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Understanding attitudes on new technologies to manage invasive species

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Abstract. Invasive animal species threaten global biodiversity. In New Zealand invasive species threaten iconic native species, and scientists are seeking approval to research new technologies that might be capable of eradicating these invasive species. The aim of this research was to understand what New Zealanders with an interest in pest control consider to be the main risks and benefits of introducing new technologies to manage invasive species. We invited key informants to participate in the focus groups, selecting people with knowledge and experience of pest control issues in New Zealand. Data were collected from seven focus groups held in three locations across New Zealand. A thematic analysis of the data was then conducted in which three key themes emerged: concern about the risk of unintended consequences, the benefits of landscape-scale technologies, and New Zealand being an early adopter of new technologies. The focus groups articulated a variety of benefits from introducing new technologies – such as replacing dangerous poisons with non-toxic alternatives – but it was the risks of the new technologies that dominated the discussions. Given these results, we recommend an education and communication strategy focussed on social learning, in conjunction with a codesigned decision-making process, to help establish social licence for the application of potentially controversial technologies.

Additional keywords: CRISPR, gene editing, pest control, pest-specific toxins, public attitudes, rats, Trojan Female Technique, wasps.

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Introduction

Invasive animal species threaten global biodiversity (Harvey-Samuel *et al.* 2017). These pests prey on native species, compete with native species for resources, modify habitats, and introduce new pathogens to ecosystems (Clavero and García-Berthou 2005; Crowl *et al.* 2008; Bergstrom *et al.* 2009). In Aotearoa New Zealand, where there is a high rate of endemism, invasive animals have caused negative ecological, economic, and social impacts (Russell 2014). Consequently, invasive species management is integral to national conservation and biosecurity policy.

In 2016 the New Zealand Government announced an ambitious conservation vision, Predator Free 2050 (we distinguish here between Predator Free New Zealand as a broader conservation vision, the Predator Free 2050 mission, and the Predator Free 2050 Ltd organisation), which aims to eliminate rats, mice, Australian brushtail possums, and stoats from the mainland and offshore islands of New Zealand by 2050. Predator Free 2050 has renewed interest in developing and researching new tools and technologies to control or eradicate invasive animal species. Scientists believe that a range of new technologies will be available in the future to resolve New Zealand's invasive animal problem (Gemmell *et al.* 2013; PCE 2017; Dearden *et al.* 2018).

However, some of these technologies are potentially very controversial, such as using gene editing techniques to pass genetic traits through pest populations. Under current New Zealand law these genetically edited organisms would be classified as genetically modified organisms (GMOs) and subject to strict regulation (Dearden *et al.* 2018). Recently, the Royal Society of New Zealand has conducted public forums on gene editing technologies for use in healthcare and pest control (Royal Society Te Apārangi 2017), and over the past two decades there has been robust discussion on GMOs, which informed the current legal arrangements. However, given public concern about GMOs, it is difficult to gauge whether New Zealanders are happy with the level of public participation in the decision to use GMOs, or whether enough has been done to explore the diversity of perspectives within New Zealand.

New Zealand's Minister for the Environment, the Honourable David Parker, has signalled that 'the first area where New Zealand may consider these [genetic] technologies could be pest control but that is many years away' (Davison 2018). The Minister's comments come as the outgoing Chief Science Advisor to the Prime Minister, Sir Peter Gluckman, endorsed a public debate on GMO regulation in New Zealand because 'the science is as settled as it will be' and 'there are no significant ecological or health concerns associated with the use of advanced genetic technologies' (Davison 2018). Despite this, research has shown that

New Zealanders remain reluctant to accept GMOs in any form (El-Kafafi 2017).

The application of new invasive species control technologies will require more than just regulatory approval: it will also require a social licence from the public. Social licence to operate is a concept that originated from the mining industry in the 1990s (Moffat *et al.* 2016), and is broadly defined as a process that seeks the 'ongoing acceptance or approval of an operation by those community stakeholders who are affected by it' (Moffat *et al.* 2016, p. 480). In the context of the acceptance of new technologies, however, social licence ought to be expanded to include the different perceptions of risks and benefits held by different stakeholders towards different types of technologies (Gluckman 2016). Scholars argue that social licence is built and maintained by meaningful engagements and information sharing between those seeking social licence and society, as well as clear accountability, two-way dialogue, and communication (Moffat *et al.* 2016; Baines and Edwards 2018). However, because public opinion and perceptions can change, social licence is a dynamic process that needs to be continually reviewed. Furthermore, perceptions of the fairness of these dynamic processes is also critical for social licence (Grimes 2017).

