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ORIGINAL PAPER

What's that bug? Community participation in biosecurity in Mount Maunganui, New Zealand

Penny R. Payne · Susanna Finlay-Smits · Bruce Small · Vanessa Cave · John Kean

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Abstract Biosecurity is essential to protect against the negative effects of non-native invasive species. As part of the government's 'Biosecurity 2025' Initiative to enlist all New Zealanders as biosecurity risk managers, Tauranga Moana has been named the 'biosecurity capital' of New Zealand. The initiative will involve large-scale citizen science, for reporting and management of pest and disease threats. In this context we measured baseline awareness, perceptions and behaviour around biosecurity among two key groups of respondents, the local community at Mount Maunganui (surrounding Tauranga's port) and school children. An online survey was completed by 324 members of the local community, while 120 school children completed a survey about their biosecurity knowledge and behaviours after using a biosecurity education kit. Results indicate that while both groups report a relatively high level of understanding about the concept of biosecurity, and acknowledge it as extremely important, knowledge of current pest threats and correct biosecurity behaviours could be improved. Mount Maunganui community members rate their understanding of biosecurity as better than the average New Zealander, but are less likely to have taken regular biosecurity action in the past year. For school children, improved biosecurity efforts could be evidenced by more active pest monitoring, and greater discussion about biosecurity outside of school (e.g. with their family at home). Key enablers for achieving more impactful citizen science for biosecurity among these groups are targeted education, and practical advice about what they can do to help.

Keywords Biological Invasions · Invasive alien species · Stakeholder engagement · Citizen science · Social learning

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P. R. Payne (✉)
Social Science Team, AgResearch Ltd, Ruakura Research Centre, 10 Bisley Road, Hamilton, New Zealand
e-mail: pennyrpayne@gmail.com
URL: https://www.linkedin.com/in/penny-payne/

S. Finlay-Smits
Social Science Team, AgResearch Ltd, Lincoln, New Zealand

B. Small
Social Science Team, AgResearch Ltd, Hamilton, New Zealand

V. Cave
Statistics and Bioinformatics Team, AgResearch Ltd, Hamilton, New Zealand

J. Kean
Biocontrol and Biosecurity Team, AgResearch Ltd, Hamilton, New Zealand

Introduction

There is a growing need for biosecurity globally, as evidenced by increasing introduction rates of non-native species (Seebens et al 2017). This is likely due to increased trade and tourism volumes, but is being compounded by a range of complex and shifting environmental variables including climate change, agricultural intensification and increased human mobility (Hulme 2020, Ja Kim et al. 2022, Thompson et al. 2009). In this everchanging environment we cannot rely solely on designated biosecurity incursion officers, or indeed technology, to successfully identify all biosecurity threats (Thompson et al 2009, Verbrugge et al. 2021). A safer, more affordable and sustainable strategy is to engage the community as a back-up line of defence against potential incursions (Campbell et al. 2017). The success of this strategy is of course however dependent on adequate levels of community awareness, knowledge and behavioural compliance (Verbrugge et al 2021).

Biosecurity in New Zealand

Biosecurity is a critical issue for New Zealand, which has unique native flora and fauna to protect, and many channels through which breaches could occur (Ministry for Primary Industries 2016). Recent high-profile biosecurity outbreaks in New Zealand include *Mycoplasma bovis*,[1] myrtle rust,[2] and kauri dieback disease[3] (Ministry for Primary Industries 2018a; du Plessis et al. 2019; Smith 2017, respectively). These diseases represent a particularly difficult biosecurity challenge because common vectors for spreading the diseases relate to human behaviour. For example, allowing contact between infected cattle spreads *M. bovis*, touching or moving myrtle rust causes spores to spread to other plants, and hiking can spread kauri dieback spores (Ministry for Primary Industries 2018b; Ministry for Primary Industries 2018c; Smith 2017). This means it is critical to involve people, including the public, in detection, management and eradication of biosecurity threats, if management efforts are to be successful (Thomas et al. 2017; Verbrugge et al 2021). Involving citizens in biosecurity management is also a useful cost-saving strategy, albeit potentially risky if not effective (Campbell et al. 2017).

One useful mechanism for involving the public in biosecurity is through citizen science projects. The use of citizen science is increasing, and international literature has shown that it can be an effective mechanism for achieving biosecurity outcomes (Tulloch et al. 2013). For example, the public can assist with early detection through biosecurity surveillance programmes (e.g. Thomas et al. 2017), mapping the distribution of invasive species (e.g. Gallo & Waitt 2011), and controlling them through trapping of "hacks" for plants (Newman et al. 2003). Moreover, although some members of the public may have little awareness and knowledge of biosecurity, they may still be concerned about it and be willing to implement biosecurity-related behaviours (Urquhart et al. 2017). New Zealand's initiative aims to do just this and use the entire population as a national biosecurity risk management force (Ministry for Primary Industries 2016). This 'team' involves both adults and children and will require a large scale and concerted effort to achieve engagement and informed reporting of biosecurity threats. Albeit these groups have not signed up as formal 'citizen scientists', many may engage in the role over their lifetime.

The New Zealand public has proved their potential value as a biosecurity risk management force in terms of post-border passive surveillance, through reporting 96% of the total reported pest and disease threats for the period 2005–2008 (Froud et al. 2008). Further, 18% of New Zealanders report having taken regular action to control plant or animal pests somewhere beyond their own property, in the year prior to the survey (Brunton 2018). These results suggest a significant degree of concern about biosecurity threats, and a willingness to help, across the New Zealand public. Despite positive intentions, however, it appears that the public need further education; reports of new exotic organisms were correct only two percent of the time (Froud et al. 2008), indicating a need to improve

[1] *Mycoplasma bovis* is a bacterium causing a range of serious conditions in cattle and other animals.

[2] Myrtle rust is a serious fungal disease, caused by *Austropuccinia psidii*, that affects plants in the myrtle family, including iconic New Zealand trees such as pōhutukawa, mānuka and rātā.

[3] Kauri dieback disease is caused by the pathogen *Phytophthora agathidicida*, which kills most kauri (a native New Zealand tree) it infects.

public familiarity with, and recognition of, current pests, weeds and diseases. Indeed, while 61% of New Zealanders say they have a good understanding of biosecurity and think it is important, only 29% agree they can identify the main pests, weeds, and diseases that pose a threat to New Zealand wildlife and the environment (Brunton 2018).

