NZ's Biological Heritage National Science Challenge
– Ngā koiora tuku iho

Part One: Research Plan – overall approach

Toitū te marae a Tāne
Toitū te marae a Tangaroa
Toitū te iwi
If the world of Tāne (all living things on land) endures
If the marae of Tangaroa (the lakes, rivers and sea) endures
The people endure

1.1 10-year Research Plan

The opportunity

New Zealanders value highly our biological heritage – the natural, production, and urban environments in which we live, work, and recreate (Statistics NZ 2012). New Zealand's natural and rural landscapes underpin our sense of national identity, and many of us have deep cultural or family connections to mountains, forests, farms, rivers, or lakes (Hughey et al. 2013).

Fundamental to New Zealand's economy and well-being are the services provided by production and natural ecosystems. Our global reputation, including in tourism and commodity markets, is founded on our ability to sustain ecosystem health and function. As natural capital contributes to 13% of our per capita wealth (OECD 2013), this is more important for New Zealand than almost anywhere else. Nothing threatens this more than biosecurity failure and biodiversity loss.

New Zealand is recognised globally as a 'biodiversity hotspot', with much of our native biota not found anywhere else in the world (Myers et al. 2000). Since human contact, the native biota has been joined by a vast number of introduced species (Atkinson & Cameron 1993). Modified (or mixed) ecosystems now cover two-thirds of our landscape. Our production (agricultural, horticultural, and forestry) ecosystems rely on a few highly-valued exotic species. *All* of our ecosystems – mixed, natural, and production – are under attack from pest species, including abundant superpredators (introduced mammals, social insects, salmonids), persistent ecosystem-transforming weeds (e.g. wilding conifers), and ongoing incursions of invertebrates, weeds, pathogens and diseases (RSNZ 2014).

Put simply, New Zealanders' economic, environmental, and cultural prosperity relies heavily on our biological heritage. This Challenge aims to deliver a step change to meet the Request for Proposal objective to 'protect and manage our biodiversity, improve our biosecurity, and enhance our resilience to harmful organisms' in New Zealand's terrestrial, freshwater, and estuarine environments. Our mission (below) seeks to directly address the RfP objective.

The 'Mission'

The Mission of the ***New Zealand's Biological Heritage*** – ***Ngā koiora tuku iho*** National Science Challenge is to:

Reverse the decline of New Zealand's biological heritage,
through a national partnership to deliver a step change in research innovation,
globally-leading technologies and community and sector action.

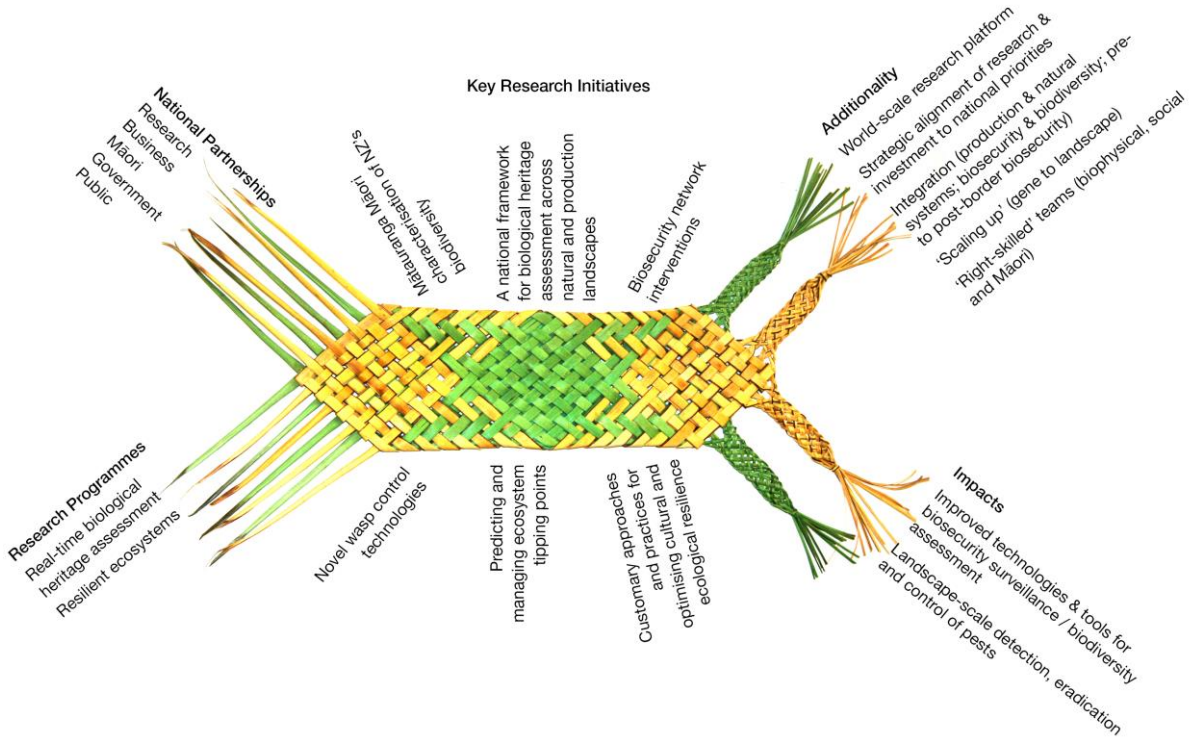
Realising the Mission

National Science Challenges go well beyond 'business as usual'. They reflect a shift in the New Zealand science system towards a more collaborative model. Accordingly, the Challenges represent both a change in culture and way of thinking, and a shift in practice and way of doing things. The *New Zealand's Biological Heritage* Challenge has been designed to support this cultural change, and is becoming a key enabler for both the *science-driven* and the *Mission-led* goals of the Challenge. We have designed the Challenge to deliver a step change in the relevance of, and value and impact from, biosecurity and biodiversity research in New Zealand by:

- Achieving synergistic benefits by integrating research across ecosystems and scales
- Deepening collaboration across research boundaries and disciplines
- Increasing the focus on and investment in 'Mission-critical' research
- 'Embedding' key stakeholders and Māori as partners within the Challenge
- Stimulating and rewarding research excellence and performance

Figure 1 provides a conceptual overview of the Challenge and how it will deliver on the Mission. In the following sections, we discuss the various elements of the Challenge shown in the figure.

Figure 1: Overview of *New Zealand's Biological Heritage* Challenge



Outcome Framework

The *Outcome Framework* (*Figure 2*) provides a high-level summary of the Challenge. Working from left to right, it describes the fundamental need for the Challenge, the Mission, and the three critical areas where science will be focused. It then summarises how the approach to the science will be different and accordingly the inputs that will be required. The large green middle column provides detail of the science itself, and the programmes of work. The blue columns describe the expected outcomes and impacts. Specific end-users are listed with the benefits they will receive. Then, aligning with the Environmental Reporting Bill and

associated reporting framework, it goes on to describe the anticipated changes to pressures on biological heritage as a result of the use of the science outputs, the flow-on effect to the state of biological heritage, and finally, the collective impact on the prosperity and well-being of New Zealanders.

Red text within the Framework comprises proposed high-level Challenge key performance indicators. These will be confirmed with the Ministry of Business, Innovation and Employment (MBIE) as their performance measurement framework (still under development) is implemented. Placing these indicators within the Framework provides context, allowing, for example, ready understanding of the flow-on effects and risks that need to be managed within a science project. The red columns and boxes provide a 'traffic light' approach to monitoring project progress, and are informed by a suite of indicators (both MBIE-common and Challenge-specific). The 'Pressure' indicators in the middle blue column are closely aligned with key delivery agencies (e.g. MPI and DOC), reflecting the 'joined up' nature of the sector and the broader efforts the Challenge supports.

The primary purpose of the Outcome Framework is to support strategic management of the Challenge through good governance. Aligned with the proposed MBIE template, it is designed to link to the MBIE common indicators (yet to be finalised), broader Challenge-specific indicators, and planning, monitoring, and reporting processes. *Section 1.10 Monitoring of performance, evaluation of impact* describes this relationship.

The Outcome Framework is expected to evolve over the 10-year Challenge period. For example, projects are likely to evolve and new ones emerge as opportunities arise, and the framework may have to respond to moving strategic focus. The key performance indicators of others are also likely to change.

A Theory of Change document will be developed and used in conjunction with the Outcome Framework. This will map in detail the theory (or 'intervention logic', to use another term) of how the approach, Programmes and Projects, and their implementation will create the change to outcomes and impacts.

Figure 2: Outcome Framework

The Challenge

Many individuals and organisations are working to protect and conserve New Zealand's natural and productive biological heritage. Despite their efforts the outlook for much of our biological heritage is poor, something most people are unaware of. As our productive and natural systems share many of the same pressures, a combined approach makes sense.

Science is central to finding the tools and approaches needed to turn this decline around. While research organisations have made progress, individually they have not been in a position to address the biggest science challenges.

Our **MISSION** is to:

Reverse the decline of New Zealand's biological heritage through a national partnership to deliver a step change in research innovation, globally leading technologies and community and sector action

The Mission is broad, complex, and inherently transdisciplinary. We are focusing on finding solutions in three **CRITICAL AREAS**. We must:

1. Have real-time information available at relevant scales to enable biodiversity and biosecurity impacts to be identified and considered – and negative impacts to be mitigated – in land and water management decisions
2. Prevent biosecurity invasions and mitigate damage to natural and production ecosystems at landscape scale
3. Increase the resilience of vulnerable ecosystems and enhance natural capital, preventing irreversible tipping points resulting from biotic invasion and biodiversity loss compounding stressors such as land-use intensification and climate change

How we will achieve it

'Business as usual' science is not working. Our **APPROACH** will break boundaries to truly:

- Form a 'national partnership', working co-innovatively to achieve the Mission.
- Collaborate across sectors, disciplines and research boundaries.
- Integrate Māori and scientific world views and approaches
- Undertake more high-risk, high-reward research
- Empower citizens to engage and act to protect New Zealand's biological heritage

INPUTS needed to make it happen:

- The full range of partners who share these common goals to join in the collaborative effort
- Alignment of existing work in the three critical areas
- Co-funding of new work

Total value of resources mobilised (direct Challenge-funded, co-funded, aligned[1]

- Talented local and international researchers from a broad range of disciplines, approaches and perspectives
- Involvement of end-users and the general public, helping do the research and making sure we produce something they will use

We will deliver **HIGH-QUALITY, WORLD-LEADING, GROUND-BREAKING SCIENCE** focusing on four large-scale mission-critical interventions, which will:

	Investment	Criteria met	Status
1. Deliver real-time, 'what is where', biological heritage information to support real-world decision-making *'Ko te whakamana pūtaiao'*			
Methodologies adopted for rapid biosecurity and biodiversity assessment and monitoring[2]	$x	✓	✓
1.1 Mātauranga characterisation of biodiversity			
1.2 Genetic characterisation of NZ's biota			
1.3 A national framework for biological heritage assessment			
2. Significantly reduce the threats posed by unwanted pests and invasive organisms across landscapes *'Whakanoa mo ngā wero me ngā whakaaro witiwiti'*			
Reduced rates of incursion/establishment and impacts of pests, diseases and weeds of significance to natural and production ecosystems[3]			
2.1 Biosecurity network interventions			
2.2 Novel wasp control technologies			
2.3 Hi-tech solutions to invasive mammal pests			
2.4 Māori solutions to biosecurity threats			
3. Enhance and restore the resilience of ecosystems to global environmental change *'He pūtaiao kaha ora tonu'*			
National and regional strategies for sustaining resilient ecosystems are reducing rates of degradation/loss of significant biodiversity in natural and production ecosystems[4]			
3.1 Predicting and managing ecosystem tipping points			
3.2 Customary approaches and practices			
3.3 Enhanced biodiversity and ecosystem services in working landscapes			
3.4 Interdependencies within and between ecosystems			

OUTPUTS

	Quality	Transfer	User support
	✓	–	✗

Expected outcomes and impacts

Short term (0–10 years+) → **Medium term** (5–10 years+) → **Long term** (10 years+)

Time frames are indicative; they will vary and be influenced by:

- Research times – the most ambitious and complex science may only be completed late in the Challenge
- Adoption and use time lags – end-users need time to adapt; building processes, capacity, and infrastructure
- Ecological response time lags – it takes a long time for a tree to grow or a lake to recover from pollution

We expect a high level of user **ADOPTION** as a wide range of end-users will benefit:

	Engaged	Using
Operational Agencies Improved priority setting, increased effectiveness and efficiency, better informed decision making & reporting		
Policy Agencies Better informed policy and evaluation, expanded range of responses		
Business Manage environmental dependency and market access risk, operate within environmental limits, improved stewardship		
Māori Wording TBC		
Researchers Improved data, models and analytical tools, better joined up science, citizen science leveraged		
Wider (e.g. general public, NGOs,) Improved information base and practical tools, more opportunities to engage, influence, and participate		

By growing knowledge and empowering action we expect an increase in **national awareness and investment**

Increasing awareness of biological heritage state, trend, issues and solutions[5]

Increasing investment in environmental protection[6]

We expect a decrease in negative **PRESSURES** on our natural and productive biological heritage to result, along with an increase in the positive factors protecting them.

No established incursions with significant economic or environmental impact, or with major impact on biosecurity[7]

50% of New Zealand's natural and production ecosystems are benefiting from management of pests, pathogens, and weeds[8]

There is a tenfold increase in the area of mainland NZ that is free of invasive mammalian predators[9]

Our biological heritage is used within environmentally sustainable limits and is resilient to adverse climatic and biosecurity events[10]

We expect these changes in pressures will reverse the decline of our natural and productive biological heritage. The **STATE** (the physical, chemical and biological characteristics) of biological heritage will have improved.

By 2025, our biological heritage trend is improving[11]

This Challenge will 'protect and manage our biodiversity, improve our biosecurity and enhance our resilience to harmful organisms'
(formal objective)

Kia mau tonu ki ngā taonga tapu o ngā mātua tūpuna – Hold fast to the treasures of the ancestors

Collectively this will have a broad **IMPACT** on the prosperity and wellbeing of New Zealanders, including:

- Economic benefits: higher value primary production; retention of market access; tourism; employment
- Cultural benefits: sustaining enjoyment and traditions associated with appreciating and using biological heritage
- Societal benefits: public goods provision (e.g. water, wild foods); public health; recreation; security from disaster

Footnotes

[1] Full definitions required
[2] Programme-specific key performance indicator
[3] Programme-specific key performance indicator
[4] Programme-specific key performance indicator
[5] Lincoln University Public Perceptions of New Zealand's Environment biennial survey
[6] Statistics New Zealand Environmental Protection Expenditure Accounts, not recently completed but is to being considered for continuation. TBC.
[7] Based on MPI Biosecurity KPIs (in draft). Use of best suite of indicators available at any point in time, in particular those relating closely to MPI biosecurity performance measures.
[8] Based on Department of Conservation, forthcoming
[9] Based on Department of Conservation, forthcoming
[10] Based on MPI medium-term Outcome 5. Use of best suite of indicators available at any point in time. In time Challenge outputs may form part of this suite.
[11] Use of best suite of indicators available at any point in time. Expected to be related to the Environmental Reporting Bill and Domain

DRAFT

A new approach

The wide-ranging submissions to the *Great New Zealand Science Project* demonstrated that New Zealanders are aware of the threats facing our biota and ecosystems, and acknowledge the importance of research in predicting, mitigating, and managing them. Recent high profile events – such as the Queensland fruit fly incursions – and national initiatives – such as Predator Free New Zealand – have only heightened New Zealanders' awareness and readiness to act.

There is a significant opportunity now to mobilise the research, business, Māori, community, and government sectors and the New Zealand public through a new, enduring partnership. This will provide a 'national platform' for authentic two-way engagement, alignment of resources and effort, and more effective technology and knowledge transfer, working *with* and *for* end-users.

The 17 Parties signing the Collaboration Agreement illustrate the very high levels of sector support for the proposed national partnership.

A step change in the management of New Zealand's biological heritage can only be achieved through an integrated '*one ecosystem*' research agenda unifying biodiversity and biosecurity research. The inclusive paradigm transfers research learnings across production and natural ecosystem boundaries, and removes barriers between pre-, at- and post-border biosecurity research.

The proposed national partnership, coupled with a high-performing, integrated research agenda, will deliver fit-for-purpose, socially acceptable, cost-effective, and well-tested solutions to address national priorities in both natural and production ecosystems.

Additionality

The Challenge will establish national-scale critical mass for biological heritage research and its application, generating new capabilities, insights, and solutions rarely possible in the current disaggregated New Zealand research system. Such an approach has the potential to be global in impact.

The Challenge Research Platform will facilitate a more comprehensive, strategically-aligned research portfolio than is currently possible, incorporating more high-risk/high-reward and high-priority research, and greater flexibility to adapt to emerging opportunities. This increases the likelihood of significant breakthroughs and step change.

The Challenge will connect currently-fragmented research areas and span traditional research boundaries – from gene to landscape scales; across ecosystem types and research disciplines – and embed a wide range of Challenge Parties (not only research organisations), Māori, and end-users in the Research Platform. This means innovations and new technologies can be rapidly (and systematically) developed, tested, deployed, and refined for optimal adoption and impact.

The Challenge will deepen international linkages to boost research impact, transfer cutting-edge approaches, and showcase New Zealand as a world-class innovator in biological heritage research.

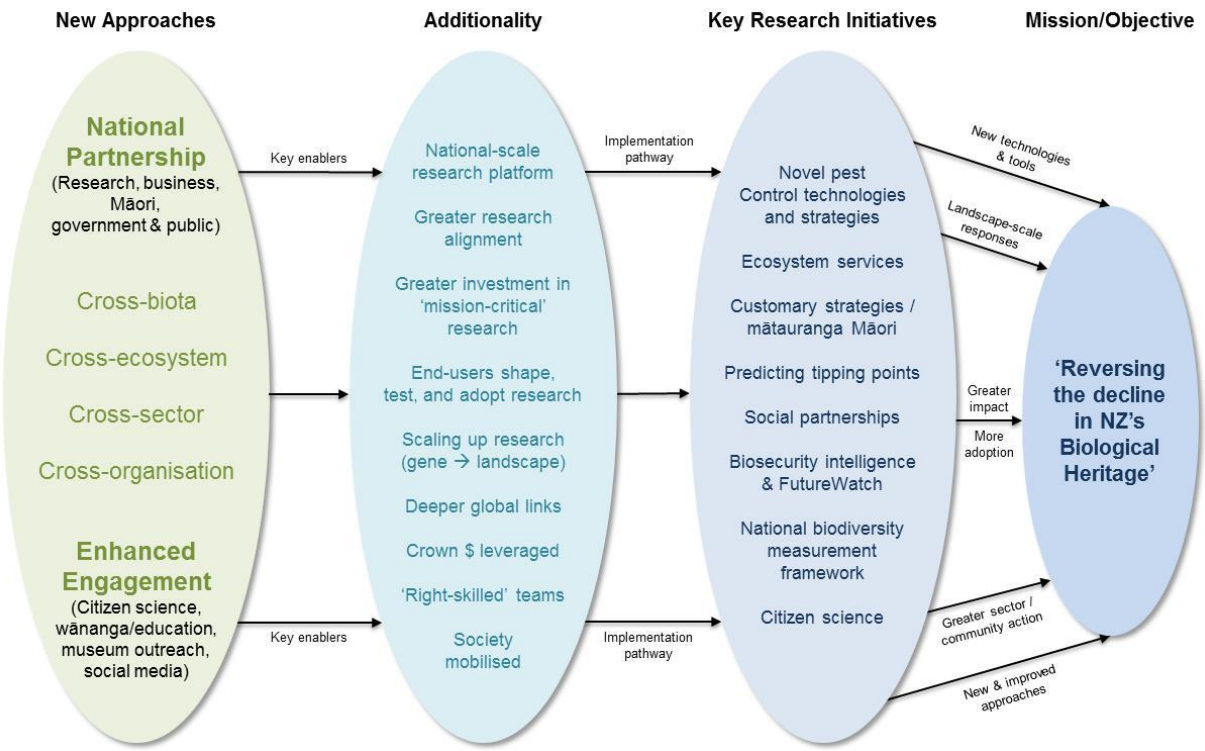
In addition, the $63.7m directly invested in this Challenge (*Figure 3*) is expected to leverage aligned research (from CRIs, universities, government departments) worth more than $200m, as well as informing and influencing relevant research and related activities across New Zealand.

Figure 3: Leveraging the Challenge Funding Envelope

The wide-reaching partnership central to this new approach will be assessed annually by the Governance Group (*Appendix 1: Governance Group – Terms of Reference*), and progressively developed throughout the 10-year Challenge period. Already, all of New Zealand's CRIs and universities, as well as a number of stakeholders (e.g. MPI, DOC) have formally committed to align research to this Challenge. A national partnership will facilitate the development, uptake, and application of key knowledge and technology platforms by a wide range of sectors and other end-users. It will also ensure better line of sight between research, policy and regulation, operational management, sector priorities and responses, and community action.

Our approach embeds Vision Mātauranga (VM) throughout the Challenge, from prioritisation and planning through to implementation of the research. The various strands of Māori-relevant research woven through the Challenge form a VM research platform in its own right (*Figure 5*). The VM platform has been developed by Māori representatives from Challenge Parties, drawing on research concepts, priorities, and feedback given by Māori scientists, managers, practitioners, kaumātua, and kaitiaki within government, research institutes, iwi and rūnanga (*Section 1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement)*. *Figure 4* provides an overview of the Challenge as a whole. It shows how the new approaches discussed earlier act as key enablers to deliver additionality, and how key initiatives within the Research Platform use this additionality to deliver benefits in support of the Challenge mission.