If new technologies are to be applied to help achieve the objectives of Predator Free 2050, their application will be greatly facilitated if they have social licence. Our research has been designed to gain greater understanding of the range of perspectives New Zealanders hold on these new technologies, the goal being to provide recommendations to conservation managers so they can begin the process of working towards social licence to potentially apply these new technologies in the New Zealand context. Given these objectives, our research asks: What do informed New Zealanders perceive as the risk and benefits of three new technologies to control wasps and rats?

Background

We examined attitude and perception of three technologies in relation to wasps and rats. The three new technologies chosen – gene drives, the Trojan female technique, and pest-specific toxins – are not currently available for use but are examples of new technologies that could potentially be used to eradicate invasive species in the future (PCE 2017, p. 67).

Gene drive is a genetic modification that ensures that particular genes will pass through a population. Generally, the offspring of a species inherit two versions of every gene, one from each parent. Each parent carries two versions of the gene as well, so normally there is a 50 : 50 chance that a variant gene will be passed to an offspring. A gene drive ensures that specific genetic changes will almost always be passed on, allowing that variant to spread throughout a population. Gene drives have been identified as a potentially powerful tool for invasive species eradication (Champer *et al.* 2016; Corlett 2017; Harvey-Samuel *et al.* 2017), and recent advances in the CRISPR-Cas9 gene-editing technique will make the creation of gene drives quicker, easier, and more cost-effective (Baltimore *et al.* 2015; Ledford 2015; Beets 2016).

The Trojan female technique takes advantage of a naturally occurring genetic mutation in females that causes male infertility. The Trojan female technique identifies and selectively breeds females with these male infertility mutations to control invasive species populations. These females give birth to sterile male offspring, but their daughters still breed and produce sterile males. Experts believe this fertility control approach has the potential to be an efficient and humane form of controlling animal pests (Gemmell *et al.* 2013).

Pest-specific toxins that will only kill target species are currently being researched in New Zealand (PCE 2017). (Pest-specific toxins are synonymous with species-specific, host-specific, or species-selective toxins. We used the phrase 'pest-specific toxin' during our focus groups and have therefore used it throughout the paper.) New Zealand uses several different toxins for vertebrate pest control, but these have some disadvantages; for example, they can affect non-target species, some persist in animal tissues and can enter the food chain, and some have animal welfare impacts. By contrast, pest-specific toxins are less likely to cause secondary poisoning, to cause undesirable animal welfare impacts, or to enter the food chain. Researchers are 'genome mining' the DNA of target species to find gene sequences that can be exploited by a pest-specific toxin (PCE 2017, p. 67).

Vespula wasps[1] (Lester *et al.* 2013) and rats[2] (Russell 2014) were chosen as target pests for this research primarily because they are destructive invasive predators, and because research examining New Zealanders' attitudes to invasive species has focussed on possums and rabbits (Kannemeyer 2017, p. 7). This narrow focus can be seen in Table 1, which highlights past research on attitudes towards invasive species in New Zealand. Another reason for choosing wasps is that they 'represent perhaps the best case for the use of gene drive systems in New Zealand' (Dearden *et al.* 2018, p. 9).

New Zealand's invasive species management has relied on trapping, shooting, and several vertebrate toxic agents to control harmful predators. Aerial release of 1080 toxin (sodium fluoroacetate) has provided landscape-scale predator control, but its application remains controversial in New Zealand, with opinions entrenched both in support of, and in opposition to, 1080 use (Green and Rohan 2012; Kannemeyer 2013; Russell 2014). The debate over 1080 use has become polarised into 'for and against' positions, reducing a complex debate to a win-or-lose game to either continue or discontinue aerial 1080 use (Crowley *et al.* 2017, p. 134).

The three new technologies examined in this paper have the potential to achieve landscape-scale eradication of invasive species. One of the factors affecting the application of new technologies beyond social licence is New Zealand's strict legislative protections covering the research and release of GMOs, toxins, and biological control agents. GMO research is regulated in New Zealand by the *Hazardous Substances and*

[1]The wasps we targeted in this research are the two introduced Vespula species (German wasp and common wasp) and not the wasp species that are native to New Zealand.