The New Zealand government has made it clear that children are also expected to be involved in biosecurity risk management (Ministry for Primary Industries 2016). Examples in the literature suggest that involving children or young people in citizen science projects can serve to do more than just increase awareness and promote positive biosecurity behaviours. Involvement may also promote a general appreciation of the local environment and enhance place-based identity, and may have a lasting effect on biosecurity knowledge (Evans et al. 2005, Schreck Reis et al. 2013). In adults, enhanced place-based identity has been found to be related to higher awareness and concern about biosecurity, so this may be a cyclical relationship which could be promoted at a younger age (Urquhart et al. 2017). Verbrugge et al. (2021) has identified a number of biosecurity related education programmes operating globally, including in the US, the Netherlands, Portugal and Finland. Clearly, this is a topic which lends itself to education for younger persons, possibly aided by the fact that many of the pests included are novel and exciting to look at, and can be transformed into a game or other fun format (Verbrugge et al 2021).

Biosecurity was also identified as a key area for inclusion in the school curriculum by Australian and New Zealand biosecurity groups (Department of Agriculture and Water Resources 2018). This is likely due to the increasing number of biosecurity concerns facing New Zealand and Australia, and the research suggesting children and young people have a gap in knowledge about, and appreciation of, biosecurity. A study of New Zealand school students (approximately age 12) found that children had poor knowledge of biosecurity, including unwanted plants, organisms, and diseases (Ram et al. 2015). Another study found that young people (under 30) were less likely to understand biosecurity, think it was important, or have awareness of the elements of the biosecurity system (Brunton 2018). New Zealanders under 24 were also found to be less confident about knowing what to do if they found an unwanted pest, weed, or disease, to do their own research, or to take direct action in controlling pests and weeds in and beyond their communities (Brunton 2018). Together, these factors suggest a need for improved education of children and young adults in New Zealand about biosecurity, and an opportunity for children to represent a long-term, intergenerational strategy for promoting biosecurity among New Zealand citizens.

We present the findings of two studies measuring awareness, perceptions, knowledge and behaviours about biosecurity among both adults (Study 1), and primary school children (Study 2).

Study site and context

Study area

The survey results reported in this paper represent the baseline data for benchmarking awareness, perceptions, knowledge, and behaviours regarding biosecurity using a sample from the Mount Maunganui and Tauranga areas; the communities surrounding the Port of Tauranga (PoT). This area was chosen as it has been named the 'Biosecurity Capital of New Zealand', and it is anticipated that there will be interventions to raise awareness and reporting among the local community (for more information see https://www.tmbiosecurity.co.nz/). Moreover, these residents live in the immediate vicinity of New Zealand's largest and fastest growing seaport (Port of Tauranga 2017). This therefore makes the public in this area critical 'eyes and ears' for incoming pest and disease threats.

Māori context relevant to New Zealand

Māori (the indigenous people of New Zealand) make up 16.5% of the New Zealand population (Statistics New Zealand 2018), and the New Zealand government are bound by The Treaty of Waitangi (Te Tiriti o Waitangi in te reo Māori) to work with Māori on all issues of governance, including biosecurity. The Treaty of Waitangi is New Zealand's founding document signed by Māori rangatira (chiefs) and the British Crown in 1840. The Treaty was created in both English and Māori, with fundamental differences in translation which resulted in Māori being stripped of their land and rights without permission. Today, Pākeha (New Zealand Europeans) and Māori are working to restore joint tino rangatiratanga (authority) over New Zealand's land and taonga (treasures), understanding that much damage has been done from the colonisation that occurred through the Treaty of Waitangi. As such, honouring the Treaty in its true meaning means working with Māori in protecting our country from biosecurity threats, and therefore the Treaty is fundamental to our biosecurity. This cultural aspect of the study is reflected on further in the results section.

Methods

Study 1: Local community survey

The adult local community survey serves as a baseline measure, which is compared with a national survey of biosecurity awareness and behaviours (Brunton 2018). Survey participants included Mount Maunganui residents from the immediate vicinity of the PoT.[4] The local community are the critical 'second line of defence' after port workers, given their proximity to the port. That is, if a biosecurity incursion were to occur just outside of the port, they may be the first to notice, such as if a new insect became established in their garden. It is therefore critical that they are able to recognise foreign or unwanted pests and diseases and report them to authorities. At the time of our survey in early 2018, the local Mount Maunganui community had not been exposed to any direct awareness-raising interventions through the Port of Tauranga aside from Biosecurity Week in 2017, where attendance was low. Their awareness of biosecurity was most likely to have derived from broadly targeted interventions such as nationally aired television advertisements.[5]

The focus of this survey was therefore to measure baseline awareness about biosecurity, including key pest and/or disease threats, and perceptions and understanding of biosecurity. Performance of, or willingness to perform biosecurity behaviours was also a key area of interest.

Questionnaire

An online survey was used to assess the local community's awareness of, perceptions about, and behaviours related to, biosecurity. The survey was largely comprised of questions taken from the Brunton (2018) nationwide survey of New Zealand public about biosecurity. Adding these questions served to provide a benchmark for comparison between the local Mount Maunganui community and the New Zealand adult community more broadly.

The survey included 23 questions in total, six of which were demographic questions. Participants were asked to provide self-assessments of their understanding, knowledge, perceptions and behaviours about biosecurity. Several different response formats were provided, to be consistent with the categories used in the Colmar Brunton survey, and according to what was most appropriate for each question (see supplementary material for full survey). For reporting of the results, all questions were scored on a scale of 1–7, for consistency and ease of interpretation (this required recoding of those items rated on the 5 and 10-point scales as used in the Colmar Brunton survey).

The survey was hosted on the platform SurveyMonkey® and advertised to the local community via social media platforms Facebook and Instagram, for a duration of two weeks. Geolocated targeting was used to ensure only Mount Maunganui residents (the ~ 15,000 i people in the immediate vicinity of the PoT) were given the opportunity to participate. Participation was incentivised by the chance to win one of ten $100 supermarket vouchers awarded randomly among the participant pool.

Study 2: School children

Study 2 involved a longitudinal evaluation of a biosecurity education kit, administered before, immediately after, and six months after using the resource, to assess knowledge gain and retention, and likelihood of performing biosecurity behaviours.

[4] Defined as being between Mount Maunganui itself and Sunrise Avenue/Hibiscus Avenue, approximately ten kilometres down the coast.

