NZ's Biological Heritage National Science Challenge Scoping Panel Report

SO4: We have state-of-the-art biosecurity surveillance systems

Section 1: Creating Impact

Vision and link to the Challenge mission

The Challenge aims to help reverse the decline of Aotearoa New Zealand's biological heritage, but we cannot manage our bioheritage unless we can "see" it, and care enough to act. Surveillance comprises the systems of tools and techniques that enable us to track and anticipate the impacts on ecosystem health and protect our export economy by monitoring biodiversity, primary production and detecting new invasive species early. Aquatic and terrestrial surveillance systems are needed to help reverse the decline of New Zealand's biological heritage. Surveillance systems have a dual role in collecting and recording pest presence or absence, as well as helping to monitor ecosystem health.

Increased global movements of people and products mean invasive species are becoming more of a problem, currently outpacing our ability to detect and constrain them. Meanwhile, our productive systems are threatened and hundreds of native species are tracking slowly and silently toward extinction. New surveillance gadgets will help, but in the face of such challenges transformational impact will only come from harnessing the potential of our people, and this is pivotal in supporting our ability to respond early and swiftly to environmental changes. In particular, using both existing and emergent understanding, values, approaches, and opportunities that recognise the contribution from both Western and Te Ao Māori experiences, and intelligence.

Surveillance systems may target particular species or groups of species by looking in new places, using cunning trapping technologies, or they may use the 'eyes and ears' of engaged communities. The risks posed to local flora and fauna from a continuous range of invasive threats both impending and established, present an ongoing challenge. The current surveillance effort delivered by a portfolio of activities operates on the premise that no one surveillance activity can handle it all. This has resulted in a fragmented system where surveillance is often constrained by duplication of effort, funding prioritisation, and a focus on exotic pests, with less focus on ensuring healthy and resilient environments.

Future shifts in climate, land use, trade patterns, biological invasions, species distributions and increasing pressure from iwi/hapū who have an expectation that they are engaged at every level of the biosecurity system, encourages that surveillance is responsive and connected to achieve our long-term aspiration for a '**future-fit adaptive and resilient biodiversity and biosecurity surveillance for New Zealand'.**

2024 Goals

Early detection: Our surveillance systems detect incursions early enough to allow eradication or other responses

Biodiversity monitoring: Our tools and approaches can accurately monitor changes in distribution and abundance of terrestrial and aquatic pests and native flora and fauna for effective management

Co-design: Māori co-designed surveillance systems recognise and are informed by the cultural economy

Involvement: Actively engaged NZ communities understand and support surveillance efforts that contribute to the protection of our biodiversity and well-being

Evaluation: We have the methodologies to evaluate the performance of surveillance systems and to prioritise allocation of resources

Our goals complement each other as shown in the figure below. Early detection and biodiversity monitoring are the main surveillance activities operating at opposite ends of the process of biological invasion and impact. Underpinning these outcomes are surveillance systems based on Māori co-design, community and industry involvement, and surveillance tools and technologies (included in the green Goals). Māori are explicitly highlighted as a specific group given dual status as kaitiaki (guardians) of New Zealand's environment and the Te Tiriti/Treaty Partner distinct from their role as New Zealand citizens. We also need to be able to evaluate and improve surveillance systems as circumstances change. There are strong links to other SOs (i.e. SO1, SO2, SO3, SO5).

Beneficiaries

Biosecurity surveillance and biodiversity monitoring are key underpinnings for managing terrestrial and aquatic ecosystems (SO2). Surveillance works together with eradication, containment and pest management (SO5) to help prevent, slow and mitigate the impacts of biological invasions on native and productive ecosystems. Surveillance in turn relies on risk analysis (SO3) to help target appropriate invaders and to make informed responses once something is found.

At the broadest level we all benefit from the biosecurity system. Explicitly linked to the permanence of our unique native flora and fauna is the cultural identity, history and narratives of tangata Māori.

Addressing impacts of exotic pests and diseases, preserving the terrestrial and freshwater ecosystems (SO1) are fundamental to our cultures, values and spirituality. Growers experience the economic advantage of a relatively low pest load, exporters can access sensitive markets by demonstrating pest freedom, and we all enjoy the social, cultural and health advantages of our natural isolation from many of the world's most challenging pests and diseases.

Specific beneficiaries from the surveillance goals include central & local government: Ministry for Primary Industries, Department of Conservation, Ministry for the Environment, and regional councils. These agencies hold operational responsibility for biosecurity and biodiversity protection. State-of-the-art surveillance systems will enable them to make better decisions and improve efficiency.

Māori, mana whenua and kaitiaki, working with their Te Tiriti/Treaty partner, science, industry and community will ensure information and data, created and being used within the surveillance effort, enables their engagement at all levels in biosecurity. Greater involvement, data sharing relationships, and acknowledgement of their expertise and data provenance that recognises and gives effect to their influence and mana as traditional indigenous guardians.

To accelerate change beyond incremental steps, investment should go towards equitable consideration of Te Ao Māori and the international surveillance standards agreed by New Zealand as part of the international trade governance institutions. Currently the primary driver for establishing biosecurity surveillance and data collection is the international standards imposed for trade, sometimes with little or no regard for Te Ao Māori. Māori and communities are both beneficiaries and collaborators.