[2]Ship rats and Norway rats are initially targeted by Predator Free 2050. New Zealand also hosts kiore (Polynesian rats) which have cultural value to indigenous Māori in New Zealand.

Table 1. A summary of research conducted in New Zealand on attitudes to invertebrate and vertebrate pest species identified in a systematic literature review

Source: Kannemeyer (2017)

	Invertebrate pests				Vertebrate pests					
	Leafrollers and mites	Moths	Wasps	Other invertebrates	Feral cats	Possums	Rabbits	Rats	Stoats	Other vertebrates
Bidwell (2012)						■				
Bidwell and Thompson (2015)						■				
Farnworth *et al.* (2011)					■					
Farnworth *et al.* (2014)					■	■	■	■	■	■
Fitzgerald *et al.* (1994)						■	■			
Fitzgerald *et al.* (1996*a*)							■			
Fitzgerald *et al.* (1996*b*, 2000)						■				
Fitzgerald *et al.* (2002, 2005)									■	
Fraser (2001)					■	■	■		■	■
Gamble *et al.* (2010)		■								
Green and Rohan (2012)						■				
Horn and Kilvington (2002)						■				
Kannemeyer (2013)						■		■	■	
McEntee (2007)		■								
Mercier *et al.* (2019)			■							
Niemic *et al.* (2017)					■	■	■	■	■	
Richardson-Harmon *et al.* (1998)	■									
Russell (2014)			■		■	■	■	■	■	■
Sheppard and Urquhart (1991)			■			■	■			
Wilkinson and Fitzgerald (1997, 1998)							■			
Wilkinson and Fitzgerald (2006)						■				
Wilkinson and Fitzgerald (2014)	■	■	■	■	■	■	■	■	■	■
Wilkinson *et al.* (2000)						■				
Wilson and Cannon (2004)						■				

New Organisms (HSNO) Act 1996. The HSNO Act promotes a precautionary approach to GMOs, arguing that there is a 'need for caution in managing the adverse effects where there is scientific and technical uncertainty about those effects' (Section 7). So far, under the HSNO Act there has been no release or conditional release of a GMO in New Zealand, but several applications have been given approval which have not yet been activated (Edwards 2017, p. 2).

Because New Zealand has robust regulation for GMOs, there has been debate about whether social licence to operate is needed, with some arguing that the rule of law should be sufficient to address the concerns of New Zealanders (Malpass 2013). The counter-argument is that 'regulatory approval for an activity does not necessarily equate to social approval' (Edwards and Trafford 2016, p. 167). Edwards and Trafford argue that regulation and social expectations operate independently of each other, with regulation considered to be an expression of the minimum standard that an activity or operation must meet (p. 167). We argue that a conversation on social licence to research new invasive species technologies is necessary despite the strong regulatory context.

Our primary research aim is to examine the range of perspectives on the risks and benefits of these new technologies. A supplementary aim is to use this new knowledge to inform the process of obtaining social licence for potential application of these new technologies before political decisions and economic investments are made, or before public opposition to technologies has formed (Wilsdon and Willis 2004; Rogers-Hayden and Pidgeon 2007). This research contributes knowledge on how to deliberate with the public on complex and controversial topics, and how to conduct this deliberation so that it does not reduce into for-or-against positions by encouraging two-way learning and engagement between scientists and the public.

Methods

Focus groups

Primary data for this research was collected through focus groups. Focus groups are commonly used to discover the attitudes and perceptions of their participants (Kruger 1994). Focus groups also help researchers to gain greater understanding of how group dynamics affect individual attitudes and decision-making processes (Bloor 2001; Stewart and Shamdasani 2014). Also, practitioners have begun to articulate how focus groups can be used as an anticipatory methodology, 'a tool to research public responses in-the-making', in order to see how the public will react to advances in science and technology (Macnaghten 2017, p. 343).