[5] See Biosecurity 2025 Implementation Plan, p. 10. Retrieved from https://www.thisisus.nz/get-involved/resources/

The biosecurity education kit

An educational biosecurity kit called 'Invasion Busters' was developed with the House of Science, a charitable trust in New Zealand which provides 'hands-on' science resource kits. The Invasion Busters kit was designed by a Resource Developer (previously a medical microbiologist), and informed by a Population Ecologist. The kit was targeted at children aged five to 12 years old (years 1 to 8) and included seven activities in total, varying in difficulty to cater to the broad age range. Six activities were related to different components of the biosecurity system, such as sorting and identifying seeds at the border, identifying pest threats (the brown marmorated stink bug, set in clear resin), and modelling insect population growth. The final activity in the kit was a board game where children collaborate to keep incoming pest threats under control, given the different 'roles' they are assigned, such as biosecurity officers, stevedores (who unload goods on port), insect trappers, and incursion investigators. Pests included in the game are real current pest threats and are accompanied by information such as the potential threat they pose, country of origin, and damage they can do to host plants. An example of the 'role cards' and 'pest cards' from the game are displayed in Fig. 1.

The Invasion Busters biosecurity education kit was piloted in schools around the Tauranga area in March and April of 2018. The data for this evaluation were collected from the classrooms who piloted the kit, because these teachers attended a 'launch' of the kit, where they were informed of the evaluation. The teachers therefore had an understanding and appreciation of the purpose of the evaluation and would be more likely to administer the questionnaires using the requested method.

The biosecurity kit survey questionnaire

Questionnaires to evaluate the education kit were administered three times; once immediately before the kit was introduced (e.g. on a Monday morning), once immediately after use of the kit (e.g. on a Friday afternoon, after using the kit several days that week) and once six months later, to test retention of knowledge. These measures will be referred to as the pre, post, and follow-up measures hereafter. The questionnaires were sent out with the kit for the pre and post measures, and teachers were re-contacted and sent the questionnaires again for the follow-up measure. Instructions for administration were included with the survey, including a request for teachers to assist with survey comprehension and completion, without explaining the answers to the questions (including avoiding explaining what biosecurity meant, prior to using the kit). The follow-up measure packet included reminder instructions for administration, a recap purpose statement and return envelopes, in addition to a list of names of the children in the class who needed to complete the questionnaire (based on children who had informed consent from their parents and had completed both the pre and post measures).

The questionnaires included two types of questions, the first being a Likert-scale question using a 5-point smiley-face Likert scale combined with word based 'degrees of agreement' as anchors (see supplementary materials for full survey). This scale was used because evidence shows that children have greater engagement with smiley face Likert scales than other evaluation instruments (e.g. scales solely using words as anchors), and 5-point smiley face Likerts are recommended for children (Hall et al. 2016).

There were nine questions rated on the smiley face Likert scale. These statements were designed to be concrete rather than abstract (avoiding 'feeling' statements), as research suggests that both younger and older children (age range 6–12) understand graded scales when making judgements about more concrete concepts (Mellor & Moore 2014). The teacher also assisted children's understanding by reading the questions aloud. These included "I know what biosecurity is" and "My family talk about stopping bad insects from hurting animals, plants, or people in New Zealand".

There were a further eight short answer questions, designed to move beyond self-perceptions and test existing knowledge and retention of knowledge. These related to specific activities within the kit, for example "Can you name three bad insects we don't want to come into New Zealand?", and "Can you think of something which might make bad insects grow faster or have lots of babies?". Children should have learnt the answers to these questions while using the kit, for example three current insect pest threats through the 'Invasion Busters' board game, and

Fig. 1 Role cards and pest threat cards from the 'Invasion Busters' biosecurity education kit board game

factors which affect insect population growth in the population modelling activity. Teachers were asked to identify which activities they completed (and did not complete) on a form delivered with the questionnaires, so this could be considered in the data analysis.

Data cleaning and analysis

Data from a total of 48 children were removed from the study, due to issues with data continuity and quality. This included 37 children who had completed either a pre *or* a post-kit survey but not both, and 11 students (one classroom) where the pre-kit survey was administered after use of the kit, rather than before. This was evident in children's answers, which included direct quotes from the kit, such as 'Catch it, snap it, report it', a catch phrase from a local biosecurity initiative (Kiwifruit Vine Health). Removal of these students left a total sample size of 120 children.

For the Likert-scale questions, the scores were analysed using repeated measures fitted as a linear mixed model in Genstat 19. To account for correlation between measurements taken for the same child (pre, post and follow-up measure), an unstructured correlation model was used. Random effects (constrained to be positive) were included to account for school, teacher, age at pre-test (as a factor) and gender variation. The fixed term assessed was 'survey session', a factor with three levels (pre, post and follow-up measure). In addition, Fisher's unprotected least significant differences at the 5% level were used to compare the predicted means. Residual plots were assessed to check that the assumptions of normality and constant variance broadly held and data for each question were analysed independently.

For the short answer questions, scoring was more difficult. Due to the diversity of the answers provided (some being very creative), the research team assembled to decide what constituted a 'correct' answer for each question. This was a difficult task, as often children identified 'bad' insects (such as wasps or tarantulas) as pests, however a majority are not considered 'biosecurity pests' because they may already be in New Zealand, or are not on an 'unwanted' pest list for New Zealand. Children also provided varying levels of detail in their responses, which demonstrated varying degrees of knowledge. For example, children were asked to identify the difference between a brown marmorated stink bug (key current pest threat for New Zealand), and a regular stink bug. This was the basis of one of the activities in the kit. Many children wrote 'colour' or 'size', which, while correct, does not provide sufficient evidence that they would be capable of successfully differentiating a brown marmorated stink bug from a regular stink bug in real life. Other children wrote "the brown marmorated stink bug has three white spots", which is a much more specific, and correct, answer. This variance and subjectivity of responses was managed by creating an 'inventory' of all answers provided, for each question. Each inventory was then marked by two independent raters, as to whether answers were correct (one point given), partially correct (half point given, indicating understanding of the underlying premise), or incorrect (zero points given). Discrepancies in ratings were discussed and resolved, to ensure ratings were consistent. All responses were then given a numeric score, which allowed use of the same method of statistical analyses as for the Likert scale questions above.

