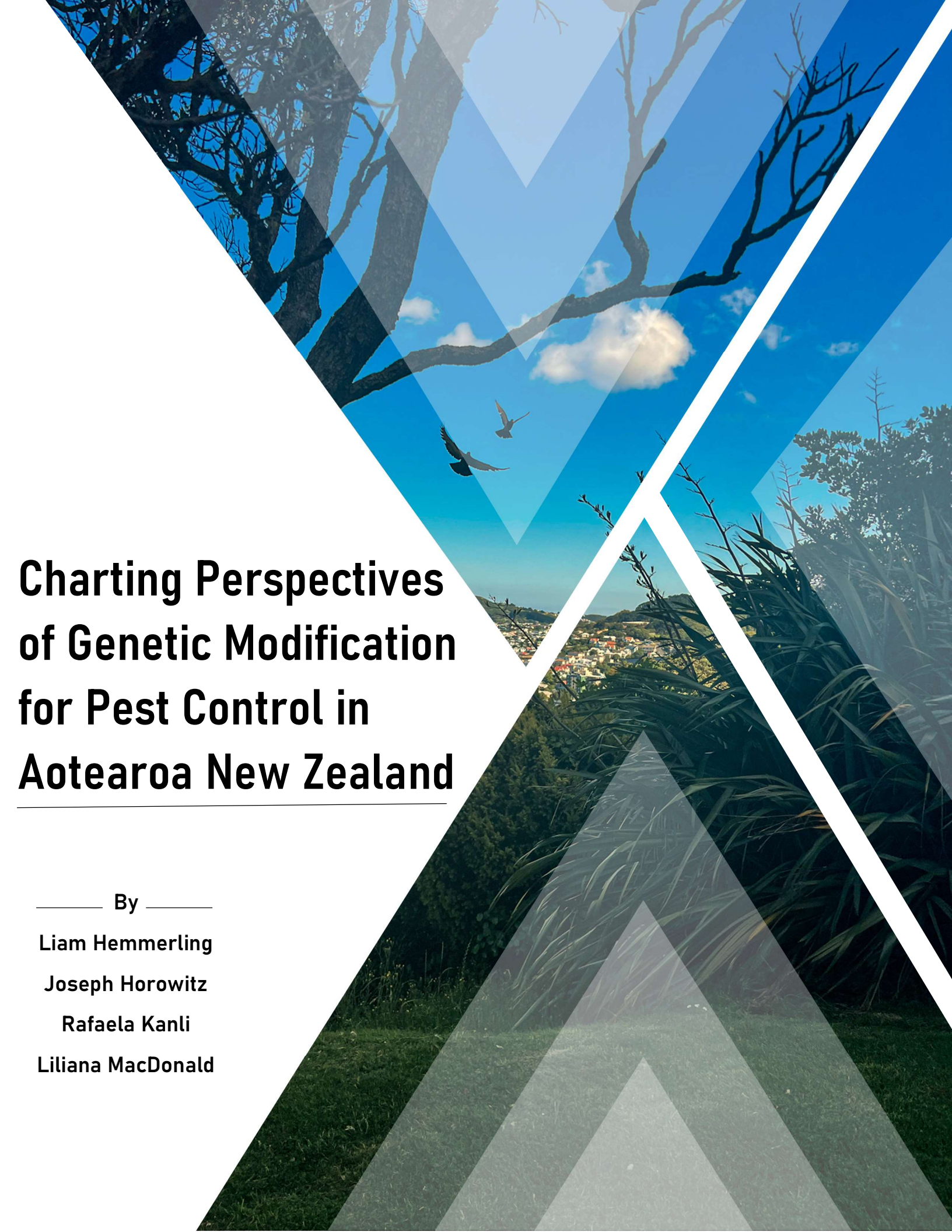

Charting Perspectives of Genetic Modification for Pest Control in Aotearoa New Zealand

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Abstract

Aotearoa New Zealand focuses on pest control to preserve the country's fragile biodiversity. Genetic modification presents a potential strategy for pest control, but it raises complex ethical, social, and political viewpoints. We collaborated with Dr. Ocean Mercier to chart researchers' and environmentalists' perspectives on gene-based pest control, which furthers her goal of understanding Aotearoa's opinions on novel biotechnologies for conservation. Through the Q-Method, we organized shared views on gene-based pest control, which will help Aotearoa reach its goal of being a predator-free country.

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Executive Summary

Aotearoa New Zealand faces numerous challenges in preserving the country's fragile biodiversity from damaging pests. Pest species cause multiple problems within the ecosystem of Aotearoa. Pests prey on and endanger native species threatening the natural balance of ecology. Exploring interventions to control pest populations or to lessen their environmental impact is crucial. Current pest control methods include trapping and pesticides. Another potential solution to the problem is genetic modification, such as gene drive or single-sex offspring selection, to control pest species.

The concept of genetic modification for pest control has raised complex ethical, social, and political viewpoints globally, but it also offers promise for a resolution to Aotearoa's problem. There are concerns that genetic modification could have unintended consequences that could permanently threaten the well-being and biodiversity of the ecosystems. Some residents prioritize protecting taonga species and preserving Aotearoa's biodiversity. Others may be less aware of the options for pest control or have no strong opinion. Therefore, finding an environmentally safe, socially acceptable, and efficient method to control pests is vital to maintaining Aotearoa's biodiversity.

In 2016, the Aotearoa government announced a goal of becoming predator free by 2050. This goal set up a company known as Predator Free 2050 Ltd. The Predator Free 2050 agenda focuses on eliminating all non-native predator species from Aotearoa by 2050. Understanding community support is essential for the Predator Free 2050 agenda, as community involvement is necessary for the program to succeed. With a better understanding of the perceptions of the communities in Aotearoa, the Predator Free 2050 program will be able to focus resources on pest control techniques that are widely accepted.

The goal of this project was to chart social perspectives of genetic modification for pest control in Aotearoa. With this goal in mind, we determined three objectives needed to be met:

- Understanding Aotearoa's general perceptions of gene-based pest control
- Gaining experts' and environmentalists' perspectives on gene-based pest control
- Charting the subjectivity of gene-based pest control

Our approach to complete these objectives included content analysis on gene-based pest control, Q-Method, and creating factor narratives. The content analysis summarized public opinions about gene-based pest control into a collection of statements. These statements touched upon the eight themes we found from current media about gene-based pest control: religion, power, ethics, environment, safety, economy, knowledge, and social. The Q-Method studied the subjectivity of people's ideas, beliefs, and opinions on gene-based pest control. The Q-Method participants included researchers, scientists, environmentalists, and pest control volunteers in the Wellington area and the suburbs around the city. The Q-Method found shared viewpoints on gene-based pest control. Subsequently, we measured these findings through the PQMethod software. This software organized the views on gene-based pest control by clustering similar views.

The PQMethod software revealed areas of agreement and disagreement and sorted the interviewees into three groupings called "factors." These factors represented groupings of participants based on similar viewpoints on gene-based pest control. Additionally, the PQMethod software showed the statements that the factors prioritized over others, which connected to the key themes that the factors valued most. After we analyzed each factor's similarities, we defined each factor that the PQMethod software created.

- Factor 1's participants strongly supported the use of gene-based pest control to achieve the Predator Free 2050 goal.
- Factor 2's participants endorsed the use of gene-based pest control but had an emphasis on the need for Treaty partners to agree upon.
- Factor 3's participants were untrusting of gene-based technology or needed more knowledge to make an informed decision on gene-based pest control technologies.

With the results and analysis of the data that the PQMethod software produced, we made several recommendations and added to the greater knowledge of genetic modification for pest control. By charting researchers' and environmentalists' perspectives on gene-based pest control, our research furthers Dr. Ocean Mercier's goal of understanding Aotearoa's opinions on novel biotechnologies for conservation. The following recommendations offer a series of actions to build upon our findings.

Recommendations about research and communication:

- We recommended that Predator Free community accelerate work towards the Predator Free 2050 goal by destigmatizing gene-based best control.
- We recommend that researchers prioritize the Predator Free 2050 goal by conducting more research on the safety and security of genetic modification.
- We recommended that researchers, professors, and scientists collaborate to provide educational programs that teach the public about genetic modification for pest control and make information on the topic more accessible.

Recommendations about Treaty partners:

- We recommended that government officials and rūnanga (Māori governing council) decide whether to implement genetic modification in pest control by including them in participant samples for future related studies.

These recommendations suggest the next steps to expand upon our research and carry on with efforts to protect Aotearoa's biodiversity. In the future, our project's comprehension of perspectives on genetic modification for pest control will aid Aotearoa in achieving its goal of a nation without pests.

Authorship Page

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Chapter 1 Introduction

Aotearoa New Zealand faces numerous challenges in preserving the country's fragile biodiversity from damaging pests. Pest species cause multiple problems within the ecosystem of Aotearoa. Pests prey on and endanger native species threatening the natural balance of ecology. Exploring interventions to control pest populations or to lessen their environmental impact is crucial. Currently, the country's system for environmental preservation focuses on trapping and pesticides ("Animal Pest Control", n.d.). Another potential solution to the problem is genetic modification, such as gene drive or single-sex offspring selection, to control pest species.

The concept of genetic modification for pest control has raised complex ethical, social, and political viewpoints globally, but it also offers promise for a resolution to Aotearoa's problem. There are concerns that genetic modification could have unintended consequences that could permanently threaten the well-being and biodiversity of the ecosystems. For some residents, protecting taonga species and preserving Aotearoa's biodiversity is a priority ("Why Biodiversity Matters", 2021). Others may be less aware of the options for pest control or have no strong opinion. Evaluating these perspectives of gene-based pest control[1] technology is essential to learn what people think of the potential solution before it can be implemented.

In 2016, the Aotearoa government announced a goal of becoming predator free by 2050. This goal set up a company known as Predator Free 2050 Ltd. The Predator Free 2050 agenda focuses on eliminating all non-native predator species from Aotearoa by 2050. Understanding community support is essential for the Predator Free 2050 agenda, as community involvement is necessary for the program to succeed. With a better understanding of the perceptions of the communities in Aotearoa, the Predator Free 2050 program will be able to focus resources on pest control techniques that are widely accepted.

Dr. Ocean Mercier, the project sponsor, has completed prior research to understand perceptions of novel pest control technologies. The goal of this project was to expand on this idea by charting perspectives of genetic modification for pest control in Aotearoa. To achieve this goal, we completed three objectives:

[1] Genetic modification for pest control (i.e., gene drives or single-sex offspring selection).

1. We understood general perceptions of gene-based pest control by summarizing public opinions into a collection of statements.
2. We gained experts' and environmentalists' perspectives on gene-based pest control by designing and administering the Q-Method.
3. We charted the subjectivity of gene-based pest control by interpreting the Q-Method results, which developed into three main groups of clustered views.

These results helped us make future recommendations to our partners, stakeholders, and suggest future studies following the results of the Q-Method. This project contributed data to the work of ethical environmental co-governance to ultimately help protect the biodiversity of Aotearoa.

We organized the paper as follows. Chapter 2 provides background research to understand Aotearoa's pest problem, potential gene-based pest control methods, and the Q-Method. Chapter 3 outlines our objectives and completion of each objective. Chapter 4 displays our results and analysis from utilizing content analysis on gene-based pest control, the Q-Method, and factor narratives. Chapter 5 presents recommendations based on our results and analysis from Chapter 4. Finally, Chapter 6 is our conclusion, which summarizes the whole paper.

Chapter 2 Literature Review

Many factors come into play with the large-scale problem of eradicating pests from Aotearoa to preserve its natural biodiversity. While Aotearoa supports efforts from individuals, community projects, and whole movements to resolve this matter, understanding the public positions on pest control provides insight into solutions. This chapter explores Aotearoa's fragile ecosystem, partners, and stakeholders while giving information on potential gene-based pest control methods in greater depth.

2.1 Understanding Aotearoa's Fragile Ecosystem

The history of Aotearoa's ecosystem is important for understanding the need for pest control to preserve its native species. The group of islands that separated from Gondwana 80 million years ago formed present-day Aotearoa (Parke et al., 2019). The island nation's flora and fauna have flourished, growing a rich biodiversity native to the land. The "taonga," or treasured species, include kiwis, native frogs, and tuatara that roam the island's lush forests. Additionally, black-eyed geckos, giant wētās, and powelliphantas are among the native species that hide in Aotearoa's rugged mountains (Hutching & Walrond, 2007).

Before human settlements arose in Aotearoa, bats were the only mammals on the island. Without mammalian predators, indigenous wildlife and natural ecosystems thrived (Dilks et al., 2020). Aotearoa was one of the last regions in the world that humans began to inhabit, as intrepid Polynesian ancestors of the Māori people migrated to this new land between the 1200s and 1300s (Parke et al., 2019). Upon initial human arrival, the Polynesian rat (*Rattus exulans*) appeared on both main islands of Aotearoa in 1280 (Wilmshurst et al., 2008). Colonization by European settlers and immigrants from other origins in the 1800s led to the introduction of more new species to the land. For example, settlers accidentally introduced ship rats (*Rattus rattu*) to Aotearoa, which became prevalent on the North Island by 1860 and South Island by 1890 (Atkinson, 2012).

The introduction of new inhabitants to Aotearoa, whether intentional or accidental, has led to changes in the ecosystem and differing opinions on the state of the environment. The debate about the impact of pests and actions to remove them increased as time went on

with some efforts to improve the balance. Both Māori and non-Māori (Pākehā) are concerned by the disappearance of fragile native species caused by pests like stoats, rats, possums, and ferrets (Parke et al., 2019). These pest species, which feed on native fruits, birds, eggs, insects, and snails, have caused a dramatic change in the ecosystem (Dowding & Murphy, 1994). The people of Aotearoa came together to protect their environment by commencing an organized removal of small non-native predators in the mid-twentieth century.

To take a more formal approach to mitigate pests, Aotearoa passed the Hazardous Substances and New Organisms (HSNO) Act in 1996, which requires approval to bring new organisms or create potentially dangerous substances in Aotearoa (Ministry for the Environment, 2001). In addition, the Te Urewera Act (2014) and Te Awa Tupua Act (2017), which were part of the Whanganui River Claims Settlement, emphasized the importance of preserving and supporting the land's biodiversity by giving it environmental personhood and a voice in legislation (Parke et al., 2019).

Through our background information research, we have gained a better understanding of the challenges Aotearoa is facing and the various potential outcomes that may arise. To that end, we appreciate the greater cause that this project advances, in alignment with UN Sustainable Development Goal 15: Life on Land (Figure 1) (United Nations, n.d.). This goal works to protect biodiversity around the world by reducing land degradation, preventing ecosystem imbalance, and protecting endangered species (United Nations, n.d.).

Figure 1: The logo of UN Sustainable Development Goal 15: Life on Land.

To protect Aotearoa's fragile ecosystem, former prime minister John Key introduced the Predator Free 2050 program in 2016 to completely rid Aotearoa of the stoats, ferrets, weasels,

rats (Norway, ship, and kiore), and possums, the five most problematic predators within the country, by 2050 ("New Zealand to be Predator Free", 2016). These introduced predators cause approximately 25 million native bird deaths annually (New Zealand Government, n.d.; "What is Predator Free 2050?", 2022). As there are over 4,000 native species currently threatened, the need for public support for the program is evident. This program is a main stakeholder that we discuss in more depth. Improving our understanding of how key stakeholders view this program will increase the chances of its success.

2.2 Partners and Stakeholders

Eliminating all non-native pests from Aotearoa will enable the native species to reestablish themselves across the island (New Zealand Government, n.d.). By assessing the opinions of key stakeholders (Dr. Mercier, Predator Free 2050 community, and researchers) we can gain insight into their views on the ethics, efficiency, and technology involved in implementing pest control methods. The sponsor of this project, Dr. Mercier, works as an Associate Professor of Physics and Māori studies at Victoria University of Wellington. Dr. Mercier's work "focuses on how mātauranga [traditional Māori knowledge] and science connect and relate, particularly in educational and environmental contexts" (Victoria University of Wellington, n.d.). Dr. Mercier's mission is to educate the public on pest control methods, explicitly analyzing Māori perspectives on potential genetic modification techniques. Analyzing the Māori perspective involves protecting the natural ecosystem and native organisms,valuing sustainable efforts, building awareness of the interconnection of different ecosystems, and proposing holistic solutions (The Law Foundation, 2018). Dr. Mercier's work fundamentally supports the Predator Free 2050 program.

Those involved in the Predator Free 2050 program are another key stakeholder within this project. To achieve the Predator Free 2050 goal, those involved in the program must support the techniques used to eradicate the pest species. With the results from this project, the individuals involved in the program can start to predict how the community will respond if Aotearoa implements gene-based pest control technologies in the future. Experts and scientists in the gene-based pest control research community are additional key stakeholders in this project. As scientists are continuing to develop the technology, their research needs

more funding and time to move gene-based pest control strategies into field usage. Because these researchers are still working on refining and understanding gene-based pest control technologies, they require support from various stakeholders (Carter et al., 2022). To gain understanding of perspectives on gene-based pest control technology, the technologies themselves must first be understood by the researchers.