Seven focus groups were conducted in three locations in New Zealand: Wellington, the Nelson region, and New Plymouth ($n = 47$). All focus groups received social ethics approval from Manaaki Whenua Landcare Research's internal social ethics review (application no. 1718/08). Two focus groups were conducted with central government agencies in Wellington (coded in-text as GFG 1 and GFG 2), and five focus groups were held with stakeholders with an interest in wasp and rat eradication in Nelson and New Plymouth (coded in-text as SFG 1 through SFG 5). The size of each focus group varied, with 11 participants in the largest focus group (GFG 2) and only three participants in the smallest focus group (SFG 3). The locations of the stakeholder focus groups were chosen due to specific pest issues in these regions. The Nelson region was chosen because wasps are a particular problem in local beech forests, and New Plymouth was chosen because of the extensive pest control work that has been done by local farmers and volunteers in the region.

We used a purposive sampling strategy to select our focus group participants (Patton 2015). Our aim was to select people who have detailed knowledge and experience of pest control issues in relation to wasps and rats, so participants were sought from industries and professions such as beekeeping, forestry, conservation, journalism, local and regional councils, the education sector, as well as professional pest control operators. We consider these participants 'key informants' – our experience supports the finding that 'significant data can be generated through in-depth interviews with small samples of key informants because they occupy significant positions of expertise or have had particular experiences' (Porth *et al.* 2015, p. 671). We make no claims that our results are representative of the New Zealand public; rather, we present a range of views and opinions of New Zealanders who are informed about and involved in pest control.

One researcher moderated each focus group, whilst other researchers observed the content and interactions of the group discussions and took notes. The government agency focus groups held in November 2017 were pilot focus groups, and the lessons from these focus groups were incorporated into the stakeholder focus groups that were held in Nelson (December 2017) and New Plymouth (March 2018). Each focus group addressed three key questions:

(1) What is important to you in a pest control technology?
(2) What comes to mind when you think of gene drives, the Trojan female technique, and/or pest-specific toxins as pest control solutions in New Zealand?
(3) What do you see as the risks and benefits of using gene drives, the Trojan female technique, and/or pest-specific toxins?

The focus groups were designed to elicit both immediate reactions to the technologies and participants' reactions after reading technology descriptions to see whether additional information changed individual or group attitudes or perceptions. To achieve this, between questions (2) and (3) participants were given a sheet that briefly explained the three technologies. At the beginning of each focus group we presented a set of ground rules for the discussion, including respect for all opinions given in the discussion.

Thematic analysis

We coded and analysed the focus group data using a thematic analysis. Thematic analysis involves searching across a dataset to find repeated themes and patterns of meaning. According to Braun and Clarke (2006, p. 10), 'a theme captures something important about the data in relation to the research question, and represents some level of *patterned* response or meaning within the data set'. A theme ought to cut across the dataset – for example, our dataset is made up of seven focus groups and a theme should be identified within several of those focus groups. However, being a qualitative analysis, there is no prescribed percentage of focus groups in which a theme must be present. Furthermore, the importance of a theme is not determined by quantifiable measures (for example, it is present in all focus groups) but rather in terms of whether it captures something important and interesting about the research topic.

We followed Braun and Clarke's (2006) six-step guide on how to conduct thematic analysis. These steps require the research team: (1) to familiarise themselves with the data, (2) to generate initial codes, (3) to search for themes, (4) to review themes, (5) to name and define themes, and (6) to report the findings in relation to the research question. Following these steps, we identified themes through a mixed inductive and deductive approach that was initially developed by Fereday and Muir-Cochrane (2006) in health research. This mixed approach allowed us to identify themes that captured something important about the research topic, themes we recognised from the literature as well as themes that emerged from the focus group text.

We audio-recorded six of the seven focus groups (one group did not consent to recording so detailed notes of the unrecorded meeting were taken). The audio recordings were then sent to be transcribed by a professional transcription service. Two of the researchers then separately coded each focus group transcription and focus group observations using the NVivo 11 qualitative data analysis software. Coding involves identifying features of the data that appear interesting, and refers to 'the most basic segment, or element, of the raw data or information that can be assessed in a meaningful way regarding the phenomenon' (Boyatzis 1998, p. 63). After the first round of coding the researchers searched for themes; following this, the researchers then recoded the data a second time and compared their results to identify overlaps or omissions. In the next section we will describe these themes and how they contribute to our understanding of what New Zealanders perceive as the risks and benefits of new invasive species control technologies.

Results

Across the seven focus groups three key themes emerged from the discussion.

