context to research, but was not actualized in the methodology, results and analysis which followed. This supports our finding that Māori-informed methods and techniques may not be commonly incorporated into ecological research for projects involving the subject of invasive mammals like mice in Aotearoa.

TABLE 6.

MĀORI SCIENCE REFERENCE COUNT BY SECTION FOR RESEARCH ARTICLES.

Total Article Count: 15 | Total Reference Count: 55	
Section	**# of References**
Abstract	7
Keywords	0
Introduction	23
Methods	1
Results	3
Discussion	20
Conclusion	1
Total	55

KEY INFORMANTS SUGGEST MĀORI VALUES ARE SOMETIMES MISSING IN INVASIVE SPECIES MANAGEMENT

Each of our key informants suggested that Māori values were missing or misrepresented in current environmental conservation in Aotearoa. *Mātauranga* Māori (Māori Traditional Knowledge) came up on multiple occasions, with staff at organizations like Zealandia and the Department of Conservation seeing *mātauranga* as a crucial factor to incorporate in invasive species management. Piata Hohaia, a Ranger at Zealandia, said that "a really important part of [Predator Free 2050] is making sure we incorporate *mātauranga*. It's missing that." Furthermore, current methods of predator control are largely governed by Western scientific ideals, which typically "[disregards] the more intuitive and holistic view often found in traditional knowledge" (Mazzocchi, 2006, p. 464). Janel Hull, a Senior Communications Advisor for the Department of Conservation (DOC), stated that "Western science gets more attention than *mātauranga*."

Piata Hohaia, Ranger at Zealandia and member of the Ngāti Toa Rangatira *iwi* (tribe), revealed the friction between environmental agencies, like the Department of Conservation, and *iwi* over matters of conservation. She explained that "[a] lot of distrust comes from the fact that a lot of our land was taken in the name of conservation." Often, methods of conservation preclude observations and knowledge from Māori culture, aiming to prevent human activities in protected conservation areas (Piata Hohaia, Personal Communication, 2024). Hohaia emphasized the need for

an approach to conservation which prioritizes a human connection with the environment, stating that "it's not always about leaving the environment alone, it's about how you interact with it," as this approach can be mutually beneficial. She shared that at Zealandia, Māori individuals had expressed interest in the harvesting of certain fibers, like Harakeke (flax), but were not allowed to due to the protected status of this land. Hohaia elaborated that tending to the land through harvesting is thought to be an action of reciprocity between humans and nature. Janel Hull, from the Department of Conservation (DOC), stated that "we need nature and nature needs us," further emphasizing the idea that humans should care for *Papatūānuku* (the Earth Mother) as she cares for us.

Alan King-Hunt, a researcher in the School of Māori Studies at Victoria University, highlighted the importance of community engagement to better contribute towards PF2050 efforts. He said that engagement with New Zealand residents is crucial to ensure clear communication between the public, scientists, and government officials while maintaining continuity of research. King-Hunt explained that there is often a disconnect between professionals and resident volunteers working towards the shared goal of predator eradication, stating that "we operate in silos, [in] more ways than one." To break out of those silos and work together more closely in matters of environmental conservation, he explained that "we need to start making connections with each other," and build upon existing ones.

Rawiri Smith, an Environment Manager for Kahungunu *ki* Wairarapa (a *hapu* within the Kahungunu *iwi*), stressed the issue of disregarding Māori perspectives in conservation by asking "what if you've got a whole ecosystem that evolved differently than anywhere else in the world? Why would you go to the rest of the world for validation about that ecosystem?" Janel Hull extended the idea that more than incorporating *mātauranga* Māori, it is important to incorporate Māori people. As Senior Communications Advisor for the DOC, one of Hull's main goals is to "make sure people have agency and control" by facilitating collaboration and motivation between different groups, such as Māori *iwi,* towards common conservation objectives, specifically PF2050.

CONCLUSION OF FINDING 1

We found that Māori knowledge was often misrepresented in the literature we studied, and it became evident through our key informant interviews that an incorporation of *mātauranga* and Māori *iwi* (tribes) in ecological management is sometimes missing in Predator Free 2050 initiatives.

FINDING 2: FIELD INTERVENTIONS COULD BENEFIT FROM A MULTI-CONTEXTUAL APPROACH THAT INCLUDES MĀORI-INFORMED METHODS

MULTI-METHOD APPROACHES TO INVASIVE SPECIES MANAGEMENT ARE UNDERREPRESENTED AS CURRENT INTERVENTIONS IN LITERATURE

Out of the 207 mentions of **current interventions**, which excludes the **eradication difficulties** "child" code, 94 belonged to **baiting** and 58 belonged to **trapping**, which together account for 73% of mentions. Having most current predator eradication techniques associated with only two intervention methods might imply that there is room for additional methods included in invasive predator management in Aotearoa. Only 15% of mentions of **current interventions** (excluding **eradication difficulties**) were also part of a **multi-method approach**. Categories like **genetic modification** also only accounted for 11.6% of **current interventions**. To further explore eradication and predator management tools, we turned to the **eradication difficulties** code to identify some of the specific challenges of current strategies.

There were 125 mentions of **eradication difficulties** with current predator eradication methods across 27 articles (Table 7). The **feasibility** of eradication was mentioned most often, with concerns of cost and scalability. This makes sense as baiting and trapping operations are expensive, and trapping operations are difficult to conduct over large areas. The issue of **reinvasion** by mammals and issues with the **effectiveness** of eradication methods on mice were also frequently mentioned, which might suggest that a focus on sustainable predator solutions could be more effective than baiting and trapping projects in the long-term.

TABLE 7.

REFERENCES OF ERADICATION DIFFICULTIES BROKEN DOWN BY THEME.

Category	Number of references
Eradication interference	5
Feasibility	45
Ineffective control	24
Lack of knowledge	8
Mesopredator release	7
Reinvasion	31
Taonga or valued species	5
Total	125

KEY INFORMANTS SUGGEST GAPS IN INVASIVE SPECIES MANAGEMENT COULD BE FILLED BY MĀORI-INFORMED TECHNIQUES

The primary goal of Predator Free 2050 is to eradicate selected invasive mammals by the year 2050. To accomplish this goal, new technologies will need to be developed to accelerate rodent eradication as described by Janel Hull, a Senior Communications Advisor at the Department of Conservation, who said "[we] can't eradicate predators from Aotearoa with the tools we have now." The findings from our NVivo analysis prompted exploration of additional invasive mammal management techniques. Conversations with key informants further emphasized the potential of adding Māori-informed management or eradication strategies.

The PF2050 mission is framed as a nationwide eradication to remove non-native species. On the topic of PF2050, Janel Hull emphasized the importance of considering the outcome of the PF2050 mission as a restoration of *taonga* (treasured species), rather than focusing on the eradication itself. Many programs under PF2050 focus on this restoration, such as Zealandia, where "restoring of *taonga* species is really important to us," as stated by Zealandia Ranger Piata Hohaia. Reframing PF2050 to focus more on the *taonga* (treasured species) than rodents is analogous to reframing the initiative around the outcome rather than the original problem statement (Piata Hohaia, Personal Communication, 2024. Rawiri Smith from Kahungunu *ki* Wairarapa, said Western

scientists and engineers are often narrow-minded in their focus on the problem statement, whereas *mātauranga* Māori (Māori Traditional Knowledge) first looks at the strengths of the environment and leverages those benefits to support the weak spots.