Results relating to Study 1 (local community)

Demographics

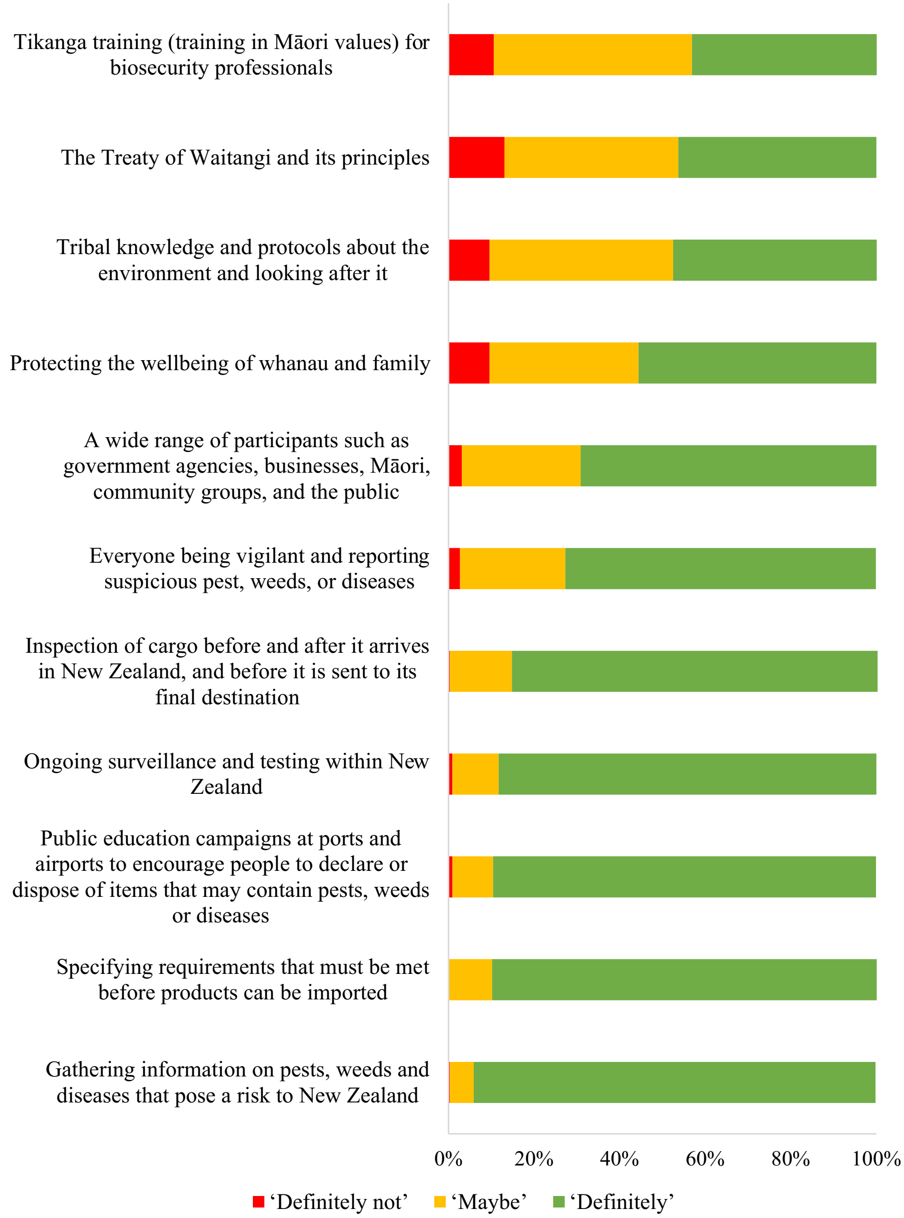
A total of 324 local community members responded to the biosecurity survey. The number of participants who responded to individual survey questions varied, from 324 to 315 (excepting the option to give further comments, to which only 84 participants responded). The median age was 49, approximately 12 years older than the national median (Statistics New Zealand 2017). Females comprised 55.2% of the sample while nationally they comprise 50.7% of the population (Statistics New Zealand, 2017). The sample also had a larger proportion of persons who had achieved higher education, relative to national statistics (Ministry of Education 2019). The largest group of the survey sample identified their ethnicity as Pākehā/NZ European (87.3%), which is higher than the national average (70.2%). For Māori the sample was close to representative, with 14% of participants identifying as Māori, compared with 16.5% nationally at that time (Statistics New Zealand, 2018). The most common annual household income bracket reported by participants was \$50,000–100,000 (31.6% of participants), while the national average annual household income is \$100,103 (Statistics New Zealand 2017).

Understanding of biosecurity

The local community rated their understanding of the term biosecurity as moderate, with a mean of 5.1 out of 7. The results are displayed in Fig. 2, listed from least to most likely to be included in the biosecurity system. Participants were more certain that gathering and promoting information about biosecurity was part of the biosecurity system, than direct biosecurity surveillance. A substantial 25% of participants were unsure whether "Everyone being vigilant and reporting suspicious pests, weeds or diseases" was included in biosecurity.

Participants expressed a higher degree of uncertainty as to whether the more abstract applications of biosecurity were included in the biosecurity system, such as protecting our wellbeing, and

Fig. 2 Local community perceptions about what is included in the biosecurity system



applying Treaty of Waitangi principles or tikanga (Māori knowledge and values). This is understandable given these aspects are less tangible, and many New Zealanders may not have a robust understanding of what the Treaty of Waitangi includes, or the ramifications of this. As discussed earlier however, the Treaty of Waitangi underpins all governance and should be considered in relation to management of biosecurity issues. As such, further education of the local community may be needed, to ensure they understand this critical document, and how it relates to biosecurity. Several other items in Fig. 2 also relate to protecting and honouring joint sovereignty, including protecting the wellbeing of family and whanau (extended family), and tribal knowledge and protocols about the environment and how to look after it, both of which are of fundamental importance to Māori. More work is needed to grow the general public's awareness and appreciation of this.

Significance and importance of biosecurity

Despite varied understandings of biosecurity, the local community did report biosecurity as a significant threat to New Zealand as a whole (mean of 6.8 out of 7), to the PoT (6.7 out of 7), and to themselves or their families (6.4 out of 7). They perceived this threat as less pressing the closer it was to themselves, but overall, still agreed or strongly agreed biosecurity was a threat at all three levels. When asked how important they thought biosecurity was, the community rated it very important, with an average of 6.8 out of 7.

Perceptions of biosecurity role, knowledge and behaviour

When asked if they could help make a difference for biosecurity, local community members agreed that, on average, they could make a difference (5.9 out of 7). They were also relatively confident that they knew what to do if they found an unwanted pest, weed or disease in New Zealand (5.9 out of 7). This is consistent with the national sample, where 59% agreed or strongly agreed they know what they should do (Brunton 2018).