2.3 Pest Control Strategies

There are many ways to control pests. They range from trapping to utilizing pesticides, diverse and often combined strategies can protect humans, their property, and the ecosystem (Hickle et al., 2022). New methods, such as genetic modification, have aided this fight as this technology has advanced (Broeders et al., 2020). Here, we highlight some primary techniques surrounding genetic modification that will be part of our pest control assessment discussion.

Genetic modification is a strong contender in the battle to control pests (Leftwich et al., 2020). Genetic modification can alter pest species' genes to prevent them from reproducing further or attacking certain parts of the ecosystem. The strategy requires genetic information to be inserted or deleted from species' genes to alter how they act (Resnik & Vorhaus, 2006). Scientists can either take the new genetic information from the genes of other species or use artificial genetic information. With this technology, there are many uses for genetic modification. For instance, implementing single sex offspring selection for reducing rat populations and gene drive for wasps are potential applications.

Gene Drive

CRISPR-based gene drive, or gene drive, increases the chance of a particular gene appearing in future generations. A gene can be copied and inserted into the genome by identifying a particular part of the genome, as shown in Figure 2 (Esvelt & Gemmell, 2017). Therefore, this genetic information is more ubiquitous in the genome and likely present in the offspring (Courtier-Orgogozo et al., 2017).

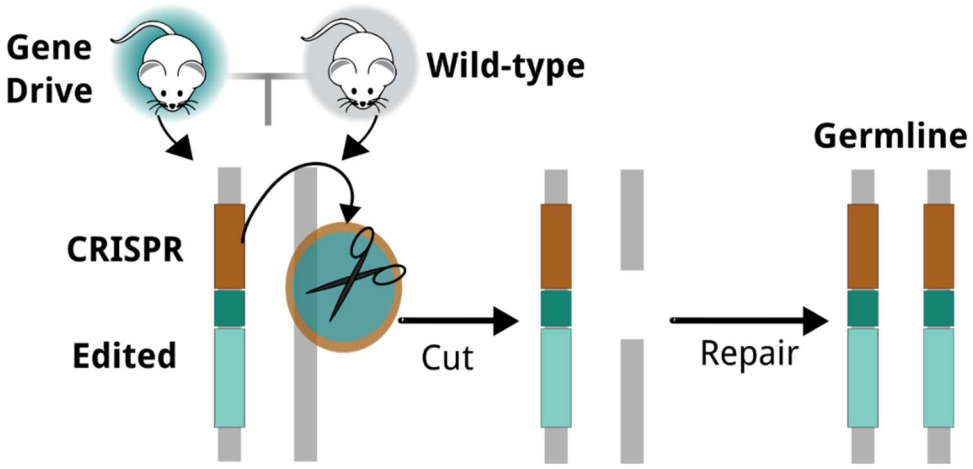

Figure 2: The insertion of an edited, cut gene into an organism's germline[2].

Gene drive would allow for the accessible introduction of a gene into the population. Scientists can insert the engineered genes directly into the species. Gene drive is different from other forms of gene editing, where a scientist would have to develop a relationship with the species. This relationship would last generations and encourage breeding, whereas gene drive is a "direct manipulation" (Courtier-Orgogozo et al., 2017). Once the engineered genes are in the species, humans do not have to do much work. The gene quickly passes through reproduction and can spread through the population quickly, as seen in Figure 3 (Esvelt & Gemmell, 2017; Lester et al., 2020). While the quick spread of the modified gene may help eradicate a species of pests quickly, unforeseen consequences could arise if a genetic mutation were to occur. The gene insertion could cause the entire modified species to die off or cause them to start preying on other species (Courtier-Orgogozo et al., 2017).

[2] Genetic material that is inherited to the offspring.

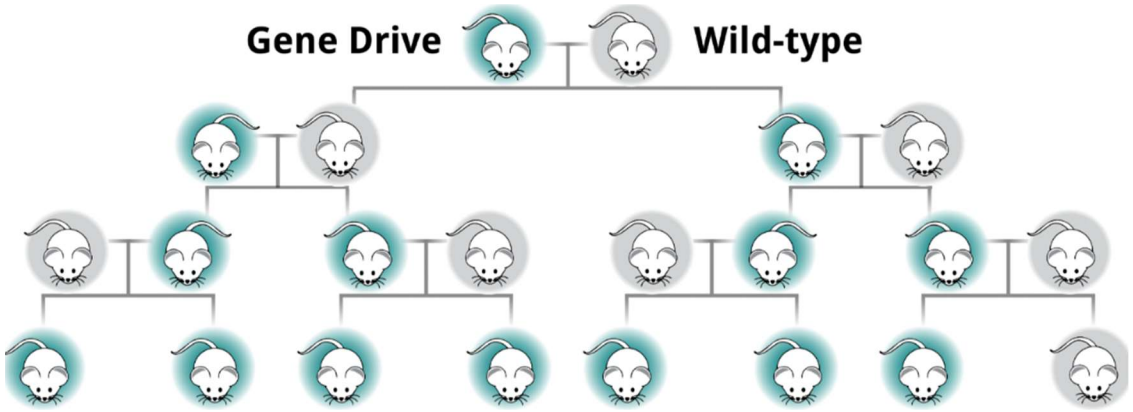

Figure 3: The gene drive organisms passed down the edited gene to all other generations.

Single-Sex Offspring Selection

Single-sex offspring selection (SSOS) or sex selection is a commonly practiced technology with many applications. SSOS is a form of genetic modification that alters the embryo, so scientists can decide the desired sex (Liao, 2005). Genetic engineering can determine and select the sex of an organism. In eutherian mammals, a mammal with a placenta to support the development of offspring, the presence of a Y chromosome determines the sex of the offspring. For example, if a Y chromosome is present in rats, the offspring will be male; if it is not, the offspring will be female. Offspring can receive an edited gene using CRISPR technology, which leads to only a single sex being born; this is much easier to accomplish by editing the genes of the homogametic sex or the sex with two identical chromosomes. In mammal species, the female is the homogametic sex, meaning it is easier to bias the offspring to be only female using current technology (Douglas & Turner, 2020). With SSOS, scientists can erase one sex from the population and inhibit a species' reproduction. If these species were known predators of another species, choosing only males would help the prey population as, over time, the predator species would not reproduce as much.

On the other hand, in a declining population, the number of females could increase through sex selection. With more females, we can increase the population size (Martínez-Ruiz & Knell, 2016). However, ethical concerns acknowledge that reproductive selection can lead to extinction (Douglas & Turner, 2020). Therefore, consideration for those species

directly affected must occur before attempting to eradicate pests.

2.4 Perspectives-Mapping for Environmental Policy Decisions

Looking at similar research on various perspectives about genetic modification for pest control helped us consider ideas to understand the possible outcomes of our study better. Before applying new technology or other methods to solve Aotearoa's pest control challenge, it is vital to acknowledge residents' values and beliefs, including Māori and non-Māori frameworks (Black et al., 2021). A research team from the Victoria University of Wellington developed a project in 2020 to understand Māori opinions on pest control, specifically for wasp eradication, to acknowledge the different beliefs regarding the biotechnology aspect (Palmer et al., 2020). Three studies within the project addressed three distinct groups of people.

Study 1 tested university students studying Māori courses in science and indigenous knowledge. These students mapped regions where wasps were a personal or public issue (Palmer et al., 2020). The students took one of three positions for the deployment of biotechnological controls for managing pest wasps: the majority saw a possibility, a smaller minority had reservations, and a third group reported that they trusted scientists to make the call. This result helped us consider trends in people's views about genetic modification for pest control, in which some people might be in support, hesitant, and trusting.

Study 2 focused on Māori businesses in the agricultural field that could have a positive impact from wasp control through a survey/interview data collection. Views of Māori enterprises on biotechnology controls ranged from rejection to acceptance; however, many were hesitant or unable to express their opinions; thus, there was a definite need for more information. Similar to this study, we needed to acknowledge that some people might be hesitant towards genetic modification for pest control because of their lack of knowledge.

Lastly, Study 3 assessed Māori participants with strong religious and philosophical beliefs. Before participating in the study, all groups were knowledgeable about the five potential biocontrols[3] (CRISPR/Cas 9, gene drive, RNAi, sex selection, NVivo coding)

[3] Biotechnological for pest control that include CRISPR/Cas 9, gene drive, RNAi, sex selection, NVivo coding.

(Palmer et al., 2020). Most Māori who were spiritual or religious saw opportunities for biotechnology. Their engagement with technology was active and multifaceted, posing new social, cultural, and spiritual issues. However, two small groups of Māori who were spiritual or religious had strong reservations about biotechnologies (Palmer et al., 2020). This result helped us to understand that we should recognize religion and spirituality as important influences in perspectives of genetic modification for pest control. These three studies' findings helped us to generate a wide range of views on implementing genetic modification for pest control.

There were some unifying ideas between these investigations. Participants indicated that *Tikanga* (customs and protocols) and *ma Tauranga* (Māori knowledge) is relevant to the discussion, and they were highly opposed to "doing nothing" about pests as well as non-targeted management approaches, such as poisons (Palmer et al., 2020). Many factors come into play and influence an individual's perspective on methods to achieve successful pest control. While these perspective-mapping cases reached out to only the Māori community, they guided this project's study to do the same work for the scientists' and environmentalists' perceptions.

To further understand the complexity of opinions on pest control, we looked at another study that expressed perceptions of pest control technologies. The Pacific Conversation of Biology published a study in 2020 that provided insight into the complex art of perspectives-mapping regarding genetic modification. This study consisted of a survey to research indigenous people's perceptions of current and future technologies for pest control on a scale from 1 (strongly disagree) to 7 (strongly agree) (Black et al., 2021). The scale measured objective and subjective scientific knowledge and objective and subjective pest control knowledge.

The difference between objective and subjective knowledge, as shown in Table 1, was important to consider when we aimed to understand people's perspectives on pest control. This study helped us conclude that the participant's objective knowledge of gene-based pest control affected their subjective knowledge in our project.

The difference between scientific and pest control knowledge, as shown in Table 1, was crucial because it helped us understand the lack of knowledge in an individual's understanding of science and pest control. In our project, we considered whether the

participants' scientific knowledge affected their pest control knowledge.

Table 1: Different types of knowledge that impacts perspectives on gene-based pest control.

	Scientific Knowledge	**Pest Control Knowledge**
Objective Knowledge	The unbiased, balanced facts that a participant knows about science and genetic modification which can be verified.	The unbiased, balanced facts that a participant knows about pest control and minimizing the effects of pests which can be verified.
Subjective Knowledge	The participant's opinions, assumptions, and interpretations about science and genetic modification.	The participant's opinions, assumptions, and interpretations about pest control and minimizing the effects of pests.

The survey results revealed clusters of common viewpoints on scientific knowledge around pest-control methods such as sex selection, gene drives, poisons, and trapping. One cluster highlighted the large difference between objective and subjective knowledge about understanding people's views on new technology for pest control. Like the cluster results in this study, we grouped similar perspectives on gene-based pest control using the Q-Method to understand the differences between each group in our study (explained in Chapter 4). Keeping the range of opinions at the center is a priority and the key to success when discussing new technologies.

2.5 Q-Method Selection Reasoning

For this project, we chose to use Q-Method as our approach to chart perceptions on gene-based pest control. To address concerns of "what" or how," researchers use the Q-Method approach to study the subjectivity of people's ideas, values, and beliefs. Users can find the shared viewpoints on a subject using the PQMethod software, which reveals areas of agreement and disagreement. We chose to use the Q-Method to study complex issues. Subsequently, though factor analysis (explained in Section 3.3), the software simplifies the complexity to an extent by condensing participant viewpoints into a smaller set of shared viewpoints.

Another important note worth mentioning about using the Q-Method is the sample size. Q-Method requires a relatively small sample size. Usually, participants represent 1/3 of the statement cards of the Q-Grid used. In our case, using a 34-cell Q-Grid (Figure 4, Section 3.2), a

sample size of around 12-15 participants was enough to interpret meaningful results. For the scope and timeline of this project, a relatively low participant requirement was essential. While this number of participants represents a relatively small population, the diversity of the sample carries more weight than its size in terms of statistical significance (Mercier et al., 2019).

2.6 Summary

With the help of various stakeholders and initiatives such as the Predator Free 2050 program, Aotearoa is working to eradicate pests within the country. Genetic modification introduces a new strategy for pest control; however, we must listen to the discussion around this technology before implementing it. We learned the importance of recording the community's voice and understanding their perspectives from recent studies to achieve our project's goal. Additionally, the outcome of this project added to the background knowledge of gene-based pest control and incorporated various perspectives to decide whether to use this technology.

Chapter 3 Methodology

The goal of this project was to chart social perspectives of genetic modification for pest control in Aotearoa. The following three objectives enabled us to meet this goal:

- Understanding Aotearoa's general perceptions of gene-based pest control
- Gaining experts' and environmentalists' perspectives on gene-based pest control
- Charting the subjectivity of gene-based pest control

This chapter presents the methodology used to achieve each objective.

3.1 Understanding Aotearoa's General Perceptions of Gene-Based Pest Control

To gauge perspectives on gene-based pest control, content analysis of news media and other public platforms helped measure public conversations on pest control and genetic modification. The content analysis included current events found within publicly available newspaper articles, government policies, news segments, documentary film clips, or social media videos created in the past ten years. The search terms we used were related to genetic modification for pest control, as shown in Table 2. We used Google, Google Scholar, YouTube, National Center for Biotechnology Information Bookshelf, *Nature*, *New Zealand Herald*, *The Atlantic*, and Taylor & Francis Online to search the listed terms in Table 2.

Table 2: Search terms for content analysis.

Key Terms	Genetic modification	Pests	Control	Perspective
Related Terms	Gene drive	Invasive species	Management	Views
	Sex selection	Non-native species	Eradication	Outlooks
	Gene technology	Introduced predators	Regulation	Attitudes towards

As detailed in Appendix A, we individually read different articles and found themes throughout the articles. From these themes, each group member created about ten statements that they believed would be beneficial to use for the final Q-Method assessment, as shown in Appendix A. Then, we created categories that fit overarching themes throughout the articles we read, as shown in Table 3. These categories aimed to encapsulate a broad range of consideration areas for participants.

Table 3: Overarching themes found in content analysis. Each color corresponded to a theme and will be used as such throughout the paper.

Themes	Significance
Religion	This theme recognized a system of beliefs and the act of worship. It encompassed the idea of spirituality by acknowledging a sense of connection to something greater than oneself.
Power	This theme recognized humans' drive for control and strength. It entailed the capability to influence nature and people.
Ethics	This theme recognized moral principles and defined right from wrong behavior. It included the ideas of trust, ideals, and virtue.
Environment	This theme recognized concerns about nature and the effects on nature. It entailed both living and non-living things in the ecosystem.
Safety	This theme recognized the health, well-being, and protection from dangers. It included the prevention of risks and hazards.
Economy	This theme recognized the financial, business-related, and monetary concerns. It encompassed the idea of gaining benefits or profiting from an endeavor.
Knowledge	This theme recognized the facts an individual knows. It entailed the information about a particular topic.
Social	This theme recognized the relationships between others. It included the connections humans had with society or a particular group.

For the religious theme, it was important to acknowledge spirituality and belief systems as considerations for supporting or rejecting gene-based pest control. For example, some people view gene-based pest control as superhuman power and a manipulation of God's title to control life (Eicheibaum et al., 2021). Believing in something bigger than humans swayed people's view on genetic modification. By including spirituality as a specific consideration in the concourse[4], this religious theme helped us distinguish whether individuals valued religion over other themes.

Similarly, we incorporated power in the concourse by addressing the concept of humans "playing God" and world leaders in scientific discovery. Some people saw gene technology for pest control as a way for humans to push beyond their limits in nature, resulting in human dominion (Mercier et al, 2019). The concept of humans "playing God"

[4] The final collection of Q-Method statements.

had a religious interpretation, as some individuals thought genetic modification for pest control gave humans the power to act as God, in this sense. For example, some participants who were atheists disagreed that genetic modification allowed humans to decide which organisms get to live or die. Additionally, it was significant to recognize that implementing genetic modification for pest control would make Aotearoa a world leader in pest eradication (Russell & Broome, 2016). People who valued power and fame viewed gene-based pest control as a tactic for global esteem. We included human power in the concourse to identify whether these views matched participants' opinions on genetic modification for pest control.

Ethics was a highly debated topic in the conversation around genetic modification for pest control throughout media. We created specific statements focused on animal rights, consent, and trust to represent this theme. In media, many scientists and environmentalists see pest control as a war, so the search for an ethically acceptable method is most appealing to them. The Journal of Agricultural and Environmental Ethics published a research article that depicted 1080 toxins as warfare against animals, which caused animal suffering (Morris, 2019). The history of 1080 toxins sparked attention on animal cruelty and the ethics of pest control. Therefore, it was essential to consider animal rights when representing public positions on gene-based pest control. Some people have different views on which species are pests in Aotearoa, so some people may think consent to use gene technology on a specific pest species does not equate to consent to use on another pest species (Palmer et al., 2020). To demonstrate, a participant could see the ship rat as a candidate for gene-based pest control but could not see a plant pest as a candidate for gene-based pest control.