One of these strengths may be utilizing *taonga* (treasured) species to protect the environment. Piata Hohaia, a Ranger at Zealandia, explained how several native *taonga* (treasured) birds have been reintroduced into Zealandia, including the weka. Controversy arose around the weka following observations that it preys on sensitive bird populations, but also on mammalian predators. Hohaia stated that the "[weka] will literally eat anything," including endemic lizards, but not to the point of decreasing overall populations. The weka also actively preys on rodents, so they could be used as supplementary predator control measures. The weka, as Hohaia stated, "could possibly help Zealandia, especially with mouse control," as wekas can kill mice. She posed the question "would you rather have rats and mice decimating the environment or the weka?" Hohaia provides clarification that while there is the adverse potential for *taonga* predators to harm vulnerable native populations, still, the reintroduction of native *taonga* predators could prove helpful in controlling small invasive mammal populations.

Standard methods of baiting and trapping frequently involve the use of mass-produced baits such as peanut butter. Alternatives though, as described by Piata Hohaia, may include the use of native fruits and plants in baiting and trapping such as the Karaka fruit and Kawakawa leaves. Many proponents of using native baits in trapping, monitoring, and baiting identify this strategy as a key example of the implementation of how *mātauranga* could be better incorporated into PF2050 and the sanctuary.

Rawiri Smith, Environment Manager for Kahungunu *ki* Wairarapa, suggested the value of ecosystem restoration over technological engineered solutions. Smith explained that rather than using water management, a versatile approach to environmental management could improve the *mauri* (life-force) and health of the land. He explained that a healthy, reestablished, wetland could also serve as a barrier to prevent the spread of invasive mammals like mice and stated that "so much more can happen from a fully recognized ecosystem." While restoration ecology is complex and is not straightforward to implement, Smith explained that flourishing native *taonga* predator species like eels, which can prey on small mammals, could benefit from the restoration of wetlands.

CONCLUSION OF FINDING 2

There were few mentions of a **multi-method approach** within our literature analysis, but our key-informant conversations highlighted the potential for this gap to be filled with Māori-informed introduced predator management techniques.

FINDING 3: INCREASED MĀORI ACCEPTANCE AND ENGAGEMENT IN CURRENT PREDATOR ERADICATION TECHNIQUES CAN HELP ACHIEVE MANAGEMENT TARGETS

MODELING THE INVOLVEMENT OF MĀORI PEOPLE IN RESOURCE MANAGEMENT USING THE ECOLOGICAL STATE ASSESSMENT TOOL

To explore the role of Māori methods in environmental conservation through the model, our team conducted multiple trials with different weightings to find out if increasing the contribution of certain factors, such as acceptance and engagement for current rodent interventions, would improve the Ecological Index (EI) – how the general health of the ecosystem is measured in ESAT. The goal was to generate two final trials: a control trial (with little to no Māori informed methods) and a trial with more Māori influence. The Māori informed methods, as defined by Dr. Belcher, were:

- **Acceptance:** the likelihood for a Māori individual to approve of a predator control intervention.
- **Engagement:** the likelihood for a Māori individual to use a predator control intervention themselves.
- **Perceived risk of Mice:** the likelihood for Māori individual to see the mice as a threat to the environment – our field data was used in part to inform this dataset.

We recorded chew card and invertebrate leaf litter sample data to analyze with Māori *ariā* (concepts) through the Ecological State Assessment Tool (ESAT) (Figure 12).

Figure 12. Setting up a chew card in the field.

Following the collection of our ten chew cards, we determined if there were rat bite marks, mouse bite marks, both, or neither (Table 8).

TABLE 8.

CHEW CARD SAMPLING DATA COLLECTED AT WRIGHTS HILL RESERVE.

Chew card number	1	2	3	4	5	6	7	8	9	10	Total
Rat bite marks	x	x	x	✓	x	x	x	x	x	x	**1**
Mouse bite marks	x	x	x	x	x	✓	x	x	✓	✓	**3**

The total number of cards with mouse bite marks was three of the ten total cards, or 30%. Dr. Belcher classified this as indicative of a low-density mouse population (Low-Mice). We recorded invertebrate counts for the two leaf litter samples conducted (Table 9).

TABLE 9.

LEAF LITTER SAMPLING DATA COLLECTED AT WRIGHTS HILL RESERVE.

Low-Mice	Isopods	Beetles	Spiders	Earwigs	Moths	Millipedes	Centipedes
Sample 1	14	1	2	1	1	1	2
Sample 2	18	0	5	0	0	0	0
Average	16	0.5	3.5	0.5	0.5	0.5	1

To compare this set of data with invertebrate counts from a high-density mouse population, Dr. Belcher provided mouse population data supplied by the Greater Wellington Regional Council from the quarterly rodent monitoring at East Harbor Regional Park, conducted from the 10th to the 14th of February 2024. To represent the high-density mouse population (High-Mice), we used data from one tracking tunnel monitoring line that found mouse footprints in nine out of ten tunnels. Dr. Belcher aided us in extrapolating values for invertebrate populations in an area with a high mouse density. By considering which invertebrates are common in mouse diet, as well as the time of year, our team was able to create a dataset representative of a High-Mice area (Table 10). For example, the High-Mice samples were assumed to have fewer spiders, as these are a common component of mouse diet (Hewitt, 2021).

TABLE 10.

EXTRAPOLATED LEAF LITTER SAMPLING DATA.

High-Mice	Isopods	Beetles	Spiders	Earwigs	Moths	Millipedes	Centipedes
Sample 1	7	0	0	2	0	0	0
Sample 2	4	0	1	1	0	0	0
Average	5.5	0	0.5	1.5	0	0	0

Using the data from Tables 9 and 10 in the Ecological State Assessment Tool (ESAT), we calculated the Shannon Wiener Diversity Index (DI), an equation that quantifies the ecological diversity of an ecosystem (Appendix B) (Nolan & Callahan, 2006). In this case, the Diversity Index (DI) considers the number of invertebrate species present, as well as the counts for each, and outputs a numerical value. A higher number represents better invertebrate diversity in the ecosystem. The DI was 1.0163 for Low-Mice and 0.7605 for High-Mice. Because the Diversity Index of the Low-Mice invertebrate sample was higher than that of the High-Mice sample, the Low-Mice sample has better biodiversity, which is corroborated by the findings of articles in the literature analysis such as Watts et. al (2022): "less diversity among these tertiary and secondary consumers can decrease competition within these trophic levels, ultimately decreasing the diversity of prey" (p. 1195). The ESAT calculated the Ecological Index (EI) by weighing other datasets with the DIs of the leaf litter invertebrate dataset (Appendix B).

To understand the role of Māori peoples in invasive mice management, we used the ESAT to manipulate three Māori variables: Māori Cultural Acceptance of current predator eradication techniques, Māori Cultural Engagement in current predator eradication techniques, and Perceived Risk of Mice by Māori. We held *iwi* Capacity, or the capabilities or presence of *iwi,* constant. This helped identify if the inclusion of the other three Māori factors were beneficial to environmental health.

The Ecological Index (EI) was lowest when Māori Cultural Acceptance, Cultural Engagement, and Perceived Risk of Mice were absent (Figure 13). Simply having *iwi* present without Māori cultural acceptance or engagement in current eradications, and without *iwi* perceiving mice as a threat to environmental wellbeing, it is unlikely that the Predator Free 2050 goal will be reached.