On the other hand, close to one-fifth of Mount Maunganui community members (17.7%) disagreed or were neutral as to whether they could make a difference, and the same percentage disagreed or were neutral that they knew what to do if they found an unwanted pest or disease. The two most common reasons listed as barriers to taking biosecurity action were not knowing what to do to help make a difference (45.9%), and a lack of knowledge about biosecurity (46.5%). Only 22%[6] of participants reported that they do not have time or were too busy to help. A very small minority reported that biosecurity is not their problem (1.3%), a potential incursion would not affect them (1%), or that what they can do would not make a difference overall (3.8%).

[6] Participants could tick multiple options therefore percentages do not add to 100.

Mount Maunganui community members were relatively confident that they could identify the main biosecurity threats (38% agreed), relative to the national population (29%). Consistent with the national sample, 54% of participants said that if they noticed an unwanted pest, weed or disease tomorrow, their first reaction would be to contact the authorities. Mount Maunganui residents were less inclined to say they would research it themselves (36% versus 49% nationally), and less likely to contact an individual or organisation they trust about biosecurity (23% versus 29% nationally). Only 10% of local residents disagreed that they knew what to do if they found a potential incursion, suggesting most of the local community are confident regarding appropriate biosecurity actions.

Regarding proactive biosecurity behaviours, one third of participants (32.1%) reported that they had actively sought or asked for information about pests, weeds and diseases in the past year. This was higher than the national average, where only 24% had actively sought information. When asked if they had seen, read or heard something about pests, weeds and diseases (passive information exposure), 83.3% of the local community surveyed responded yes. Thus, a majority of local community members had been exposed to material about biosecurity in the past year. This rate is markedly higher than the national average, where only 50% recalled hearing, seeing or reading something about biosecurity. Mount Maunganui residents also tended to agree this information about biosecurity was easy to find (average of 4.9 out of 7) and easy to understand (5.2 out of 7).

Local community members were then asked about biosecurity-related behaviours that they are currently performing or had performed over the past 12 months. Approximately half (48%) reported taking action to control pests or weeds at least once or twice in the past year, on their own property. A further 25.6% had not taken action in the past year, but had prior to this, while 26.5% had never taken actions to control pests or weeds on their own property. Community members reported less action outside of their own properties, with 28.9% having taken action in the last year and 28.8% having taken action to control pests or weeds at some prior stage. These rates are comparable to national averages.

Finally, local community members were presented with a list of stakeholders and asked to rate how

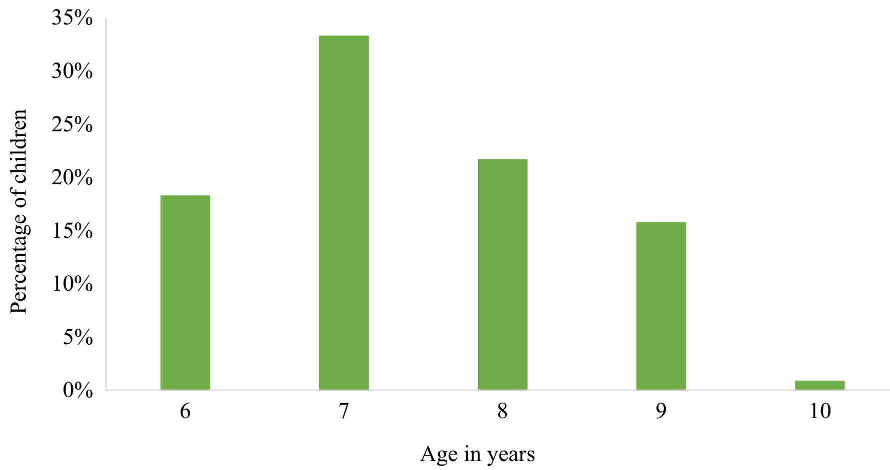


Fig. 3 Age distribution of children in Study 2

large a role they thought the stakeholder should play in biosecurity, from no role (1) to a large role (7). Government was clearly identified as the group that should have the most significant role (6.6 out of 7), with 81.6% of participants rating they should have a large role. Non-governmental organisations were also expected to play a significant part, with 44% of participants rating they should have a large role (average 5.8 out of 7), followed by community groups (5.5 out of 7) and businesses (5.2 out of 7). Interestingly, participants were less certain about whether they themselves should have a role (4.8 out of 7), and whether local iwi (tribes), hapū (sub-tribes) and marae (Māori meeting houses) should be involved (5 out of 7). This suggests a broader discussion is needed, about the possible role iwi Māori can and wish to play in regard to biosecurity, and ultimately who is accountable for New Zealand's biosecurity outcomes.

Results relating to study 2 (an educational biosecurity kit for school children)

Demographics

One hundred and twenty children participated in the research, spread across three schools in the Tauranga area,[7] with a total of six teachers across the children. All New Zealand schools are given a decile rating from 1 to 10, as a measure of the socio-economic positions of a school's student community, where decile 1 schools are the 10% with the highest proportion of students from low socio-economic background. The schools in this study varied in their decile rating, from decile 4 (32% of children), 6 (23% of children) and 9 (45% of children). Children ranged from six to ten years old, with the largest number aged 7–8 years old, as displayed in Fig. 3. There were equal numbers of boys and girls (60 each).

Self-reported understanding of biosecurity

Results for the smiley face Likert scale questions are reported in text here. For five of the eight questions children showed a statistically significant improvement over time, for two questions there was no difference, and for one question, children showed a decline in correct answers at the six-month follow up.

After using the kit, children demonstrated an increase in their self-rated understanding of biosecurity ($t_{87} = 12.7$; $p < 0.001$), and this was retained six months later ($t_{87} = 11.1$; $p < 0.001$). Children were also more likely to rate that they understood 'that some insects can hurt other animals, plants or people', however this was only significant between the pre-test and the follow-up ($t_{87} = 11.1$; $p < 0.001$). This finding triangulates with the first question as a proxy measure for biosecurity understanding, reinforcing that understanding did improve. Children appeared less confident in their understanding when the term 'biosecurity' was used, as opposed to the general statement that insects may cause harm, which is a simpler explanation of the premise of biosecurity.

[7] Schools will remain unnamed, for discretion and confidentiality purposes.