Similarly, increased public participation in surveillance will benefit communities by building a common purpose, engaging youth along with retirees, bridging class and ethnic boundaries, and raising fluency in Western science and mātauranga Māori. A good example of increased public participation is the Tauranga Moana Biosecurity Capital initiative. As part of engaging the public, artists, musicians and story-tellers should be encouraged to explore themes of biosecurity and biodiversity. Both the people and the biosecurity system will benefit when surveillance and monitoring activities are relevant and made interesting, interactive and engaging.

There may also be opportunities for commercial development of surveillance and monitoring tools, which should be explored with the private sector. Internationally surveillance for biosecurity and ecosystem health is a large aspect of many countries' land management objectives (e.g. USA, Canada, Russia) and there is potential for large return for the private sector.

Progress towards achieving the Goals outlined will require new collaborations between separate parts of the research community. University and CRI scientists will need to engage with hapū/iwi, kaitiaki, engineers, artists and entrepreneurs from the private sector and civil society. There will be long-term benefits from cross-fertilisation of ideas, tools and techniques from Te Ao Māori, epidemiology, ecology, animal behaviour, social sciences, modelling, engineering, other physical sciences, arts and culture, creative industries, etc., and with stakeholder knowledge and local community knowledge.

Delivery pathways

Working together is essential for delivering state-of-the-art surveillance systems, as expressed in the Biosecurity 2025 Strategic Direction 1 "A biosecurity team of 4.7 million". Detecting new pests early and monitoring biodiversity effectively will be facilitated by biosecurity surveillance becoming a fundamental and sustained part of our public consciousness. If we work together to create and operate biosecurity systems, this also ensures that the relationships are in place to deliver the results to those who make effective and responsive management decisions.

A Māori co-designed surveillance system is an important foundation to this work. The pre-existing knowledge and infrastructure embodied in Te Ao Māori provides a strong foundation for a lasting surveillance system and encouraging Māori to engage more fully in biosecurity decision making. A key

component of this work (with crossover to SO2) is to value New Zealand's cultural economy and monitor terrestrial and aquatic ecosystem health. Māori will form the core of new surveillance systems, with hapū/iwi/whānau centric to the dissemination of biosecurity information and results.

The Challenge has an opportunity to facilitate the sharing of surveillance data through the development of minimum data standards, thereby allowing distributed databases to be queried while preserving data integrity, ownership and provenance. Gaining permissions for free-flowing data will help engage more people in biosecurity surveillance and biodiversity monitoring with key data holders, that will need to be involved in the process from the start to ensure that sensitivities are respected, and that new standards and technologies are adopted.

Hubs and data sharing will engage with hapū/iwi and the wider New Zealand public. Public participation can be promoted by using competitions and challenges, appealing to the competitive nature of New Zealanders and exploring their creative potential to promote and participate in biosecurity surveillance, and mapping its relationships to biodiversity and well-being. By using existing social media platforms to connect and inform (and creating new platforms which enable linking/competition with friends through the application), more people will be encouraged to actively participate in the surveillance effort to protect our biodiversity.

A diverse and engaged community of surveillance champions will naturally achieve a degree of self-evaluation and production of peer-reviewed literature (in co-authorship with whānau, kaitiaki, rangatira, ahikaa) ensuring that this work remains grounded within Te Ao Māori as well as our scientific and education sectors.

Risks

We are proposing a reasonably risky portfolio of investments (see Essential Activities below) as we believe a step change in surveillance efficacy is not possible through incremental improvement of current systems. Many of the activities we propose have been raised before but little progress has been made. The Challenge can make a difference by progressing these work streams and providing independent, multi-year leadership.

The biggest risk here is that data owners will not see the benefits of sharing, or will become disenfranchised due to the use of their data not being handled appropriately. Data holders, including hapū/iwi and community groups, will be encouraged to participate from the outset in order to be influential in shaping the results. As a dynamic and responsive platform, it will address the biggest risks so data owners who may be distrusting and unwilling to cooperate can instead see the benefits of sharing their data, and be confident that it is being managed and/or held appropriately. If done well, the central data sharing platform would encourage public participation in surveillance, biosecurity, and biodiversity and provide a neutral platform that facilities discussion and decision making.

Previous work has aimed to adapt new technologies (e.g. camera traps, volatile sensors, self-reporting traps) for use in surveillance, but little of this has been widely taken up. Part of the problem is the economies of scale – New Zealand's biosecurity and biodiversity spaces do not require sufficiently high numbers of gadgets that would incentivise commercial partners to streamline mass production and bring the per-unit costs down. This does not mean we should stop trying to harness new technologies for surveillance; rather it shows that it may be important to work together across biosecurity and biodiversity to identify common needs to generate sufficient demand.

Any development or modification of sensors will need to be done in partnership with commercial vendors. These vendors will need convincing of the potential for a strong economic benefit for themselves, in addition to value in supporting and protecting NZ's biological heritage from a cultural, social and environmental perspective. International needs can help to inspire investment and the Challenge can facilitate these relationships. This implies a commitment to adoption and use of new

tools, which will require involvement of end-users early on, where hapū/iwi and community groups with proven capability and capacity are poised and ready to implement. It will also be challenging to commit to developing a particular tool when new technologies seem to appear almost daily, and some direction must contribute to developing a market for new tools.