Another noteworthy consideration was the ethicality of science and the trust in scientists and the government. Currently, there is some hesitation to fully trust scientists to provide a safe solution for pest control because of the concerns with genetically modified organisms for crops and food (Fritsche et al., 2018). Some people expressed their lack of trust in the government by doubting its inclusivity. In the past, the government undermined Treaty values, which caused a negative ripple effect of distrust (Palmer et al., 2020). All of these components of gene technology for pest control were crucial to include in the statements, so we could understand if people thought this method is in accordance with ethics.

The most prominent theme across media was the environment, ranging from a discussion on mauri (life essence), climate change, Predator Free 2050, and population

changes. Many people feared gene-based pest control would damage mauri (life essence) because it would increase other invasive species (Lester et al., 2020). The off-target effects of gene technology for pest control worried people, so wavering opinions on implementing this method were important to include in the statements. The *New Zealand Herald* released a news article that expressed views on the hot summer climate increasing rat breeding ("Climate Change's Hot Summers", 2019). Mentioning climate change as a possible stimulus for using gene-based pest control was useful to include in the statements. This idea tested if people agreed that this method would solve the explosion of pest populations due to global warming. This concourse must reference the Predator Free 2050 goal as the goal encourages people to act efficiently when controlling pest numbers. Some people believe Aotearoa will not achieve Predator Free 2050 without gene-based pest control because trapping, baiting, and poisons will take too long to eradicate pests (Scott & Penman, 2019). By including Predator Free 2050 in the concourse, we distinguished whether individuals prioritized this goal and believed gene-based pest control was crucial to reaching it. Additionally, it was essential to include statements about population changes, such as impacts on the food web and worldwide pest species eradication. There is controversy around the idea that if Aotearoa removed a pest species like ship rats, it would cause the food web to collapse because other organisms might depend on ship rats for food (Myszkowski & Cieplak-Mayr von Baldegg, 2019). Some people view gene-based pest control as an existential threat to life on Earth because it would wipe out pest species internationally (Palmer et al., 2020). We incorporated these topics of mauri, climate change, Predator Free 2050, and impact on population into the concourse to represent people's environmental concerns and gauge how much they valued them above other concerns.

The safety of gene-based pest control appeared as a common issue in many pieces of media. To represent this theme, we introduced laboratory use and causes of harm as specific components to the concourse. Individuals who were hesitant towards genetic modification required a precautionary approach to implementing it outside the laboratory (Dearden et al., 2017). This precautionary approach related to the social theme of listening to different perspectives on gene-based pest control for decision-making processes. Consequently, themes often overlapped in the concourse, showing that some statements had multiple ideas that factor into a participant's opinion. Views that expressed uncertainty about genetic

modification causing harm to native species were relevant in discussions (Morton, 2021). Harm to native species could encompass an alteration in the food web or an increase in food competition, which connected to the environmental theme. Addressing safety as a key consideration in the perspective of genetic modification for pest control allowed individuals to share how much they cared about it.

The effect on Aotearoa's economy was a frequent concern across current perspectives on genetic modification for pest control. It was significant to mention the views about keeping hidden agendas, enhancing the economy, providing more funding, and using resources. Some perspectives depicted skepticism about gene-based pest control, such as corporations or the government keeping a hidden agenda from the public (Dixson et al., 2022). By proposing the idea that people viewed gene-based pest control as a part of a hidden agenda, we allowed them to voice their opinions on conspiracy theories. The idea of a hidden agenda suggested that corporations or the government kept information or received benefits from implementing genetic modification. This opinion related to the ethics theme because some people refrained from trusting checks and balances systems. On the financial aspect of genetic modification for pest control, some people believe that this method would be economically efficient (TEDxYouth@Christchurch, 2019). With gene-based pest control, time and energy would not be wasted on maintaining traps. Furthermore, whether it would take too long to implement gene-based pest control provided insight into efficiency. Currently, some people see trapping and hunting as a direct way of eradicating pests, and others see it as a waste of resources because gene-based pest control could do the work for them. Bringing attention to economic effects allowed us to see how much people prioritized money, efficiency, and conspiracies.

Various sources of media discussed knowledge as a component of the public positions on gene-based pest control. These positions comprised sufficient information and communication about gene-based pest control. It was crucial to acknowledge if people had enough information on genetic modification to count in the decision-making process. Some people felt that accessibility to understanding the mechanics and limitations of gene-based pest control was inadequate (Dearden et al., 2017). Open communication about gene-based pest control would help people learn more about this method to make an informed decision whether to support it. In addition, statements on knowledge allowed us to measure whether

people's understanding of genetic modification impacted their opinions on gene-based pest control.

Considering the social aspects of gene-based pest control, we chose to incorporate ideas about mātauranga (knowledge) Māori, Treaty/Tiriti partners, guardianship, personal satisfaction, overall agreement, and individual opinion accountability. Currently, Aotearoa acknowledges Māori perspectives, but there is a need for more emphasis on Treaty relationships. For example, Pacific Conservation Biology published a research article that considered rangatiratanga (Māori self-rule) and Tikanga (Māori practices) as a focus for discussing genetic modification for pest control (Palmer et al., 2020). By including Māori culture as a specific consideration in the concourse, this religious theme helped us distinguish whether individuals valued the social theme over other themes. Many environmentalists were passionate about killing pests because they knew they were making a difference in protecting the natural ecosystem (King & Scurr, 2014). Therefore, it was important to gauge whether people would approve of gene-based pest control even if it meant they would sacrifice a direct sense of satisfaction. Utilizing gene-based pest control if only everyone agrees poses a utopian outlook on society, which is important to address in the concourse. Overall agreement is ideal for choosing to implement this method and testing if people value this opinion above other considerations. Including a statement about individual opinion accountability allowed us to identify if individuals think Aotearoa values their views. This result is helpful for us to make recommendations for improving social considerations in future gene modification decisions. In addition, the variety of statements required participants to prioritize them based on their values, showing that it was important to incorporate each theme in the concourse.

An expert with Q-Method, Alan Hunt, also added multiple statements which were effective to use for our set of statements. Next, we sorted all statements into categories. As a team, we went through each category and identified overlapping statements and especially useful statements to measure a participant's perception of gene-based pest control. This process enabled us to reduce the original forty statements down to thirty-four, as shown in Appendix B. Prior to administering the Q-Method interview, both Alan Hunt and Dr. Mercier reviewed the statements and gave suggestions back to the team. After all the edits were made and Dr. Mercier gave her final approval, the statements were printed out. These broad

perspectives helped us prepare a range of perceptions about gene-based pest control to create effective statements for the Q-Method, explained in Section 3.2.

3.2 Gaining Experts' and Environmentalists' Perspectives on Gene-Based Pest Control

Our second objective to meet our goal was designing a Q-Method assessment. This method was used for our interview process and provided us with information on different perceptions of gene-based best control. This method worked by positioning different statements about gene-based pest control on a grid scale from strongly disagree (-4) to strongly agree (+4) from left to right, with zero signifying neutral (Figure 4).

In the Q-Grid[5] sample structure, the bell curve shape of the grid allowed participants to place more statements in the neutral zone, as participants typically had more neutral opinions about the statements. Additionally, the Q-Grid required participants to place fewer statements in the strongly opinionated cells (-4, +4). The participants provided a reason behind the placements of the statements in the strongly opinionated cells.

[5] A grid in the shape of a bell curve with a negative to positive scale.

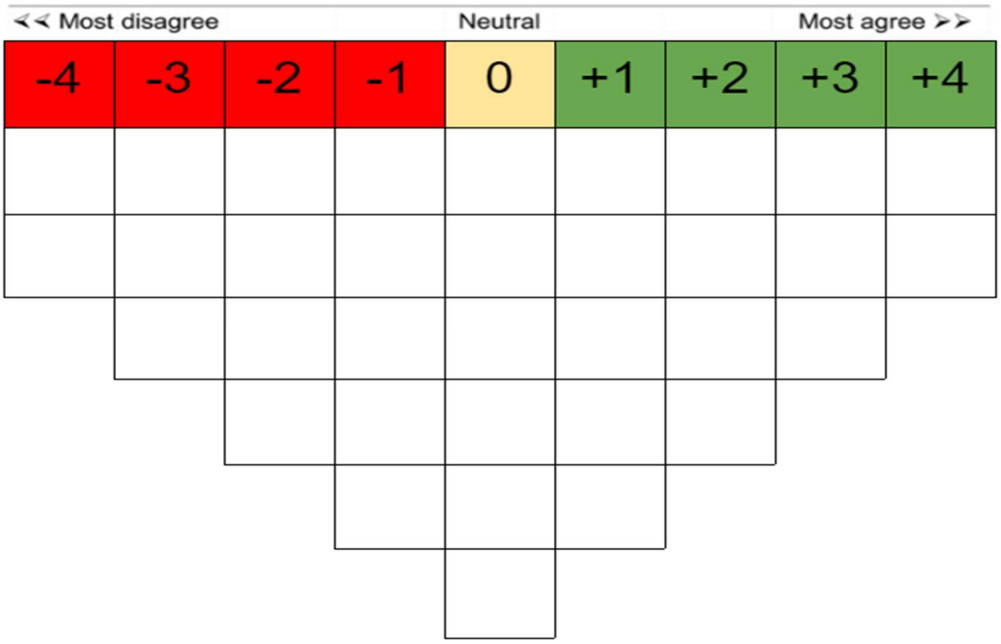

Figure 4: A Q-Grid sample structure.

Once we developed our Q-Method statements, we identified participants interested in environmental issues, such as rat and wasp control volunteers, selected researchers working on pest control projects, and academics from Victoria University of Wellington. We were interested in an environmentally educated sample set because of their knowledge and experience in protecting Aotearoa's biodiversity. Furthermore, our participant sample included academics from the science department to engage with professors, lecturers, and graduate students who were familiar with genetic modification. While not representative of the entire population of Aotearoa, this group of individuals were representative of the people working to implement this technology in the future. We did not select participants based on ethnicity, gender, or age range. However, most of the participants were from Wellington and the surrounding suburbs. Additionally, Figure 5 shows the age ranges for each participant interviewed.

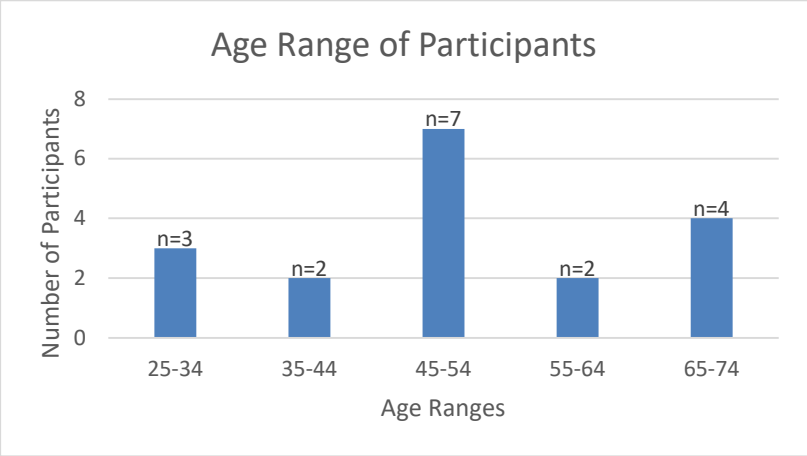

Figure 5: Age ranges for all participants interviewed.

Researchers of this study recruited potential participants by emailing an invitation with this study's goals, as shown in Appendix C.

For the interview process, we chose to conduct interviews with two interviewers (a facilitator and a note-taker), and one interviewee. We began the interview by asking interviewees a few questions about their experience with pest species, experience with pest control programs, and prior knowledge of gene-based pest control technologies, as shown in Appendix D. We asked them to complete consent and demographic information forms, as shown in Appendix E. The introductory questions allowed us to break the ice with the participant and begin discussion on their knowledge of gene-based pest control methods. After, we provided the participants with thirty-four statements and asked them to place them on the grid according to their own opinions and beliefs. Each statement was a double-sided card with an identifying number on the back that helped us analyze the data subsequently. To further our engagement with participants, we facilitated a post-discussion about the challenges that the participants faced when placing the statements. This conversation pinpointed the participant's feelings of uncertainty when it came to choosing the placements of specific statements. The post-discussion provided us with additional data to interpret the Q-Method results. We audio-recorded and transcribed the interviews with granted permission. We read the transcriptions and entered the summarized details into an Excel spreadsheet along with each participants' demographic information. We assigned each interviewee an identifying number for confidentiality purposes. Once we conduced all Q-Method interviews, we analyzed the results to chart the participants' subjectivity of gene-based pest control.

3.3 Charting the Subjectivity of Gene-Based Pest Control

We interpreted the Q-Method results to chart the subjectivity of gene-based pest control by identifying patterns that showed a correlation between participants' sorting arrangements. Different outlooks on ethics and protecting Aotearoa's biodiversity were challenging to navigate because of the complexity of environmental priorities and consequences. The Q-Method results organized opinions on gene-based pest control and enabled us to compare trends among the participants.

After each participant finalized their statement placements, we photographed each participant's Q-Sort[6]. Then, we entered each Q-Sort into a statistical program that computed factor analysis to output numerical data that revealed participants' subjectivity about gene-based pest control methods (Watts, 2008). Factor analysis was a data reduction method that found underlying dimensions through statistics to analyze all the Q-Sorts (Baker, 2016). Factor analysis showed if similarities between participants' Q-Sorts existed and identified arrangement patterns. Beginning with the correlation matrix, the factor analysis determined a correlation between one Q-Sort and the other Q-Sorts. Commonalities between Q-Sorts formed clusters of shared opinions on gene-based pest control. The factor analysis program labeled each cluster as a factor, which acts as a composite Q-Sort that combines similar statement arrangements. Using these factors, the factor analysis program identified variance in opinions through number values. Additionally, the factor analysis determined consensus statements that did not vary in Q-Sort placements between all factors. These measurements of similarities and differences between factors allowed us to find trends between perceptions of gene-based pest control and structure participants' subjective opinions (White, 2022).

The factor analysis program we used was the PQMethod software, which coded statistical relationships among Q-Sorts. Once we entered the Q-Method statements and Q-Sort values into the PQMethod software, the program ran a QPCA factor extraction method. This factor extraction outputted factor loadings, which computed the degree of similarity between Q-Sort clusters or factors (Webler et al, 2009). A wide range of factor loadings helped create variety in the dataset to distinguish perspectives of gene-based pest control

[6] The final arrangement of Q-Method statements on the Q-Grid.

technology. To ensure that the factor analysis results were statistically significant, we needed to interview at least twelve participants to provide enough representation of opinions. As discussed in Section 2.5, it was optimal to have a 3:1 ratio for statements to participants because more participants created marginal differences in results. In contrast, if we used fewer participants, we would miss major perspectives (White, 2022).

For the data analysis method within the PQMethod software, we made multiple choices regarding how the data would be analyzed. The first decision we made related to how the factors would be extracted from the raw data. Specifically, we decided between using QCENT, a centroid analysis method, or using QPCA, a principal component analysis method. As the principal component analysis method accounted for as much variability in the data as possible, it was widely accepted as the default extraction method for Q-Method analysis software packages (Ramlo, 2016). For this reason, the team chose to use the QPCA option within the PQMethod software program.

The second decision we made concerned how the PQMethod software rotated the factors. PQMethod software required factor rotation to provide more structure to the factors and to make them interpretable (Ramlo, 2016). The PQMethod software gave the option of using the Varimax method to automatically rotate the factors or to manually rotate the factors by hand. The Varimax method for factor rotations was the default choice for standard statistical analysis software such as the PQMethod software (Ramlo, 2016). Since the Varimax method required less practice and statistical knowledge to successfully utilize, the team decided to use the Varimax option within the PQMethod software. Combining the QPCA option with the Varimax rotation method meant that the factors were both automatically extracted and rotated based on default statistical methods.

Next, the team decided how many factors would be rotated. Based on previous Q-Method research performed by Alan Hunt, the team opted to rotate three factors (Mercier et al., 2019). Rotating only three factors allowed each factor to contain multiple Q-Sorts, strengthening the narrative attached to each factor. Lastly, the team chose to use the PQROT add-on program to add flags to the Q-Sorts. The PQMethod software required flagging to place each Q-Sort into the appropriate factor based on the similarities and differences of the distinguishing statements' placements. The PQROT add-on program automatically flagged a Q-Sort into a factor when the Q-Sort was more alike to that specific factor than any other factors. An exception to this process

occurred when a Q-Sort was equally alike or approximately equally alike to two or more factors. Another exception occurred when a Q-Sort was not alike to any of the factors enough to flag it into any factors.

After finalizing the factors via the PQMethod software, we wrote narratives for each factor that translated the Q-sorts into viewpoints. These narratives summarized common opinions on gene-based pest control technology that helped us distinguish similarities and differences in perspectives. Through interpreting Q-Method results with the PQMethod software, we organized shared views of gene-based pest control to make recommendations for preserving Aotearoa's biodiversity.