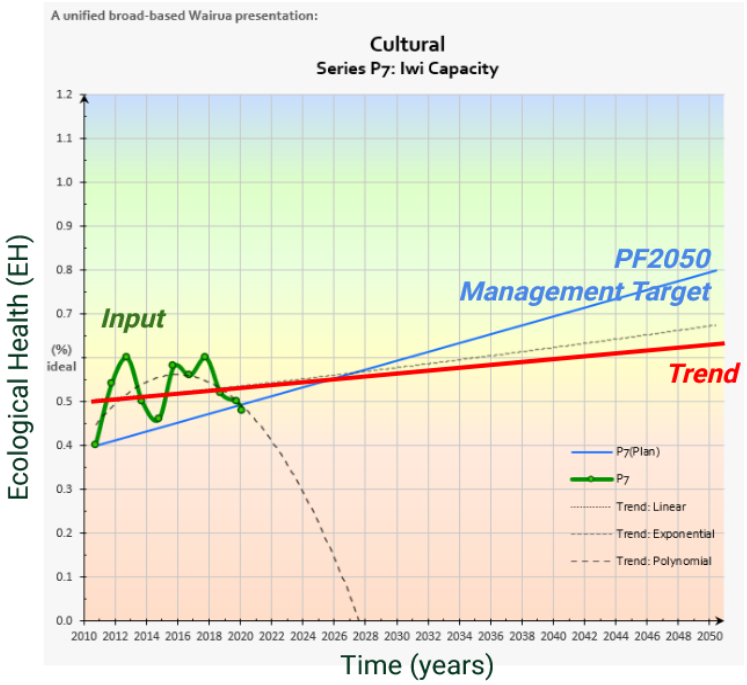


Figure 13. The Ecological Index (EI) outcome when Māori acceptance, engagement, and the perceived risk of mice are low. The red trendline does not meet Predator Free 2050 goals.

While increasing any one of these three factors alone did increase the EH, we found that the EI was highest when the Cultural Acceptance, Cultural Engagement, and Perceived Risk of Mice were all increased to their full capacities (Figure 14). ESAT shows that Māori acceptance, engagement, and the perceived risk of mice all complement each other, and might contribute to the improvement of ecological health in mice-infested environments.

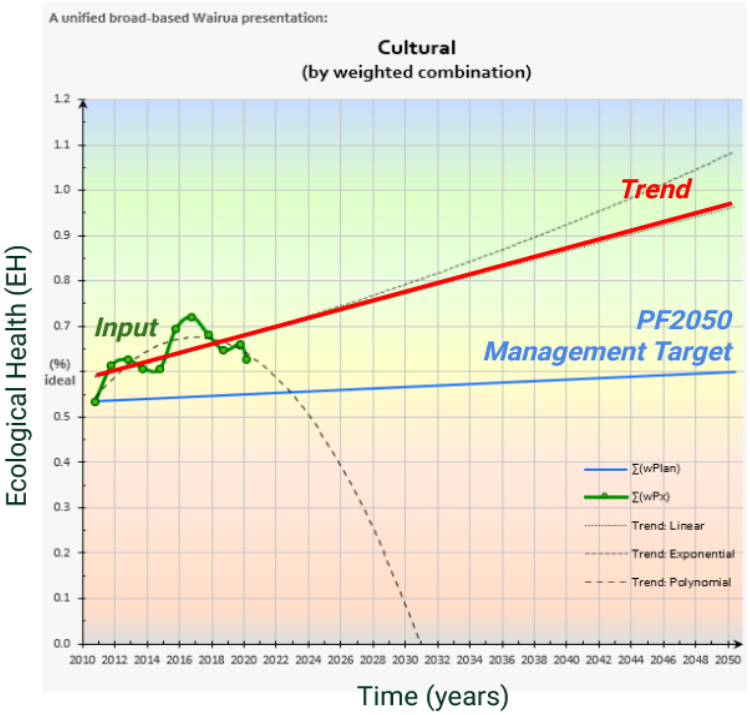


Figure 14. The Ecological Index (EI) outcome when Māori acceptance, engagement, and the perceived risk of mice are high. The red trendline exceeds Predator Free 2050 goals.

CONCLUSION OF FINDING 3

The Ecological State Assessment Tool (ESAT) suggests that the inclusion of Māori acceptance, engagement, and perceived risk of mice in invasive mouse management may benefit ecological health outcomes for invertebrates and other native species in Aotearoa.

FINDING 4: AREAS FOR FURTHER RESEARCH IN INVASIVE MICE BEHAVIOR

AREAS FOR FURTHER RESEARCH IN MICE BEHAVIOR IDENTIFIED IN LITERATURE

We sought to identify areas for further research from the analyzed literature. Most of the references under the **areas for further research code** were questions or areas of further research for mice and rats. We found 28% of the rodent mentions were about rats. This may indicate that many unanswered questions about the behavior of mice are intertwined with the behavior of rats.

A common theme in the 66 references to mice in **areas for further research** was the need for more accurate rodent monitoring. If populations of mice and their prey were better tracked, then one question that could be answered is the impacts that mice have on native species in Aotearoa. Samaniego et al. (2024) wrote that "most mouse impacts on biodiversity in NZ remain unknown, as threatened species are neither monitored in tandem with invasive predator dynamics nor with sufficient frequency and resolution to clarify the relationship" (p. 2). Samaniego et al. (2024) proposes this is because mice have been "understudied and therefore underestimated for decades" and they have "not [been] explicitly targeted (or even detected) during early rat eradications" (p. 2).

Across 29 total invertebrate references in **areas for further research**, numerous questions were raised about the difficulties of monitoring mice effects on invertebrates. For instance, Hewitt (2021) stated that "in any case it is difficult to know precisely how wētā are impacted by mice at different densities" (p. 75). Miller and Webb (2001) found there to be a significant "importance of invertebrates in the diet of feral house mice," but there is the "need for more detailed research into the largely ignored impacts of house mice on endemic invertebrate populations in New Zealand" (p. 54). To have a clearer understanding of mice behavior and their impacts on the environment, the "importance [of mice] as predators of endangered invertebrates" needs to be determined through further observations (Miller & Webb, 2001, p. 49).

Studying the impacts of mice on invertebrates is made more difficult due to there being an estimated 11,000 invertebrate species in Aotearoa, including wētā, beetles, and spiders (Hewitt, 2021). Ward and Larivière (2004) describe this phenomenon as the "taxonomic impediment" (p. 151), showing that the lack of data on invertebrate taxa makes it difficult to track predator impacts, particularly rats and mice. To analyze the conservation status of invertebrates, and other biota, the New Zealand Threat Classification database (NZTCS) classifies species into one of four categories:

data deficient, threatened, at risk, or not threatened. In 2021, more than 34% of NZTCS species were classified as "data deficient" (Figure 15) (Department of Conservation, 2023).

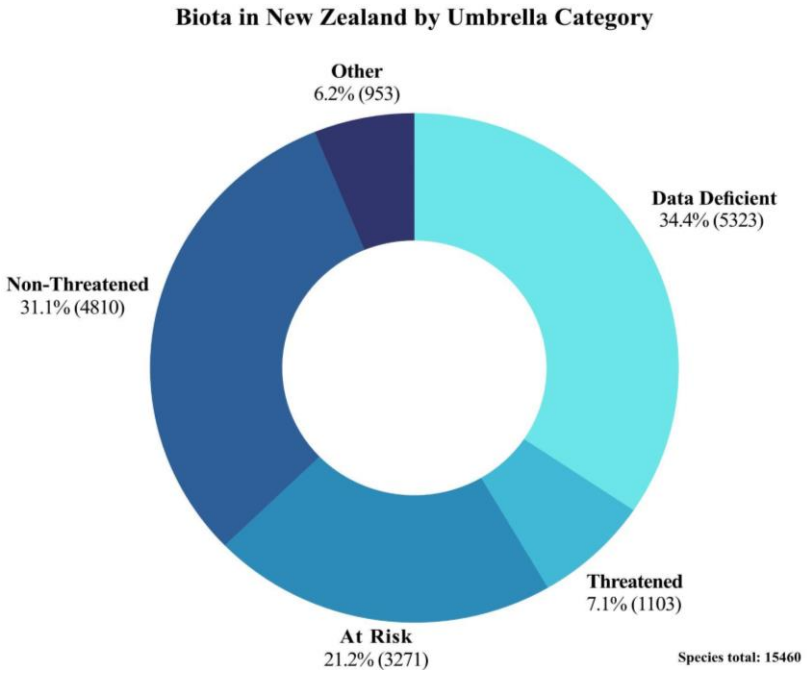


Figure 15. Data collected from the New Zealand Threat Classification Database (NZTCS), current as of 2021, on the conservation status of New Zealand biota (Department of Conservation, 2023).