Science has always struggled to achieve adoption of new tools and technologies, and surveillance is certainly no exception. Involving end-users early will help, but successful local exemplars may also be essential for catalysing widespread adoption. Case studies and target groups should be chosen carefully and become appropriate models for wider adoption. Furthermore, by their nature, surveillance tools rely on accessing areas of private or mixed ownership. For example, remote sensing technologies (e.g. drones, aerial imagery) are not accepted by all in Aotearoa, with many New Zealanders rejecting their intrusive nature. Wide-scale consultation may be required before using new technologies. It is also likely that "social and cultural licence" will not be granted to operate in some areas. As part of this report the permission (or lack of) should be adhered to; this will promote trust and strengthen relationships, and may even provide fertile ground for development of new methods and tools that revolutionise current practice across Biodiversity Management Areas (BMAs).

Finally, it should be recognised that New Zealand's biological heritage cannot be fully catalogued and monitored by 2024. Our goals will use exemplars and case studies to test for longer term success.

Communications and relationship management

Effective communications are the basis for a state-of-the art biosecurity surveillance system, therefore successful collaborative relationships are essential to this goal. We recognise that communications and relationships will be similar across all five goals.

Government agencies will continue to play a critical role overseeing the public good aspects of surveillance, including the important job of liaising with trading partners. But there is a recent trend towards a partnership approach for surveillance. Under the GIAs, MPI is increasingly working with industry groups around readiness and response, including surveillance for early detection.

Meanwhile the Biosecurity 2025 strategy encourages greater participation by all New Zealanders in biosecurity, especially around surveillance. Along these lines, we propose a model for data sharing and participation based at a local/regional level. Recognition of trade implications is important within our biosecurity surveillance system, therefore complete and immediate open access to all data is not recommended and unlikely to get support. This is overcome by tiered access to the data where levels of openness progress through the system from highly secure (only MPI can see it), to medium (MPI + GIA, hapū/iwi, Te Tira Whakamātaki, science organisations, other industry), to open (public), with the eventuality that security needs will diminish, and data will go public when the trade threat is addressed. This approach also leads to improved methods for demonstrating Areas of Freedom within NZ for addressing trade implications. Ecosystem health surveillance may be immediately open access if there are no trade implications.

Working across Biodiversity Management Areas we envisage better engagement with hapū/iwi, whānau, kaitiaki and Māori business, who will be engaged at all levels. This is a more collaborative and inclusive model for surveillance, leveraging off mātauranga Māori/current Māori surveillance, and existing work undertaken by tangata whenua/kaitiaki, and their communities. In particular, the Co-design goal recognises the importance of traditional knowledge, understanding and values that need to be incorporated into biosecurity and biodiversity surveillance. A critical step is recognising and building enduring, strategic trust relationships with hapū/iwi and whānau across the BMAs, in addition to supporting relationships with government agencies, industry and communities.

An appropriate IT infrastructure will link marae/hapū hubs and communities, ensuring everyone has appropriate access to real-time surveillance and biodiversity data for timely decision making. Biosecurity surveillance needs to reach out beyond those communities already engaged, building on

their commitment to drive recruitment into wider segments of society. Involving communities from creative and health industries to support the growth of interest in biodiversity and wellbeing will be an important new direction for expanding the reach of state-of-the-art biosecurity surveillance. Additionally, social media may enable communication and knowledge transfer amongst the public, allowing local people to kōrero (discuss) and tell their own stories which reinforce the link of effective biosecurity surveillance with sustained biodiversity. A starting model for this general approach is the Tauranga Moana Biosecurity Capital (TMBC); recognising that it is essential that regional differences will shape the nature of partnership approaches.

Given the diversity of important contributors to surveillance, it will be important to be flexible and engage different groups in the different ways that are appropriate to them. It may be useful to have a project manager to coordinate across diverse interests, that brings different contributors together to demonstrate the benefit of sharing data and collecting standardised data for developing longer-term analytical capacities and capabilities.

Section 2: Incentivising Investment

Essential activities

Goal: Early Detection

Activity 1: Surveillance and biodiversity data sharing infrastructure

Data sharing is essential for surveillance success, so establishing a robust data infrastructure is a key activity. This is also one of the five Strategic Directions from the Biosecurity 2025 strategy, and the initial work done there will kickstart progress. Importantly, this is not necessarily about creating a new master database for surveillance information. Rather, the work needs to engage and empower data holders to share, using a set of data standards, while maintaining the traceability, purpose integrity and provenance of the data. An example of a comparable system is the Global Biodiversity Information Facility (GBIF, www.gbif.org).

We have compiled a register of over 40 existing surveillance programmes along with key contacts for each (see Appendix). An early step will be to hold a workshop/hui with these data holders and potential end users. Issues of ownership and cultural authority must be addressed, and minimum data standards defined and agreed. The appropriate infrastructure design should be determined, whether based on centralised or distributed data, and core data sets integrated. By 2024 we envision a successful data case-study used for early detection, delimitation or proof of freedom.

Activity 2: Leveraging elements of natural ecosystems for surveillance

An exciting area for innovation is utilising ecosystem processes or taxa to obtain or amplify surveillance data signals. For example, honeybees and dogs have been trained to detect specific volatiles that indicate the presence of a target pest or disease; in the USA wasps were used to collect emerald ash borers for delimitation; pheromone traps may attract insects searching for mates; and stream baiting uses natural waterways to detect *Phytophthora* spp. In many environments effective use of eDNA and eRNA technologies will rely on some element of the ecosystem to collect and concentrate target molecules, such as foraging bees returning to the hive after visiting flowers in an orchard. More generally, the abundance or decline of key taxa may indicate ecosystem health and impacts of invasive pests.