The qualitative and quantitative analyses of attitudes towards gene-based pest control contributed to a data visualization of views about the genetic modification for pest control. In future research, Dr. Mercier will expand upon the perceptions of genetic modification to help find approaches that advance towards the Predator Free 2050 program. Overall, content analysis, Q-Method, and factor analysis were the approaches for understanding various outlooks on genetic modification for pest control. To further analyze the three objectives, we continued the research by interpreting the data we received from content analysis, the Q-Method, and the data from the PQMethod software.

Chapter 4 Results and Analysis

We identified three factors about peoples' perception of gene-based pest control. The three factors are one, those in support of gene-based pest control, two, those in support of the technology with an emphasis on Treaty partners/mātauranga Māori, and three, those untrusting of the technology due to a lack of knowledge. Our sample size for this research included 18 interviewees from around the Wellington area, including Miramar, Glenside, Upper Hutt, and Wilton suburbs. This sample represents participants who were experts in the field of conservation (n=4), pest control volunteers (n=9), science professors/lecturers (n=3), or those with a passion for the environment (n=2). The results of the content analysis, PQMethod software, and factor narratives revealed overarching themes in people's perspectives, which are presented below.

4.1 Identification of Main Themes Affecting Gene-Based Pest Control Opinions

The data from content analysis highlighted a widespread collection of public positions on gene-based pest control. Several themes were prevalent across various current events displayed in media. These themes touched upon religion, power, ethics, environment, safety, economy, knowledge, and social impacts, as shown in Appendix A. The result of our content analysis was the concourse, which comprised of these themes that influence participants' subjectivity of implementing gene-based pest control, as shown in Table 4. The content analysis helped us achieve our first objective of understanding Aotearoa's general perceptions of gene-based pest control.

Table 4: Statements included in the concourse categorized by theme.

Themes	Statements
Religion	Religion and spirituality offer guidance on gene-based pest control.
	Gene-based pest control is a technical fix for broader social, cultural, and spiritual issues.
Power	*Gene-based pest control* is an example of humans "playing god".
	Gene-based pest control would help Aotearoa lead the world in achieving pest eradication.
	Gene-based pest control is an existential threat to life on planet Earth.
Ethics	Animal rights are not relevant to discussions about *gene-based pest control.*
	My consent to *gene-based pest control* for some species is consent for *gene-based pest control* of other pest species.
	Gene-based pest control will have unforeseen circumstances.
	I trust the government to only implement *gene-based pest control* if a majority of people agree.
Environment	The mauri (life essence) of threatened ecosystems would be enhanced by using *gene-based pest control.*
	Climate change would push the population of pest species to require a *gene-based pest control* solution in the future.
	Gene-based pest control would be a crucial step towards a Predator Free 2050.
	Gene-based pest control would increase population of other invasive species.
	Pests could be eradicated from Aotearoa without *gene-based pest control.*
	Gene-based pest control in Aotearoa would lead to global extinction of the pest species.
	Gene-based pest control would contribute to the food web collapsing.
Safety	*Gene-based pest control* would cause harm to native species in the environment.
	Gene-based pest control should only be used inside the laboratory.
	Gene-based pest control is a safe solution to getting rid of pests.
	I trust the scientists to develop ethical *gene-based pest control.*
	Genetic techniques like *gene-based pest control* minimize off-target effects.
Economy	*Gene-based pest control* would enhance the Aotearoa economy.
	The government should invest more funding into *gene-based pest control.*
	Gene-based pest control is part of a hidden agenda.
	Gene-based pest control would take too long to eradicate the pests from Aotearoa.
Knowledge	There is enough information/research on GMOs to proceed with *gene-based pest control.*
	Scientists communicate effectively about *gene-based pest control.*
	I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.
	Gene-based pest control for pest species in Aotearoa will inspire technological advancement elsewhere.
Social	Matauranga Māori (Māori knowledge) counts in the decision to use *gene-based pest control.*
	Treaty/Tiriti partners should agree on *gene-based pest control* before it is used.
	My opinion counts in the decision whether to use *gene-based pest control.*
	Gene-based pest control would enhance the Māori guardianship over the environment.
	Pest trapping gives me more personal satisfaction than *gene-based pest control* would.

Based on the content analysis results, people had the most concerns in the environment and social themes. There were more statements in the environment and social theme because these themes were recurrent throughout social media, newspaper, and journal articles about gene-based pest control. Our Q-Method results confirmed that the environment and social themes were important in the public conversation around gene-based pest control because participants were concerned most about the statements under these two themes.

Additionally, we found that the knowledge theme in our concourse was a critical theme that affected participants' opinions on gene-based pest control. To illustrate, people's lack of knowledge on genetic modification influenced their final arrangement of the statements on the Q-Grid. Participants who strongly agreed on the statement "I am not knowledgeable enough to decide if gene-based pest control should be implemented", helped the team conclude that there was a lack of available knowledge on the topic, as discussed in Section 4.3.

Finally, to ensure that we captured all participants' views in the study, we concluded the interview by asking the participants if they had any non-represented views. While fourteen interviewees answered "no" to having any un-represented views, the remaining four interviewees touched upon a few topics that we could discuss further. One of the topics mentioned was the need for greater discussion about comparing gene-based pest control to traditional pest control methods, such as trapping, poison, and detector dogs. In greater depth, participant 7 mentioned the comparative value of gene-based pest control to other traditional methods by saying:

> *In the backyard, it is a reasonable place to manage the problem but in other areas really remote the tools that exist do not really solve the problem and that way we can see the different implications that we can see on gene-based pest control method in comparison to other methods.*

Participant 8 had a similar thought to participant 7's thought, emphasizing a need for more statements that compare gene-based pest control with traditional pest control methods. Additionally, participant 8 stated that a species-specific statement could also be helpful. While the concourse represented government-specific views (statement number 11 & 25), participant 5 expressed views on the matter that Aotearoa needed to prioritize social license, and the government needed to prioritize conservation:

Slightly absent here, I think, is the discussion around scientists and this discussion around Treaty partners, but I guess it's about ownership of this work. I think we need more leadership and continuity of leadership around this whole project, Predator Free 2050. This is not necessarily something for the scope of your work, but in terms of our connects with the reality of it, we need a social license to go ahead.

Future research could consider adding more statements that mention the unrepresented views in our concourse, suggested in more depth in Section 5.1. Acknowledging the main concerns under the themes, we identified key differences throughout the participants' views when analyzing the data from the PQMethod software.

4.2 PQMethod Software Findings

As a result of entering the Q-Sorts for all 18 participants into the PQMethod software, the software flagged Q-Sorts into 3 factors. A *factor* is a group assigned to a collection of Q-Sorts based on the similarity in their responses. Factor 1 encompassed participants that strongly supported the use of gene-based pest control. Factor 2 comprised participants that also strongly endorsed the use of gene-based pest control but had an emphasis on the need for Treaty partners and mātauranga Māori in the conversation. Factor 3 included participants who were untrusting of gene-based technology or needed more knowledge to make an informed decision on gene-based pest control technologies. These factors helped us achieve our second objective of gaining experts' and environmentalists' perspectives on gene-based pest control. The following section details the outputs of the PQMethod software while Section 4.3 includes the analysis and interpretations of those results. Throughout this section and appendices, the color of the statement and the statement identifying number corresponds to the color of each theme shown in Table 4.

PQMethod software outputted consensus statements for the Q-method, as shown in Table 5. A *consensus statement* is a statement that generally appears in the same placement for each Q-Sort regardless of the Q-Sort's factor. The PQMethod software identified five consensus statements: 13, 18, 23, 25, and 33. In addition, the PQMethod software calculated Z-Scores for each consensus statement within each factor, as shown in Table 5. A Z-score shows how many

standard deviations away the statement is from 0, or the neutral opinionated column. The greater the value, the more strongly opinionated the statement was. A positive Z-Score represented agreement among Q-Sorts, while a negative score represented disagreement. For instance, statement 18 was 1.10 standard deviations from its average placement in Q-Sorts in factor 1. The negative value indicated that the statement was below the mean average instead of a positive value above the average. The PQMethod software used Q-Sort values as another representation of data about the consensus statements, as shown in Appendix F.

Table 5: Consensus statements and Z-Score values for each factor.

Statement Identifying Number	Consensus Statement	Z-Score for Factor 1	Z-Score for Factor 2	Z-Score for Factor 3
13	Climate change would push the population of pest species to require a *gene-based pest control* solution in the future	0.31	0.07	-0.00
18	*Gene-based pest* control would contribute to the food web collapsing	-1.10	-0.88	-1.43
23	Genetic techniques like *gene-based pest control* minimize off-target effects	0.84	0.22	0.60
25	The government should invest more funding into *gene-based pest control*	1.20	0.72	0.76
33	*Gene-based pest control* would enhance Māori guardianship over the environment	0.68	0.24	0.16

This data helped identify which statements did not play a role in determining factor narratives. Since a consensus statement represented a commonality between Q-Sorts, regardless of factor placement, the statements did not distinguish any one factor from another. On the other hand, the consensus statements were valuable in creating recommendations, detailed in Chapter 5. Understanding the concerns all participants agreed and disagreed on could help Aotearoa plan actions before the implementation of gene-based pest control technologies.

Using factor loadings, the PQMethod software flagged each Q-Sort to place them in designated factors, as shown in Table 6. Factor loadings were values that measured the similarity between one Q-Sort to a particular factor, shown in Appendix G. The PQMethod software placed each Q-Sort into only one factor, which shared similar arrangements. The PQMethod software flagged Q-Sorts 5, 7, 10, 12, 14, 16, 17, and 18 into factor 1, Q-Sorts 1, 3, 6, 11, and 13 into factor 2, and Q-Sorts 2, 4, and 9 into factor 3. However, the PQMethod software did not place Q-

Sort 8 into a factor since it had almost equal factor loadings for factor 1 and factor 2. In this case, the PQMethod software could not accurately flag the Q-Sort into either factor. Similarly, the PQMethod software did not flag Q-Sort 15 into any factor since the factor loading value for each factor did not meet the minimum threshold in place by the software. This data helped identify which Q-Sorts belonged to which factor and helped generate narratives about each factor, discussed further in Section 4.3.

Table 6: Q-Sorts flagged into a factor.

	Factor 1	Factor 2	Factor 3
Q-Sort Number	5	1	2
	7	3	4
	10	6	9
	12	11	
	14	13	
	16		
	17		
	18		

The PQMethod software organized the distinguishing statements for each factor, as shown in Table 7. Factor 1 had 14 distinguishing statements: 14, 6, 24, 30, 29, 28, 9, 10, 11, 27, 1, 20, 26, and 5. Factor 2 had 12 distinguishing statements: 7, 2, 32, 11, 16, 19, 12, 5, 29, 30, 1, and 26. Factor 3 had 10 distinguishing statements: 5, 30, 3, 34, 26, 4, 31, 11, 29, and 22.

Table 7: Distinguishing statements for each factor.

Factor Number	Distinguishing Statement	Statement Identifying Number
1	Religion and spirituality offer guidance on *gene-based pest control*.	1
	Gene-based pest control is an example of humans "playing god".	5
	Gene-based pest control in Aotearoa would lead to global extinction of the pest species.	6
	My consent to gene-based pest control for some species is consent for *gene-based pest control* of other pest species.	9
	Gene-based pest control will have unforeseen circumstances.	10
	I trust the government to only implement *gene-based pest control* if a majority of people agree.	11
	Gene-based pest control would be a crucial step towards a Predator Free 2050.	14

	Gene-based pest control should only be used inside the laboratory.	20
	Gene-based pest control would enhance the Aotearoa economy.	24
	Gene-based pest control is part of a hidden agenda.	26
	Gene-based pest control would take too long to eradicate the pests from Aotearoa.	27
	There is enough information/research on GMOs to proceed with *gene-based pest control*.	28
	Scientists communicate effectively about *gene-based pest control*.	29
	I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.	30
2	Matauranga Māori (Māori knowledge) counts in the decision to use *gene-based pest control*.	2
	Gene-based pest control is an example of humans "playing god".	5
	Treaty/Tiriti partners should agree on *gene-based pest control* before it is used.	7
	I trust the government to only implement *gene-based pest control* if a majority of people agree.	11
	The mauri (life essence) of threatened ecosystems would be enhanced by using *gene-based pest control*.	12
	Pests could be eradicated from Aotearoa without *gene-based pest control*.	16
	Gene-based pest control in Aotearoa would lead to global extinction of the pest species.	17
	Gene-based pest control would cause harm to native species in the environment.	19
	Gene-based pest control is part of a hidden agenda.	26
	Scientists communicate effectively about *gene-based pest control*.	29
	I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.	30
	My opinion counts in the decision whether to use *gene-based pest control*.	32
3	*Gene-based pest control* is a technical fix for broader social, cultural, and spiritual issues.	3
	Gene-based pest control is an existential threat to life on planet Earth.	4
	Gene-based pest control is an example of humans "playing god".	5
	I trust the government to only implement *gene-based pest control* if a majority of people agree.	11
	I trust scientists to develop ethical *gene-based pest control*.	22
	Gene-based pest control is part of a hidden agenda.	26
	Scientists communicate effectively about *gene-based pest control*.	29
	I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.	30

	Gene-based pest control for pest species in Aotearoa will inspire technological advancement elsewhere.	31
	Pest trapping gives me more personal satisfaction than *gene-based pest control* would.	34

There are more details about the distinguishing statements placement in the Appendices. Specifically, the Z-Score and Q-Sort value for each distinguishing statement and the comparison to each factor are in Appendix H and I respectively. For the PQMethod software to consider a statement as "distinguishing," the Z-Score value for the given factor had to be significantly different than the Z-Score of the same statement within another factor. The data in Appendices H and I helped identify the distinguishing statements. Additionally, the distinguishing statements helped create the narratives in Section 4.3. Using statements placed in a different spot from factor to factor allowed us to understand why the PQMethod software flagged participants into a particular factor. With an understanding of what made the Q-Sorts in one factor similar, we made a recommendation based on each factor, as discussed in Chapter 5.

We organized the factor score as a Z-Score for each statement in each factor, as shown in Appendix J. This data helped create the composite Q-Sort for each factor. A *composite Q-Sort* was a Q-Sort that illustrated the placement of each statement based on its factor score. We placed the statement with the greatest positive value into the +4 column (strongly agree), while we placed the statement with the greatest negative value into the -4 column (strongly disagree). Each factor had its own composite Q-Sort as seen in Section 4.3.

As shown in Appendix K, the PQMethod software outputted the percentage of unique data each Q-Sort contributed, and the cumulative percentage of total data accounted for from the Q-Sorts at that point. This data helps support the validity of our research by showing 18 participants was enough to utilize the Q-Method.

We created factor narratives unique within each factor based on the output discussed above. These factor narratives provided a holistic approach to understanding both what the participants believed and why they felt that way. The next section describes in detail each factor narrative and provides evidence supporting each narrative.

4.3 Factor Narratives

As each factor grouped participants with similar perceptions of gene-based pest control techniques, the composite Q-Sorts and interview transcripts created an underlying reasoning or narrative to their thoughts. We designed the narratives to explain why a participant agreed/disagreed with a particular statement and to encapsulate the entire perception each respective factor represented, giving a "summary perception" for each factor. By focusing on the most agreeable and most disagreeable columns during the interview, the strongest opinions of the participants contributed most to the narrative. Additional insight into participants' perceptions of gene-based pest control technology came from asking which statements were difficult to place or if any statements jumped out at them. The narratives focused on distinguishing statements for that factor and the placements of the distinguishing statements in the composite Q-Sort. The factor narratives helped us achieve our third objective of charting the subjectivity of gene-based pest control. We created the composite Q-Sorts based on the Z-Scores of each factor that the PQMethod software created. The following sub-sections include an overview of the narrative, a summary as a single viewpoint, and addresses distinguishing statements placed in strongly opinionated columns for each narrative. These summaries are in first person as if the narrative was speaking to us, as previous Q-Method research had similar summaries (Mercier et al., 2019).

Factor 1 Narrative

Overview

The eight participants grouped into factor 1 generally supported gene-based pest control technologies. All the participants in this factor had a sense that the goal of Predator Free 2050 was not achievable with the current methods in place. This thinking could explain the bias towards accepting gene-based technology, as they knew they had to try something new to achieve this goal. To further understand the shared perspective of this factor, each distinguishing statement, along with its placement on the composite Q-Sort, will be studied in detail. The composite Q-Sort (Figure 6) displays the average placement of each statement card for factor 1 participants.