Figure 4: Overview of Challenge approach



Challenge Research Platform

This Challenge is broad, complex, and inherently transdisciplinary, reflecting the issues impacting natural and production systems in New Zealand. We will focus resources on critical areas, rather than attempt a comprehensive response to all of the Challenge themes and outcomes. Our proposed research will:

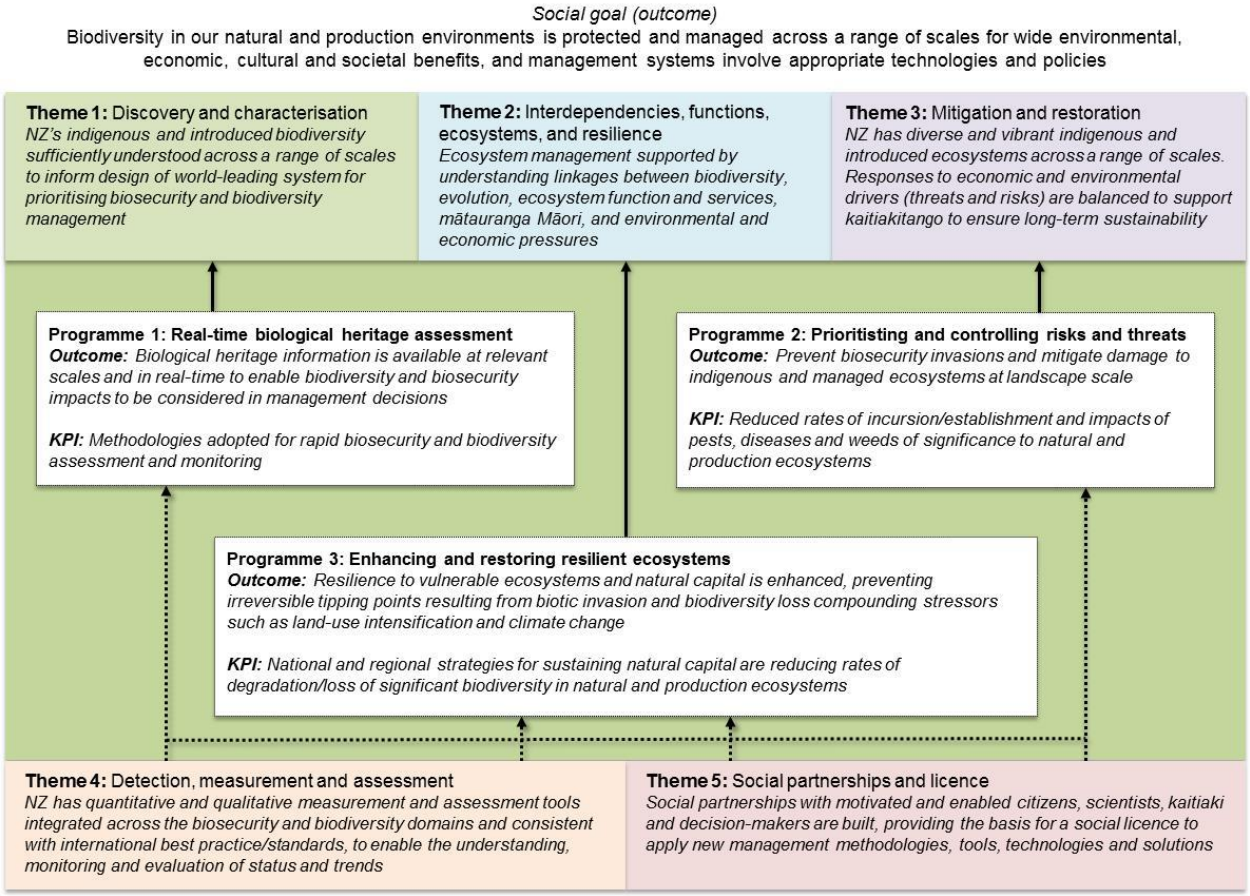
- *Deliver real-time, 'what is where', biological heritage information to support real-world decision making.* Prediction and early detection of invasions, and control of widespread, multiple pests are urgently needed because complex, diverse landscapes and multiple land-use regimes hamper cost-effective solutions. We will combine exciting new advances in genomic techniques with 'big data' approaches to overcome the currently fragmented understanding of the identity and location of priority species, both native and introduced.
- *Significantly reduce the threats posed by unwanted pests and invasive organisms across landscapes.* Collaboration between researchers working in production and natural ecosystems will provide synergistic benefits and deliver 'next-generation' technologies and tools to 'scale up' local pre- and post-border incursion and control approaches regionally and nationally, and improve accuracy, cost-effectiveness, and efficacy.
- *Build resilient ecosystems in the face of environmental and climate change.* The health of our biological heritage depends on sustaining resilient ecosystems in an ever-changing biotic, economic, and social environment. Recent international advances have shown the benefit of a quantitative analysis of ecosystems and their derived services. This Challenge will provide the underpinning research to make this a reality in New Zealand.
- *Empower citizens to engage and act to protect New Zealand's biological heritage.* Innovative engagement, governance, technology, and research approaches will broaden awareness of and social support for biosecurity and biodiversity surveillance and management approaches, and mobilise community participation and response. The Challenge will systematically integrate mātauranga Māori and kaitiakitanga in managing biodiversity and biosecurity threats. These approaches will overcome an outmoded model in which citizens are passive recipients of science.

The proposed Research Platform comprises three Programmes that directly contribute to the Challenge's Mission and the Science & Societal Goals agreed by Cabinet. The three Programmes address three core

Challenge themes, integrate the two enabling themes, and have line of sight to the Challenge Goals (*Figure* 5), as described in the Challenge RfP.

The three Programmes will introduce new research initiatives to achieve the outcomes shown in *Figure 5*, to be implemented progressively over the duration of the Challenge. The dynamic management of the research portfolio (*Section 1.4 Research portfolio and quality*) will be based on a continuous *plan–monitor–review* cycle designed to update regularly 'what remains to be done' to achieve the intended outcomes. This process will also involve active alignment of research and related activities by Challenge Parties, but funded from other sources, to expand the scope and pace of these initiatives. Indeed, the willingness of Parties to align research will represent an active check on the ongoing performance and value of specific initiatives. Challenge Parties will also align research and other activities for further development, uptake, and application of key knowledge and technology by a wide range of end-users.

Figure 5: Challenge research platform – line of sight to Challenge themes and goals



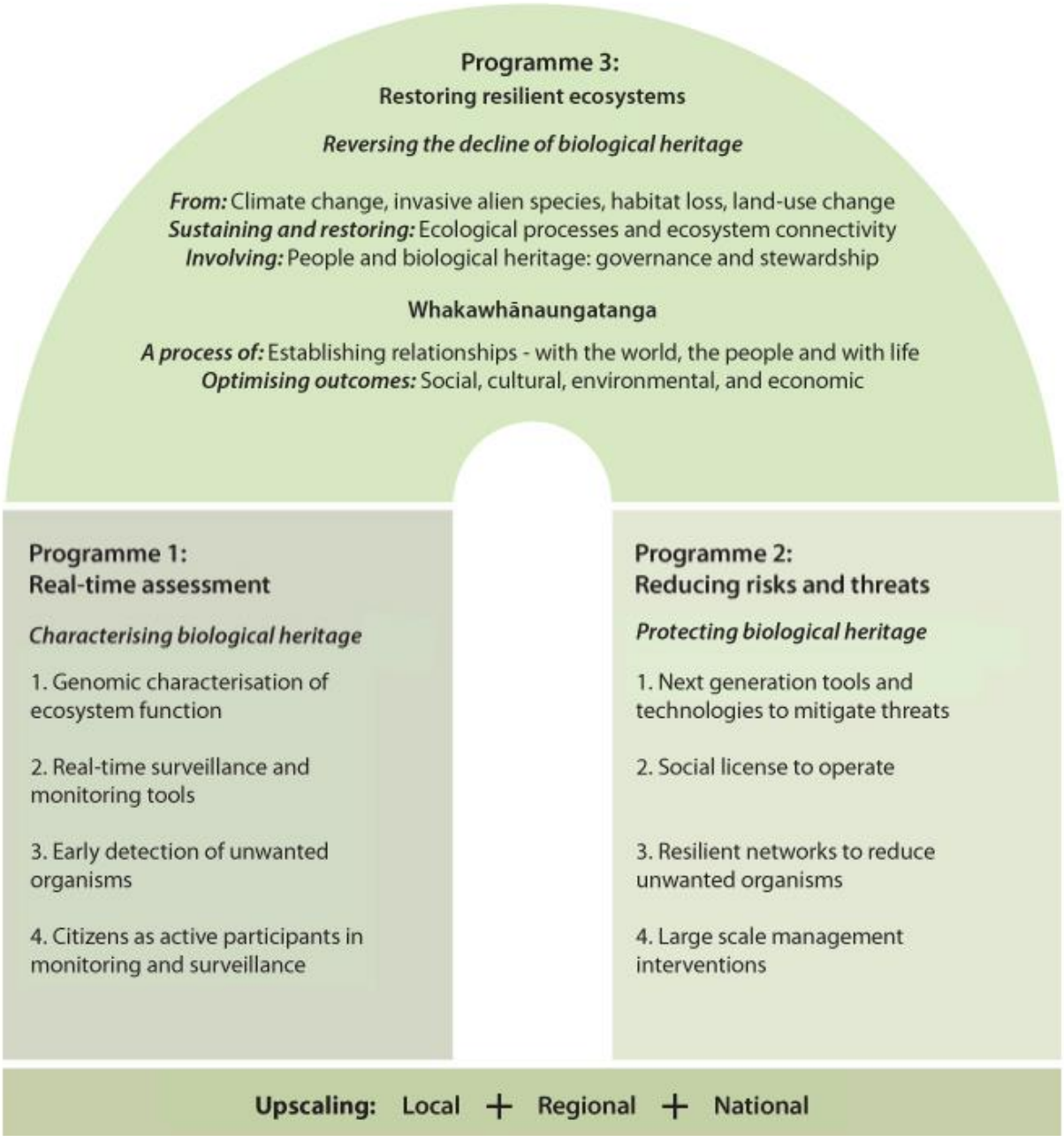
New Zealand – a resilient ecosystem

New Zealanders' economic, environmental, and cultural prosperity relies heavily on our biological heritage. Healthy ecosystems are needed to meet societal aspirations for a full range of values, from biodiversity conservation, to customary use, to intensive primary production. Improved whole-system management, based on understanding the most important social and environmental drivers influencing social-ecological systems, will enable New Zealand to sustain natural and production ecosystems, ecosystem services, and the national economy. Central to managing whole-of-system responses to change is the concept of resilience, which is defined as the capacity to absorb disturbance and maintain function.

Research on social-ecological systems is embodied in Programme 3. This Programme addresses the urgent need for New Zealand to build resilience at local, regional, and national scales, in response to global environmental changes such as climate change, biotic invasions, and land-use intensification. As such, the Programme provides the overarching framework for the *New Zealand's Biological Heritage* Challenge, because it draws on genomic approaches developed to measure biodiversity and quantify ecosystem function

in Programme 1, as well as the improved understanding of large-scale management interventions and technologies developed in Programme 2. Structuring the Challenge in this way represents a major shift towards a unified and objective approach based on tangible outcomes in terms of ecosystem function. Our resilience framework explicitly builds in the concept of whakawhānaungatanga, the process of establishing relationships with the world, with people, and with life (*Figure 6*). Additionalities obtained by combining the technological, social, and biophysical advances developed in Programmes 1 and 2 into the resilience framework in Programme 3 will enable us to simultaneously deliver social, cultural, environmental, and economic outcomes for New Zealand.