Theme 1: Unintended consequences

One of the risks identified by our focus group participants can be broadly summarised under the theme *unintended consequences.* This risk of unintended consequences was expressed in several ways; for example, the effect of predator loss on ecosystems, the spread of a technology beyond New Zealand's borders, the possibility of genetic technologies jumping between species, and the notion of 'playing god'. The recurrence of unintended consequences as a theme highlights that our focus group participants perceive potential unintended consequences as a serious issue when introducing new technologies, and this supports Wynne's (2006, p. 216) argument that members of the public focus on unpredicted effects rather than scientifically described risks. In addition, Duckworth *et al.* (2006) suggest that public acceptance of new technologies for control of introduced mammalian predators may depend on how these technologies are introduced to the public and how much control people feel they have over possible long-term effects.

A concern raised with all three technologies was that eradication of introduced predators might upset New Zealand's fragile ecosystems. The quandary can be summarised as follows: if a pest-specific toxin eradicates rats from New Zealand, will other predators fill the void left by rats? In other words, will the deployment of technology actually achieve its aim to protect New Zealand's native species from harm? One participant from a stakeholder focus group summed up the issue by stating:

> *… ecology is complex and the systems we are playing with are really complex. If you tweak one thing you can get flow on effects, and by reducing the predators itself that will be a flow effect and there's nothing you can really do about that. You don't want to add other things into the system that are also going to have a lot of flow on effects.* [SFG 3]

Ecosystem effects are a concern when deploying any invasive species control technology, but most risks identified under the unintended consequences theme relate specifically to the use of genetic technologies.

The issue of unintended consequences with genetic technologies was raised in all seven focus groups. For example, if German wasps were given gene drives to ensure all of their offspring were male, and one or more of these wasps surreptitiously returned to continental Europe through freight or other means, it could disrupt the ecosystems of continental Europe. Although the issue of international leakage of technology is relevant to wasps and rats, the most commonly cited example in our focus groups was possums. Possums are an invasive folivore predator in New Zealand, but in neighbouring Australia they are a treasured native species, and the possible spread of some form of biological control such as infertility would be viewed negatively (Duckworth *et al.* 2006). If a genetically modified possum were to find its way to Australia, it could have a devastating effect on the local possum population.

Another unintended consequence that focus group participants were wary of was the spread of genetic technology from species to species. When one stakeholder focus group was asked what they see as the risk of genetic predator control technologies, the first response was:

> *Species jumping would be the biggest risk. And that would put most people off, if there was even a slight chance.* [SFG 4]

There was a concern that wasps with gene drives might breed with native bees, and this breeding could subsequently spread the gene drives from the wasps through to the bees. The likelihood of species jumping might be extremely low with CRISPR-Cas9 gene editing, but the focus groups did express the fear that this might occur.

'Playing god' with genetics was another risk identified by participants. Some might not consider this a consequential argument because those opposed to gene drives on these grounds are taking a principled stand against any form of genetic manipulation free from any calculation of risk and benefit. Despite this, a participant from the stakeholder focus groups framed 'playing god' as a risk:

> *Changing nature – changing the blueprint. We cannot reverse it once it's changed.* [SFG 4]

One participant from the government agency focus groups stated:

> *I can imagine like most things, [there is a] bell-shaped curve of perception from 'yeah, cool science, go for it', through to, 'oh my god, this is GE food now in wildlife, and it's the mad scientist becoming Frankenstein and just messing with nature'.* [GFG 2]

These concerns refer not only to the unintended consequences that might occur from the use of genetic predator control technologies, but the idea that once genes are altered there is no way to go back. We can monitor the effect that poisons and toxins have on the environment, and can subsequently reduce or increase their use given these measurable effects. By contrast, gene drives are perceived to create permanent changes that cannot be reversed.