-4	-3	-2	-1	0	1	2	3	4
Gene-based pest control is an example of humans "playing god"	Religion and spirituality offer guidance on *gene-based pest control*	*Gene-based pest control* would cause harm to native species in the environment	*Gene-based pest control* is a technical fix for broader social, cultural, and spiritual issues	Treaty/Tiriti partners should agree on *gene-based pest control* before it is used	Matauranga Māori (Māori knowledge) counts in the decision to use *gene-based pest control*	*Gene-based pest control* for pest species in Aotearoa will inspire technological advancement elsewhere	*Gene-based pest control* would enhance the Aotearoa economy	*Gene-based pest control* would be a crucial step towards a Predator Free 2050
Gene-based pest control is an existential threat to life on planet Earth	*Gene-based pest control* should only be used inside the laboratory	Pests could be eradicated from Aotearoa without *gene-based pest control*	*Gene-based pest control* in Aotearoa would lead to global extinction of the pest species	There is enough information/research on GMOs to proceed with *gene-based pest control*	*Gene-based pest control* would enhance Māori guardianship over the environment	Genetic techniques like *gene-based pest control* minimize off-target effects	The government should invest more funding into *gene-based pest control*	*Gene-based pest control* would help Aotearoa lead the world in achieving pest eradication
	Gene-based pest control is part of a hidden agenda	*Gene-based pest control* would contribute to the food web collapsing	I trust the government to only implement *gene-based pest control* if a majority of people agree	My opinion counts in the decision whether to use *gene-based pest control*	I am not knowledgeable enough to decide if *gene-based pest control* should be implemented	I trust scientists to develop ethical *gene-based pest control*	The mauri (life essence) of threatened ecosystems would be enhanced by using *gene-based pest control*	
		Gene-based pest control would take too long to eradicate the pests from Aotearoa	*Gene-based pest control* would increase populations of other invasive species	My consent to *gene-based pest control* for some species is consent for gene-based pest control of other pest species	Climate change would push the population of pest species to require a *gene-based pest control* solution in the future	*Gene-based pest control* is a safe solution to getting rid of pests		
			Pest trapping gives me more personal satisfaction than *gene-based pest control* would	Animal rights are not relevant to discussions about *gene-based pest control*	Scientists communicate effectively about *gene-based pest control*			
				Gene-based pest control will have unforeseen circumstances				

Figure 6: The composite Q-Sort for factor 1. This image shows the average placements of each statement card across all Q-Sorts grouped into factor 1.

To better understand factor 1's narrative, we provide a summary as a single viewpoint for factor 1 below.

Summary as a Single Viewpoint

I firmly support gene-based pest control. I feel that it can make a difference in the pest problem. I feel gene-based pest control is worth investing in as it will be the only way to achieve Predator Free 2050 in time and boost the economy. I do not care what religion or spirituality might have to offer. Additionally, I think ethical concerns do not play a significant role. The potential benefits of this technology outweigh whatever other methods can offer. Because of this outlook, I also feel that why would this be a part of a corporate agenda? This is just a conspiracy theory that is not true and just a false statement.

The following distinguishing statements were strongly agreed or strongly disagreed upon, giving us a better understanding of the participants' viewpoint. Additionally, quotes from the participants' transcripts were included to support the factor narrative.

***Gene-based pest control* is a crucial step towards a Predator Free 2050 [Statement #14]**

The PQMethod software placed this statement at in the +4 column on the composite Q-Sort for factor 1, meaning participants strongly agreed with the statement. Participants felt they needed to do more for Predator Free 2050. For example, participant 5, who had ease placing this statement, said:

> *I absolutely agree. As I said, I think we've got 27 years left to run on this objective. With the current tools we have, we are not going to get there. This a known tool that has been up our sleeve but has not been deployed.*

From this participant's testimony, they understood the current pest control methods and said we must do something else to achieve Predator Free 2050. Furthermore, five out of the seven other participants in this factor also placed this statement in the +4 column, with the other two placing it in the +3 and +2 categories. People's agreement with this statement suggested that, given the current techniques for pest control, gene-based pest control would be a critical factor.

***Gene-based pest control* in Aotearoa would lead to global extinction of the pest species [Statement #6]**

The PQMethod software again placed this statement in the +4 column on the composite Q-Sort for factor 1, indicating a strong agreement with the statement from participants. Participants in this factor were in support of gene-based pest control. Agreeing with this statement showed that the thought of implementing gene-based pest control could be successful. For example. participant 16, who placed the statement in the +4 column, said:

> *Aotearoa has a unique opportunity to prove these concepts are possible on a relatively small island nation that might not be achievable in other small countries because of geological location.*

This quote showed the support behind the technology because the participant believed that other parts of the world would replicate Aotearoa's use of gene-based pest control. Therefore, even if it were still untrusted by someone upon first utilization in Aotearoa, its use by other countries may be enough for some to start to trust it.

***Gene-based pest control* would enhance the Aotearoa economy [Statement #24]**

The PQMethod software placed this statement under the +3 column on the composite Q-Sort for factor 1, indicating a moderate-strong agreement with the statement from participants. Participants within this factor felt that gene-based technology could be beneficial in many ways. For instance, participant 5 referenced that gene-based pest control could lead to the global extinction of pest species and mentioned:

> *Arguably, I think we already do lead the world, but this would be a good step and is tied up with the boost of the economy. There is a positive spinoff.*

From this participant's testimony, it was clear that the participant acknowledged the other potential benefits of gene-based pest control, such as benefits for the economy. Moderately strong agreement with this statement was a common theme throughout the participants in factor 1, as every participant placed this statement in the +2 or +3 columns. This placement might

suggest that, because of the potential boost to the economy, someone was willing to take a chance with gene-based pest control.

***Gene-based pest control* is an example of human "playing god" [Statement 5]**

The PQMethod software placed this statement in the -4 column on the composite Q-Sort for factor 1, indicating a strong disagreement with the statement from participants. Participants in this factor did not feel that gene-based technology was humans "playing god." For example, participant 17 stated:

> *I don't think pest control is "playing god". It's actually taking proactive steps to try to get rid of the problem that is obviously a problem. And you don't need to be a scientist to see that it's a problem.*

Participant 17's testimony showed a clear understanding that Aotearoa should use gene-based pest control, and any ethical concerns related to gene-based pest control were unwarranted. In factor 1, seven out of the eight participants had this statement in the -4 and -3 columns, representing a common idea. This placement suggested that there are people willing to brush off ethical concerns to obtain a better grasp on solving the pest problem.

***Gene-based pest control* is part of a hidden agenda [Statement #26]**

The PQMethod software placed this statement in the -3 column on the composite Q-Sort for factor 1, indicating a moderate-strong disagreement with the statement from participants. Participants in this factor did not think gene-based pest control was a corporation's or government's hidden agenda. Instead, there was consensus around the idea that a hidden agenda is a conspiracy theory with no truth, that the statement was "rubbish," or that they did not believe in the statement at all. Hence, they placed it in the disagree column.

***Gene-based pest control* should only be used inside the laboratory [Statement #20]**

The PQMethod software again placed this statement in the -3 column on the composite Q-Sort for factor 1, indicating a moderate-strong disagreement with the statement from participants.

As mentioned in the previous quotes, participants in factor 1 indicated a strong agreement with the potential benefits of gene-based pest control. Therefore, disagreement with keeping this technology inside a lab makes sense. Subsequently, participants in factor 1 wanted Aotearoa to apply the gene-based pest control in the field and to see it help achieve Predator Free 2050.

Religion and spirituality offer guidance on *gene-based pest control* [Statement #1]

The PQMethod software again placed this statement in the -3 column on the composite Q-Sort for factor 1, indicating a moderate-strong disagreement with the statement from participants. Like previous testimonies, participants in factor 1 did not feel the need to consider other perspectives as potential benefits of utilizing such technology could be tremendous. In addition, participants did not have an ethical concern nor a concern about how religion or spirituality might perceive gene-based pest control. Hence, participants in factor 1 placed this statement in the disagree column.

Factor 2 Narrative

Overview

The five participants grouped into factor 2 generally supported gene-based pest control technologies. However, they strongly emphasized the need for diversity and included the Treaty of Waitangi in the conversation. The composite Q-Sort (Figure 7) displays the average placement of each statement card for factor 2 participants.

-4	-3	-2	-1	0	1	2	3	4
Gene-based pest control is part of a hidden agenda	There is enough information/research on GMOs to proceed with *gene-based pest control*	My consent to gene-based pest control for some species is consent for *gene-based pest control* of other pest species	Scientists communicate effectively about *gene-based pest control*	*Gene-based pest control* would enhance Māori guardianship over the environment	*Gene-based pest control* would help Aotearoa lead the world in achieving pest eradication	*Gene-based pest control* would enhance the Aotearoa economy	*Gene-based pest control* for pest species in Aotearoa will inspire technological advancement elsewhere	Treaty/Tiriti partners should agree on *gene-based pest control* before it is used
Gene-based pest control is an existential threat to life on planet Earth	*Gene-based pest control* in Aotearoa would lead to global extinction of the pest species	Pest trapping gives me more personal satisfaction than *gene-based pest control* would	*Gene-based pest control* is a technical fix for broader social, cultural, and spiritual issues	*Gene-based pest control* is a safe solution to getting rid of pests	I trust scientists to develop ethical *gene-based pest control*	Religion and spirituality offer guidance on *gene-based pest control*	*Gene-based pest control* will have unforeseen circumstances	Matauranga Māori (Māori knowledge) counts in the decision to use *gene-based pest control*
	Animal rights are not relevant to discussions about *gene-based pest control*	I am not knowledgeable enough to decide if *gene-based pest control* should be implemented	*Gene-based pest control* should only be used inside the laboratory	Genetic techniques like *gene-based pest control* minimize off-target effects	I trust the government to only implement *gene-based pest control* if a majority of people agree	*Gene-based pest control* would increase populations of other invasive species	My opinion counts in the decision whether to use *gene-based pest control*	
		Gene-based pest control would contribute to the food web collapsing	*Gene-based pest control* is an example of humans "playing god"	Climate change would push the population of pest species to require a *gene-based pest control* solution in the future	*Gene-based pest control* would be a crucial step towards a Predator Free 2050	The government should invest more funding into *gene-based pest control*		
			The mauri (life essence) of threatened ecosystems would be enhanced by using *gene-based pest control*	*Gene-based pest control* would take too long to eradicate the pests from Aotearoa	Pests could be eradicated from Aotearoa without *gene-based pest control*			
				Gene-based pest control would cause harm to native species in the environment				

Figure 7: The composite Q-Sort for factor 2. This image shows the average placements of each statement card across all Q-Sorts grouped into factor 2.

To better understand factor 2's narrative, we provide a summary as a single viewpoint for factor 2 below.

Summary as a Single Viewpoint

I understand the importance of looking into new methods for pest control in Aotearoa, but we cannot ignore the history and beliefs of Māori culture. Although I am skeptical whether to use gene-based pest control, if I had to decide, I do somewhat agree that it would support the Predator Free 2050 goal. If we implement gene-based pest control, you cannot change my mind about the importance of inclusivity and the fact that all opinions should matter. When making a decision that affects all members of the society and the ecosystem, all peoples' opinions should be taken into consideration. Finally, I am still uncertain of how this technology works, but agree that we need more funding for research.

The participants in factor 2 strongly agreed or strongly disagreed with the following distinguishing statements, giving us a better understanding of the participants' viewpoint. Additionally, we included quotes from the participants' transcripts to support the factor narrative.

Treaty/Tiriti partners should agree on *gene-based pest control* before it is used [Statement #7]

While factor 2 is in favor of gene-based pest control with a heavy emphasis on Treaty partners, this statement's placement in the +4 column represented strong agreement among all participants. Participant 3 expressed their emphasis on diversity by saying:

> *Treaty/Tiriti partners should agree on gene-based pest control before it is used. That is not negotiable to me. We live in a Treaty based country and Tiriti partners should be in dialogue about any significant government decisions including the environment and our species, specifically, the species that are affected and not the species that are targeted.*

This participant strongly agreed that Treaty partners should be included in decision-making when it comes to implementing gene-based pest control, which is a decision that impacts the ecosystem.

Mātauranga Māori (Māori knowledge) counts in the decision to use *gene-based pest control* [Statement #2]

Similarly, this statement's placement in the +4 column highlights the importance of the Māori knowledge that should be accounted for in decision-making, like gene-based pest control. Again, it was not surprising that this statement was in the +4 column, as factor 2 highly valued mātauranga Māori and Treaty partners. Participant 11, who placed this statement in the +3 column, which represents a moderate-strong opinion, stated:

> *It is very similar to the Treaty partner, I do agree that Māori knowledge does count.*

The participant related statement 2 to statement 7, which validated Treaty partners' opinion on whether Aotearoa should use gene-based pest control. Thus, this statement acted as another Māori-based opinion that defined factor 2.

My opinion counts in the decision whether to use *gene-based pest control* [Statement #32]

The PQMethod software placed this statement in the +3 column of the composite Q-Sort of factor 2, suggesting moderate-strong agreement. Participant 11, who moderately agreed with this statement, stated:

> *Yeah. I think that everyone's opinions count, or I suppose I am being naïve, but I believe it should count.*

The participant placed this statement in the +3 column; their testimony validated this placement since they believed everyone should have a say. Going back to factor 2 interpretation relying on Māori specific knowledge, this statement can tell us a lot about inclusivity and that all opinions count on this matter.

Gene-based pest control **in Aotearoa would lead to global extinction of the pest species [Statement #17]**

The PQMethod software placed this statement in the -3 column of the composite Q-Sort of factor 2, expressing a moderate-strong disagreement. Participant 11 addressed doubt on this statement by saying:

> *I think it is totally unplausible to think that things that happen in Aotearoa would lead to global extinction in another country, let alone all the countries. I just don't think there is any evidence for all that.*

This statement's placement in the -3 column was viable as all participants had a strong disagreement with this concern and doubted that anything impacting Aotearoa's ecosystem would lead to global extinction.

Gene-based pest control **is part of a hidden agenda [Statement #26]**

This statement was consistent throughout all participants in this factor. The PQMethod software placed this statement in the -4 column of the composite Q-Sort, expressing strong disagreement. All participants of factor 2 agreed that gene-based pest control is not part of a hidden agenda, and they interpreted it to be conspiratorial thinking. Participant 6 stated:

> *That would give government organization far too much credit for what it is worth. Yeah no. That kind of conspiracy is not, at least in New Zealand, [they] just haven't got the organization to do it.*

Surprisingly, this statement sparked strong opinions from all participants in factor 2, stating that "gene-based pest control is part of a hidden agenda" is not the case. Participant 1 also said:

> *I don't believe that. I am not aware of a hidden agenda, which I guess is the point. At least from my understanding, it's pretty open about what they want to achieve.*

Factor 3 Narrative

Overview

The three participants grouped into factor 3 were either wary of trusting science or needed more knowledge to make an informed decision on gene-based pest control technologies. All participants in this factor had personal experience with traditional pest control techniques. Still, before the interview, they did not understand the technical details about the specific gene-based pest control technologies analyzed. This lack of knowledge could explain the bias toward being wary of trusting science, as they had minimal experience with science but had extensive experience with traditional techniques. To further understand the shared perspective of this factor, we studied each distinguishing statement and its placement on the composite Q-Sort, in more depth. The composite Q-Sort displayed the average placement of each statement card for factor 3 participants, as shown in Figure 8.

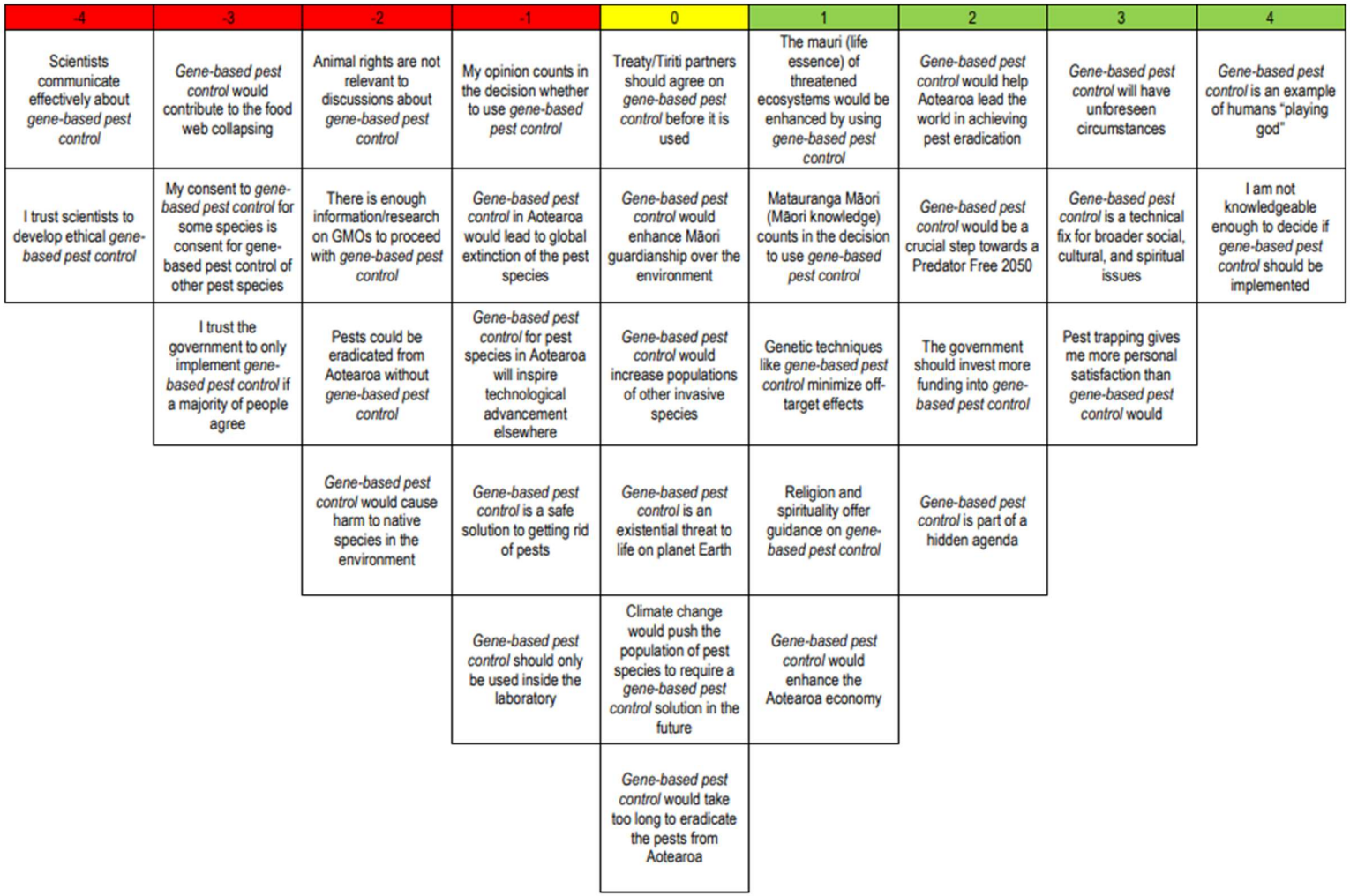

Figure 8: The composite Q-Sort for factor 3. This image shows the average placements of each statement card across all Q-Sorts grouped into factor 3.