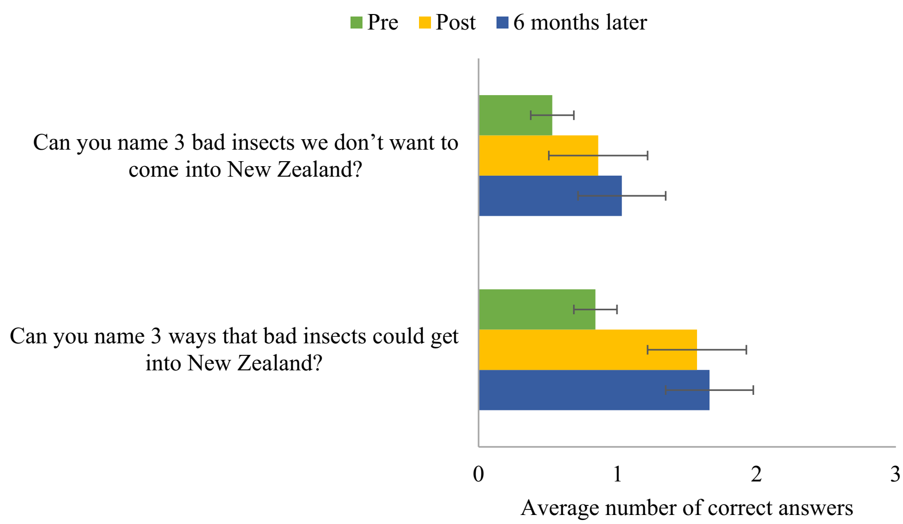


Fig. 4 Children's average scores for correctly naming biosecurity threats and pathways, before, after and six months after using the biosecurity kit

Children demonstrated an increased and sustained recognition of the importance of border surveillance for biosecurity risks, acknowledging 'it is important to stop new insects coming into New Zealand' (pre vs. post $t_{80}=5.9$; $p<0.001$) (post vs follow up $t_{80}=6.1$; $p<0.001$). On the other hand, children's ratings for biosecurity behaviours did not significantly improve, with no change in likelihood of reporting potential biosecurity incursions or talking with family about biosecurity. Surprisingly, the third biosecurity behaviour, 'looking for insects around home or school' actually saw a significant decrease six months after completing the kit, relative to before using the kit, where a majority of children reported they did not look for insects at school or at home ($t_{87}=-3.3$; $p=0.001$).

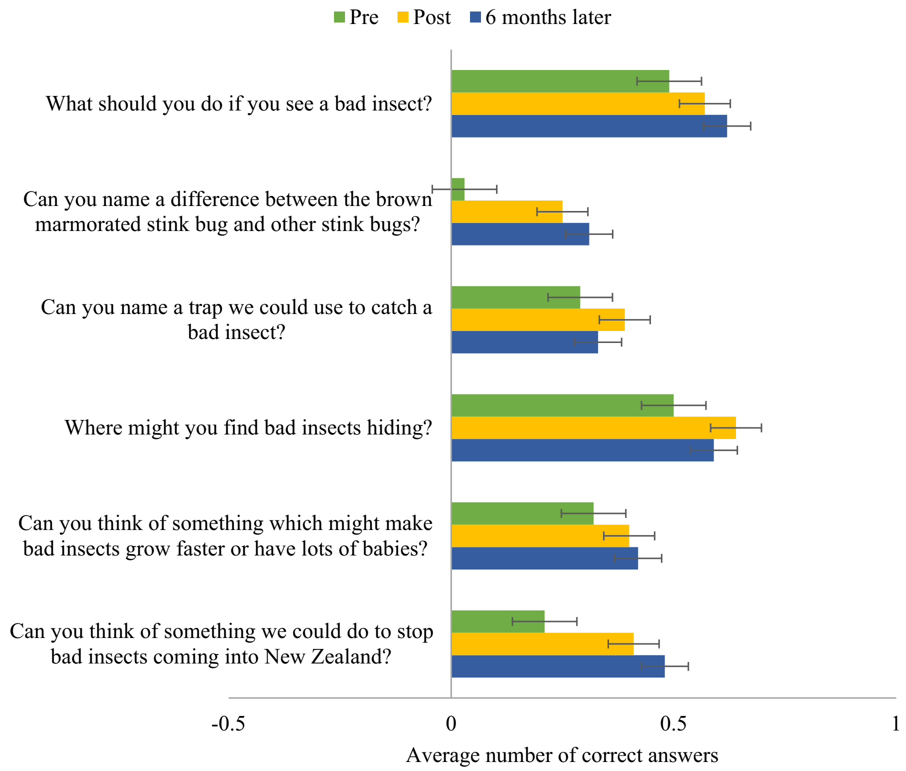
The final measurements on the Likert scale related to knowledge of insect pests ('which insects might hurt animals, plants or people'), and knowledge of appropriate reporting protocols ('I know what to do if I see a bad insect'). Immediately after completing the kit, there was weak evidence that self-rated knowledge of pest insects had increased ($t_{90}=1.7$; $p=0.097$), although this was not maintained at the follow-up.

Written understandings of biosecurity

Despite children rating that their knowledge of pest insects had not been retained when asked to name current pest threats directly (rather than self-rating their confidence about naming pests), children demonstrated a significant improvement, both immediately after using the kit ($t_{87}=3.5$; $p<0.001$), and at the follow-up ($t_{87}=3.7$; $p<0.001$). This result is substantiated in that children were more than twice as likely to name the stink bug as a pest (featured in the kit), after using the kit. Children did demonstrate increased confidence in their knowledge of reporting protocols ($t_{92}=3.1$; $p=0.002$), however this was not maintained at follow-up. Finally, children were better at identifying incursion pathways, both after using the kit ($t_{93}=6.7$; $p<0.001$) and at the follow-up ($t_{93}=5.7$; $p<0.001$). A portion of these results are displayed in Fig. 4.

Further questions where children demonstrated improved knowledge included differentiating the brown marmorated stink bug from regular stink bugs (pre vs. post $t_{91}=5.6$; $p<0.001$) (post vs. follow-up $t_{91}=5.1$; $p<0.001$), naming locations one might find insects (pre vs. post $t_{167}=3.1$; $p=0.002$) (post vs. follow-up $t_{167}=2.1$; $p=0.04$), and identifying potential biosecurity strategies for New Zealand (pre vs. post $t_{93}=3.8$, $p<0.001$) (post vs. follow-up $t_{93}=4.0$; $p<0.001$) as shown in Fig. 5. Some of these questions were clearly more complex, with considerably lower baseline averages (differentiating stink bug and identifying biosecurity strategies), however demonstrated marked improvements over time. Children's answers also demonstrated highly creative thinking, where some individuals (perhaps unknowingly) identified or alluded to sophisticated biosecurity control mechanisms currently used by New Zealand. This

Fig. 5 Children's average scores for a range of open-ended biosecurity questions, before, after and six months after using the biosecurity kit (where 0.5 was a partially correct answer)



included "getting their DNA" (DNA sequencing), "spray smoke in their eyes so they can't see" (fumigation), and "releasing a new species of insect and make it eat it" (biological control). Other humorous answers are displayed in Table 1. Overall, the children demonstrated a good awareness of current border biosecurity measures, such as checking bags, disposing of food before entering the country, and pest trapping.