Figure 6: Overarching resilience framework



Each Programme will include a suite of projects, selected following consultation with end-users (via the End-user Advisory Panel) and Māori (via the Kāhui Māori) to provide knowledge and technologies to address the most important end-user priorities *(*

Table 1*)*. Projects in the first five years will focus on specific objectives to achieve a step change in obtaining real-time biodiversity information, reduce threats from multiple invasive species across landscapes, and

sustain valued, resilient ecosystems. The potential of citizen science for improved biological heritage outcomes will be embedded in all relevant projects. Specific Vision Mātauranga Projects have been developed within the broader focus of the research Programmes. Research Projects will be initiated progressively over the first two years of the Challenge. In the first instance, lead-off Projects will focus on rapidly meeting Challenge goals for innovative solutions applied nationally to enhance the production and natural sectors. Research aligned by Challenge Parties to these Projects, subject to initial progress and achievements, will enable scaling-up of Projects over time. In this way, our ambitious research agenda will progressively integrate staff, infrastructure, and other resources from the diverse range of Challenge Parties involved.

Table 1: Structure of Research Programmes showing fit with end-user priorities

Research Programmes *Science goal: to support evidence-based decisions on biodiversity and biosecurity management, for protecting and enhancing natural and production environments and the provision of ecosystem services, by resolving interactions and interdependencies of biodiversity and the impacts of invasive organisms*			
Key end-users: Beef + Lamb New Zealand DairyNZ Department of Conservation Fonterra Forest Owners Association Kiwifruit Vine Health Ministry for Primary Industries Ministry for the Environment Predator Free New Zealand QEII National Trust Regional councils Sanctuaries of NZ Sustainable Business Council TBfree New Zealand	**1. Real-time biological heritage assessment**	**2. Reducing risks and threats across landscapes**	**3. Enhancing and restoring resilient ecosystems**
	Biodiversity and biosecurity reporting Improved prediction, detection, surveillance and measurement technologies Reconnecting New Zealanders to the environment	New and improved technologies and tools for control and eradication of high-priority pests (plant, weed, insects, other animals and diseases) Improved threat detection, surveillance and measurement technologies Prioritisation methodologies and frameworks for threat management intervention	Integrating native biodiversity into production landscapes Delivering a comprehensive range of ecosystem services from terrestrial and freshwater ecosystems Determining how disturbances alter interdependencies and linkages among ecosystems Partnership with communities, including Māori, in order to increase community awareness to achieve improved environmental outcomes Māori biocultural approaches and economic development

More detail on current Projects is provided in *Part Two: Research Plan – detailed description*.

Supplementary information to support this Challenge is contained in *Appendices 1–8*.

Research organisations

Our Research Plan involves researchers from all of New Zealand's seven CRIs and eight universities, reflecting the wide range of skills and expertise that can be brought together in a new way to address the mission for this Challenge. The Department of Conservation (DOC) and the Ministry for Primary Industries (MPI) will also contribute scientific resources. Many of these researchers are also engaged in supra-institutional collaborations (e.g. Centre for Complex Systems and Networks, Bio-Protection Research Centre, and the Better Border Biosecurity consortium). The Challenge has therefore accessed every important biodiversity and biosecurity research group, associated postgraduate students, and relevant research infrastructure in New Zealand. This includes laboratories, demonstration sites, world-class molecular ecology, diagnostic, bio-containment, and remote sensing facilities and capability.

New Zealand's biodiversity and biosecurity researchers are among the most productive and highest quality in the world. For example, from 1996 to 2012, New Zealand environmental research was the sixth most cited per publication globally, and within ecology, evolution, behaviour, and systematics was second most cited (SCImago, Country Reports 1996–2012). New Zealand environmental researchers are well integrated into international research, via positions in international organisations, memberships of high-impact workshops, involvement in international collaborative programmes, and informal networks. New collaborations secured by the Challenge within this already productive workforce should quickly generate new insights and facilitate more effective, landscape-scale solutions for managing natural and production ecosystems.

The development of this plan reflects extensive and open engagement across the research community, to highlight key research options to address Challenge goals and theme outcomes. This process is fostering a stronger awareness across the community of the diverse and complementary skills and interests relevant to the Challenge. The process of building new collaborations, central to the success of this Challenge, has already made considerable progress.

End-users

Our plan reflects the priorities of a wide range of end-users (*Table 1*), identified both through direct consultation and through extensive end-user networks of the research organisations involved. End-users are also likely to invest alongside the Challenge Programmes to facilitate more effective development, uptake and application of solutions to national priorities and improve outcomes in both natural and production ecosystems (highlighted in the *Outcome Framework* in *Figure* 2).

The Government 'Natural Resources Sector' group has played a key role in developing our proposal, particularly through MPI and DOC. Similarly, representatives of agriculture, horticulture, and forestry industry groups (e.g. OSPRI New Zealand, Forest Owners Association (FOA), Fonterra, Kiwifruit Vine Health, Horticulture™ New Zealand), regional councils, and sectoral initiatives (e.g. Predator Free New Zealand) have played an active role in shaping the Research Platform *(Section 3.3 Investment strategy and prioritisation* and *Section 3.8 Advisory groups*).

This engagement with diverse end-users, and the ongoing involvement of the End-user Advisory Panel for the Challenge, are creating common interests in managing and enhancing our biological heritage that until now, have been considered only in a fragmented way.

1.2 The research landscape

Our platform for stepping up

As noted in *Section 1.1 10-year Research Plan*, this Challenge will implement a fundamental shift in research thinking, alignment, and collaboration. The proposed research will require new ideas to flourish and work at much larger scales than is currently the case. New partnerships will also be needed (such as those to link biodiversity and biosecurity across production and natural ecosystems; integrate all phases of border biosecurity research; embed social, economic and Māori researchers in teams; and bring in transdisciplinary skill sets such as informatics and engineering). These new partnerships are occurring through the process of bringing together nationally-leading researchers in CRIs and universities to formulate the Research Programme and develop Projects. Some existing partnerships have been developed in different ways or strengthened, for example through the engagement of biodiversity and biosecurity end-users (including business, government, Māori, and community groups) in setting the research priorities for this Challenge.

The research landscape outlined below highlights key features and strengths to underpin the Challenge. Given the wide range of organisations involved, there is much more potentially relevant capability and investment than can be represented in detail here. Nevertheless, further negotiation with these organisations, as Challenge Projects solidify and are implemented, and co-funding is confirmed, is ensuring access to this wider capability. Our understanding of the research landscape is being enhanced by collation and analysis of current responses from our 17 research partners to formal requests for information on potential aligned research programmes as part of the development of collaboration agreements.

Fit with existing research

CRI core funding – all seven CRIs have aligned research to the Challenge, indicatively valued (as per *Request for Proposal*) at $14.87m p.a. for the first 10 years (*Table 2*).

Table 2: CRI core-funding ($ million p.a.) potentially aligned to the Challenge

Organisation	Theme					
	Discovery and characterisation	Interdependencies, functions, ecosystems and resilience	Mitigation and restoration	Detection, measurement and assessment	Social partnerships and licence	Total
Landcare Research	1.352	1.700	2.327	0.567	0.540	**6.486**
Plant & Food Research	0.334	1.450	1.147	0.761	–	**3.692**
AgResearch	0.878	0.843	0.204	0.051	–	**1.976**
Scion	0.582	0.169	0.284	–	–	**1.035**
GNS	0.400	0.100	–	–	–	**0.500**
NIWA	0.030	0.311	0.470	–	0.070	**0.881**
ESR	0.300	–	–	–	–	**0.300**
TOTAL	**3.876**	**4.573**	**4.432**	**1.379**	**0.610**	**14.870**

This co-funding is currently weighted towards Themes 1–3 (core themes), which can be aligned to the three new Research Programmes proposed (*Figure 5*). In particular, it includes a wide range of predator control and biodiversity management research carried out by Landcare Research, and all CRI investment in the *Better Border Biosecurity* (B3) collaboration.

MBIE contestable contracts – funding from MBIE contestable contracts, totalling $3.73m p.a., will be mapped into the Challenge as current contracts terminate, as shown in *Table 3*.

Table 3: Contestable MBIE research programmes mapped to the Challenge

Contract	Short title	End	Holder	$m p.a.
C10X1009	Innovative tools for bovine TB	September 2015	AgResearch	**0.67**
C09X1002	Restoring wetland ecosystem functioning	September 2016	Landcare Research	**0.53**
C09X0909	Invasive mammal impacts on biodiversity	September 2015	Landcare Research	**0.35**
C09X1007	Strategic technologies for managing pests	September 2015	Landcare Research	**0.71**
LINX0902	Pest control for the 21st century	September 2015	Lincoln University	**0.79**
LINX1003	Completing the arsenal for possum and TB control	September 2015	Lincoln University	**0.68**
TOTAL				**3.73**

The investment strategy and prioritisation for this Challenge (set out in *Section 3.3 Investment strategy and prioritisation*) has implications for the research teams currently involved in the concluding MBIE contracts. Mapping funding from these terminating MBIE contracts directly into the Challenge Envelope will at least guarantee that such funding will continue to be applied to research relevant to this Challenge. Furthermore, many of the researchers currently funded through these concluding MBIE contracts are directly involved in the Challenge Programmes set out in *Part Two: Research Plan – detailed description*.

University research – all eight universities have aligned research to the Challenge. Two multi-institute research collaborations hosted by universities relevant to this Challenge are the Bio-Protection Research Centre (hosted by Lincoln University) and Te Pūnaha Matatini Centre for Complex Systems and Networks (hosted by the University of Auckland). All eight universities have designated research centres supporting

Challenge objectives (including those listed in ***Error! Reference source not found.***), involving at least 200 cademic researchers and postdocs, and 300 PhDs, with a research focus on biodiversity or biosecurity. These research centres represent substantial capability for biodiversity and biosecurity, management, economics, conservation and restoration research in our three Research Programmes. The university contributions are funded from sources such as TEC (PBRF, CoRE), RSNZ (Marsden grants), contestable funding, and other grants. In responding to our request to indicate research alignment, the universities identified a large number of potentially aligned programmes and projects; a subset of some of the most relevant are listed below (*Table 4*).

Marsden Fund – grants totalling $8.6m were awarded for biodiversity and biosecurity research to Challenge Parties in 2011–2013 inclusive. Projects closely aligned to the Programmes proposed here include studies of wasp invasion, infectious disease transmission, toxin production in lakes, ecological climate change effects, and Māori conservation.