To better understand factor 3's narrative, we provide a summary as a single viewpoint for factor 3 below.

Summary as a Single Viewpoint

I am wary of using gene-based pest control within Aotearoa. I'm very familiar with traditional pest control methods, but I'm not very knowledgeable on gene-based technologies. I want more research to be done in this area before I trust scientists and the government to implement this technology. I believe that, in addition to evaluating the technical feasibility of solving the pest problem in Aotearoa, there are important social factors that must also be taken into consideration.

The following distinguishing statements were strongly agreed or strongly disagreed upon, giving us a better understanding of the participants' viewpoint. Additionally, quotes from the participants' transcripts were included to support the factor narrative.

***Gene-based pest control* is an example of humans "playing god" [Statement #5]**

The PQMethod software placed this statement at a +4 on the composite Q-Sort for factor 3, meaning participants strongly agreed with the statement. For participants in this factor, participants felt that any form of editing a living being's genome is "playing God" to some degree. Participant 2, who had difficulty placing this statement, stated:

> *Probably 20 years ago I would have said gene-based pest control is an example of humans playing God, I would have agreed with that. Now I can see that we are understanding more and more how genes work and DNA works and it's becoming more matter of fact and we just have the knowledge. That's why now I've put I in the neutral. Yeah, I don't think its playing god, but I don't feel strongly about it. Yeah, some of these things there I have some knowledge as I was explaining before, but I don't have a lot knowledge and I think if I had more knowledge, I might shift some of these left or right.*

From this participant's testimony, they clearly lacked knowledge on the topic. While they placed the statement in the neutral category, they explained that 20 years ago, they would have

agreed with it. Only because they have gained more knowledge, they were able to change their opinion. The other participants in this factor placed the statement under the +4 column, suggesting they are where the quoted participant was 20 years ago. This information might indicate that, given more knowledge, the participants might change their answers.

I am not knowledgeable enough to decide if *gene-based pest control* should be implemented [Statement #30]

The PQMethod software again placed this statement under the +4 on the composite Q-Sort for factor 3, indicating a strong agreement with the statement from participants. As mentioned in the previous testimony, a lack of knowledge can severely impact the placement of a statement. Gaining knowledge in the future may cause participants to alter their placement on the grid, leading to their current untrust in science without adequate information.

***Gene-based pest control* is a technical fix for broader social, cultural, and spiritual issues [Statement #3]**

This statement was placed at a +3 on the composite Q-Sort from the PQMethod software, suggesting moderate-strong agreement with the statement from participants. Participants within this factor felt that there were many different issues to keep in mind when considering gene-based pest control. Participant 4 noted:

> *It is most definitely a technical fix. It gets back to this thing, community participation. I will say this, people actually get a lot of satisfaction from being involved.*

As this participant noted, applying gene-based pest control would be a technical fix, eliminating the community participation required for traditional pest control techniques. As community members get satisfaction from being involved in the pest control effort, eliminating the need for community participation may have negative consequences if it were treated simply as a technical solution.

Pest trapping gives me more personal satisfaction than *gene-based pest control* would [Statement #34]

This statement was placed at a +3 on the composite Q-Sort for factor 3, again suggesting moderate-strong agreement with the statement from participants. As participants within this factor had first-hand experience with traditional pest control methods, which they know and trust, implementing a new technology that they are unfamiliar with and lack experience with leads to mistrust. While this statement does not suggest whether Aotearoa should or should not use gene-based pest control, it is important to understand the personal ties to traditional pest control techniques.

I trust the government to only implement *gene-based pest control* if a majority of people agree [Statement #11]

This statement was placed at a -3 on the composite Q-Sort for factor 3, suggesting a moderate-strong disagreement with the statement. As the statement reads, participants within this factor did not trust the government handling a decision like implementing gene-based pest control. Participant 4 stated:

> *I think we have seen many cases of things being implemented despite what the majority of people think. That gets back to this trust thing and communication.*

This testimony suggests the lack of trust stems from a lack of communication within the scientific community. Participant 9 felt similarly, stating:

> *Gene-based pest control is an agenda to make us look good internationally, so I do not trust the government to make the right decision.*

This account aligned with participant 4's statement; however, participant 9 believed that there were ulterior motives for implementing gene-based pest control.

Scientists communicate effectively about *gene-based pest control* [Statement #29]

This statement landed a -4 on the composite Q-Sort for factor 3, suggesting a strong disagreement with the statement. Participant 4 stated:

> *I am a bit doubtful about that. I think the whole vaccine thing has probably created a lot of distrust of scientists and governments, me included.*

This testament suggests the lack of trust stemmed from a lack of communication regarding other issues unrelated to gene-based pest control.

I trust scientists to develop ethical gene-based pest control [Statement #22]

This statement was also placed at a -4 on the composite Q-Sort for factor 3, again suggesting a strong disagreement with the statement. Not trusting scientists to gene-based pest control ethically aligns similarly with participants' views that scientists do not communicate effectively on the subject.

Based on the testimony of all participants in this study and the output from the PQMethod software, we developed narratives for each factor explaining why the factor included the participants it did. The composite Q-Sorts provided the general thoughts of participants within the factor, while the answers from the interviews provided direct reasoning behind their thoughts. The factor narratives provided meaningful insight into both the qualitative and quantitative data provided during the Q-Method interview process, combining both to formulate the collective perspective within each factor.

In order to expand on our effort and, foster the expansion of the dialogue surrounding genetic modification, following are the recommendations that the team suggests.

Chapter 5 Recommendations

Our results and analysis presented three distinct factors that act as a microcosm of the scientific and environmental perspectives on genetic modification for pest control. By distinguishing the differences between factors, we identified the most valued opinions. These most valued opinions are crucial to respect when considering and implementing genetic modification for pest control. The following sections detail our recommendations for stakeholders of this research.

5.1 Recommendations about Research and Communication

The main scope of this project was to engage with researchers and environmentalists to understand their perspectives on genetic modification for pest control in Aotearoa. By understanding the researchers' and environmentalists' perspectives gained from this project, the team added to the collective knowledge of gene-based pest control. The Predator Free 2050 program could utilize this new knowledge to work towards its goal with more agreed-upon approaches. Because all factors agreed that gene-based pest control would be crucial to eradicating pests by 2050, we recommend that the Predator Free 2050 community accelerate work towards their goal. Specific actions include destigmatizing genetic modification technologies and gaining national awareness. Gaining national awareness about the technology would accelerate the Predator Free 2050 goal by efficiently spreading information about gene-based pest control.

Additionally, to change the conversation around genetic modification, we recommend that further investigation on gene-based pest control is necessary. It is important to conduct more research on the safety and security of gene-based pest control to decide upon implementation approaches. This need for more research corresponded to the consensus statement of "the government should invest more funding into gene-based pest control." This statement's placement at +2 or +3 on all composite Q-Sorts suggested that all participants believe this approach would require more funding to continue research on this topic. In addition, the shared perspective suggests that the current levels of research would not be sufficient to implement the

technology in an adequate time frame. This view again suggests the need for more funding to continue the development of this technology.

To achieve community acceptance of implementing genetic modification for pest control, researchers, professors, and scientists need to educate the public on genetic modification and make the technology easier to understand. Both factor 1 and factor 3 disagreed that they were knowledgeable enough to decide whether gene-based pest control should be implemented. This lack of knowledge caused distrust in gene-based pest control for factor 3. To prevent a lack of knowledge from causing distrust in this technology, Aotearoa could establish educational programs that teach people about genetic modification for pest control. Educational programs have worked to get the public's attention and inform them about a topic. Starting in 1967, advertisements displaying smoking-related health concerns heavily impacted the tobacco industry (Health New Zealand, 2020). Since then, the number of smokers has continued to decline, demonstrating the effectiveness of an education program in delivering a message (Verrall, 2022).

Alongside educating people about genetic modification for pest control, researchers and scientists could make information about genetic modification more accessible in terms of availability and clarity. Future teams could find an approach to educate and communicate with the public on genetic modification for pest control. Additionally, our study was limited by the scientific knowledge of gene-based pest control because this technology is still developing. Continuing research on this technology could provide a better understanding of the application and implications in Aotearoa. While all participants suggested that more technology research, development, and communication is needed, some participants stressed the need for inclusivity as well.

5.2 Recommendations about Treaty Partners

The Q-Method concourse, which included statements related to Māori contributions, allowed participants to highlight the significance of inclusivity upon which all interviewees in factor 2 agreed. In addition, the participants grouped in factor 2 demonstrated their dedication to making such important decisions with Treaty partners. Factor 2's emphasis on Treaty/Tiriti partners and mātauranga Māori showed that it would be necessary to set up a framework for

decision-making processes on implementing genetic modification that will include Māori representatives.

To build off our project and, ultimately, continue the growth of the conversation around this issue, future teams could reach out to government officials and rūnanga (iwi/tribal governing council) representatives to engage in political discussions. Such discussions could touch on the topic of genetic modification and decide whether the mechanisms supporting the implementation of the technology for pest control uphold the Treaty of Waitangi. In that way, Treaty partners and mātauranga Māori can be part of the discussion, decision-making process, and potential implementation of genetic modification for pest control in Aotearoa. This recommendation of focusing on government officials and rūnanga representatives as a participant sample could be a pathway to co-governance on gene-based pest control. While factor 2 suggested these recommendations, factor 3 gave insight into other areas of recommendation.

All these recommendations resulted from our Q-Method interviews and analysis and represent some of what needs to be done before implementing genetic modification for pest control.

Chapter 6 Conclusion

Pests threaten many native species in Aotearoa that will soon become extinct. Predator Free 2050 sets a goal for many researchers, individuals who care for the environment, and volunteers to preserve Aotearoa's biodiversity promptly. This program will help protect the many endangered species endemic to Aotearoa and ensure they can continue existing on the island. Although this goal depicts the larger picture of preserving biodiversity, we must take smaller steps before achieving it. Understanding the social, political, and economic aspects of genetic modification for pest control is critical to this goal.

To understand Aotearoa's general perceptions of gene-based pest control, we conducted content analysis on current media about genetic modification and pest control to encapsulate public opinions on gene-based pest control into thirty-four statements, which became the concourse for the Q-Method. The concourse was organized around eight themes (religion, power, ethics, environment, safety, economy, knowledge, and social). We obtained experts' and environmentalists' perspectives on gene-based pest control by implementing the Q-Method and interview process. By interpreting the Q-Method results, we charted the subjectivity of gene-based pest control, which resulted in three factors that grouped shared views:

- Factor 1 supported gene-based pest control to achieve Predator Free 2050.
- Factor 2 also supported gene-based pest control with an emphasis on Treaty/Tiriti partners and mātauranga Māori.
- Factor 3 was wary of gene-based pest control due to a lack of knowledge about it.

By highlighting approaches to integrate the three factor narratives into the conversation about gene-based pest control, we provided recommendations to partners, stakeholders, and suggested future studies. Our research adds to the knowledge about genetic modification for pest control and offers a new outlook on gaining opinions about this technology. We recommend that future research expands upon our findings to continue the discussion and development of gene-based pest control. Additionally, we suggest that:

- Researchers prioritize the Predator Free 2050 goal by conducting more research on the safety and security of genetic modification.

- Researchers, professors, and scientists collaborate to provide educational programs that teach the public about genetic modification for pest control.
- Researchers and scientists make information about genetic modification more accessible to the public in terms of availability and clarity.
- Government officials and rūnanga (tribal governing council) decide whether to implement genetic modification for pest control by including them in participant samples for future related studies.

These recommendations outline the next steps to expand our project and continue efforts to protect Aotearoa's biodiversity. Ultimately, our project's understanding of social perspectives on genetic modification for pest control will help Aotearoa reach its goal of being a predator-free country.

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Appendix A: Content Analysis Procedure Flowchart

Step 1: Identify common themes throughout publicly available newspaper articles, government policies, news segments, documentary film clips, or social media videos published in the last five years which pertain to gene-based pest control.

Researcher #1's Sources

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Step 2: Create the statements. The color of the researcher box in Step 1 correlates to the statements of the same color in the list below.

Original Forty Statements from Content Analysis:

1. Meaningfully implementing *gene-based pest control* across Aotearoa would be a waste of money.
2. Pests will always find a way into pest free locations, despite *gene-based pest control* implementation.
3. Climate change would push the population of pest species to require a *gene-based pest control* solution in the future.
4. Non-genetic technologies for pest control methods as alternatives to *gene-based pest control* will continue to be more regulated and restricted as time goes forward.
5. *Gene-based pest control* alone would be enough to reach the Predator Free 2050 goal if properly implemented.
6. Allowing *gene-based pest control* for pest control will inevitably lead to human usage to some degree.
7. Field usage of *gene-based pest control* technology for pest control would improve the general understanding on the subject.
8. Pests have become a part of the ecosystems in Aotearoa, so *gene-based pest control* will harm all levels.
9. *Gene-based pest control* for pest eradication will never be legalized by the government and thus shouldn't be funded for research.
10. All people must agree to the use of *gene-based pest control* otherwise it would be unethical to implement.
11. Humans have the right to force *gene-based pest control* on pest species.
12. *Gene-based pest control* should only be utilized if everyone agrees to use it.
13. *Gene-based pest control* should have more government oversight due to it being untested in the environment.
14. *Gene-based pest control* would cause harm to native species in the environment.
15. Other forms of technology would be more useful than *gene-based pest control* to achieve the goal of PF 2050.
16. *Gene-based pest control* should not be used since all living things will die eventually.
17. Due to PF 2050's huge goal, a more versatile form of pest control, other than *gene-based pest control*, should be used.
18. I would be more interested in *gene-based pest control* if it was more financially beneficial.
19. *Gene-based pest control* for pest species in Aotearoa will inspire technological advancement elsewhere.
20. *Gene-based pest control* should be used since it can prevent genetic conditions.
21. *Gene-based pest control* is a safe solution to getting rid of pests.
22. *Gene-based pest control* will ignore animal rights.
23. I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.
24. *Gene-based pest control* can be a solution to eradicating pests in Aotearoa.
25. *Gene-based pest control* will negatively affect the Aotearoa economy.
26. *Gene-based pest control* will help Aotearoa lead the world in achieving pest eradication.

27. Religion plays a big role in implementing gene-based pest control.
28. *Gene-based pest control* in Aotearoa would lead to global extinction of the pest species.
29. *Gene-based pest control* would contribute to the food web collapsing.
30. *Gene-based pest control* would take too long to eradicate the pests from Aotearoa.
31. *Gene-based pest control* is economically efficient.
32. *Gene-based pest control* would allow for unpredictable hybridization with genetically modified pests and other related species to occur.
33. *Gene-based pest control* would not affect an off-target population.
34. *Gene-based pest control* should only be used if it is limited to a specific area.
35. *Gene-based pest control* would increase populations of other invasive species.
36. *Gene-based pest control* allows humans to push beyond their limits in nature.
37. Genetic modification for desirable traits in food justifies *gene-based pest control*.
38. I trust scientists to make *gene-based pest control* precise and have no off-target effects.
39. *Gene-based pest control* could make Aotearoa a world leader in pest control.
40. My own views on *gene-based pest control* for Aotearoa matter.

Step 3: Create categories based on the statements.

Religion	**Power**	**Ethics**	**Environmental**
Safety	**Economy**	**Knowledge**	**Social**

Step 4: Discuss statements with expert, Alan Hunt, and add suggested statements.