Science is still unravelling the complex webs of interactions and invisible signalling that bind ecosystems together, but there may be further potential for these to yield information for surveillance. We suggest beginning with a literature review coupled with a meeting or wānanga to identify the elements of ecosystems amenable to surveillance activation. Cultural licence is of significant importance as Māori are yet to support the use of e-technologies and many have yet to establish its

appropriateness in the New Zealand landscape. This is an area where Māori knowledge and intimacy of their natural ecosystems are particularly important.

Activity 3: Sensors for surveillance

New environmental sensors are being developed and miniaturised at increasingly rapid rates. It will be important to keep abreast of developments and identify their potential value to surveillance and how/when they might be used. It may soon be economically viable to deploy short-term biodegradable sensors *en masse* for targeted surveillance activities such as delimitation of a pest population. With all new surveillance technologies it will be necessary to assess their sensitivity and specificity for target organisms as well as their social and cultural appropriateness and acceptability. New sensor technology will be trialled bringing in the Co-design the Biodiversity Monitoring goals (see below).

Goal: Biodiversity Monitoring

Activity 4: Developing methods to establish baseline distributions of exemplar taxa

Ecosystem management would be made much easier if we had accurate and complete information on the distribution and abundance of all terrestrial and aquatic flora and fauna, both native and non-native. However, this is far too big a job for the current programme, so a few exemplar ecosystems and taxa should be systematically selected around which to develop new survey, modelling and monitoring tools and techniques. The data sharing infrastructure of Activity 1 will play a key part, and the exemplars could be used as case studies for other surveillance activities in the programme.

Activity 5: Remote sensing techniques

Remote sensing techniques (e.g. drones, satellite data) are now very accessible, but there remain some key challenges for their use in surveillance and biodiversity monitoring. Primarily, what useful information can actually be gleaned from the data collected? Image analysis and artificial intelligence need to investigate the range of hyper-spectral and other data that may be collected remotely, ultimately aiming to produce useful information for mapping biodiversity and/or ecosystem health. Ground-truthing will be an important and potentially costly step. The social and cultural acceptability of remote sensing is not assured, but may change over time in some locations as drones (e.g. pizza delivery drones) and remote sensing are socialised and debated.

Activity 6: Biosecurity surveillance apps

Apps have become a ubiquitous part of society and are natural fit for general surveillance. Existing apps like iNaturalist do not yet have widespread adoption and use. Social science could be used to help identify the barriers to adoption and use of apps for surveillance and biodiversity monitoring. There may be options to "gamify" biosecurity surveillance through apps, or to partner with other app-based searching games (e.g. geo-caching, Pokémon-Go) to further engage the public to be the "eyes and ears" of biosecurity and biodiversity. The resulting data also need to integrate with other surveillance systems (Activity 1A). Proposed activities could be one or both of the following:

- A study of the barriers to adoption and use of apps for surveillance & monitoring
- Development of a biosecurity game that generates data useful for management

Goal: Co-design

Activity 7: Establish surveillance systems based on Māori centric hubs

Māori hold much mātauranga of relevance to biosecurity surveillance and biodiversity monitoring, but little of this is currently recognised or utilised in surveillance systems. Marae and other Māori centric environments (kohanga reo, kura kaupapa, kapa haka, etc.) could form the bones of a nationwide

network of local surveillance programmes, owned and coordinated by hapū/iwi, potentially also involving local government, businesses and other members of the public. To make this happen we need to review the indigenous experience, Māori narrative and Māori approaches to surveillance.

Activity 8: Build understanding of Aotearoa's cultural economy

Surveillance implicitly involves valuation and prioritisation of elements of the environment. To engage fully in co-design we must build a better understanding of the cultural economy of Aotearoa. This requires an awareness that in the first instance, the foundation for the cultural economy is the value of nature is unto itself. It will be useful to examine international models or views on cultural economy, and test the Māori narrative with other indigenous understandings. In addition, we would find and engage champions and experts, identify missing local capability, hold an indigenous cultural economy think tank, and create an indigenous cultural economy collective. Kauri forests may be a case study for surveillance informed by our emergent understandings of its cultural economy (using the work on-going in Ngā Rākau Taketake).

Activity 9: Surveillance architecture

It is important to match the purpose of the surveillance with its design. Risk based surveillance for early detection should most effectively be targeted at entry points/areas of greatest likelihood of arrival and establishment. Sentinel surveillance might be based in geographic areas where assets (natural or productive) at risk are located. Biodiversity monitoring is typically best placed in the natural estate but could also occur in productive ecosystems. This activity would map out how these different types of surveillance systems connect into surveillance hubs and build the architecture of these different networks, defining where they interconnect and how to best draw in local communities.

Goal: Engagement/Involvement

Activity 10: Design methods to measure changes in states of biodiversity and community engagement

To quantify improvement, we must first develop baseline measures for community engagement in surveillance and the extent to which it can improve biosecurity and biodiversity outcomes. A stocktake of the existing example of biosecurity science and biodiversity engagement can provide a baseline for initiatives and measures of effectiveness. An extension through community biosecurity surveillance and biodiversity monitoring activities will also be needed, to adequately gauge the breadth of current engagement. Recent Better Border Biosecurity (B3) work in Tauranga might act as a model here. Three underlying areas for improvement will be based on performance measures in: i) improved mobility of citizen science responses in priority areas; ii) improved coverage and granularity of biosecurity-relevant data across Aotearoa; and iii) greater industry engagement (monitoring and responses) in key sectors.