Table 4: University Research Centres associated with this Challenge

University	Centre	Examples of potential aligned research programmes/projects
University of Auckland	Centre for Biodiversity and Biosecurity (CBB)	New statistical methods for estimating abundance of wild animal populations CatchIT!: storing and analysing data from community pest control monitoring
AUT University	Institute for Applied Ecology New Zealand (AENZ)	Insular ecosystem restoration
University of Canterbury	Centre for Integrative Ecology Waterways Centre for Freshwater Management	Biodiversity and functional responses to environmental change; assessing ecosystem function after large-scale predator control
Lincoln University	Isaac Centre for Nature Conservation (ICNC) Centre for Wildlife Management and Conservation (CWMC)	People and pīngao Dairying and biodiversity
Massey University	Ecological Economics Research New Zealand (EERNZ) Infectious Diseases Research Centre	Improving sensing technology Molecular host–pathogen interactions of aerial *Phytophthora*
University of Otago	Centre for Sustainability: Agriculture, Food, Energy, Environment (CSAFE) Webster Centre for Infectious Diseases	Selective (next-generation) insecticides Resilience and communities
Victoria University of Wellington	Centre for Biodiversity and Restoration Ecology	Super-lure pest control technology
University of Waikato	Environmental Research Institute Centre for Biodiversity and Ecology Research	Lake Ecosystem Restoration New Zealand (LERNZ) Ngā tohu o te taiao: Sustaining and enhancing wai Māori and mahinga kai (UOWX1304)

Alignment to Research Programmes

The three Research Programmes build on existing research (as outlined earlier):

Programme 1: Real-time biological heritage assessment – this programme is underpinned by long-standing CRI, university, and museum biosystematics research. It will build on this by incorporating research underway on genetic characterisation, rapid biodiversity assessment, and biosecurity diagnostics, detection, and surveillance for new organisms. In turn, the new techniques, sampling strategies, and assessment frameworks developed will greatly improve the utility of nationally significant collections, current biodiversity assessment methodologies, and existing programmes seeking to provide early warning of pest and disease outbreaks or detection of new incursions, as well as characterise New Zealand's native biota.

Programme 2: Reducing risks and threats across landscapes – this programme is underpinned by over half of the CRI core funding aligned to this Challenge, and most of the MBIE contestable contracts mapped into the Challenge. This includes current CRI biosecurity research on border and regional surveillance, invasion pathways, invasive impacts, and techniques for effective control or mitigation. Invasive species research across previously separate research groups will be integrated, so that research in this Programme benefits from reciprocal insights into natural or production ecosystems and across pre-, at-, and post-border

biosecurity research. Programmes currently focused on a subset of organisms and ecosystems will assist with development of more effective surveillance, detection, and control approaches.

Programme 3: Enhancing and restoring resilient ecosystems – this Programme is underpinned by CRI research on specific aspects of ecosystems (e.g. invasive species) or environmental drivers (e.g. climate change and land-use change). The Programme will integrate this into whole-of-ecosystem approaches (using empirical data and conceptual models generated by ongoing aligned research) to understand gradual change in ecosystems, social drivers of ecosystem change, potential ecosystem thresholds ('tipping points'), and critical linkages among ecosystems and connectivity across landscapes, in order to build resilience.

End-user co-funding

We will develop end-user co-funding for the proposed Research Programmes, beyond those agencies that have signed the Collaboration Agreement. While it is too early to confirm specific funding sources and amounts at the Project level, Challenge Parties are confident they can secure significant co-funding from end-users as Projects develop through to the contracting stage.

Natural ecosystems – end-user co-funding from regional councils, community groups, DOC, and business already contributes significantly to research aligned and related to the Challenge. For example, in the broad areas of biodiversity management and protection, Landcare Research raises a minimum of $0.50 for every $1 of core funding invested. Programmes directly aligned to stakeholder issues raise more. For example, the Landcare Research *Restoring wetland ecosystem functioning* programme (collaborative with NIWA and the University of Waikato) averages $2 per $1 MBIE dollar invested. Similarly, we aim to secure co-funding administered by central and regional government to support relevant research (e.g. Sustainable Farming Fund, Primary Growth Partnerships, Envirolink), as well as explore opportunities for philanthropic funding. For example, we are in discussion with the recently announced 'Zero Invasive Predators' (ZIP) initiative, funded by the NEXT Foundation to explore how it can be directly aligned to, and complement, the goals of Programme 2.

Production ecosystems – primary industry groups (e.g. DairyNZ, Beef + Lamb New Zealand, Kiwifruit Vine Health, Forest Owners Association, Fonterra, OSPRI New Zealand) continue to expand their investment in research, technology development, and other activities related to the Challenge Mission. Our Challenge is well-timed to align to the new 'Government Industry Agreement' (GIA) processes to support biosecurity preparedness and response. As this process will include joint decision making and cost sharing, primary industry groups are likely to require new research and technology capabilities to underpin their investment in agreed priority areas of (1) intelligence, information, and risk identification, (2) import health standards, and (3) border/system performance. Such new investment will build on substantial direct investment by industry groups to develop and improve pest management systems that meet increasingly tough regulatory and market demands. We expect that industry groups seeking to build new capabilities to support their obligations under GIAs will engage directly with Challenge Parties.

Linkages to international research

We understand the importance for this Challenge of (1) working in an international context, (2) maintaining international standards of excellence, and (3) having an active programme of international linkages and advice. Most Challenge researchers already engage in numerous global collaborations, ranging from investigator-to-investigator interactions, to formal agency involvement in international consortia. Many Challenge researchers have positions in international organisations, edit international journals, or are invited scholars at overseas institutions. While these interactions will continue, we will also strengthen international engagement for this Challenge through three key areas:

Phase-change workshops – these will be based on the highly successful *National Center for Ecological Analysis and Synthesis* (NCEAS) workshops. Groups of New Zealand and international researchers will assemble to work for 1–2 weeks on topics identified by the Challenge as key gaps. They will have two products: (1) high-impact, original papers advancing the field; (2) recommendations for advancing Challenge projects.

Challenge fellowships – Programme budgets will include funding for travel fellowships to bring in international visitors or to refresh research effort by sending New Zealanders to international centres of excellence.

Linkages with international consortia – we will reinforce linkages with key international programmes, including:

- **Australia** – Invasive Animals Cooperative Research Centre, University of New England, School of Biological Sciences, University of Sydney; Border Rivers-Gwydir Catchment Management Authority; Plant Biosecurity Cooperative Research Centre; CSIRO Sustainable Agriculture and Biosecurity Flagships
- **China** – Chinese Academy of Sciences (Nanjing Institute of Geography and Limnology, Institute of Hydrobiology, Jinan University and Institute of Zoology) and China Agricultural University
- **European Union** – Centre National de la Recherche Scientifique (France); FunDivEUROPE (France); German Centre for Integrative Biodiversity Research (Germany); Centre for Biological Control (Sweden); Bioforsk – Norwegian Institute for Agricultural and Environmental Research (Norway); Imperial College, London, Grand Challenges in Ecosystems and the Environment (UK)
- **United States** – United States Department of Agriculture (USDA)
- **South America** – Southern Temperate Ecosystem Research Network (Chile–Argentina); Instituto de Ecología y Biodiversidad, Chile
- **Multinational** – The International Union of Forest Research Organization's 'Task Force on Biodiversity and Ecosystem Services' (Canada, US, Europe, Japan, China); Intergovernmental Panel on Biodiversity & Ecosystem Services (IPBES); (IUCN members)

During the contracting and review phases, existing international linkages will be reviewed across all programmes, with a view to building on these and identifying any new collaborations that would help the Challenge achieve its goals (e.g. the International Council for Science's 'Future Earth') and promote the Challenge as a globally leading national biological heritage research consortium, forging international partnerships in its own right, and attracting enhanced international interest in new collaborations. We envisage agreements to share findings, interchange personnel including PhD candidates, collaborate on research topics, and to collectively promote our research and influence international policy development.

Fit with sector and research strategies

The research outlined for this Challenge is well aligned with *Tiakina Aotearoa Protect New Zealand: the Biosecurity Strategy for New Zealand* (Biosecurity Council 2003), *A Biosecurity Science Strategy for New Zealand: Mahere Rautaki Pūtaiao Whakamaru* (MAF Biosecurity 2007), the *Strategic Roadmap for Biodiversity and Biosecurity research for Regional Councils and Unitary Authorities* (2015) and MPI's (2014–2019) and DOC's (2014–2018) *Statements of Intent*. Biosecurity is the highest priority for the Minister for Primary Industries, the number one issue for New Zealand primary sector business leaders (KPMG Agribusiness Agenda 2014), and is highlighted in many industry strategies. Biosecurity outcomes are embedded in the Statements of Core Purpose of most CRIs.

The non-statutory New Zealand Biodiversity Strategy (DOC & MfE 2000) provides strategic guidance for protecting, managing, and sustainably using native and introduced biodiversity. Many of the strategy themes – biodiversity on land, freshwater biodiversity, biosecurity and biodiversity, community participation and awareness – remain strongly relevant to the present Challenge. The goals acknowledge Māori as partners in protection of indigenous biodiversity and the importance of enhancing community involvement and support for biodiversity. A review of the Strategy (Green & Clarkson 2005) highlighted the need for a wider and more inclusive approach, involving the whole country, if the visionary goals were to be achieved. The Environmental Protection Authority, established in 2012, seeks to protect people and the environment and controls importation of new organisms and manages the decision making process around the Resource Management Act.

The present Challenge seeks to deliver the step changes and up-scaling to provide the science needed to meet the goals of the Strategy.

The Challenge will also support other high-priority national, regional and sector strategies, including:

- The *Business Growth Agenda* (Natural Resources) (2011)
- The *Resource Management Reforms* (MfE 2013), which establish more stringent environmental thresholds and limits for environmental protection
- The *Water Reforms* (MfE 2013), which establish quality and allocation limits for fresh water
- *Science Counts!* – DOC's Strategic Science and Research Priorities 2011–2016
- The *Regional Council Research, Science & Technology Strategy* (Regional Council Science Advisory Group 2011)
- The *New Zealand Forest Owners Association Forest Biosecurity Strategy* (2011) and Science and Innovation Plan (2012)
- A variety of agricultural sector strategies (e.g. Fonterra Sustainability and Environmental Policy; DairyNZ Strategy for Sustainable Dairy Farming 2013–2020; Beef + Lamb's Sustainable Land Management Policy; Horticulture Industry Strategy 'Growing a New Future'; Kiwifruit Vine Health Biosecurity Strategy (2014); FAR Research and Extension Strategy and Portfolio; National Bovine Tuberculosis Pest Management Plan (2013))

This Challenge supports the emerging national priority for trustworthy State of Environment reporting and associated Natural Capital Assessments. New Zealand is obliged to report regularly on its environmental performance to the OECD and the UN Environment Programme. The Challenge will help New Zealand meet its global obligations, including assessments of national progress towards the Aichi Biodiversity Targets of the *Convention on Biological Diversity*, and regional and global assessments for the *Intergovernmental Platform on Biodiversity & Ecosystem Services* (IPBES).

Linkages to other Challenges

This Challenge has important links to four other National Science Challenges:

Our Land and Water aims to ensure that sustainable primary production systems are delivering improved land and water quality and accelerating the enhancement of export value. There are opportunities for aligned or even collaborative research with our Research Programme 3 – *Enhancing and restoring resilient ecosystems* (e.g. research on stressed ecosystems approaching tipping points and research on nutrient-loaded lakes and over-exploited production landscapes are envisaged as potential targets, as is biodiversity management in relation to ecosystem services, and interdependencies among terrestrial and freshwater ecosystems. We also propose to share back-office support with this Challenge (*Section 3.7 Management arrangements).*

Deep South will provide *New Zealand's Biological Heritage* with enhanced climate projections originating from a New Zealand-led Earth Systems Model that includes improved representations of *Deep South* influences on regional climate. These improved climate projections will contribute to more accurate understanding of potential impacts and implications of climate change for New Zealand ecosystems, species, and habitats.