Rat predation on mice in Aotearoa was largely unexplored in the literature set we studied and was only mentioned in 19% of rat references in **areas for further research**. Bridgman et al. (2018) explained that "[rat] predation may be common when mice are very abundant, but it is unknown if or how predation levels vary with mouse density, or whether ship rats could kill mice frequently enough to influence their abundance" (p. 253). Understanding the predation of rats on mice could aid in understanding the behavior of mice, including in the absence of rats.

Indirect and direct effects accounted for five references in **areas for further research**; this included the indirect influence of rodents on birds, through resource competition, and direct predation of mice on native birds. For instance, Angel et al. (2008) identified that "the impacts of mouse predation could be/become significant" when birds do not have a "strong nest defense or predator-avoidance instincts" (p. 1750). In addition to birds, we identified one mention of rodent effects on native reptiles in this set of literature. Watts et al. (2024) explained that "if mice can also be eradicated, and extirpated bird and lizard fauna can be at least partially restored by

translocation, then there may be even greater predation pressure on invertebrates from these native predators'' (p. 11). Increased exploration of mice impacts on native birds and reptiles, either by competition for resources or direct predation, could present a stronger basis for the inclusion of mice in PF2050.

The effects of climate change on mice were largely unstudied in this set of literature; we found only 4 out of 148 references in **areas for further research** mentioned climate change. Angel et al. (2009) stated that "The impacts of climate change may affect mouse populations… [with] higher densities at the start of the breeding season" and climate change has "the potential to increase mouse densities by enhancing terrestrial productivity" (p. 1749).

Another environmental factor to consider for future research is nitrogen fixation; only 3 references in **areas for further research** mentioned nitrogen. Angel et al. (2008) stated that, on Gough Island, "increased mouse densities in response to climate linked variables could be offset by reduced terrestrial productivity due to lower seabird densities and concomitant reduction in nitrogenous fertilisation" (p. 1749). During masting events, beech trees produce an increase in "plentiful nitrogenous food source[s]" like the rimu seed may result in mice population booms (Ruscoe et al., 2004, p. 263). Exploring the link between climate change, nitrogen fixation, and mice may prove beneficial in better understanding the behavior and population dynamics of mice.

KEY INFORMANTS SUGGEST THE BEHAVIOR OF INVASIVE MICE COULD BENEFIT FROM FURTHER INVESTIGATION

The effects of sodium fluoroacetate, or 1080, on mice was mentioned in several key informant interviews and in literature. Wright (2017) identified that "the effectiveness of 1080 in killing mice is variable, and research is needed to understand why" (p. 101). This highlights the need for further research into the effects of 1080 on mice. Janel Hull from the Department of Conservation said, "there are five new toxins in the process of getting registered, there is a lot of investment in this." Hull stated that the use of the controversial 1080 as a poison bait is an "emergency medicine," a short-term solution until a better alternative can be found.

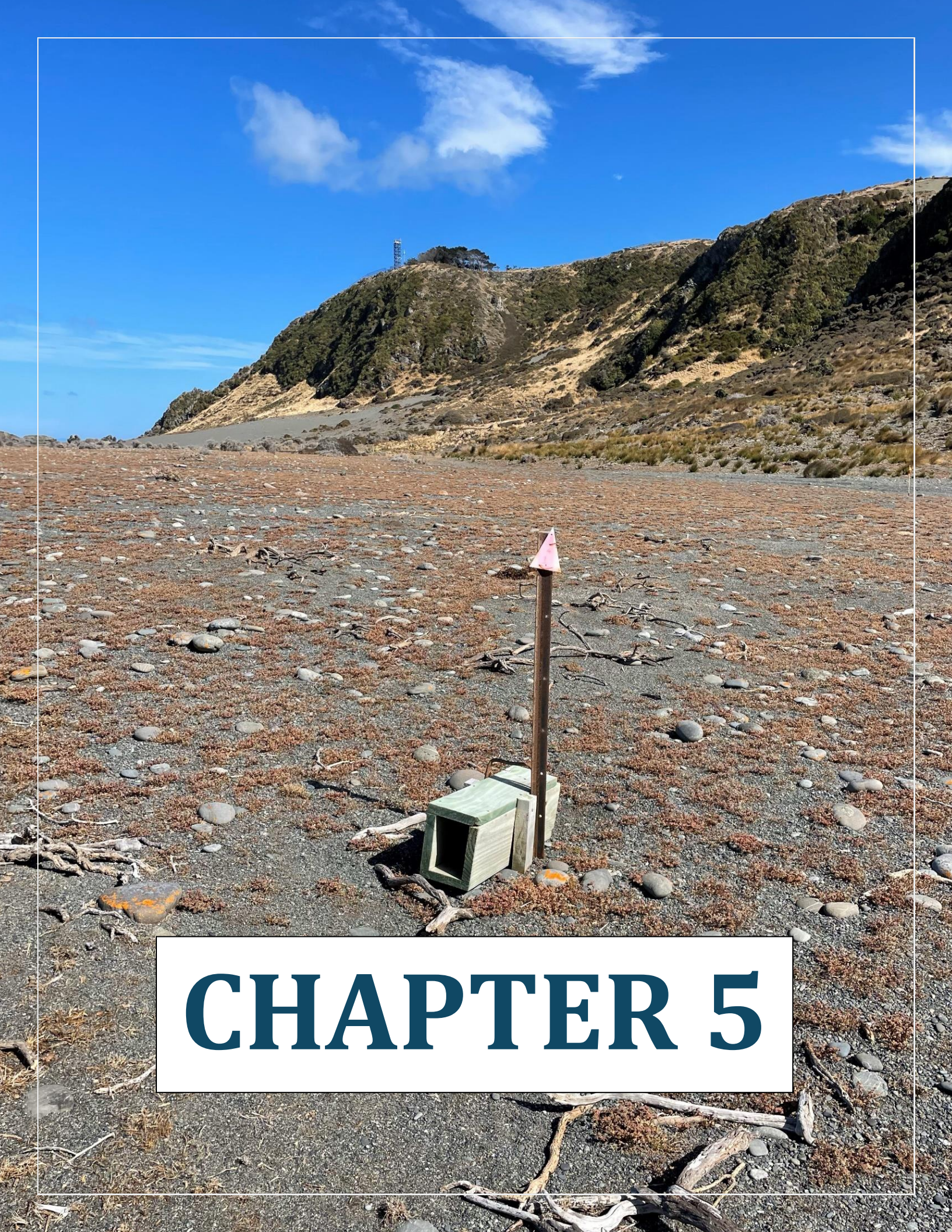
Additionally, Janel Hull described instances where mice would eat through the scalps of albatross that will not move because they are guarding their eggs (Figure 16). This contrasted typical examples of mice harming birds include mice eating eggs or fledglings. Becoming more knowledgeable about mice predation on larger birds could justify the implementation of active mice control measures to protect endemic birds and the basis for the inclusion of mice in PF2050.