Theme 2: Spatial and temporal scales of control

The control of invasive animals is limited by what can be achieved with current technology, primarily because of cost. New Zealanders have traditionally preferred non-toxic control methods such as trapping and shooting (Fraser 2006), but due to the size and topography of New Zealand these preferred control methods are unsuitable for eradicating entire species over large areas because of their costs. This has resulted in poisons being used as the primary invasive animal pest control tool, despite the public's reluctance to use these methods. As one of the stakeholder participants said:

> *For the work we do at the moment, we've only really two choices: toxins and killing pests directly using trapping. We know that trapping is not cost-effective on a large scale, so we need to broaden the toxin tool bo*x. [SFG 3]

Our participants identified that one benefit of introducing new technologies is that they could potentially address invasive species control at a landscape scale. As one participant noted:

> *[Any technology]… has to be acceptable, but if it's not [applicable] at the landscape scale then there is no point.* [SFG 2]

Another stated:

> *… controlling [pests] in little areas all over the country is pretty ineffective at solving the big issue … if they controlled birds in some little patch of bush down in Nelson, the actual effect on the bird population will be nothing.* [SFG 2]

New Zealand needs technologies that can control invasive species effectively at landscape scales, and new technologies such as gene drives could potentially provide this. Invasive species control at the landscape scale must not only be affordable but also practical and easy to implement. Currently, aerial 1080 application is the most cost-effective predator control method at the landscape scale, especially on steep and

Table 2. An overview of the key themes identified in focus group discussions on three new technologies with potential for pest control of wasps and rats

Theme	Perceived risks	Perceived benefits
Unintended consequences	• Effect of predator loss on ecosystems and other predators • International leakage of technologies • Species jumping with gene technologies • 'Playing God' and being unable to reverse genetic modification	
Spatial and temporal scales of control		• Used at landscape scale • Alternatives to aerial 1080 • Ability to use a mixture of old and new technologies • Sustainable over time
New Zealand as an early adopter of new technologies	• Economic effects on primary production • Livelihood of pest control contractors	• Potential benefits of being a world leader in invasive species eradication • Tourism benefits from pest-free environment • Benefits to industries directly affected by pests, such as honey exportation

inaccessible conservation land. A new technology would need to be just as effective and practical as aerial 1080.

Our participants also noted that a mix of new and existing technologies could enable New Zealand to have the most comprehensive invasive species control toolkit in the world. In one stakeholder focus group they argued that aerial 1080 could be used as a first step, and then a combination of the three emerging technologies used afterwards to eradicate hard-to-reach pests. The more new technologies that become available, the more options there will be to undertake invasive species control at the landscape scale that are ethically acceptable and affordable.

In addition to a new technology being deployable at the landscape scale, participants commented that new technologies need to be sustainable over time:

> *We have lots of energy at the moment to keep trapping but whether it is going to be the same in 20 years' time – I might be a bit over it by then.* [SFG 3]

There was a sense in our focus groups that while the Predator Free 2050 movement is currently receiving a lot of publicity, if volunteers and the public do not see immediate beneficial results they might lose interest and discontinue their efforts. Given this, the potential of new technologies to self-perpetuate, reducing the need for time-consuming labour, would be very beneficial:

> *Sustainability for the future – manifests itself and grows by itself so you don't have to keep doing the labour over and over. Sow the seeds and walk away and it will carry on by itself.* [SFG 2]

Theme 3: New Zealand as an early adopter of new technologies

The introduction of new technologies to manage invasive species could make New Zealand a world leader in invasive species eradication, but our focus group participants perceived both benefits and risks from being an early adopter. A participant from a government agency focus group suggested that New Zealand already leads the world in off-shore island pest eradication, and so is ideally suited to test new eradication technologies. Others in this discussion responded by arguing that there were significant ethical questions to be answered before genetic technologies could be used for invasive species eradication. Participants noted that using genetic technologies could affect New Zealand's GMO-free status, and if this status was threatened it could have a negative effect on the primary production and tourism sectors.

The benefits of being an early adopter of invasive species technologies were not elaborated in great detail by the focus group participants. This was illustrated in one exchange between the focus group moderator and participants:

> *Participant A: I think a potential benefit is sharing the techniques. If we can show it works here [in New Zealand] we are potentially world leaders.*
> *Moderator: Do you feel like this is something New Zealand should be a world leader on?*
> *Participant A: Yes.*
> *Participant B: Yes. We could be world leaders – [we] already lead the way in eradicating pests. We are about innovation and technology.* [SFG 3]

Developing the technology in New Zealand and then sharing it globally could result in economic benefits for New Zealand. The focus groups also felt that if problem species were eradicated, this could have a positive flow-on effect for New Zealand's tourism industry, and other industries such as beekeeping and honey exportation. Focus group members employed as pest control specialists understood that it could negatively affect their livelihood, and it could also affect farmers who market their produce as GMO-free.