Science for Technological Innovation will be approached to provide expertise and assistance to our real-time biological heritage assessment, to accelerate developments of new technologies (e.g. high-resolution remote sensing and sensor-nets) for biosecurity surveillance and biodiversity assessment. Many promising technologies are emerging with the potential to revolutionise biodiversity detection, spatial extrapolation, and forecasting.

Sustainable Seas: marine ecosystems are not within the scope of this Challenge – they are included in the *Sustainable Seas* Challenge, which has an objective to enhance utilisation of marine resources within environmental/biological constraints. We will continue to liaise with *Sustainable Seas* on the boundaries of research efforts in the coastal zone, particularly estuarine systems, the interface between riverine and riparian systems, and the need to ensure attenuation of land-based nutrients that impact on biosecurity and opportunities such as aquaculture.

The *Science in Society* project provides opportunities to link with this Challenge's Projects to engage and support citizens, and with its outreach, communication, and education activities *(Section 1.9 Related activities – public outreach, communication, and education activities*).

To ensure these linkages maximise opportunities to achieve Challenge goals, we will support regular meetings of Directors, Programme Leaders, and expertise in science communication to explore collaborative and data-sharing options.

1.3 Research team and skills

Composition of research team

As noted above (*Section 1.2 The research landscape*), this Challenge represents virtually the entire New Zealand biological heritage scientific workforce. We have advanced to appoint three Programme Leaders (*Appendix 2: Governance and Management Positions*), based largely on the researchers' capability and leadership in the relevant areas. Governance Group and programme leadership will be reviewed annually to ensure that Challenge goals are being achieved. An Interim Director, Professor Bruce Clarkson (University of Waikato) is currently leading the Challenge while we are advertising for a permanent Director. Professor Clarkson brings considerable end-user and research leadership experience from both university and CRI appointments, and over the past 8 months has worked to establish the Challenge profile and processes with end-user and research communities, and to build the best teams for each Programme as research priorities are refined.

International linkages

As noted in *Section 1.2 Linkages to international research* above, the Research Team has extensive international networks, as illustrated by international co-authorship of research publications, editorial roles on key international journals, and membership/participation in international fora relevant to this Challenge. In addition, teams involved in the *Biological Heritage* Challenge have formal links to counterpart groups in other countries. For example, the *Better Border Biosecurity* research team has formal links to the Australian Plant Biosecurity CRC, through Plant & Food Research and Lincoln University, and Landcare Research has formal links to the Invasive Animals CRC.

Our proposal assumes ongoing interactions among New Zealand researchers and international colleagues. Programme teams will actively identify opportunities to link our research to relevant global programmes, thereby enhancing the overall scope and depth of the research effort underpinning the Challenge mission. The management of Challenge Programmes will include specific funding to maintain and enhance connections with relevant international researchers.

Skills development

This Challenge will improve research skills and increase capability by training postgraduate researchers and supporting early-career scientists who are essential to keep the Programme fresh, particularly in areas dependent on new skills and emerging techniques (e.g. social science, economics, modelling, and informatics). The Challenge Programmes will enhance scientific expertise across biodiversity and biosecurity practitioners, strengthen science capability, and create long-term partnerships with industry.

We will establish a pan-university postgraduate programme to support PhD and MSc candidates and projects aligned directly with Challenge Programmes. This will include targeting for Māori students. These young researchers will be co-supervised and mentored by scientists from a variety of agencies and disciplines, promoting collaboration among Challenge Parties. We will also provide a supportive environment for the development of talented early-career scientists, including support for postdoctoral researchers in cross-institutional collaborations, and for mentoring by experienced researchers. We will also establish links with postgraduate programmes across all university Parties to enhance the expertise of biodiversity and biosecurity practitioners. Already several of our university partners have indicated their intention to align some of their PhD scholarships and/or provide matching scholarship funding to Challenge projects.

Infrastructure

Through the Challenge Parties, all required infrastructures will be available, including:

- Nationally Significant Databases and Collections (Landcare Research)
- National laboratories/containment facilities, e.g. pathogen and invertebrate containment facilities (Lincoln University, Landcare Research, Plant & Food Research), toxicology laboratory (Landcare Research), laboratory and field containment for small (Landcare Research) and large animals (AgResearch), plant genetics containment (AgResearch, Plant & Food Research)
- The Margot Forde Germplasm Centre (AgResearch)
- Molecular genomic laboratories (University of Auckland, Plant & Food Research, University of Otago)
- Numerous experimental field sites (large- and small-scale), including those run by a number of Challenge Parties as well as end-users
- Supercomputing facilities, e.g. NeSI (consortium housed at the University of Auckland)

Detailed arrangements enabling access to such infrastructure will be negotiated in subcontracts between the Challenge Contractor and individual Challenge Parties. We expect these arrangements will often reference related (co-funded) research using such infrastructure. We do not anticipate using Challenge Funding to acquire new infrastructure for the purposes of this Challenge. Rather, such infrastructure acquisitions, as well as investments to maintain/replace existing infrastructure, will remain within the authority of individual Challenge Parties. Likewise, CAPEX requirements for co-funded research will be met by the relevant Challenge Party. However, it is likely that Challenge Research Projects will be used to leverage new infrastructure among the parties involved.

Collaboration

This Challenge is achieving an unprecedented level of research collaboration (as illustrated in *Part Two: Research Plan – detailed description*), across currently dispersed research teams, and including researchers from key operational agencies (e.g. DOC, MPI, and OSPRI New Zealand) as well as specialists in research-related activities, such as science communication, knowledge transfer, and data management.

The extensive incorporation of aligned research to support Challenge outcomes and an ongoing strategic management focus on 'what remains to be done' (*Section 1.4 Research portfolio and quality*) will generate a new intensity of collaboration between research, government, business, Māori, and the community/public. While many Challenge Parties already have deep linkages with key end-users, the level of integration and shared focus on the Challenge Mission and goals represents a step change in how the national research effort can contribute to biological heritage outcomes for New Zealand.

Formal arrangements for engaging with end-users are described in *Part Three: Business Plan*. The Challenge is developing new ways to collaborate with Māori, as discussed in *Section 1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement* and *Section 3.8 Advisory groups*.

1.4 Research portfolio and quality

Prioritisation

The process for identifying the Challenge Research Programmes and associated Research Projects included the following key elements:

- *Intervention logic* – logic for defining a structure of Research Programmes, and Research Areas within these, ensured research planning aligned to the Challenge Mission. The logic targeted the areas of focus needed to achieve the long-term outcome, to permit definition and implementation of specific research priorities.

- *Science-led inputs* – since mid-2013, there has been open dialogue among interested researchers. A cross-science system 'facilitation group' focused this dialogue, identifying a mission for the Challenge, as well as initial research opportunities.
- *Stakeholder inputs* – a wide range of stakeholders was engaged in the development of the proposal for this Challenge and have continued to be involved in the design of Challenge projects. Stakeholder priorities were identified in early 2014 and have guided definition of research priorities and development of the detailed Research Plan (*Part Two: Research Plan – detailed description*).

Strategic portfolio management

The initial prioritisation of Research Programmes as presented in this plan is enabling the Challenge to get underway, but further refinements will be made over time. We undertook a detailed planning process during the Start-up Phase, involving all Parties, the End-user Advisory Panel (EAP) and the Kāhui Māori (*Part Three: Business Plan*).

Ongoing strategic management of the Research Portfolio will involve an integrated and continuous process of annual 'planning, monitoring, and review' focused on assessing progress towards the 10-year Challenge Mission, quantifying impact, uptake, and application of the research outputs and outcomes (*Figure 7*). End-users will contribute to this monitoring and review, as will the Kāhui Māori, as without their uptake and adoption of research the Challenge mission cannot be achieved.

Quality and dynamism, as well as ongoing prioritisation, will be assessed and addressed via this strategic management approach. This continuous *plan–monitor–review* approach will ensure a focus on 'what remains to be done', and will guide resource allocation decisions throughout the 10-year Challenge.

Figure 7: Review and monitoring process for strategic management of the research portfolio

Funding for the three Challenge Programmes will be allocated to Research Projects within these. Our Programmes and Projects are, for the most part, a combination of high-risk and low-risk research objectives. As the projects outlined in the detailed Research Plan (*Part Two: Research Plan – detailed description*) cannot be sustained with resource from the Challenge Envelope alone, aligned research from Challenge Parties will be a key factor for determining the size, pace, and sequencing of these Projects. As noted in

Section 1.1 10-year Research Plan, we expect the value of aligned research to exceed $200m over the 10-year Challenge period, expanding the investment pool by 4× relative to the Challenge Envelope. A critical component of the *plan–monitor–review* cycle will therefore be the integration of aligned research from CRIs, universities, and other Challenge Parties. This will depend on the confidence Challenge Parties have that specific Challenge projects will provide value-for-money results that they can in turn apply in related research or in sector activities.

During the Start-up Phase, lead Projects will start with new Challenge Envelope funding alone, as the negotiation of aligned research and other arrangements is likely to be constrained while Challenge Parties fulfil existing commitments. From Years 2 to 5, a full portfolio of Challenge Projects will be implemented, at a pace and scale determined by the alignment of Challenge Party research. This will enable refinements to the overall Programme at the end of the Start-up Phase, based on our experience in assembling teams and engaging end-users and the public.

In Year 5, a full assessment will involve independent review of progress and achievements, additionality realised and 'fitness for purpose', integration and impact of co-funding, end-user engagement and uptake. An external panel will be engaged to carry out this review (*Section 3.8 Advisory groups*) and provide recommendations to the Governance Group regarding the focus, structure and management of the research portfolio in Years 6–10.

Quality

The Research Programmes were initially developed by three teams of 5–7 nationally-leading researchers, then subjected to review and feedback from research colleagues (including the cross-system Facilitation Group of researchers convened in 2013 to help guide the research prioritisation process), as well as end-users, and internally reviewed by the Oversight Group.

A team of four eminent senior researchers – Professor Bill Lee (Landcare Research, University of Auckland, University of Otago), Professor Stephen Goldson FNZIAR, FRSNZ, ONZM (Principal Scientist AgResearch, Lincoln University), Associate Professor David Teulon (Plant & Food Research, Director B3, Lincoln University), and Dr Matt McGlone FRSNZ (Principal Scientist, Landcare Research) – provided oversight and review of the Research Plan proposal. This was also critiqued by independent international researchers (Professors David Wardle and Lars Walker).

This revised Research Plan was developed by the Interim Director (Professor Bruce Clarkson) and Programme Leaders (Associate Professor Thomas Buckley, Professor Phil Hulme, and Dr Andrea Byrom) and then reviewed/approved by the Governance Group. The prioritisation process developed and applied by the Governance Group is set out in the Business Plan (*Section 3.3 Investment strategy and prioritisation*).