Activity 11: Involve communities in biosecurity surveillance

Several initial steps need to be taken to ensure we have enough community engagement and our resources are targeted to areas that will likely generate the most benefit. We will need to decide on a sensible community of interest and develop a stakeholder analysis and engagement plan. Following initial engagement, we will need to design an appropriate biosecurity challenge that will meet the aims of multiple stakeholders and work as seamlessly as possible with existing biosecurity and community engagement activities. An inventory of existing research outreach and engagement activities involving communities in biosecurity and biodiversity operations, such as Unlocking Curious Minds and Participatory Science Platforms, will be undertaken to learn from best practice and design new targeted areas of engagement. Regional councils, education boards, marae, community groups, community hubs, libraries, art galleries, museums, etc. will be consulted to support decisions on what challenges communities can meaningfully tackle, and what is the best 'way in' to communities.

Further steps to undertake will include engagement of school boards to initiate a robotics or other tool innovation activities with students, regional councils to work constructively within existing health monitoring activities already underway, and the set-up of a steering group from our community of interest to support the selection of case study sites with key stakeholders. This will be co-designed with hapū/iwi.

Goal: Evaluation

Activity 12: Development and application of a surveillance system evaluation framework (SurF)

This area is closely aligned to the scorecard being developed in SO1 and should be influenced by that work. Activity 1A engages a community of surveillance providers including hapū/iwi to cooperate on data sharing, and the same group will be instrumental in developing a set of agreed metrics for the performance of surveillance systems (MPI's SurF evaluation framework will provide a starting point). Not all metrics may be appropriate for all surveillance and monitoring activities, and we must also consider qualitative datasets, so the SurF needs to be flexible and inclusive. The system should be reviewed by local and international experts.

Activity 13: Prioritization of surveillance resources

The resources available for surveillance and biodiversity monitoring are much less than what is needed, so prioritisation is important. We must choose the right biosecurity threats to target for early detection (SO3). Current development of international cooperation in data sharing and cost benefit analysis of surveillance investments may be key. Analysis of environmental and aquatic risks can be improved through international collaboration and re-purposing of sector-based analytical tools. The sensitivity of targeted surveillance programmes should be proportional to the cost and benefit to New Zealand, inclusive of values determined in the development of the cultural economy; less sensitive surveillance should have minimal investment (prioritization of annual budgets) with forecasts informing pre-emptive resourcing to address a serious risk. Hindcast modelling may overtime, enable some flexibility to respond to previously unrecognised emergent serious risks.

Optimisation relies on measuring the sensitivity and specificity of surveillance tools, and modelling detection accordingly. Few surveillance systems have been evaluated this way and there has been even less research on optimising investment across different surveillance targets.

These key activities span the range from scientific discovery to adoption and scale out, as shown below.

Essential partnerships and relationships

Researchers in the kaupapa Māori, physical and social sciences and engineers will be essential to achieving our goals, but will need to work in partnership with the following:

Māori: First and foremost, partnerships with whānau, hapū and iwi are essential to seeing this goal achieved. Our goal is to develop a Māori centric kaitiaki network which will lead on-ground delivery of biosecurity surveillance across Biodiversity Management Areas in Aotearoa. This will require relationship and partnership between the geographically dispersed hapū/iwi networks, as well as between kaitiaki groups and government agencies. To build our understanding of Aotearoa's cultural economy, indigenous tribes and nations, Māori indigenous academics/economists as well as overseas indigenous communities may need to inform our understanding of this work

Government: Currently both central and local government organisations/agencies are mandated to lead biosecurity surveillance in New Zealand, specifically the Ministry for Primary Industries (MPI), Department of Conservation (DOC) and regional councils. Along with hapū/iwi, MPI, DOC, regional councils and CRIs are custodians of existing data, and will help develop the systems, tools and methods to detect, monitor and evaluate how well our systems are working. MPI can advise on the value of surveillance for pest-free trade, allowing a quantifiable valuation for purposes of determining economic wellbeing. When layered with understanding gained from building our cultural economy, we will have a far stronger way to evaluate the performance of our surveillance system and prioritise resource allocation.

Primary producers: Surveillance is critical to maintaining NZ's primary production industries, and several primary industries (notably forestry, but also others) operate their own formal surveillance systems. The Government Industry Agreements (GIAs) are resulting in increased participation of primary industries in readiness and response decision-making. This includes surveillance.

Private companies: Biodiversity monitoring tools may be developed through relationships with technology companies and private companies who already work in the biosecurity and/or surveillance space (e.g. with satellites, drones, planes etc). Satellite companies (e.g. Sentinel, Landsat, Worldview)

will be important to link with. Likewise, software developers/engineers will be vital to ensuring we have the IT systems available to allow open access to data. Private research providers and developers should be proactively consulted with. The Science for Technological Innovation (SfTI) Challenge may be a particularly useful partner in this space.