Attitudes to the risks and benefits of introducing new technologies to manage wasps and rats in New Zealand are summarised in Table 2.

Discussion

The focus groups uncovered diverse attitudes to the risks and benefits of introducing new technologies to manage wasps and rats in New Zealand. Although our research participants articulated a variety of benefits from introducing new technologies – such as landscape-scale eradication, replacing dangerous poisons with non-toxic alternatives, as well as New Zealand being a world leader in invasive species eradication – the risks of the new technologies dominated the discussions. The risks were often related to the hypothetical unknown consequences of the technology, such as gene drives swapping between species. The opinion of focus group participants on the technologies did not change significantly after we provided them with more information. Given that our focus group participants were selected as key informants, these attitudes will be informed by their intimate knowledge of invasive species control in New Zealand. For those seeking data on general public attitudes, a paper is in preparation that reports the results of a survey undertaken into public attitudes on new invasive species technologies, in particular gene-drive technology (E. MacDonald, pers. comm).

There are multiple public perspectives on invasive species management in New Zealand (Russell 2014; Bidwell and Thompson 2015), and this is reflected in the themes that emerged from our analysis. Some of the themes resonate with past research on attitudes to invasive species technologies in New Zealand. For example, the issue of unintended consequences is one theme that has been revealed in past research (Horn and Kilvington 2002; Kannemeyer 2013; Wilkinson and Fitzgerald 2014). However, the importance of new technologies being effective at the landscape scale and sustainable over time, and New Zealand being a world leader in testing new invasive species eradication technologies, are themes that have not previously been identified.

The concept of social licence emerged in an era when faith in government assessment processes was low and demand for public engagement in decision-making was increasing (Zhang *et al.* 2018). Typically, informal social licence has been sought by resource development companies who seek the approval of local communities for their activities (Baines and Edwards 2018). In our example, the approval of communities is sought for technologies that will most likely be implemented and funded by government for public benefit, an arrangement that risks blurring the line between a government agency's formal regulatory responsibilities and informal social licence (Zhang *et al.* 2018). Given this, it is particularly important that the principles of engagement, trust building, information sharing, accountability, and clear two-way communication are observed to obtain and maintain social licence (Moffat *et al.* 2016; Baines and Edwards 2018, p. 140).

The following recommendations provide guidance on how to work towards the principles of social licence in the context of the themes that emerged from our focus group analysis. We argue that these recommendations are important starting steps in public deliberation, but we recognise they are not an ideal or perfect process for deliberating about invasive species control (Hagendijk and Irwin 2006, p. 183). It should also be noted that these recommendations have been developed in the New Zealand context. Regardless, we believe that these recommendations could help countries to begin an open and honest debate regarding ethical and moral concerns stemming from invasive species eradication, or the introduction of new and potentially disruptive technologies.

We follow the recommendation of Mercer-Mapstone *et al.* (2017) to establish an initial phase of dialogue focussed on social learning, followed by a phase of strategic dialogue that is more goal driven. In the first stage the public can inform the parameters of the discussion, while in the second stage the process of building social licence can begin.

Recommendation 1: Develop an education and communication strategy on gene drives, the Trojan female technique, and pest-specific toxins

Trust, legitimacy and credibility are core components in developing social licence with communities (Thomson and Joyce 2008; Moffat and Zhang 2014; Moffat *et al.* 2016). An important step in developing an engagement strategy will be to build trust with decision makers and scientists. Hipkins *et al.* (2002, p. 2) argue that for most New Zealanders 'seeing is believing', and they are not inclined to accept scientific claims on trust alone. Given this, it is not surprising that some of our focus group participants felt that a science-led approach to education was not going to convince the public to accept new technologies:

> *The more you push facts down their throat, the more they won't agree with you.* [GFG 1] *... when you attack them with science, they're not going to believe it a lot of the time because they don't understand the science.* [GFG 1]

Distrust in science has a direct effect on how people perceive the risks of new technologies and whether they would be willing to permit their use in New Zealand. As one participant noted:

> *We've worked for a very, very long time to [gain acceptability for] ... the use of toxins in their current form and still we do not have faith and trust from the whole community. If something new is implemented and subsequently fails to be able to take the public on another positive journey [it] might be a really, really difficult task [to gain social licence to operate].* [SFG 4]