Our process for Project development has several phases to allow for realistic assessment to ensure they meet Challenge objectives. Project options were identified during consultative meetings with researchers and end-users, and then developed by Programme Leaders with a group of leading New Zealand researchers. These Projects were subsequently assessed by the Science Leadership Group (Director and Programme Leaders), assessed and prioritised by the End-user Advisory Panel (*Appendix 3: End-user Advisory Panel – Terms of Reference* and *Appendix 4 – End-user Advisory Panel Assessment Process*) and Kāhui Māori (*Appendix 2: Governance and Management Positions* and *Appendix 5: Kāhui Māori – Proposed Terms of Reference*). EAP and the Kāhui Māori reports were then considered by the Governance Group in their decision making process. The Governance Group makes the final decision about accepting Challenge Projects and has set a very high standard to ensure these are Mission-focused.

Thus far (as of April 2015) three 'lead-off' Projects have been endorsed by the Governance Group to be developed for contract, a further three are being developed following Governance Group feedback and will be resubmitted within a few months, while the remainder will go through an inclusive national workshop process to clarify critical questions and focus before being considered further.

Further refinement and quality-check of Research Projects will be carried out as the lead-off projects are implemented. Leading international researchers will work with Challenge researchers to assess project objectives, plans, and progress. Ongoing quality management and assurance will be facilitated through the strategic Portfolio management approach outlined earlier. Similarly, research productivity and quality will be monitored, relative to international benchmarks for related research. As Challenge Projects will increasingly

involve aligned research from Challenge Parties, we will also use internal quality-control mechanisms of the Parties to underpin day-to-day quality for the Challenge.

We will reinforce the referencing of Challenge research to international standards through sponsored engagement of leading international researchers, to contribute directly to Challenge projects and provide recommendations for the further development of the Challenge.

Dynamism

We plan to allocate 80% of Challenge research funding to Projects identified in the detailed Research Plan (*Part Two: Research Plan – detailed description*) through a negotiated process, based on the *plan–monitor–review* cycle outlined above, and incorporating aligned research from Challenge Parties. The remaining 20% will be retained for open, contestable funding.

Contestable funding rounds will be operated at 2-yearly intervals, starting in Year 2 of the Challenge. An invitation to submit proposals will be distributed widely, to attract proposals from a variety of applicants. These invitations will retain a 'Mission-led' focus linked to topic areas where there is a need to resolve specific problems or develop new approaches, with the primary selection criteria being the skill set and proven record in achievement and a feasible research pathway. Proposals received will be independently reviewed before funding decisions are recommended to the Governance Group by the Challenge Director.

The Challenge Director and Science Leadership Group will refine the Research Programmes over time, through the *plan–monitor–review* cycle outlined above. Given the large and comprehensive scale of the Research Programme, including a mix of risk and operational profiles, it is almost inevitable that some Research Projects will be more successful than others in making valuable contributions to Programme outcomes. It will be important to identify 'failures' early so that resources can be redirected to more promising initiatives.

The Challenge provides a critical opportunity to develop new skills and capability. Challenge research funding will include a mix of mechanisms, including PhD and postdoctoral research fellowships, for sponsoring the development and inclusion of new capability. In the first instance, progress in the new Programmes may be constrained by limited availability of some key skills (e.g. citizen science, social science, modelling). Active investment to develop such capability will be a core focus for the Challenge Director and Science Leadership Group, working closely with Challenge Parties who employ relevant staff. Over time, new capability gaps may emerge, and these will be a core issue for consideration – alongside research progress and outcomes – in the annual *plan–monitor–review* cycle.

1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement

Kia mau tonu ki ngā taonga tapu o ngā mātua tūpuna – Hold fast to the treasures of the ancestors

Treaty and Partnership – Mātauranga Māori is a strategic priority and this Challenge acknowledges its role and responsibility in supporting the implementation of mātauranga Māori by iwi, hapū, and whānau. We recognise the importance of the Vision Mātauranga (VM) policy and consider engaging with Māori in research to be a shared responsibility for both the Crown (including its agents) and Māori (as is consistent with the Treaty principles of participation and partnership – *Appendix 6: Draft principles – Te Tiriti o Waitangi/Māori engagement*). As a Crown-funded Challenge, the Treaty principles of partnership, participation, and protection are foundational, and the Challenge considers the recommendations of the Waitangi Tribunal's WAI 262 report (*Ko Aotearoa Tēnei*) in its practices (Waitangi Tribunal 2011). The Challenge accepts the importance of meaningful engagement and consultation with Māori and has accordingly drafted *Appendix 6: Draft principles – Te Tiriti o Waitangi/Māori engagement* to be confirmed by the Kāhui Māori.

Vision Mātauranga – the Kāhui Māori, with assistance from the Kaihautū and Māori Manager, will offer guidance to the Challenge, on Te Tiriti, Māori engagement, integration, participation and consultation, and research priorities for Māori. It will support Māori and Pākehā researchers with their engagement of Māori stakeholders and their reporting and implementation of results and outcomes respectively. All projects funded by the Challenge will be assessed by the Kāhui Māori. The Challenge has also appointed four Kaihautū Māori aligned to the Research Programmes (*Appendix 2: Governance and management positions*).

Their role is to develop the stand-alone VM-flagship projects and also to help integrate Vision Mātauranga Māori approaches, themes and capability into other Projects within each of the three Programmes. Another key role of the Kaihautū is to support the Kāhui Māori, Māori Manager, and Programme Leaders. The Māori Manager works with the Science Leadership Group to support the inclusion of Vision Mātauranga across the whole Challenge, and specifically supports the Kaihautū and the Kāhui Māori.

The Challenge will dedicate resources to biological heritage issues of importance to Māori and the interface between mātauranga Māori and contemporary biodiversity and biosecurity research. This includes independent VM Projects, as well as Projects that incorporate issues of importance to Māori within the research focus. The Challenge acknowledges government investment in Māori-oriented research is supported by the VM policy, which aspired to '*unlock the innovation potential of Māori knowledge, resources and people to assist New Zealanders to create a better future*'. The Challenge is also mindful of other relevant policies and documents, including The Māori Education Strategy*: Ka Hikitia – Accelerating Success 2013–2017*, and *He kai kei aku ringa*, the Crown–Māori Economic Growth Partnership.

Of the four themes in the VM policy, '*taiao/environment – achieving environmental sustainability through iwi, hapū and whānau relationships with land and sea*', and '*mātauranga/knowledge – exploring indigenous knowledge, science and innovation*' are central to this Challenge. Māori relationship with the natural world is founded on their descent from Papatūānuku and Ranginui. Māori knowledge-practitioner systems (e.g. *kaitiakitanga*), shaped and influenced by individual and community engagement with the local environment, represent a store of experience to draw on. Kaitiaki take inspiration from the old ways, but also look to innovation, technologies, and science to define, measure, understand, create economic opportunity, and form culturally-explicit responses to safeguard their biocultural diversity.

Vision Mātauranga research within this Challenge will create genuine opportunities for Māori to engage in environmental science. The Challenge is committed to encouraging and mentoring Māori students, and engaging Māori communities directly and indirectly in the research programmes, and the Challenge's 'citizen science' components. Our researchers will link their research to the proposed curriculum and educational outcomes within the Māori charter schools programme (e.g. Tū Toa/Manu Kura in the Manawatū).

This Challenge will address '*Indigenous innovation – contributing to economic growth through distinctive science and innovation*' by exploring ways in which Māori communities can benefit from mitigating risks to biodiversity in their rohe (traditional tribal boundaries). Key to this is understanding the distinctive contribution that indigenous knowledge can make to this Challenge, particularly the discovery or rediscovery of knowledge that contributes to better relationships with the natural world and the revitalisation of traditional knowledge systems, values, and worldviews.

The Challenge will deliver on '*hauora/health – improving health and social well-being*' primarily by reconnecting Māori communities to their terrestrial and freshwater taonga. This is in line with our guiding whakataukī: *Toitū te marae a Tāne, toitū te marae a Tangaroa, toitū te iwi*. Our Vision Mātauranga programme reflects that Māori (and Pākehā) who connect with their biocultural heritage will invest more effort in its conservation if their interests are respected and retained.

1.6 Impact

Benefits and costs

As noted above (*Section 1.1 10-year Research Plan*), the value or 'additionality' from this Challenge will come from a step change in innovation, new technologies, and community and sector action to reverse the decline of New Zealand's biological heritage. With the value of directly funded and aligned research in this Challenge likely to total $250m–$300m over 10 years, we are targeting impacts of much greater magnitude and value than previously.

Economic benefits will result from reducing the economic damage caused by invasive pests, diseases, and weeds, better prioritising of efforts to manage risks and threats to our biological heritage, and strengthening the international competitiveness of production sectors. Natural capital contributes 13% to per capita wealth in New Zealand, compared with an average of 2% for high-income OECD countries (OECD 2013). Pests, diseases and weeds cost the production sectors $1.28b each year ($2.45b including downstream effects;

MAF 2009). One incursion alone – Psa in kiwifruit – has been estimated as costing $310m–$410m over 5 years (Greer & Saunders 2012). A reduction of only a small percentage of these production losses attributable to this Challenge would offset the Crown investment involved.

The Ministry for Primary Industries currently spends over $50m p.a. managing biosecurity risks; this escalates during a major biosecurity response. The estimated surveillance cost after a single fruit fly was recently discovered in Whangarei was about $1m. However, the establishment of a fruit fly population would threaten $3.6b of exported horticultural products. A foot-and-mouth outbreak in New Zealand would result in very significant economic costs and long-term impacts.

For natural ecosystem sectors, the current response to kauri dieback is costing over $1m p.a. DOC spends $73.5m p.a. on pest-led and site-led pest control, while additional significant costs are incurred by regional authorities, private companies, farmers and ordinary citizens. Trusts such as Kiwis for Kiwi and Predator Free New Zealand have recently commissioned studies of the potential economic benefits of wide-scale predator control for the production sectors, tourism, and non-monetary biodiversity benefits. Climate change and increased travel and trade will increase our vulnerability to tropical pests and diseases. Improving biosecurity outcomes will have huge benefits relative to costs. For example, if the rate at which unwanted new organisms are intercepted at the border is improved by 10%, biosecurity costs involved in responding to new incursions will fall by $16m p.a., whereas reducing pest establishment (through improved surveillance and eradication) by 15.5% would reduce direct impact and mitigation costs by a further $96m p.a. (Kriticos et al. 2005).

Our land-based production systems face increased environmental regulation and market demand for environmental credentials (e.g. the EU Product Environmental Footprint Initiative). Ongoing market access and premium pricing for our export goods is increasingly dependent on eco-verification, which relies on New Zealand developing internationally credible, science-based metrics and relationships that link management actions to biodiversity and ecosystem services. New Zealand must invest strategically in this area if it is to achieve the Business Growth Agenda target of increasing exports to 40% of GDP by 2025 (New Zealand Cabinet 2012).

The Māori economy is an integral part of the New Zealand economy and Māori businesses have an estimated asset base of $36.9b (BERL 2011). This Challenge can assist realising the potential of natural capital on Māori land by growing the adoption of innovative new techniques and technology to drive productivity increases in a way consistent with environmental and cultural safeguards.