Communities: Education authorities, kura, wānanga, kohanga reo, schools and school boards will be utilised to ensure New Zealanders understand and are actively involved in biosecurity surveillance from an early age. Key engagement tools will be utilised with children to ensure biosecurity surveillance is as ingrained as the "keep New Zealand beautiful" message. The media, including social media, should be utilised to educate and engage communities in surveillance and can provide a powerful monitoring tool as a proxy for community engagement, but should not replace actual activities. New initiatives with the galleries, libraries, arts and museum communities should extend the current reach of surveillance activities and outreach.

Key stakeholders like regional councils, DOC, MPI and hapū/iwi along with health boards, Federated Farmers, TTW and environmental groups should also be utilised to bring people on the journey, ensuring New Zealanders not only understand and support surveillance work, but are also actively engaged and contributing to the protection of Aotearoa's biodiversity through biosecurity surveillance.

Essential resources

As emphasised above, investment in people (capability and capacity) is essential to ensuring our biosecurity surveillance system is an enduring system. Investment in new technologies will also require resourcing to ensure we are utilising "state-of-the-art" methods and approaches for biosecurity surveillance.

Capable laboratories and gadgets are required for testing, to ensure early detection of biological invasions in time to allow appropriate responses. The infrastructure to enable shared data, and shared data sets themselves, will help ensure everyone has access to these data – an agreed centralised IT system and/or connected systems, and access to scientific and IP sensitive information will be critical to seeing this happen.

Development of tools and approaches will also require investment to monitor change in distribution and abundance of both pest and native species. Essential to this work will be hapū/iwi kaitiaki, university and CRI researchers and communities (thus the need for capability and capacity) to ensure we are working on the right tools to effectively monitor this change. Firstly, access to and coordination of existing and relevant data will help us understand what data we need. This will result in investment for data collection and software storage (e.g. satellite imagery and drones to help us gather information).

Engagement of hapū/iwi will be critical to the success of the co-design goal, to build surveillance systems which recognise and are informed by the cultural economy. Knowledge on cultural economy will be gained by investing in research undertaking by both international indigenous & Māori cultural economy practitioners. Resourcing Māori surveillance approaches, and capacity of people to undertake the surveillance, is critical to the success of this goal. Existing technology/social media platforms which are frequently used (particularly by youth) can be used to disseminate data.

The focus of the Involvement goal is to ensure actively engaged hapū/iwi and NZ communities understand and support surveillance efforts. One of the first steps will be to research what biosecurity tools are out there that could be shared with the public to demystify biosecurity. Connecting with SO1 ("We assess our progress using a biological scorecard for Aotearoa") will be important to initiate and test indicators with end-users. This will enable the development of an open-access map to portray local environment health for communities. Resourcing will be required to develop a game, which

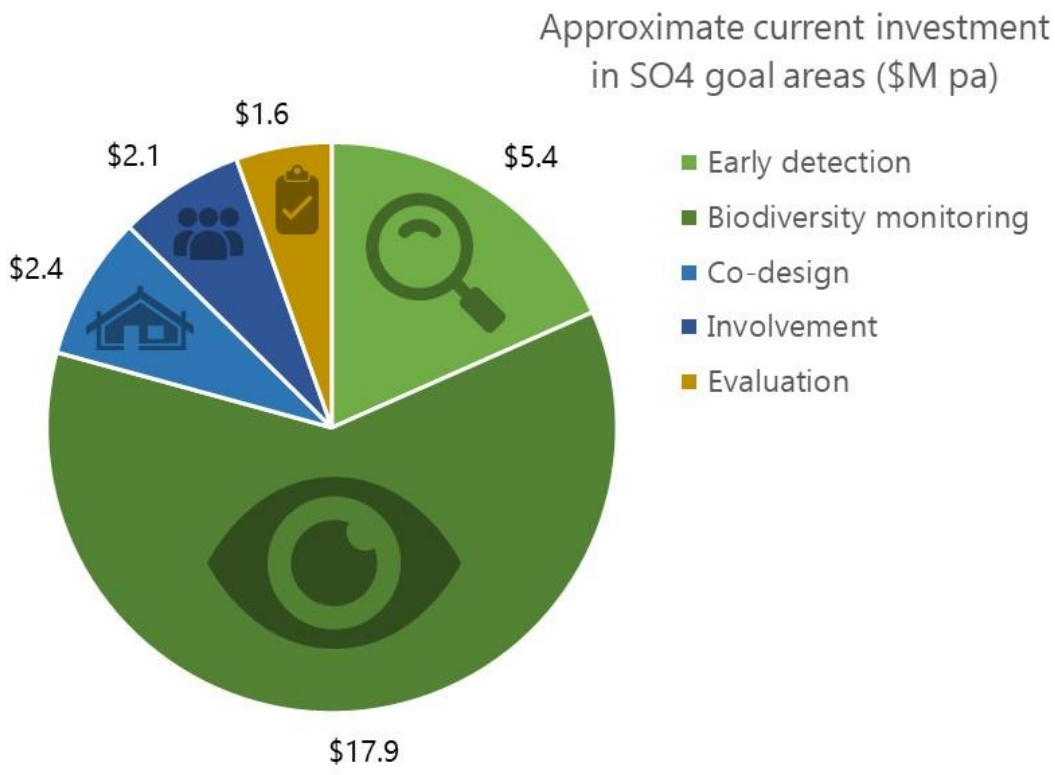
builds on this, and appeals to New Zealanders' competitive nature. Technical expertise on game development and other expertise on biosecurity challenges in that area will be required.