Our first recommendation is to establish a two-way communication strategy between the public and scientists in which social concern about the technologies is transmitted from the public to scientists, and scientists present information to the public about the new technologies while recognising knowledge gaps, uncertainties, and risks. The problem with public education initiatives, as identified in our focus groups, is that they often assume that the public do not support the introduction of new science and technology due to lack of information. Following Wynne's (2006) caution, we do not want to replicate this deficit model of science communication in the creation of our new communication strategy, but we also recognise that there is a lack of information available to the public about these potentially powerful new technologies. Thus we recommend a genuine shift from one-way, top-down communication between science providers and the public towards public engagement with science that results in a genuine dialogue (Burns and Medvecky 2018).

One way of achieving this dialogue is by selecting 'front-room' scientists – scientists who are skilled communicators and can engage in a dialogue with the public – to play a brokering role between science and the public (Berkett *et al.* 2018). Two-way communication can ensure that the framing of the discussion includes the public's concern about unpredicted effects as well as scientifically described risks (Wynne 2006, p. 216). We believe a reflexive education and communication strategy will enhance trust and enable greater information sharing and engagement between information providers, advocates for new technologies, and the public.

Independent authorities such as the Parliamentary Commissioner for the Environment or an expert panel could provide information to the communication strategy, which would be as objective and neutral as possible. The process of public engagement ought to be led by professional organisations such as the Royal Society of New Zealand, or institutions such as museums (Priest 2017). New Zealand's Department of Conservation, or organisations such as the Predator Free New Zealand Trust, should not be involved in these processes because they are likely to advocate for one or more of the technologies to be introduced, and opponents to new technologies might not trust them as a source of objective and neutral information.

Recommendation 2: Codesign decision-making processes

In order to establish social licence, our second recommendation is to codesign decision-making processes with stakeholders and the public (Blomkamp 2018). Just as the engagement and communication initiatives ought to be a dialogue, so should the processes to decide whether to apply a new technology. In this process it should be put to both decision-makers and the public whether the aim of becoming a world leader in applying new invasive species eradication technologies is desirable. Once again, these processes ought to be led by independent authorities such as the Royal Society of New Zealand, rather than institutions that might be perceived to have a vested interest in applying new technologies for invasive species control. Further research is required to identify which existing or potential new organisations would be best placed to provide the stewardship-oriented leadership that is required to moderate such a process.

Ceding some decision-making authority to the public will help legitimise the decisions that are made. Techniques such as deliberative dialogue, citizen juries, or community collaborations could be introduced, whereby authority is devolved from politicians and public servants to community representatives (Cronin 2008). The focus ought to be on bringing together divergent interests to form a shared vision, although in creating this shared vision it should be stressed that differences of opinion are good and valuable, whereas polarisation is divisive (Olsson *et al.* 2006). Many of these techniques are being developed and tested through the responsible research and innovation agenda in Europe (Owen *et al.* 2012; Von Schomberg 2013; Burget *et al.* 2017).

One of the difficulties in establishing social licence for the application of new technologies is that a range of different social licences would need to be negotiated with those affected at local, regional, national, and international scales (Dare *et al.* 2014). Initially, social licence to research these technologies might be limited to a small geographical space, as technologies would be located in laboratories. But if there was a desire for field testing or conditional release, the scope of social licence would rapidly expand. Social licence ought to be obtained at multiple scales if New Zealand were to become a world leader in the application of these technologies, but seeking social licence at all these scales simultaneously would also be costly, time consuming and difficult.

Conclusion

To conclude, we identified a series of themes, some of which resonate with past research and some of which are new. In the past, debates over the use of particular technologies to control invasive species, such as aerial 1080, have resulted in social polarisation and distrust in government institutions. In order to avoid entrenching new conflicts, new communication and decision-making processes ought to be introduced regarding the research and potential future application of the three new technologies examined. Diverse communities at different scales ought to be included in the design and enactment of these education and decision-making processes to enhance their legitimacy.

Obtaining social licence for new invasive species control technologies is complex and multifaceted. Even if our recommendations are thoughtfully and thoroughly implemented, obtaining social licence to apply new invasive species control technologies in New Zealand is not guaranteed.

Conflicts of interest

The authors declare no conflicts of interest.

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