Statements Suggested from Alan Hunt and Dr. Mercier:

- Animal rights are not relevant to discussions about *gene-based pest control.*
- *Gene-based pest control* is a technical fix for broader social, cultural, and spiritual issues.
- *Gene-based pest control* is an example of humans "playing god".
- *Gene-based pest control* is an existential threat to life on planet Earth.
- *Gene-based pest control* is part of a hidden agenda.
- *Gene-based pest control* should only be used inside the laboratory.
- *Gene-based pest control* will have unforeseen circumstances.
- *Gene-based pest control* would be a crucial step towards a Predator Free 2050.
- *Gene-based pest control* would enhance the Aotearoa economy.
- *Gene-based pest control* would enhance the Māori guardianship over the environment.
- Genetic techniques like *gene-based pest control* minimize off-target effects.
- I trust the government to only implement *gene-based pest control* if a majority of people agree.
- I trust the scientists to develop ethical *gene-based pest control.*
- Matauranga Māori (Māori knowledge) counts in the decision to use *gene-based pest control*.

- My consent to *gene-based pest control* for some species is consent for *gene-based pest control* of other pest species.
- My opinion counts in the decision whether to use *gene-based pest control.*
- Pest trapping gives me more personal satisfaction than *gene-based pest control* would.
- Pests could be eradicated from Aotearoa without *gene-based pest control.*
- Religion and spirituality offer guidance on *gene-based pest control*.
- Scientists communicate effectively about *gene-based pest control.*
- The government should invest more funding into *gene-based pest control.*
- The mauri (life essence) of threatened ecosystems would be enhanced by using *gene-based pest control.*
- There is enough information/research on GMOs to proceed with *gene-based pest control.*
- Treaty/Tiriti partners should agree on *gene-based pest control* before it is used.

Step 5: Sort statements into categories.

Religion:
Religion and spirituality offer guidance on *gene-based pest control*.
Matauranga Māori (Māori knowledge) counts in the decision to use *gene-based pest control*.
Gene-based pest control is a technical fix for broader social, cultural, and spiritual issues.
Religion plays a big role in implementing *gene-based pest control*.

Power:
Gene-based pest control is an example of humans "playing god".
Gene-based pest control would help Aotearoa lead the world in achieving pest eradication.
Treaty/Tiriti partners should agree on *gene-based pest control* before it is used.
Gene-based pest control is an existential threat to life on planet Earth.
Humans have the right to force *gene-based pest control* on pest species.
Gene-based pest control allows humans to push beyond their limits in nature.
Gene-based pest control could make Aotearoa a world leader in pest control.

Ethics:
Animal rights are not relevant to discussions about *gene-based pest control.*
My consent to *gene-based pest control* for some species is consent for *gene-based pest control gene-based pest control* of other pest species.
Gene-based pest control will have unforeseen circumstances.
I trust the government to only implement *gene-based pest control* if a majority of people agree.
Allowing *gene-based pest control* for pest control will inevitably lead to human usage to some degree.
All people must agree to the use of *gene-based pest control* otherwise it would be unethical to implement.
Gene-based pest control should not be used since all living things will die eventually.
Genetic modification for desirable traits in food justifies *gene-based pest control*.

Environmental:
The mauri (life essence) of threatened ecosystems would be enhanced by using *gene-based pest*

control.
Climate change would push the population if pest species to require a *gene-based pest control* solution in the future.
Gene-based pest control would be a crucial step towards a Predator Free 2050.
Gene-based pest control would increase population of other invasive species.
Pests could be eradicated from Aotearoa without *gene-based pest control.*
Gene-based pest control in Aotearoa would lead to global extinction of the pest species.
Gene-based pest control would contribute to the food web collapsing.
Gene-based pest control would cause harm to native species in the environment.
Gene-based pest control alone would be enough to reach the Predator Free 2050 goal if properly implemented.
Gene-based pest control will ignore animal rights.
Gene-based pest control can be a solution to eradicating pest in Aotearoa.
Gene-based pest control would allow for unpredictable hybridization with genetically modified pests and other related species to occur.
Gene-based pest control would not affect an off-target population.
Gene-based pest control should only be used if it is limited to a specific area.

Safety:
Gene-based pest control should only be used inside the laboratory.
Gene-based pest control is a safe solution to getting rid of pests.
I trust the scientists to develop ethical *gene-based pest control.*
Genetic techniques like *gene-based pest control* minimize off-target effects.
Non-genetic technologies for pest control methods as alternatives to *gene-based pest control* will continue to be more regulated and restricted as time goes forward.
Gene-based pest control should have more government oversight due to it being untested in the environment.
I trust scientists to make *gene-based pest control* precise and have no off-target effects.

Economy:
Gene-based pest control would enhance the Aotearoa economy.
The government should invest more funding into *gene-based pest control.*
Gene-based pest control is part of a hidden agenda.
Gene-based pest control would take too long to eradicate the pests from Aotearoa.
Meaningfully implementing *gene-based pest control* across Aotearoa would be a waste of money.
Gene-based pest control for pest eradication will never be legalized by the government and thus shouldn't be funded for research.
Due to PF 2050's huge goal, a more versatile form of pest control, other than *gene-based pest control*, should be used.
I would be more interested in *gene-based pest control* if it was more financially beneficial.
Gene-based pest control will negatively affect the Aotearoa economy.
Gene-based pest control is economically efficient.

Knowledge:
There is enough information/research on GMOs to proceed with *gene-based pest control.*

Scientists communicate effectively about *gene-based pest control.*
I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.
Gene-based pest control for pest species in Aotearoa will inspire technological advancement elsewhere.
Pests will always find a way into pest free locations, despite *gene-based pest control* implementation.
Field usage of *gene-based pest control* technology for pest control would improve the general understanding on the subject.
Pests have become a part of the ecosystems in Aotearoa, so *gene-based pest control* will harm all levels.
Gene-based pest control should be used since it can prevent genetic conditions.

Social:
My opinion counts in the decision whether to use *gene-based pest control.*
Gene-based pest control would enhance the Māori guardianship over the environment.
Pest trapping gives me more personal satisfaction than *gene-based pest control* would.
Gene-based pest control should only be utilized if everyone agrees to use it.
Other forms of technology would be more useful than *gene-based pest control* to achieve the goal of PF 2050.
My own views on *gene-based pest control* for Aotearoa matter.

Step 6: Discuss statements within each category and select final statements, as shown in Appendix B.

Appendix B: Q-Statements

1. Religion and spirituality offer guidance on *gene-based pest control*.
2. Matauranga Māori (Māori knowledge) counts in the decision to use *gene-based pest control.*
3. *Gene-based pest control* is a technical fix for broader social, cultural, and spiritual issues.
4. *Gene-based pest control* is an example of humans "playing god".
5. *Gene-based pest control* would help Aotearoa lead the world in achieving pest eradication.
6. Treaty/Tiriti partners should agree on *gene-based pest control* before it is used.
7. *Gene-based pest control* is an existential threat to life on planet Earth.
8. Animal rights are not relevant to discussions about *gene-based pest control.*
9. My consent to *gene-based pest control* for some species is consent for *gene-based pest control* of other pest species.
10. *Gene-based pest control* will have unforeseen circumstances.
11. I trust the government to only implement *gene-based pest control* if a majority of people agree.
12. The mauri (life essence) of threatened ecosystems would be enhanced by using *gene-based pest control.*
13. Climate change would push the population of pest species to require a *gene-based pest control* solution in the future.
14. *Gene-based pest control* would be a crucial step towards a Predator Free 2050.
15. *Gene-based pest control* would increase population of other invasive species.
16. Pests could be eradicated from Aotearoa without *gene-based pest control.*
17. *Gene-based pest control* in Aotearoa would lead to global extinction of the pest species.
18. *Gene-based pest control* would contribute to the food web collapsing.
19. *Gene-based pest control* would cause harm to native species in the environment.
20. *Gene-based pest control* should only be used inside the laboratory.
21. *Gene-based pest control* is a safe solution to getting rid of pests.
22. I trust the scientists to develop ethical *gene-based pest control.*
23. Genetic techniques like *gene-based pest control* minimize off-target effects.
24. *Gene-based pest control* would enhance the Aotearoa economy.
25. The government should invest more funding into *gene-based pest control.*
26. *Gene-based pest control* is part of a hidden agenda.
27. *Gene-based pest control* would take too long to eradicate the pests from Aotearoa.
28. There is enough information/research on GMOs to proceed with *gene-based pest control.*
29. Scientists communicate effectively about *gene-based pest control.*
30. I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.
31. *Gene-based pest control* for pest species in Aotearoa will inspire technological advancement elsewhere.
32. My opinion counts in the decision whether to use *gene-based pest control.*
33. *Gene-based pest control* would enhance the Māori guardianship over the environment.
34. Pest trapping gives me more personal satisfaction than *gene-based pest control* would.

Appendix C: Participant Invitation Email

Subject: Invited to Participate in a Study to Gain Your Perspective on Pest Control in Aotearoa

Kia ora [Insert Name],

We hope this email finds you well! We are a team of four students from Worcester Polytechnic Institute (WPI), a university located in the USA. We are working on a summer project to understand social perspectives on gene-based technology for pest control in New Zealand.

This project is in collaboration with Dr. Ocean Mercier (Ngāti Porou), Alan Rangitāne Hunt (Ngāti Hauā, Ngāti Te Oro), and Symon Palmer (Ngāi Te Rangi) at Victoria University of Wellington. This research addresses the New Zealand Predator Free 2050 goal that aims to eradicate predator species from the country by 2050 to enhance native biodiversity.

Norway rats while also German and common wasps are widespread non-native species in New Zealand. For this reason, New Zealand scientists have been researching biotechnological methods, like single-sex offspring selection, as a method to get rid of rats; and gene drive to eradicate wasps from New Zealand.

Given your expertise, we would like to invite you (or anyone you might recommend) to participate in a 1-hour interview in late January or the beginning of February. Your perspectives will help us to understand levels of support and identify concerns regarding gene-based pest control. Your contribution to this study will be greatly appreciated and will be valuable to this research. This will not be a test of your knowledge but more of a conversation about your views: no prior knowledge of gene-based technologies is needed. We aim to conduct these interviews in person at Victoria University of Wellington, or we can travel to a more convenient location of yours. In appreciation of your time, we would like to offer you a 30$ gift card.

For this interview, we will use Q-Method. You will be asked to sort a collection of statements onto a scaled grid based on your opinions of the gene-based control being developed for the pest (rats or wasps) of most interest to you. Some introductory and follow-up questions will be asked during this process. All the information collected during this study will be kept confidential, which means the researchers on this project will be aware of your identity but will not share it in any of the reports. This research has been approved by the Worcester Polytechnic Institute's Institutional Review Board (WPI IRB).

Please respond to this email if you are interested in participating in this study. Additionally, if you have any questions, feel free to contact us at gr-nz-2223-gm@wpi.edu.

Thank you for your time and consideration!

Best,
Liam Hemmerling
Joey Horowitz
Rafaela Kanli
Lily MacDonald

Appendix D: Q-Method Interview Procedure

Introductory Interview:
Interviews will take place in the office space provided by Dr. Ocean Mercier at the Victoria University of Wellington Te Kawa a Māui School of Māori Studies building, or the team may travel to a more convenient place for the participant. The interview will include two members of the group, a facilitator and a note-taker, and one interviewee.

Introductory Interview:
"Welcome! Thank you for being here today! My name is _____, and I will be facilitating the interview. My name is _____, and I will be taking notes during the interview. We are both students from Worcester Polytechnic Institute (WPI), a university located in the USA. We are working on a summer project to understand social perspectives on gene-based technology for pest control in Aotearoa New Zealand. We have invited you to this interview to gain your perspective on this matter. This interview will not be a test of your knowledge but more of a conversation about your views: no prior knowledge of gene-based technologies is needed. First, we would like to inform you about the interview process."

Then, the interviewers will discuss essential considerations of the interview process. These considerations are consent forms, confidentiality, the withdrawing process, and reiterating that this is not a test of knowledge but a conversation about their views on gene-based pest control in Aotearoa. **Hand out the consent form.**

"Here is a consent form that will explain the purpose of the study, record keeping, and confidentiality. This interview will be ***confidential.*** *Our findings and interpretations from the interview data will be included in our final report* ***without attribution****. Your name and any identifying details will be removed for confidentiality.* ***You may stop the interview process at any time****. I will give you a few minutes to read over the form and sign it. If you have any questions about the consent form, please let me know."*

"Additionally, there is a personal information form attached to the consent form that we ask you to fill out for our data collection purposes."

After all forms are signed, **turn on the recording device** if given permission. Finally, the participant will be able to introduce themselves. We will inform the participant that the entire session should take no longer than one hour of their time.

"Now, let us move on to the interview. Would you be comfortable if I recorded this interview? Only the study investigators and the sponsor of this project will have access to your responses."

"Alright, let us begin. This interview will take an hour of your time. ***Could you please introduce yourself?****"*

After the participant introduction, the participant will be asked a series of questions to gauge their understanding of the importance of this topic and their knowledge of gene technology.

"We will now ask you a series of introductory questions to get a better understanding of your familiarity with pests and gene technology in general. Just to reiterate, no prior knowledge of gene-based technologies is needed. This is just an icebreaker to get you comfortable with the interview process."

- *Q1: Are pest species like rats or wasps a problem where you come from? If so, how do they impact your daily lives? Additionally, how do they impact the ecosystem?*
- *Q2: Have you ever been involved in a rat or wasp control program? Or any other pest species control programs?*
- *Q3: Are you familiar with the sex selection method or the gene drive method?*

"Today, we will be discussing gene-based pest control. Currently, research is addressing the New Zealand Predator Free 2050 goal that aims to eradicate predator species from the country by 2050 to enhance native biodiversity. Norway and ship rats and German and common wasps are widespread non-native species in Aotearoa. For this reason, scientists have been researching more on the use of biotechnological methods, like single-sex offspring selection, as a method to get rid of rats; and gene drive to eradicate wasps from Aotearoa.

***Sex selection is a form of genetic modification that alters the embryo so that a species population, like a rat litter, produces only male offspring**. Researchers overseas have produced all-male populations in mice using genetic techniques. Modeling this method indicates the potential to reduce pest species populations. Researchers in Aotearoa are also looking at making the trait heritable, so the modification is disseminated through rats breeding."*

*"**Gene drive is another form of genetic modification that introduces copied genes into the species' genome that are passed on to future generations.***

Q4: Do you have any initial impressions or further questions about these gene technologies?

If participants have any questions about gene technology that we do not know the answer to, provide a response like: *"That's a good question, but I do not know the answer to that. We are not experts in the field, but we will note that question and pass it along to the scientists."*

Condition for Instruction of the Q-Method:
Once we complete the introductory interview, we will introduce the Q-Method and provide instructions for sorting the statement cards.

"Thank you for your responses to the introductory interview. We will now move on to the Q-Method, where you will be given a collection of statement cards about gene-based pest control to sort into groups based on how well they match your opinions."

Next, we will **give the participant an envelope of statement cards**, which is called the concourse. The participant will open the envelope and initially sort the statement cards into three groups: disagree, neutral, and agree.

"Here is an envelope of statement cards that you may now sort into three piles of items you might agree with, disagree with, or be indifferent about. Take a few minutes to sort the statement cards. This will not be the final assortment as you will be asked to further sort the statement cards later."

After the initial assortment, we will **give the participant the Q-Sort grid**, which is in the shape of a bell curve. Each participant's Q-Sort grid will be labeled with a designated number for data entry purposes.

"Now that you have sorted the statement cards into these three initial groups, try placing them on the grid with one statement card per square. The statement cards that you strongly agree with will be placed on the far right of the grid. The statement cards that you strongly disagree with will be placed on the far left of the grid. The other statement cards will be placed in the middle. The meaning of each statement card is up to your own interpretation. Please let me know if you have any clarifying questions throughout the sorting process."

Post Q-Method Interview:
When the participant completes the Q-Sort, we will ask a series of questions to allow the participant to provide reasoning about their assortment of statement cards.

"Now that you have finalized the arrangement of the statement cards, we will move on to a post Q-Method interview. I will ask you a series of questions about specific placements of the statement cards to understand your thinking process and reasoning."

- *Q5: Which statements did you place in the far-right column? And why?*
- *Q6: Which statements did you place in the far-left column? And why?*
- *Q7: What are some statement cards that jumped out to you?*
- *Q8:Were there any statement cards that were difficult to place? And why?*
- *Q9: Do you have any views that were not represented in this collection of statements?*

Once the participant finishes answering the interview questions, we will **take a picture of their finalized Q-Sort** using our phone. We will thank the participant for their time and **offer them a gift card**.

"Considering your time, I would now like to end this interview by taking a picture of your finalized arrangement of the statement cards. Additionally, my team and I would like to thank you for participating in this study and meeting us today. In appreciation of your time, we would like to offer you this gift card.

Q10:Do you have any last-minute questions that we can answer for you?"

Interview Data Organization:
We will use an Excel Spreadsheet to organize all possible contact lists and a separate sheet for each participant's personal info while also match their interview data and consent form responses. This information will help us formulate a narrative to describe better the factors based on their responses to the questions asked.

Q-Method Data Organization:
We will keep a copy of each participant's consent form, the photographs of each Q-Sort, and the interview recordings in the shared Google Drive. We will summarize the main points of each interview recording and store them in the Interview Data Excel Spreadsheet. These summaries provide information for creating the descriptions for each factor from the factor analysis. The PQMethod software will store the numerical Q-Sort and factor analysis data. We will input the numerical arrangement of each participant's statement cards into the PQMethod software and save the statistical files in the shared OneDrive.