Modelling and surveillance programme expertise will need to be resourced to ensure we are able to appropriately evaluate the performance of our surveillance systems. Software will need to be developed to enable scenario testing, helping us to investigate alternate systems for resourcing (and funding) surveillance.

Section 3: Quantifying Cost Elements

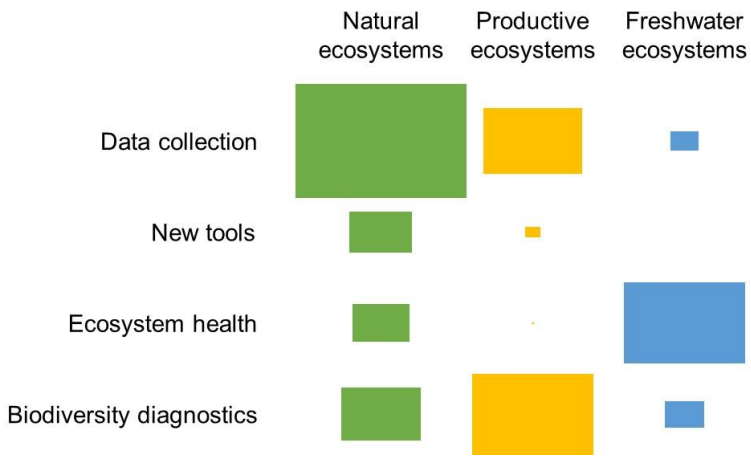
Budget details and cost narrative

We mapped current surveillance investments of $50,000 or more to each of our five goals, using the data provided to the Challenge. A total of around $30 M was identified as relating to surveillance, with biodiversity monitoring comprising almost two thirds of that. (It should be noted that this is a very coarse analysis, and there were errors noted in the data provided.)

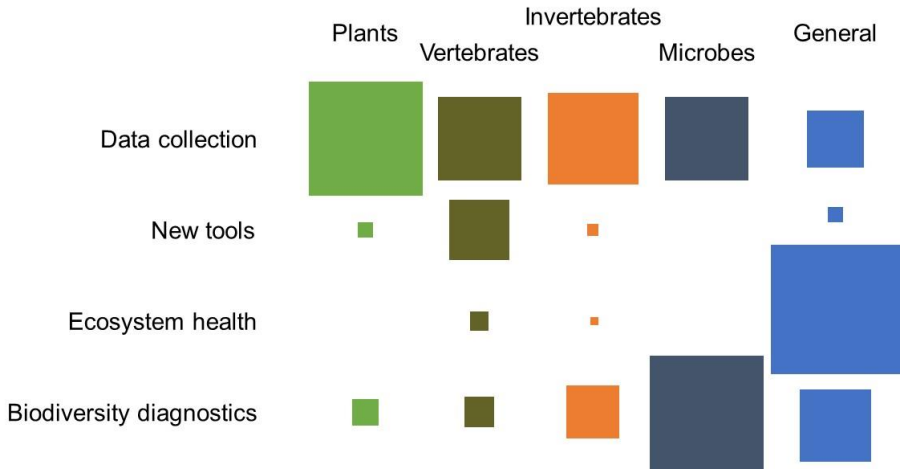


Three quarters of the current investment in early detection is in new traps and sensors, while the remaining quarter is in diagnostics.

Almost two thirds of current investment in surveillance is allocated to biodiversity monitoring. Looking more closely at that investment, almost half ($8.2 M pa) comprises operational data acquisition rather than research. A big chunk of this is DOC work in natural ecosystems. There is little or no current investment in new surveillance tools for productive or freshwater ecosystems, and ecosystem health in productive systems.



Categorising the Biodiversity Monitoring goal investments by organism type suggests there is little current work developing new tools for surveillance for plants (weeds) or invertebrates. Tools for detecting microbes typically rely on DNA technologies which were classified under biodiversity diagnostics. Ecosystem health work tends to be general, but there may be a need for investment in monitoring plant and microbe ecosystem health.



Rather than suggest budget amounts appropriate for particular activities, we instead identify areas where the Challenge's limited funding might be used to bolster gaps or provide leadership across the portfolio of current surveillance research investment. Our recommendations for new research investment are shown in the table below. This does not directly reflect the proportions of funding needed to achieve the goals because we have taken into account other funding sources. Rather, this suggests where we see the NZBH resources being most useful for *enabling* achievement of the goals. For example, there is much current investment already in biodiversity monitoring, so a relatively small investment from NZBH might help to better coordinate these activities and develop some new tools to enhance current practices. Although there is already a reasonable amount of funding for early detection, the focus for this is heavily in productive ecosystems. We recommend investment in enabling data sharing and in early detection tools for natural ecosystems.

Research Focus	Opportunities for investment	Research Investment Priority
Early Detection	1. Surveillance and biodiversity data sharing infrastructure 2. Leveraging elements of natural ecosystems for surveillance 3. Sensors for surveillance	30%
Biodiversity Monitoring	4. Approaches to establish baseline distribution of exemplar taxa 5. Remote sensing techniques 6. Biosecurity surveillance apps	10%
Co-Design	7. Establish surveillance systems (Māori centric hubs) 8. Understand our cultural economy 9. Surveillance architecture	30%
Engagement/Involvement	10. Methods to measure community engagement and effectiveness (changes) 11. Involve communities in biosecurity surveillance	15%
Evaluation	12. Development and application of a surveillance system evaluation framework 13. Prioritisation of surveillance resources	15%

Section 4: Evaluating Success

2024 Goal Metrics

Goal: Early Detection: Our surveillance systems detect incursions early enough to allow eradication or other responses.