Figure 16. Mouse "scalping" a wandering albatross chick (Dilley et al., 2015).

Likewise, Dr. Sara Belcher posed the question of whether lizards were impacted by mice, an idea which was supported by literature. Similar to the case of mice preying on mature birds, there was record of mice preying on mature reptiles. Samaniego et al. (2024) for instance, shared that "mice have been recorded preying on large … threatened skinks" (p. 4). This predation was also found to be significant as it caused a "strong decline in survival compared to a population protected from mice." This reinforces that further research into not only the risks posed to reptile eggs, but mature endemic reptiles such as skinks may be necessary.

CONCLUSION OF FINDING 4

We identified topics to better understand the impacts of mice as an invasive species in Aotearoa using information collected from our literature analysis and key informant interviews. Notably, this included mouse predation on birds and reptiles, as well as the role of nitrogen fixation and climate change on eruptions of mice populations.



CHAPTER 5

RECOMMENDATIONS AND CONCLUSION

The Predator Free 2050 (PF2050) initiative is accompanied by five-year action plans, which provide specific deadlines, strategies, and organization roles for that term. Upcoming PF2050 reviews and subsequent start of the next five-year action plan are due in 2026 and 2031 (Department of Conservation, 2020). The following recommendations which may contribute towards the realization of Māori-informed methods, and mice as a target species, in future PF2050 management plans. Our suggestions include researching topics such as climate change, wetland restoration, nitrogen fixation, and others to build upon the literature and Ecological State Assessment Tool (ESAT). More evidence can be collected supporting the inclusion of Māori-informed methods and mice as a target species in PF2050.

RECOMMENDATION 1: CONDUCT A MORE EXTENSIVE LITERATURE ANALYSIS

Although our literature analysis provided valuable insights, our findings were limited by the focused scope of our literature collection. An improved literature analysis could incorporate the following suggestions:

- We recommend that future literature analyses cultivate a robust set of coding criteria for Māori *ariā* by considering the perspectives of a range of Māori authors, scientists, or key informants.

- We recommend gathering a more extensive set of literature across multiple years, journals, and types of literature, regarding broader topics of predator eradication in Aotearoa. Literature in our analysis focused primarily on the impacts of mice on invertebrates.

- We recommend creating multiple NVivo projects, each utilizing the same codebook (collection of coding categories), to discern articles by type. This might entail separate projects for research articles, forum articles, review articles, and editorials. Our team found that the representation of Māori values between different types of literature varied greatly.

RECOMMENDATION 2: FURTHER EXPLORE THE ROLE OF MĀORI PERSPECTIVES IN MOUSE-INVERTEBRATE INTERACTIONS

Our literature analysis and key informant interviews were primarily focused on Māori perspectives regarding mice preying on invertebrates in Aotearoa. Some important topics arose from our **areas for further research codebook** and key informant interviews that could benefit from further investigation through a longer-term monitoring study observing the effects of mice on native biota in the field as investigated using the Ecological State Assessment Tool (ESAT). Our team utilized these topics identified by key informants and authors about mice eradication to inform research questions which connect to *mātauranga* (Māori traditional knowledge). We recommend that the following topics be explored in ESAT using data inputs from a long-term monitoring study:

- In the absence of other predators, mice become opportunistic and present a greater threat to the health of native *taonga* (treasured) species by harming eggs, youth, and adults of bird and reptile species. Can a better understanding of the structure and *mana atua* of the ecosystem help devise solutions that incorporate existing predator-prey relationships?

- Masting events provide opportunities for mouse populations to irrupt and devastate local ecosystems. With changes in climate, these events are becoming more frequent, ultimately leading to mice degrading the *mauri* of the ecosystem at great scale.

- The populations of mice and their negative impacts on invertebrates have been associated with changes in nitrogen fixation due to masting cycles and certain plant species. Could principles of *whakapapa* help better understand the role of nitrogen in the environment and how it may be leveraged to eradicate mice?

- Current baits, such as peanut butter, are generally reliable; however, it may be beneficial to explore the effectiveness of native baits, such as the Karaka fruit (Piata Hohaia, Personal Communication, 2024). Could the incorporation of baits, native to New Zealand, make existing poison bait traps more effective in rodent eradication?

- The reestablishment of native *taonga* predator species, like weka and eels, which can prey on small mammals could be a means of regulating rodent populations. What is the diet composition of key native predators, and would their predation on invasive mammals be significant enough to offset the damage they inflict on vulnerable native prey species in Aotearoa?

- Traditional harvesting practices of plants like Harakeke (Flax) for weaving is an example of reciprocity or caring for the environment. Are there overlaps between these harvested resources and invasive mammal diet? Could collaboration between Māori *iwi* and protected conservation areas serve to limit available resources for invasive mammals?

LIMITATIONS

Our ability to interpret or identify mentions of *mātauranga* Māori (Māori Traditional Knowledge) in literature was affected by our own professional, academic, and cultural biases. As engineers, we have been immersed in Western scientific methods throughout our education and have had little to no exposure to Indigenous Knowledge frameworks prior to this project. While we have read numerous articles about *mātauranga* Māori and interviewed several Māori individuals and experts in Māori studies, we recognize that as none of us are of Māori descent, it was crucial that we approached every angle of this project with caution, respect, and care regarding definitive claims. We recommend that teams review all annotations of Māori *ariā* as a group to minimize these individual biases in coding.

CONCLUSION

Our project aimed to highlight the value of considering Māori perspectives in the research of invasive mammalian predators. We sought to employ Māori perspectives to identify research gaps in literature and in the field surrounding which changes in Aotearoa's invertebrate populations are due to mice. Although concepts in Māori science were often discussed in a meaningful way, the amount of non-meaningful uses of Māori *ariā* (concepts) is substantial. In addition, academic research rarely actualized these concepts, rather Māori concepts were used to contextualize the research. There is a significant gap in the incorporation of Māori-informed methods in research on introduced species impacts in Aotearoa, in the sample of 57 articles we studied. Focusing on the larger mission statement of Predator Free 2050, Traditional Knowledge could work with Western practices, to help inform them.

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APPENDICES

APPENDIX A: IMPACTS OF RODENTS ON INVERTEBRATES

Rodents are omnivores with a diet consisting of both plants and invertebrates (Hewitt, 2021). Mouse diet varies based on habitat, but invertebrates, namely spiders and wētā, are a major dietary component (Badan, 1986; Watts et al., 2022). A 2011 study at Sanctuary Mountain Maungatautari, a mainland island South of Auckland, observed a decrease in invertebrate populations when mice were present, particularly "preferred diet taxa such as wētā" (Watts et al., 2022, p. 10). Mice can also cause major vegetation damage by consuming plants, which has a negative, indirect effect on invertebrates by hindering their ability to forage (Angel et al., 2009; Livingstone et al., 2022). Also, although mice seldom target birds, they still threaten some ground-dwelling birds and others with weak nest defense, such as Albatrosses and Storm-petrels (Angel et al., 2009; Broome, 2009).