Despite using the Likert scale to indicate they did not feel an increased confidence in knowing what to do if they saw a pest threat, children were significantly better at identifying correct biosecurity behaviours after using the kit. This included reporting (telling someone, such as an adult), trapping, or killing the pest (the least encouraged response, but marked as correct).

There were two final questions where children showed no improvement over time. These were 'Can you name a trap we might use to catch a bad insect?', and 'Can you think of something which might make bad insects grow faster or have lots of babies?'. These questions were related to specific activities within the kit, where children got to build and use insect traps, and do population modelling, where changes in different variables in the environment affected population growth. They were therefore reliant on the extent to which they had completed these activities, which will have varied between classrooms, and may explain the absence of change. Many children did provide accurate answers to this question which indicated an understanding of the premise, particularly around providing a food source for the insects, inaction ("not killing") and mating with other insects.

Table 1 Examples of children’s responses to various survey questions

Q	Can you name a trap we could use to catch a bad insect?
A	• When it is sleeping tie a string around it
	• Sleep smoke
	• A rat trap with fly spray in it
	• A micronet
Q	Can you name a way that bad insects could get into NZ?
A	• Ride on fish
	• They could walk in a group
	• Camouflage
Q	What should you do if you see a bad insect?
A	• Call for help and tell the pound
	• Tell your mum
	• Step on it and say goodnight
Q	Can you think of something which might make bad insects grow faster or have lots of babies?
A	• Finding a wife or husband
	• Hope
	• Eating, killing and stealing
	• Eat, eat, eat and eat
Q	Can you think of something we could do to stop bad insects from coming into NZ?
A	• Build a wall like Donald Trump did
	• Releasing a new species of insect and make it eat it
	• Make a force field around NZ
	• Putting smoke in their eyes so they can’t see
	• Make robots that search for them in NZ
	• Make the government stop them

Discussion

Local communities’ knowledge and perceptions of biosecurity

While the local community were moderately confident about their understanding of biosecurity, the lack of agreement and uncertainty regarding what is included in the biosecurity system suggest there is significant room for improvement in this understanding. This is particularly the case given the government’s emphasis on the role of citizen science, and the uncertainty from participants as to whether citizens assisting with surveillance constitutes biosecurity. It is also curious that although on average participants rate that they *can* make a difference for biosecurity, they appear unsure whether they should be playing this role, rating many groups as having a larger responsibility than themselves (including government, NGOs, community groups and businesses). Research suggests that once community members are more informed they are more empowered and want to become involved, therefore education and information is likely to be a catalyst for biosecurity action (Ram 2021).

There was also confusion regarding cultural aspects of biosecurity, such as the extent to which Māori knowledge and equal representation for Māori were related to biosecurity. This is understandable given the complex cultural and historical context discussed earlier, and speaks to the need for greater discussion on the topic. This includes the extent to which each iwi group wants to be involved, the capacity they have to do so, and reimbursement for this investment. There are many recognised issues in this area including underrepresentation and under compensation of Māori in science, and incongruence between Mātauranga Māori (Māori knowledge and ways) and western science (New Zealand Science Review 2019). It appears that perceived accountability for biosecurity in New Zealand is both dispersed, and complex, with wide-ranging opinions about who responsibility sits with, particularly with regard to involvement of indigenous groups. This is reminiscent of the national Colmar Brunton (2018) survey which indicated people were most likely to mention the environmental and economic impacts of a biosecurity breach, as opposed to cultural or social aspects, which may be less considered. Participants also rated pre-border and border activities as more clearly biosecurity than post-border elements such as multi-stakeholder involvement and protecting the wellbeing of New Zealanders. These findings suggest a need to broaden the community’s conception of biosecurity, as an underpinning part of a broader system which is fundamentally connected to all aspects of our wellbeing. Awareness-raising efforts may also be targeted at ensuring community members are aware that biosecurity involves everyone.

On a positive note, most participants had been exposed to information about biosecurity and one-third had actively sought out information. Moreover, half had taken action to support biosecurity efforts in the year prior to the survey. It may be that local biosecurity initiatives[8] are having an impact, or that Mount

[8] For example, see http://www.tmbiosecurity.co.nz/.

Maunganui residents may be particularly attentive to national-level campaigns, possibly due to an awareness of how fragile their local environment is, through past events such as the Rena oil spill which affected the surrounding region (Smith et al. 2015). Certainly high-profile, local biosecurity events have been shown to increase biosecurity awareness and behavioural compliance with biosecurity protocols (Ram 2021). Seeing biosecurity processes in action can help the community to feel engaged in and trusting of biosecurity officials, which can in turn help them to support the cause (Ram 2021). Either way, this supports the notion that community members are enthusiastic about helping the biosecurity cause, and would like to work to address the key barriers inhibiting their participation; lack of knowledge, and not knowing what to do.

The present research suggests awareness campaigns are likely to be well received, given community members are concerned about biosecurity, think it is important, and believe they can help to make a difference. This is supported by previous literature (Ram 2020; (Ram 2021). The high degree of perceived self-efficacy (belief that they can make a difference) and confidence in biosecurity action suggests that a majority of community members (around 80%) would be amenable to contributing to the biosecurity cause. Research suggests this is particularly true for those who own their home and might therefore have a stronger place-based identity and be more willing to help their community (Ram 2021; Urquhart et al 2017). Campaigns should focus on what the key threats are, how to report them, and how to otherwise help with biosecurity (surveillance, trapping, weeding, etc.). On a positive note, the literature suggests that these are already focus areas for biosecurity awareness raising initiatives, particularly common invasive species and weeds, and how to identify them (Verbrugge et al. 2021).

Finally, there is a sub-group of participants who are uncertain and lacking confidence surrounding biosecurity; they are unsure whether they can make a material difference, and do not know what to do to help. This seems consistent with the “blissfully ignorant” proportion of the population identified in the national biosecurity survey (Brunton 2018 p. 39). It may be most beneficial to target the majority of the community who are interested and engaged in protecting New Zealand from biosecurity threats; experience suggests that targeted education initiatives suited to the specific audience are more effective (Verbrugge et al 2021).