2020
- Workshop/hui with surveillance data owners identifies potential issues and results in a commitment to share data
- Literature review for using natural elements as surveillance tools, measurable by detection of targets

2021
- Minimum data standards agreed to; draft data access infrastructure developed
- Partner with selected suppliers or developers to develop new sensors

2022
- Data access infrastructure operational for at least 5 surveillance data sets

2023
- Proof of concept is demonstrated for a novel surveillance sensor

2024
- Successful demonstration of the value of the surveillance data access infrastructure

Goal: Biodiversity Monitoring: Our tools and approaches can accurately monitor changes in distribution and abundance of terrestrial and aquatic pests, and native flora and fauna for effective management.

2020
- Select case study taxa and identify new technologies that might be used to improve understanding of their distribution and abundance

- Social science to understand barriers to the use of surveillance apps

2021
- Develop or refine surveillance app (including trial)

2022
- Social science measures acceptability and confidence in new sensing technology

2023
- Proof of concept for new remote sensing technology

2024
- Ground-truth new maps for distribution and abundance of case study taxa

Goal: Co-design: Māori co-designed surveillance systems recognise and are informed by the cultural economy.

2020
- Engage local champions and international experts in a cultural economy think tank

2021
- Assemble spatial data that informs mapping the cultural economy across Biodiversity Management Areas
- Determine Māori centric hubs informed by hapū/iwi and select Biodiversity Management Areas for initial development

2022
- Review and develop Māori approaches and methods for surveillance
- Increase number of marae hubs

2023
- Indigenous cultural economy network improves monitoring of kauri dieback

2024
- Hapū/iwi informed by Hub engagement, identify one significant, new biosecurity or biodiversity issue

Goal: Involvement: Actively engaged NZ communities understand and support surveillance efforts that contribute to the protection of our biodiversity and well-being.

2020
- Identify those who already have an interest in this space, with a view to re-engaging and expanding their latent enthusiasm
- Compile baseline inventory of activity against which to measure changes in community engagement and effectiveness

2021
- Identify and engage champions and experts to build a community of interest
- Engage arts-science community of interest in challenge design work
- Design a participatory challenge with a community of interest for testing in one to three regions

2022
- Case site determined, regional councils on board, schools enrolled - designers engaged and working with councils/schools on challenge prototype
- Arts-museum community engaged and coordinated network events planned
- Health and wellbeing community of interest formed and parameters for integration of biodiversity with existing monitoring activities determined
- Competition/showcase initiated: i) schools 'tool' co-design design and competitive monitoring dashboard; ii) science-art challenge in representation; iii) metrics of dashboard created and health indicators co-developed

2023
- Registration begins and baseline generated
- Competition rolling and score table running

2024
- Arts-science challenge showcase across multiple locations
- Media broadcast – including TED talks, pecha kucha events
- Social media runs on board and engaged in event participation

Goal: Evaluation: We have the methodologies to evaluate the performance of surveillance systems and to prioritise allocation of resources.

2020	• Workshop to develop framework for evaluating surveillance systems SurF
2021	• SurF used to evaluate >10 surveillance systems • Modelling used to optimise resources allocated in one surveillance system or across several
2022	• SurF refined and used to evaluate >half of applicable surveillance systems
2023	• Modelling used to optimise resources allocated in one further surveillance system
2024	• SurF used to evaluate and fine-tune all applicable surveillance systems

Appendix

Summary of some existing surveillance programmes

Primary purpose is early detection: Apiculture surveillance programme, BMSB "catch it, snap it, report it" campaign, BMSB trapping trial, Chatham Islands risk site surveillance, Dutch elm disease management programme, Forest Biosecurity System, Find-A-Pest app, Fruit fly surveillance system, General surveillance, Gypsy moth surveillance trapping, High Risk Site Surveillance (HRSS), National Invasive Ant Survey (NIAS), Saltmarsh mosquito surveillance system. It is noted that many of these are not for pests/disease of the natural estate but implemented for the primary industry.

Primary purpose is biodiversity monitoring: BioBlitz, Birds New Zealand survey and atlas, DOC Tier One monitoring programme, Forest and Bird backyard bird survey, iNaturalist, Lakes 380 MBIE programme, Te Hā o Te Wai Māreparepa.

Primary purpose is pest management: Arhopalus monitoring, Cape to City predator monitoring and similar local projects around the country, Forest Health Assessment (FHA), Lake SPI, Lake snow monitoring, Myrtle Rust Reporter app, TB free, Catfish monitoring (Rotorua).

Primary purpose is proof of freedom: Animal health programme, Arbovirus surveillance, *Phytophthora ramorum* and *P. kernoviae* surveys, Transmissible spongiform encephalopathy (TSE) surveillance.

Out of scope marine surveillance activities

Primary purpose is pest management: Oyster herpes virus diagnostics.

Primary purpose is proof of freedom: Marlborough Shellfish Quality Programme, Surveillance for *Bonamia ostreae* in dredge oysters.

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