APPENDIX B: SHANNON WIENER DIVERSITY INDEX FOR ESAT POPULATION DATA

CALCULATING DIVERSITY INDICES

The Shannon Wiener Diversity Index (DI) is a statistical tool used by environmental scientists to represent ecological health via the total number of species present in an ecosystem and the proportions in which they are present. Nolan & Callahan (2006) gives the following equation for calculating this index, where a higher number represents better ecological diversity, represented by *H'*:

$$H' = -\sum_{i=1}^{S} p_i ln(p)$$

S = the different species present

p = the proportion as a decimal of any particular species out of the total

ECOLOGICAL STATE ASSESSMENT TOOL DATA INPUT

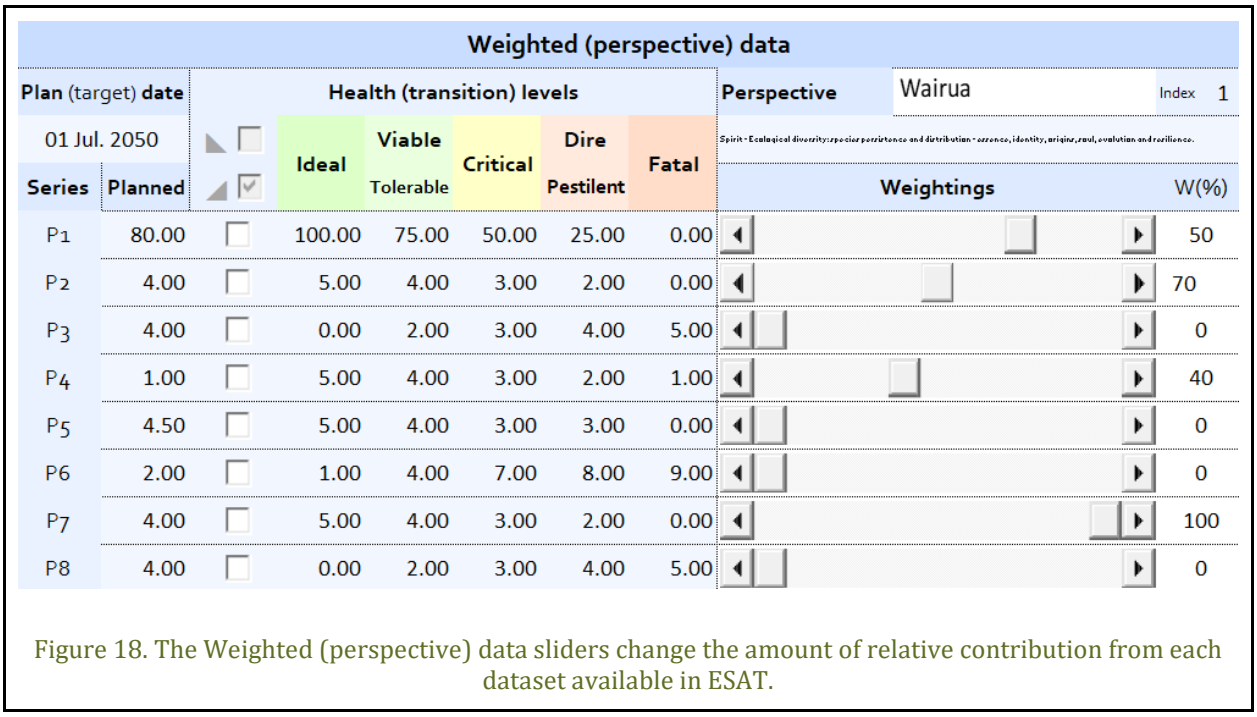
The main output of the ESAT includes multiple graphs predicting resource factors such as Māori individual attitudes on sanctuaries (survey data) or mice population size (field data) (Figure 17). This survey data includes a mixture of data collected and extrapolated by Dr. Sara Belcher for datasets on factors like cultural acceptance – defined as how much a Māori individual would approve of someone else in the community partaking in a predator intervention (Belcher et al., 2021). Each graph has time on the x-axis and a numerical index on the y-axis, which tracks the Ecological Index (EI) or general well-being of the ecosystem on a five-point scale from Critical to Fair and can give different prediction lines depending on the Māori perspective chosen. The prediction line is a linear or curved line on the graph that predicts if the selected factor will improve or not in the future. After the ESAT model is populated, the Māori *ariā* (weights) or data itself can be manipulated to isolate the impact of mice, for example, on invertebrates.

Record		Collector			Collected (raw) data								
No	Date	Name	Org.(Iwi)	mob.	Source (Ref.)	R1	R2	R3	R4	R5	R6	R7	R8
1	10/10/2010	Sara	VUW			80.00	2.00	79.00	60.00	20.00	5.00	1.02	0.76
2	2/16/2011	Sara	VUW			86.00	1.00	77.00	66.00	18.00	3.00	0.95	0.60
3	5/22/2011	Sara	VUW			70.00	2.00	75.00	59.00	17.00	2.00	0.99	0.65
4	8/10/2011	Sara	VUW			76.00	4.00	78.00	55.00	21.00	0.00	1.01	0.75
5	11/3/2011	Sara	VUW			79.00	5.00	80.00	61.00	22.00	1.00	1.03	0.80
6	2/16/2012	Sara	VUW			75.00	3.00	69.00	57.00	10.00	2.00	1.01	0.78
7	5/22/2012	Sara	VUW			82.00	4.00	66.00	54.00	12.00	3.00	0.97	0.72
8	8/10/2012	Sara	VUW			86.00	7.00	68.00	63.00	14.00	4.00	0.99	0.88
9	11/3/2012	Sara	VUW			71.00	8.00	65.00	68.00	15.00	4.00	0.90	0.79
10	2/16/2013	Sara	VUW			77.00	5.00	57.00	55.00	9.00	5.00	0.94	0.82

Figure 17. The Weighted (perspective) data sliders change the amount of relative contribution from each dataset available in ESAT.

Using Dr. Belcher's knowledge that mouse populations generally increase during warmer seasons, we extrapolated DIs for each season, filling in rows from 2010 to 2020. Higher DIs were given to the autumn and winter quarters, as mouse density decreases during these seasons, allowing invertebrate populations to flourish. It is important to note that the field work contributions of this project to the Ecological State Assessment Tool (ESAT) were minimal, and data was extrapolated to provide a basis of data for the comparison of prospects when Māori were and were not involved in predator eradication.

Following entry of our extrapolated field data, targets were set according to Dr. Sara Belcher's Predator Free 2050 target parameters. This is shown in the Ideal to Fatal categories in the "Weighted (perspective) data" panel and depends on the dataset (Figure 10). For example, it may be Ideal to have a larger number for Māori engagement but not Rat population. Then, the Weightings were adjusted to maximize Ecological Index (EI) (Figure 18).



Weighted (perspective) data

Plan (target) date		Health (transition) levels					Perspective	Wairua	Index 1
01 Jul. 2050		Ideal	Viable Tolerable	Critical	Dire Pestilent	Fatal	Spirit - Ecological diversity: species persistence and distribution - essence, identity, origins, soul, evolution and resilience.		
Series	Planned						Weightings		W(%)
P1	80.00		100.00	75.00	50.00	25.00	0.00		50
P2	4.00		5.00	4.00	3.00	2.00	0.00		70
P3	4.00		0.00	2.00	3.00	4.00	5.00		0
P4	1.00		5.00	4.00	3.00	2.00	1.00		40
P5	4.50		5.00	4.00	3.00	3.00	0.00		0
P6	2.00		1.00	4.00	7.00	8.00	9.00		0
P7	4.00		5.00	4.00	3.00	2.00	0.00		100
P8	4.00		0.00	2.00	3.00	4.00	5.00		0

Figure 18. The Weighted (perspective) data sliders change the amount of relative contribution from each dataset available in ESAT.