There are several potential limitations to note regarding the local community sample, which relate to the sampling and surveying methods used. First, it was difficult to gain a sufficiently large sample which was also representative. Using social media to recruit local community members is likely to have resulted in a slightly different sample than alternative methods such as collecting data in person ‘on-the-ground’. The statistics comparing our sample with national demographics suggested a slight overrepresentation of women, and a skew toward older participants. Nevertheless, comparison with the Colmar Brunton national biosecurity survey saw similar results, suggesting the sample provided a reasonable measure for the local community situated at Mount Maunganui.

School children and the educational biosecurity kit

The biosecurity kit was successful at improving children’s understanding of biosecurity, perceived importance of biosecurity, and their critical knowledge about biosecurity, including current pest threats, incursion pathways, and biosecurity control strategies. The kit was somewhat less successful at improving biosecurity behaviours, with no change in reporting behaviours, or discussion with family about biosecurity. This is consistent with a previous study which used narrative methods for environmental education of children and found that while environmental attitudes improved, behavioural intention did not (Yang et al. 2022). Further, there was a decrease in the likelihood that children would search for insects at home or school, however one possible explanation for this finding may be seasonal differences—the six-month post measure was undertaken during early spring and therefore children may have spent less time outdoors during this period due to rain or colder temperatures. Overall, these results suggest the kit is an excellent learning resource, but is less effective as a behaviour change tool, as least without additional interventions, such as encouragement from parents to keep looking for and discussing insects or pests at home. Indeed, research suggests getting out into nature helps children learn about similar concepts such as biodiversity (Beery & Jørgensen 2016). This is particularly the case with regard to exploring a local environment, as previous research suggests children may have a distorted perception of biodiversity focusing on exotic, iconic foreign species as result of media exposure (e.g. television) (Ballouard et al. 2011). Including the wider household in these experiences may also have greater spill-over benefits, in generating interest and learnings for parents, siblings and others living in the home.

The findings also provided some key learnings about measurement of biosecurity knowledge among children. The term biosecurity may be a barrier for some children, as children were more likely to rate that they understood the premise of biosecurity, rather than the term itself. This may emphasise a need to reduce jargon when communicating about biosecurity with children, and in particular when measuring children's understanding of the concept, to gain an accurate measure. This is congruent with the literature, which acknowledges that conceptions of biosecurity are complicated, variable by setting, and may be confusing for a lay audience, especially children (Verbrugge et al. 2021). Similarly, there was some contradiction apparent in children's self-rated knowledge about biosecurity, versus their actual performance when providing short answers. That is, while children rated that they did not have significantly greater knowledge after completing the kit, their answers indicated that they did in fact increase and retain biosecurity knowledge. This suggests that a short answer format may be more accurate than self-ratings, and that children underestimated the amount of learning they achieved through the kit.

Collecting data with children is always a difficult task which requires careful consideration. Our sample is relatively small, due to the need for informed consent, and participation on three different occasions from each participant. The researchers were also mindful of any responses which appeared invalid (i.e. initial survey administration occurred after use of the kit). Meeting these requirements resulted in removal of many participants, to ensure the data used was both ethical and sound.

The second concern related to accurately measuring children's perceptions, knowledge, awareness and behaviours of biosecurity. This required the design of survey questions and survey scales which were both easy to understand and easy to respond to. In the survey question design, use of jargon was minimised, and complex concepts were translated into simple terms (e.g. population modelling of insect reproduction was phrased 'have lots of babies'). Answers indicated that most children who responded to the open-ended questions understood the concept being assessed. It was clear that some children struggled to communicate their knowledge and may have scored better on the questions if they had assistance to write or read their responses (for example children who spelled words phonetically which made answers difficult to interpret e.g. "soga bug" for 'soldier bug').

Responses on the smiley face Likert were more difficult to assess. The smiley face Likert scale utilised here is widely used in research involving children, however is known to bring a number of issues, such as garnering different responses from different age children (varying language abilities) and acquiescence bias (for example see Hall et al. 2016; Mellor & Moore 2014; Read & MacFarlane 2006). For this reason, this scale was combined with the open-ended free recall questions, to triangulate against and complement the Likert scale responses, to provide a more complete picture.

Finally, the extent to which the children absorbed the information from the biosecurity kit and were able to recall this information will have depended partly on the teacher who administered it, and which activities were completed. These variables are difficult to control and may have impacted the results.

Conclusions

This research provides evidence of two target community groups for awareness raising and behaviour promotion surrounding biosecurity; adult members of the local community (public) and school children. Both groups demonstrated a moderate level of understanding of biosecurity, and a very high understanding of the importance of biosecurity for protecting New Zealand. They report moderate awareness regarding current pest threats and appropriate reporting protocols, however low rates of actual performance of biosecurity-related behaviours, including surveillance, management, and having discussions about biosecurity. This suggests that interventions now need to shift focus from the early stage awareness raising, into provision of straight-forward advice regarding what they can practically do to help. It will also be beneficial to continue education regarding current pest threats and appropriate biosecurity behaviours. Overall these results are highly positive, as they suggest a willingness and interest to help, with the key barrier for these groups being not knowing what more they can do, or how they should do it. While Mount Maunganui community members rate their understanding of biosecurity as better than the average New Zealander (Brunton 2018), results suggest they are actually performing less regular biosecurity action in the past year. As such, key enablers for achieving more impactful community involvement for biosecurity may be more action focused, underpinned by targeted education and practical advice about what citizens can do to help. Similarly, school children may benefit from greater experience in biosecurity actions, such as active pest monitoring, and undertaking biosecurity behaviours with their family at home. Given the biosecurity kit was successful at improving biosecurity awareness and knowledge, a beneficial intervention post-kit could be behaviour related. While it may be unrealistic to assume 100% of the population will assist with biosecurity preparedness and response, these results suggest a significant proportion of the population would be willing to help, particularly if given targeted advice about how.

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Declarations

Conflicts of interest The authors are not aware of any competing interests.

Data availability The data is not available due to confidentiality issues, but the authors are happy to discuss the material.

Ethical approval. Ethical approval for this research was provided through the AgResearch Human Ethics Committee.

Informed consent Local community members who did not provide their informed consent at the beginning of the survey were excluded from participating. All children who were invited to participate were sent home with an informed consent form, for their parent(s) or legal guardian to approve their participation in this study. This form included a description of the research, and explained that children's identities would remain confidential, with average age and gender statistics being the only details reported. One consent form was sought for each child's participation throughout the research. Any data obtained from children who did not have signed informed consent from their parent or legal guardian was not included in this study.

Consent to participate All participants or legal guardians of the participants in this study gave their consent to participate.

Consent for publication All authors gave their consent for this material to be published.

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