Appendix E: Consent & Demographic Handout Form

Informed Consent Agreement for Participation in Research Study

Investigator(s): Liam Hemmerling, Joey Horowitz, Rafaela Kanli, Lily MacDonald

Contact Information: gr-nz-2223-gm@wpi.edu

Title of Research Study: Charting Social Perspectives of Genetic Technology for Pest Control in Aotearoa New Zealand

Sponsor: Dr Ocean Mercier of Te Kawa a Māui, the School of Māori Studies at Victoria University of Wellington (VUW)

Introduction:
You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks, or discomforts that you may experience because of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the Study:
The goal of this study is to chart perceptions on gene-based pest control in Aotearoa. Sex selection and gene drive are two technologies under early investigation by teams at AgResearch, University of Otago, and VUW. Single-Sex Offspring Selection works by altering the genes so that a litter only produces male offspring. Gene drive works by introducing copied genes into the species genome that are passed onto future generations. We would like to learn your opinion on whether, when, and how these techniques should or should not ultimately be utilized.

Procedures to be followed:
Initially, you will be asked a series of questions about your involvement in environmental protection in Aotearoa, rats, and other 'pests'. We will then discuss the gene-based method that researchers are exploring as a possible method for rat and wasp control, and you will have an opportunity to ask questions. Then you will begin the process of the Q-method. This will involve reading a series of statements, deciding whether you agree, disagree, or are neutral about them, and placing them onto a pyramid-shaped Q-grid. After the Q-sort is complete you will be asked about why you placed statements in a particular spot.

Risks to Study Participation:
By participating in the study, you will be exposed to ideas that you may find confronting and may cause emotional discomfort. If the study brings up questions for you during or after the session, please do not hesitate to raise and talk these through with us and/or contact our sponsor.

Benefits to Research Participants and Others:
By participating in this study, you will be contributing to research towards the goal of Predator Free New Zealand 2050.

Record Keeping and Confidentiality:
All answers to any questions asked during the interview as well as all placements of the Q-statements during the Q-study procedure may be reported, but only ever in an aggregated fashion that will not identify or single out any individual. Only the investigators and the sponsor will have access to your responses. Records of your participation in this study will be held confidential so far as permitted by United States law. However, the study investigators, the sponsor, or its designee and, under certain circumstances the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

Compensation or Treatment in the Event of Injury:
By participating in the study, you will not be exposed to any foreseeable risks or discomforts. You do not give up any of your legal rights by signing this statement.

For more information about research or about the rights of research participants, or in case of research-related injury:
Reach out directly to the group at gr-nz-2223-gm@wpi.edu with any questions/concerns. Additional information can be found from the Internal Review Board at Worcester Polytechnic Institute. Contact the IRB Manager, Ruth McKeogh, at +1 (508) 831-6699 or by email at irb@wpi.edu. Alternatively, contact the Human Protection Administrator, Gabriel Johnson, at +1 (508) 831-4989 or by email at gjohnson@wpi.edu.

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without loss of other benefits. The project investigators also retain the right to cancel or postpone the interview at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

_____ **Date:** _____
Participant Signature

_____
Participant Name (Please print)

_____ **Date:** _____
Signature of Person who explained this study

Profession/Study:_____

Region/Suburb: _____

Age: ☐ <24 ☐ 25-34 ☐ 35-44 ☐ 45-54
☐ 55-64 ☐ 65-74 ☐ 75+ ☐ Prefer not to say

Gender Identity: _____ ☐ Prefer not to say

Ethnicity: _____ ☐ Prefer not to say

Would you like a copy of the final report sent to you via email?

☐ Yes ☐ No

If yes, email: _____

Q Sort No ____

Appendix F: Consensus Statement Q-Sort Values

Consensus Statement	Statement Identifying Number	Q-Sort Value for Factor 1	Q-Sort Value for Factor 2	Q-Sort Value for Factor 3
Climate change would push the population of pest species to require a *gene-based pest control* solution in the future	13	1	0	0
Gene-based pest control would contribute to the food web collapsing	18	-2	-2	-3
Genetic techniques like *gene-based pest control* minimize off-target effects	23	2	0	1
The government should invest more funding into *gene-based pest control*	25	3	2	2
Gene-based pest control would enhance Māori guardianship over the environment	33	1	0	0

This table shows Q-Sort values for the consensus statements for the Q-method. The Q-Sort values show the average placement on the Q-Grid, within each factor. For instance, the average placement of statement 18 in Q-Sorts flagged into factor 1 was -2. The negative value indicates disagreement with the statement, whereas a positive value indicates agreement. These values show the average placement of the statement for Q-Sorts within each factor.

Appendix G: Factor Loadings for Each Q-Sort

Q-Sort	Factor 1	Factor 2	Factor 3
1	0.5566	**0.6428**	0.1357
2	0.4056	0.1671	**0.4568**
3	0.1510	**0.7286**	0.1041
4	0.0407	-0.1532	**0.8198**
5	**0.7833**	0.1825	0.2484
6	0.2535	**0.7376**	-0.0061
7	**0.6954**	0.5209	-0.0148
8*	0.5860	0.5867	0.0331
9	-0.0991	0.4286	**0.6454**
10	**0.8822**	0.0582	-0.1107
11	-0.0980	**0.8778**	0.1323
12	**0.6851**	0.5325	0.0430
13	0.5110	**0.6735**	-0.1842
14	**0.6998**	0.4250	0.2958
15*	0.2407	0.3146	0.0617
16	**0.8843**	0.1784	-0.0262
17	**0.8016**	0.0392	0.1218
18	**0.7586**	0.2248	-0.0179

This table shows the factor loading for each Q-Sort. Q-Sorts with a '*' were not flagged into a factor. The greatest factor loading for each Q-Sort is bolded to represent which factor the Q-Sort was flagged into by the PQMethod software. The greater the factor loading value, the more similar the Q-Sort was with the factor. A negative value indicates no agreement between the statement and the factor.

Appendix H: Distinguishing Statement Z-Scores

The factor groupings and Z-Scores for distinguishing statements of the Q-Method. The bold Z-Score values indicate the factor which distinguished the statement.

Factor Number	Q-Sorts	Distinguishing Statement	Statement Identifying Number	Z-Score for Factor 1	Z-Score for Factor 2	Z-Score for Factor 3
1	5, 7, 10, 12, 14, 16, 17, 18	*Gene-based pest control* would be a crucial step towards a Predator Free 2050.	14	**2.02**	0.45	0.80
		Gene-based pest control in Aotearoa would lead to global extinction of the pest species.	6	**1.85**	0.70	0.92
		Gene-based pest control would enhance the Aotearoa economy.	24	**1.48**	0.85	0.40
		I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.	30	**0.47**	-0.95	1.63
		Scientists communicate effectively about *gene-based pest control*.	29	**0.29**	-0.70	-1.75
		There is enough information/research on GMOs to proceed with *gene-based pest control*.	28	**0.16**	-1.55	-0.95
		My consent to gene-based pest control for some species is consent for *gene-based pest control* of other pest species.	9	**-0.11**	-1.05	-1.56
		Gene-based pest control will have unforeseen circumstances.	10	**-0.20**	1.07	1.26
		I trust the government to only implement *gene-based pest control* if a majority of people agree.	11	**-0.42**	0.51	-1.71
		Gene-based pest control would take too long to eradicate the pests from Aotearoa.	27	**-1.14**	-0.04	-0.05
		Religion and spirituality offer guidance on *gene-based pest control*.	1	**-1.17**	0.82	0.43
		Gene-based pest control should only be used inside the laboratory.	20	**-1.41**	-0.15	-0.36
		Gene-based pest control is part of a hidden agenda.	26	**-1.57**	-2.24	0.70
		Gene-based pest control is an example of humans "playing god".	5	**-1.57**	-0.12	1.90
2	1, 3, 6, 11, 13	Treaty/Tiriti partners should agree on *gene-based pest control* before it is used.	7	0.29	**2.10**	0.32
		Matauranga Māori (Māori knowledge) counts in the decision to use *gene-based pest control*.	2	0.71	**1.54**	0.64
		My opinion counts in the decision whether to use *gene-based pest control*.	32	0.12	**0.93**	-0.12
		I trust the government to only implement *gene-based pest control* if a majority of people agree.	11	-0.42	**0.51**	-1.71
		Pests could be eradicated from Aotearoa without *gene-based pest control*.	16	-0.91	**0.44**	-1.07
		Gene-based pest control would cause harm to native species in the environment.	19	-0.82	**-0.08**	-1.12
		The mauri (life essence) of threatened ecosystems would be enhanced by using *gene-based pest control*.	12	1.15	**-0.09**	0.65
		Gene-based pest control is an example of humans "playing god".	5	-1.57	**-0.12**	1.90
		Scientists communicate effectively about *gene-based pest control*.	29	0.29	**-0.70**	-1.75
		I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.	30	0.47	**-0.95**	1.63
		Gene-based pest control in Aotearoa would lead to global extinction of the pest species.	17	-0.32	**-1.52**	-0.12
		Gene-based pest control is part of a hidden agenda.	26	-1.57	**-2.24**	0.70
3	2, 4, 9	*Gene-based pest control* is an example of humans "playing god".	5	-1.57	-0.12	**1.90**
		I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.	30	0.47	-0.95	**1.63**

		Gene-based pest control is a technical fix for broader social, cultural, and spiritual issues.	3	-0.23	-0.16	**1.30**
		Pest trapping gives me more personal satisfaction than *gene-based pest control* would.	34	-0.59	-1.00	**0.95**
		Gene-based pest control is part of a hidden agenda.	26	-1.57	-2.24	**0.70**
		Gene-based pest control is an existential threat to life on planet Earth.	4	-1.75	-1.77	**0.01**
		Gene-based pest control for pest species in Aotearoa will inspire technological advancement elsewhere.	31	0.85	1.22	**-0.27**
		I trust the government to only implement *gene-based pest control* if a majority of people agree.	11	-0.42	0.51	**-1.71**
		Scientists communicate effectively about *gene-based pest control*.	29	0.29	-0.70	**-1.75**
		I trust scientists to develop ethical *gene-based pest control*.	22	0.82	0.62	**-1.91**

Appendix I: Distinguishing Statement Q-Sort Values

The factor groupings and Q-Sort values for distinguishing statements of the Q-Method. The bold Q-Sort values indicate the factor which distinguished the statement.

Factor Number	Q-Sorts	Distinguishing Statement	Statement Identifying Number	Q-Sort Value for Factor 1	Q-Sort Value for Factor 2	Q-Sort Value for Factor 3
1	5, 7, 10, 12, 14, 16, 17, 18	*Gene-based pest control* would be a crucial step towards a Predator Free 2050.	14	**4**	1	2
		Gene-based pest control in Aotearoa would lead to global extinction of the pest species.	6	**4**	1	2
		Gene-based pest control would enhance the Aotearoa economy.	24	**3**	2	1
		I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.	30	**1**	-2	4
		Scientists communicate effectively about *gene-based pest control*.	29	**1**	-1	-4
		There is enough information/research on GMOs to proceed with *gene-based pest control*.	28	**0**	-3	-2
		My consent to gene-based pest control for some species is consent for *gene-based pest control* of other pest species.	9	**0**	-2	-3
		Gene-based pest control will have unforeseen circumstances.	10	**0**	3	3
		I trust the government to only implement *gene-based pest control* if a majority of people agree.	11	**-1**	1	-3
		Gene-based pest control would take too long to eradicate the pests from Aotearoa.	27	**-2**	0	0
		Religion and spirituality offer guidance on *gene-based pest control*.	1	**-3**	2	1
		Gene-based pest control should only be used inside the laboratory.	20	**-3**	-1	-1
		Gene-based pest control is part of a hidden agenda.	26	**-3**	-4	2
		Gene-based pest control is an example of humans "playing god".	5	**-4**	-1	4
2	1, 3, 6, 11, 13	Treaty/Tiriti partners should agree on *gene-based pest control* before it is used.	7	0	**4**	0
		Matauranga Māori (Māori knowledge) counts in the decision to use *gene-based pest control*.	2	1	**4**	1
		My opinion counts in the decision whether to use *gene-based pest control*.	32	0	**3**	-1
		I trust the government to only implement *gene-based pest control* if a majority of people agree.	11	-1	**1**	-3
		Pests could be eradicated from Aotearoa without *gene-based pest control*.	16	-2	**1**	-2
		Gene-based pest control would cause harm to native species in the environment.	19	-2	**0**	-2
		The mauri (life essence) of threatened ecosystems would be enhanced by using *gene-based pest control*.	12	3	**-1**	1
		Gene-based pest control is an example of humans "playing god".	5	-4	**-1**	4
		Scientists communicate effectively about *gene-based pest control*.	29	1	**-1**	-4
		I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.	30	1	**-2**	4
		Gene-based pest control in Aotearoa would lead to global extinction of the pest species.	17	-1	**-3**	-1

		Gene-based pest control is part of a hidden agenda.	26	-3	**-4**	2
3	2, 4, 9	*Gene-based pest control* is an example of humans "playing god".	5	-4	-1	**4**
		I am not knowledgeable enough to decide if *gene-based pest control* should be implemented.	30	1	-2	**4**
		Gene-based pest control is a technical fix for broader social, cultural, and spiritual issues.	3	-1	-1	**3**
		Pest trapping gives me more personal satisfaction than *gene-based pest control* would.	34	-1	-2	**3**
		Gene-based pest control is part of a hidden agenda.	26	-3	-4	**2**
		Gene-based pest control is an existential threat to life on planet Earth.	4	-4	-4	**0**
		Gene-based pest control for pest species in Aotearoa will inspire technological advancement elsewhere.	31	2	3	**-1**
		I trust the government to only implement *gene-based pest control* if a majority of people agree.	11	-1	1	**-3**
		Scientists communicate effectively about *gene-based pest control*.	29	1	-1	**-4**
		I trust scientists to develop ethical *gene-based pest control*.	22	2	1	**-4**

This table shows the average placement of the distinguishing statement within each factor as a Q-Sort value. The Q-Sort values represent the average placement on the Q-Grid, within each factor. For instance, the average placement of statement 14 in factor 1 was 4. The negative value indicates disagreement with the statement, whereas a positive value indicates agreement.

Appendix J: Factor Scores as Z-Scores

Statement Number	Factor Score for Factor 1	Factor Score for Factor 2	Factor Score for Factor 3
1	-1.173	0.820	0.432
2	0.714	1.537	0.638
3	-0.229	-0.156	1.304
4	-1.747	-1.774	0.014
5	-1.573	-0.116	1.901
6	1.850	0.702	0.920
7	0.291	2.096	0.323
8	-0.197	-1.180	-0.741
9	-0.112	-1.052	-1.558
10	-0.201	1.068	1.263
11	-0.419	0.505	-1.709
12	1.152	-0.090	0.645
13	0.310	0.069	-0.000
14	2.022	0.449	0.796
15	-0.496	0.758	0.083
16	-0.909	0.443	-1.071
17	-0.321	-1.518	-0.117
18	-1.097	-0.876	-1.435
19	-0.816	-0.081	-1.119
20	-1.411	-0.151	-0.357
21	0.730	0.221	-0.357
22	0.824	0.617	-1.908
23	0.839	0.217	0.604
24	1.485	0.846	0.398
25	1.204	0.718	0.762
26	-1.573	-2.236	0.700
27	-1.137	-0.035	-0.048
28	0.159	-1.549	-0.954
29	0.294	-0.699	-1.750
30	0.471	-0.951	1.627
31	0.847	1.222	-0.274
32	0.120	0.929	-0.117
33	0.685	0.245	0.158
34	-0.586	-0.998	0.947

This table shows the factor score as a Z-Score for each statement in each factor. The factor score is how agreed or disagreed the statement was within the factor. The greater the value, the more strongly opinionated the statement was. A positive factor score represented

agreeance among Q-Sorts, while a negative score represented disagreement. For instance, statement 14 in factor 1 was strongly agreed with, while statement 4, in the same factor, was strongly disagreed with among Q-Sorts.

Appendix K: Unique Data Percentage

Q-Sort	Percentage of Unique Data Represented out of Total Data	Cumulative Percentage of Total Data Represented
1	46.2629	46.2629
2	11.8121	58.0750
3	7.9723	66.0473
4	7.0403	73.0876
5	4.9721	78.0597
6	4.3662	82.4259
7	3.8276	86.2535
8	2.9217	89.1752
9	2.2073	91.3825
10	2.0941	93.4765
11	1.8445	95.3210
12	1.3389	96.6600
13	1.0305	97.6905
14	0.7645	98.4550
15	0.6091	99.0641
16	0.4487	99.5128
17	0.2529	99.7656
18	0.2344	100.00

This table shows the percentage of unique data each Q-Sort contributed, and the cumulative percentage of total data accounted for from Q-Sorts at that point. The first 12 Q-Sorts accounted for over 96% of the final data. The final 6 Q-Sorts entered only changed the total data by approximately 4%, proving the need for only 12 participants for a 34-statement concourse. The PQMethod output would be identical regardless of the order we entered the Q-Sorts.