APPENDIX C: LITERATURE ANALYZED USING NVIVO

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APPENDIX D: FULL LIST OF NVIVO CODING CATEGORIES FOR THE LITERATURE ANALYSIS

Many of these definitions are founded on information received either by personal communication with Dr. Sara Belcher, or from her paper *Ecological State Assessment Tool (ESAT): a cross-cultural natural resource management tool from Aotearoa, New Zealand* (2021).

"Parent" and "Child" Coding Categories	Category Guidelines
Māori Science	Keywords, phrases, or sentences which mention Māori *ariā* (concepts)/values, topics in Māori traditional ecological knowledge, or Māori perceptions of mammalian predator management. If not stated explicitly, this may also include keywords, phases, or sentence(s) whose topics align closely with concepts in Māori knowledge systems, as informed by (Belcher et al., 2021).
➔ Whakapapa	Explicitly mentions "*whakapapa*," or mentions "community composition (richness or abundance)," connectedness, and "indigenous dominance" (Belcher et al., 2021, p. 471).
➔ Connectedness	Refers to the connectedness element of *whakapapa*, either in respect to the connection between all living things, or the connection between all living things and the land.
➔ Generational	Refers to the intergenerational aspect of *whakapapa,* especially in the context of inheriting from ancestors and safeguarding for descendants.
➔ Genetics	Refers to the nature of genes of the same and different organisms to flow organically, influence each other, and change over time.
➔ Mauri	Explicitly mentions "*mauri*," or mentions the concept of a life-force or integrity of an animal and its authenticity (Belcher et al., 2021, p. 471).
➔ Climate Change	Refers to the impacts that climate change may have on *mauri* through exacerbated natural conditions.
➔ Holistic	Refers to a holistic understanding of *mauri* which takes into account several factors to determine the ecological well-being or spirit.
➔ Indicators	Refers to the use of the *mauri* of a particular organism or some other sign to indicate the overall well-being of an ecosystem.

➔ Integrity	Refers to the originality of a species or organism that is seen in a positive light worth protecting in its own right.
➔ Translocation	Refers to the movement of a species or organisms of a species to another location, with particular focus on the resulting impact to *mauri*
➔ Taonga	Explicitly mentions "*taonga*," or mentions natural treasures that include the sky, land, species, and *rawa* or resources (Belcher et al., 2021, p. 471).
➔ Land	Refers to treasured parts of the land, water, and sky that ought to be protected for the sake of their own being.
➔ Sanctuaries	Refers to the use of sanctuaries to protect *taonga.*
➔ Species	Refers to treasured animal or plant species that ought to be protected for the sake of their own being.
◆ Birds	Refers to treasured bird species that ought to be protected for the sake of their own being.
◆ Invertebrates	Refers to treasured invertebrate species that ought to be protected for the sake of their own being.
◆ *Kiore*	Refers to treasured kiore species that ought to be protected for the sake of their own being.
◆ Mammals	Refers to treasured mammals species that ought to be protected for the sake of their own being.
◆ Reptiles	Refers to treasured reptile species that ought to be protected for the sake of their own being.
➔ Wairua	Explicitly mentions "*wairua*," or mentions the spirit of a land or species via its "ecological diversity," distribution, and essence (Belcher et al., 2021, p. 471).
➔ Biodiversity	Refers to the biodiversity of an ecosystem.
➔ Spirit	Refers to the spiritual elements related to an ecosystem.
➔ Kaitiakitanga	Explicitly mentions "*kaitiakitanga*," or mentions the act of guardianship or responsibility that those who belong to a land (*tangata whenua*) have in taking care of the land (Belcher et al., 2021, p. 471).
➔ Holistic view	Refers to broadening the definition of *kaitiakitanga*, either with respect to who may be classified as a guardian or with respect to an increase in their responsibilities.
➔ Collaboration	Refers to the collaborative element conducive to practicing *kaitiakitanga.*

➔ Conflict	Refers to disagreement about either who classifies as a *kaitiaki* (guardian), or in the execution of practicing *kaitiakitanga.*
➔ Exclusion	Refers to the exclusion of certain people, usually academics, from being *kaitiaki* (guardians), but can also extend to different *iwi* too for example.
➔ Volunteer	Refers to the involvement of individuals who help manage the environment and land.
➔ Waitangi	Refers to the Treaty of Waitangi.
➔ Mana atua	Explicitly mentions "*mana atua*," or mentions "habitat quality," "ecosystem functions," and "structural diversity" (Belcher et al., 2021, p. 471).
➔ Adjustment	Refers to adjustments or changes in the food webs, hierarchies, or any other forms of structure in an ecosystem.
➔ Structure	Refers to strength or stability in food webs, hierarchies, or any other forms of structure in an ecosystem.
Mouse Diet	Keywords, phrases, or sentences which mention foods consumed by mice. Items mentioning mouse predation on
➔ Plant Life	Mentions plant or seed life in relation to the diet, activity, or populations of mouse, rat, or other predators.
➔ Masting	Mentions mouse diet or behaviors in reference to masting cycles or high annual/ seasonal fruiting by trees or shrubs. Can be referred to as a "temporary bonanza" (King, 2023).
➔ Impacts on Birdlife	Mentions mouse diet in relation to predation on bird eggs, chicks, or youth. May also mention mouse impacts on birdlife due to competition for resources; if this the case in relation to competition for invertebrates, also code for **Mouse and Invertebrate Interactions.**
➔ Invertebrates	Mentions mouse diet in relation to predation on invertebrate species. Does not expand upon how this predation impacts invertebrate populations/behavior as a whole, or how invertebrate populations/ behavior impact mice activity.
Invertebrate Interactions	Keywords, phrases, or sentences which mention mammalian predator behaviors in the presence of invertebrates and/or their impact on invertebrate populations.

➔ Mouse and Invertebrate Interactions	Mentions mouse predation on invertebrates and/or impacts of mice on invertebrate populations. This may also include the influence of invertebrate populations/behavior on mice activity.
➔ Rat and Invertebrate Interactions	Mentions rat predation on invertebrates and/or impacts of rats on invertebrate populations.
➔ Other Mammal and Invertebrate Interactions	Mentions other mammalian (stoat, weasel, possum, cat, etc.) predation on invertebrates and/or impacts of that mammal on invertebrate populations.
Rat and Mice Interactions	Keywords, phrases, or sentences which mention the impacts of the presence/absence of mice or rats on the behaviors and populations of one another.
Current Interventions	Keywords, phrases, or sentences which mention eradication or management strategies for invasive mice.
➔ Baiting	Mentions poisons, baits, or anticoagulants utilized to manage or reduce mice populations.
➔ Trapping	Mentions the use of trapping technologies to manage or reduce mice populations.
➔ Genetic Modification	Mentions the potential of genetic modification (Single Sex Offspring Selection, etc.) as a method of managing or reducing mice populations.
➔ Eradication Difficulties	Mentions the challenges of eradicating mice, or reasons why mice are targeted less frequently as a mammalian predator of concern.
➔ Eradication Interference	Mentions an introduced species interfering with eradication measures put in place for a different species.
➔ Feasibility	Mentions feasibility challenges, such as monetary cost, larger scalability, or labor needs.
➔ Cost	Discusses feasibility challenges due to monetary cost or lack of funding.
➔ Scale	Discusses feasibility challenges related to scaling up eradication measures.
➔ Ineffective Control	Mentions that an eradication method did not work to eradicate a particular introduced species.
➔ Lack of Knowledge	Attributes difficulties with eradication to a lack of knowledge.
➔ Mesopredator Release	Mentions the increase in an introduced species' population due to the eradication of another introduced species.

➔ Reinvasion	Mentions the return of predator species to an area where they had previously been eradicated.
➔ Mice	Discusses reinvasion of mice.
➔ Rats	Discusses reinvasion of rats.
➔ Taonga or Valued Species	Mentions a *taonga* (treasured) species or a species valued by hunters.
➔ Multi-method Approach	Mentions the use or benefit of using multiple management practices simultaneously.
Areas for Further Research	Typically found in the Results/Findings or Discussion sections of journal articles, this category includes keywords, phrases, or sentences which mention research topics which have not yet been explored but should be in the future. This may also include information about limitations or gaps in the author(s) research process. This category might overlap with **Eradication Difficulties**.
➔ 1080	Mentions a problem or unexplored suggestion regarding the design of or use of 1080 or Sodium Fluoroacetate.
➔ Animals	Mentions a problem or unexplored suggestion regarding one of the following subcategories.
➔ Birds	Mentions a problem or unexplored suggestion regarding birds.
➔ Hedgehogs	Mentions a problem or unexplored suggestion regarding hedgehogs.
➔ Invertebrates	Mentions a problem or unexplored suggestion regarding the design of or use of 1080 or Sodium Fluoroacetate.
➔ Amphipods	Mentions a problem or unexplored suggestion regarding amphipods.
➔ Arachnids	Mentions a problem or unexplored suggestion regarding arachnids.
➔ Arthropods	Mentions a problem or unexplored suggestion regarding arthropods.
➔ Moths	Mentions a problem or unexplored suggestion regarding moths.
➔ Wētā	Mentions a problem or unexplored suggestion regarding wētā.
➔ Mammals	Mentions a problem or unexplored suggestion regarding mammals.

➔ Possums	Mentions a problem or unexplored suggestion regarding possums.
➔ Rodents	Mentions a problem or unexplored suggestion regarding rodents.
➔ Mice	Mentions a problem or unexplored suggestion regarding mice.
➔ Rats	Mentions a problem or unexplored suggestion regarding rats.
➔ Stoats	Mentions a problem or unexplored suggestion regarding stoats.
➔ Ungulates	Mentions a problem or unexplored suggestion regarding ungulates.
➔ Biotech	Mentions a problem or unexplored suggestion regarding biotechnology.
➔ Climate Change	Mentions a problem or unexplored suggestion regarding climate change.
➔ Māori Questions	Mentions a problem or unexplored suggestion regarding the execution of Māori values in interventions.
➔ Nitrogen	Mentions a problem or unexplored suggestion regarding nitrogen fixation and effects on population booms.
➔ Sanctuaries	Mentions a problem or unexplored suggestion regarding sanctuaries.

APPENDIX E: SEMI-STRUCTURED KEY INFORMANT INTERVIEW TEMPLATE

Introductions
Our names are Ronit, Laura, Matt, and Drema. We are a team of third-year undergraduates from the U.S. working in partnership with Dr. Sara Belcher (Victoria University Wellington). We are utilizing Māori perspectives to identify the gaps in research surrounding the change in ecological health due to invasive mice on Aotearoa's fragile ecosystem. We are hoping to better understand a range of perspectives and attitudes about invasive predator management through semi-structured interviews.
We wanted to speak to you because of your expertise/involvement in/as an active member of [insert affiliation or organization here]. Please introduce yourself and tell us more about your background/ profession.
Project Specific Questions
What does a healthy ecosystem look like to you? What does it include? How would you define your relationship to *momo* Māori (native species) in Aotearoa? How do you think that relationship has changed over the past decade or so? How do rats and mice affect your work with Predator Free 2050? How have rats and mice affected your personal life, if at all? How do you believe rats and mice are affecting the land and *momo* Māori?
What does ecosystem management mean to you? The Predator Free 2050 initiative is working to remove rats and mice from Aotearoa. What are your thoughts on this effort? How do you think that Predator Free 2050 accounts for the health and well-being of *Papatūānuku* (the land)? What are your thoughts on measures that governmental agencies or environmental organizations in Aotearoa have taken to protect native species from invasive predators? How do you think the government is handling invasive species management? Do you think they are taking into consideration *mātauranga* Māori and Māori values?
Should all introduced predators be removed from Aotearoa?

Do you think Aotearoa has been successful in the removal of predators thus far?

What would it take to resolve the issue of introduced predators in Aotearoa?

Concluding the Conversation

Thank you for taking the time to talk with us today. We value your perspectives on the health of the ecosystem in Aotearoa. If you have any follow up questions, please feel free to contact us at the NZ-24-Mice email alias.

APPENDIX F: TYPES OF PUBLICATIONS FROM LITERATURE ANALYSIS

Concepts in Māori Science are Predominant in Discussion-Style Articles

In the 57 articles we coded for the literature analysis, we identified five publication types:

(1) Research articles: An author reports on the research/experiment they conducted.

(2) Forum articles: An author presents an overview of a topic to better inform the reader.

(3) Review articles: An author analyzes published material.

(4) Editorials: An author includes their own opinions.

(5) White papers: A government agency outlines a problem with a solution.

We found that all six review articles, four of five editorials, and four of five forum articles included mentions to Māori values. This contrasted with research articles, where less than half (16 out of 39) had mentions of **Māori science** (Table 11). In total, 88% of discussion-style articles we analyzed (editorials, forum articles, and review articles) featured Māori values versus 41% of research articles. It is important to note that despite there being significantly more articles from the New Zealand Journal of Ecology, we found the article type to be more correlated with the frequency of Māori values than journal-type.

TABLE 11.

FREQUENCY OF MĀORI VALUES ACROSS DIFFERENT PUBLICATION TYPES.

Quantity of Publications that Mentioned Māori Values			
Article Type	**Sorting Criteria**	**Mentioned Māori Values**	**Total # of papers**
Research articles	Author reports on original research that they conducted and performs data collection	16	39
Editorials	Articles with a strong opinion	4	5
Forum articles	Explicitly stated to be a forum article	4	5
Review articles	Explicitly stated to be a review article	6	6
White Paper	Written by the Department of Conservation for public release	1	2
		31	57

We sought to understand whether there was an association between publication type and references under the **Māori science** code. To accomplish this, we created two groupings of the articles which had referenced Māori values or concepts: (1) research articles (included methodology and result sections); (2) editorials, forums, and review articles (had general body content, but rarely included methods or results). This distinction was essential, given that editorials, forums, and review papers are generally discussion-based pieces which might be more likely to discuss concepts of Māori Traditional Knowledge explicitly. For example, *Connecting Science to Indigenous Knowledge: Kaitiakitanga, Conservation, and Resource Management* (McAllister et al., 2023), a forum article, accounted for more than half of all mentions of *kaitiakitanga* in the literature we analyzed. Isolating research articles further provided the opportunity to determine if **Māori science** concepts were applied substantially throughout a research project or experiment.

The New Zealand Journal of Ecology (NZJE) is a journal funded by over 550 members of The New Zealand Ecology Society (NZES). In our literature analysis, 47% of the articles we coded were from the NZJE; the next closest journal, Biological Invasions, accounted for only 5%. Furthermore, 52% of publications with Māori mentions were from the NZJE, much greater than Biological

Invasions at only 6% (Table 12). Literature coded from NZJE varied from editorials and review articles to research and forum articles.

TABLE 12.

PUBLISHERS OF JOURNAL ARTICLES BY COUNT AND MENTION OF MĀORI VALUES.

Journal Publications Incorporating Māori Values in Literature Analysis		
Journal Publication	**Mentioned Māori Values**	**Total # of publications**
NZ Journal of Ecology	16	27
Biological Invasions	2	3
NZ Journal of Zoology	1	3
Other journals (≤ 2 publications total per journal)	12	24