Environmental benefits will result from more widespread and timelier use of advanced technologies, tools, and approaches to better manage our biological heritage and sustain New Zealand's natural capital. However, environmental benefits can be difficult to quantify. Recent synthesis reports (e.g. RSNZ 2014) have shown there are significant ecological benefits from pest control activities in New Zealand. However, while New Zealand currently spends over $100m p.a. on controlling possums, rats, and other small mammal pests to reduce impacts on native biodiversity and eradicate bovine TB, biodiversity continues to decline and bovine TB remains widespread. This Challenge has been designed to develop tools and strategies to permit order-of-magnitude cheaper delivery of control, and more precise understanding of when, where, and how best to intervene.

We can also obtain a quantitative sense of the environmental benefits of good management practice by considering the impacts of poor practice and the associated costs. For example, recent government funding for clean-up and restoration projects demonstrates downstream clean-up costs can be large (e.g. Lake Ellesmere, $11.6m; Lake Taupō, $72.4m; and $6.8m; Rotorua Lakes $72.1m).

Environmental reporting will be substantially enhanced through this Challenge. A wide range of end-users, including central and regional government, iwi, and business sectors, will have access to coherent terrestrial, freshwater, and estuarine data for reporting and associated policy, regulation, and decision making. Improved data will also underpin readily-acceptable indicators to predict impending tipping points and, through restoration activities, reverse these trends before thresholds are crossed.

Social benefits from this Challenge will be substantial, leveraging the wide-reaching partnership of research, community and public, government, business, and Māori. The overall approach and especially the 'citizen science' initiatives will enable communities to engage more effectively in managing their local biological heritage. This in turn will lead to more timely detection of threats and risks as well as more effective responses, and more aligned community restoration activities focused on priority species, ecosystems, and

localities. In particular, linking community and other interests nationally will facilitate the step-change required by scaling-up of key initiatives.

The Challenge will also deliver more humane, societally acceptable, and culturally appropriate technologies for managing threats and risks to New Zealand's biological heritage. This in turn is likely to motivate increased community and public involvement in practical initiatives.

Reversing the decline in New Zealand's biological heritage is expected to maintain or improve the abundance of culturally important biodiversity, including taonga species and mahinga kai.

Impact pathways

This Challenge has been structured to incorporate a wide range of aligned research for further developing technologies and to engage end-users in the uptake and application of these technologies to create solutions and value for New Zealand's biological heritage. The impact pathways are at the heart of this integrated approach (*Figure 4*). In practice, the specific nature of this pathway will depend on research area and type. As discussed in *Section 1.1 10-year Research Plan*, we are 'embedding' a wide range of Māori and end-users in the Challenge to help shape, review, and implement the research agenda. This means innovations and new technologies can be rapidly (and systematically) developed, piloted, deployed, and refined for optimal adoption and impact across production and natural ecosystems.

The EAP will play a key role in helping monitor progress towards implementation and impact. The EAP will provide advice on adoption pathways to maximise uptake through the life of the Challenge (*Section 3.8 Advisory groups*). In Year 1 of the Challenge, indicative implementation partners, pathways and mechanisms will be refined, as part of reviewing aligned research and with input from the EAP, for all projects. Such pathways and mechanisms will build on existing partnerships between providers and end-users, particularly for aligned research. In practice, the pathway to impact will involve a mix of basic and applied research, technology development and application. This is not a linear process, so close and regular interaction between researchers and end-users will be vital to retain a clear focus on 'what remains to be done' (*Section 1.4 Research portfolio and quality*) to achieve Programme outcomes and the Challenge Mission.

The new knowledge, tools, and approaches resulting from this Challenge will be represented and communicated in a variety of forms as outlined below.

Publications. At a fundamental level, all of the novel research will be promulgated as international research publications. New findings and concepts will be assessed and adopted by the research community. Popular publications, newsletters, websites, field days, and media releases via the Challenge directly, and through partner and end-user organisations will ensure that stakeholders understand the implications of the research findings. Our institutions actively disseminate research findings as a part of their core business and their infrastructure will be available to the Challenge.

New methodologies and analytical techniques. Uptake relies to a large extent on demonstrations, and applications to real-life situations. The main pathway for uptake and outcomes here is therefore via networks of research providers and end-users in the production and natural ecosystem sectors (including government, business, and Māori).

Provision of new data and information. Because of the unprecedented scale and scope of the Challenge, most Projects will develop or need active databases. Many will be national and most will involve inter-institutional and cross-sectoral collaboration. With the limited funding available, the Challenge will re-purpose existing biological heritage database infrastructure and assist with efforts to create a more comprehensive and operationally relevant system. This accords with the Open Government policy and NZGOAL principles (*Section 1.7 Open data*), and will achieve significant cost-savings and other benefits. The well-supported Nationally Significant Databases (biological heritage databases, mainly held by our CRI partners), the associated Global Biodiversity Information Facility, and existing initiatives such as NatureWatch will be used where appropriate. The Environmental Domain Plan to be refined through the Natural Resources Sector (Central Government) information work stream will be very relevant to this Challenge. Refer to *Appendix 7: Data Management Plan*.

Web-based information exchange. Full use will be made of existing and emerging web-based information systems. This rapidly growing area will be monitored carefully and opportunities exploited from both the end-user and scientific community perspectives. Such mechanisms are likely to be highly cost-effective and

prompt in the promulgation of new information (*Section 3.10 Programme management* and *Section 3.12 Indicative budget*).

New community networks and partnerships. Our plan to facilitate several major citizen science and Vision Mātauranga initiatives represents a new approach for biological heritage research in New Zealand, with the potential to deliver greatly improved, more aware and alert communities, and organised forums for online surveys, discussions, and feedback for informative decision making (*Section 3.12 Indicative budget*). This will require building new capability, especially through new linkages. A new initiative in this Challenge is to work closely with major museums to develop public outreach programmes.

Commercialisation of new products. New products (e.g. novel pest management tools) are the most difficult output to transition to demonstrable outcomes, as they require commercial partners who in turn need scale and investment to create viable products. However, we will maximise the likelihood of success by linking with commercial development expertise early in the process (e.g. via existing Parties' networks such as KiwiNet). There will also be a need for early interaction with regulatory agencies to understand registration and approval requirements, especially for novel approaches. Appropriate Intellectual Property (IP) protection also plays a role. Exploratory investigations will be encouraged that can be quickly scaled up if they show promise.

The main barriers to successful implementation include a disparity of benefits across different end-user groups, and the absence of necessary organisational infrastructure. The main steps outlined above have been designed with these barriers in mind, to minimise the likelihood that they will constrain actual progress. Overall, the wide range of Parties involved in this Challenge and the use of specialist external advice (e.g. the EAP) will help address these barriers.

Risks

From inception it was recognised that one of the greatest risks affecting this Challenge is that this investment will make great research progress but fail to lead to measurable improvements in the state of New Zealand's biological heritage. To mitigate this and to ensure there is a continual focus on delivering value and outcomes from this Challenge, we have incorporated structural elements to manage risk within the governance and management structures (see *Part Three: Business Plan*). For example the EAP and the Kāhui Māori have key roles in ensuring that the research is focused on activities that deliver impact, and they will help review progress as part of the strategic management approach outlined in *Section 1.4 Research portfolio and quality*. These groups also have access to formal escalation pathways if there are concerns about the Challenge's direction, focus, or delivery.

Further risk identification and the development of associated processes and mitigation actions have been a focus during the first Challenge Programme Agreement period. *Appendix 8: Risk Register* is a work in progress. The Governance Group, at their 5 March 2015 meeting, provided direction on the further development of the Risk Register, including:

- The first and second pages of the Register to be merged.
- Consolidation to approximately 12 strategic risks, with an additional column to define the specific risk(s) at the time.
- A map of risk against the *Outcome Framework* and/or implementation pathway.
- In terms of responsibility for mitigation actions, to list 'groups' (e.g. Governance Group, Science Leadership Group, Programme Leaders, Support Team) and actions associated with each group for each risk.

The Governance Group recognised that some risks contained in the Register are not currently relevant, due to not being present at this early phase of the Challenge. They also noted risk management actions are not discrete, meaning they must cross-reference to management plans.

Table 5 contains the Governance Group's four highest risks and associated mitigation strategies.

Table 5: Key Challenge risks and mitigations

Risk	Mitigation
Diversion to a new immediate issue such as a new nationally significant biosecurity invasion or widespread novel threat to indigenous species or ecosystem	Clear description of Challenge focus, what is in and out of scope. If risk eventuates, the response will have to be considered and managed at the time through the Governance structures and in accordance with the nature of the issue, being very clear on the benefits lost through the trade-off.
Lack of external organisational resources/infrastructure to take up new Challenge research discoveries and/or capture full benefit	Early and ongoing engagement with end-users with a view to ensuring outputs are 'fit-for-purpose' and can realistically be implemented. Understand and plan for user implementation pathways and ensure projects plan for and resource user support – 'planning for impacts'. Where appropriate, support end-users in developing internal or external cases for funds. It some cases this may be overcome by sharing platforms and having a lead-agency adopt the necessary technology and then make this available to others.
Loss of reputation and political risk due to slow traction and no 'runs on the board'	Focus hard on gaining traction quickly and delivering some quick 'runs' that demonstrate the added value possible through the Challenge structure and processes; the 'threats-risk' focus in Programme 2 may be particularly important in this regard. At the same time manage expectations around the nature of the work, the size of the issues, the process and work required to address them and the time lags involved. The communications plan should include such messaging.
Inadequate internal and external communication create a loss of momentum, particularly during early stages of the Challenge	Engage Communications Leader as soon as possible, and support development and implement of strategy. Governance Group and Science Leadership Group to prioritise communication needs.

1.7 Open data

As signalled in the Heads of Agreement, the underlying purpose of this Challenge is to create benefit for New Zealand. Accordingly, we propose a number of objectives relating to:

- 'Embedding' stakeholders to shape, pilot, and apply Challenge outputs and data (*Section 3.10 Programme management*)
- The role of 'citizen science' as a driver for change and associated provision of data to *New Zealand's Biological Heritage* Challenge
- Building a strong bioinformatics foundation to leverage earlier Crown investment in relevant Nationally Significant Collections and Databases for wider application and benefit (*Section 1.3 Research team and skills*)
- The opportunities from bringing together research providers to more openly share data, information and knowledge, and work together to achieve the Challenge goals (*Section 1.9 Related activities – public outreach, communication, and education activities* and *Section 3.10 Programme management*)

A key enabler to achieve these objectives will be availability and two-way-flows of data and associated information across the research, business, Māori, and government sectors, and the public. Such availability can only be achieved through the effective application of open-access principles, standardised data and metadata management, data federation and interoperability, common Challenge policies and practices, and underpinning cultural change in relation to open data.

We are committed to open-access principles for publicly-funded research data. Consequently, unless there are ethical, privacy, or cultural reasons, or issues of commercial sensitivity, publicly-funded research data from the Challenge will be made open for public access and reuse. We will do so in accordance with the *New Zealand Government Open Access Licensing* framework (*NZGOAL*) and the *New Zealand Data and Information Management Principles (NZDIMP).*

We have developed a draft Data Management Plan (DMP) (*Appendix 7: Data Management Plan*) to ensure researchers prepare and maintain data management plans that explicitly address data capture, management, integrity, confidentiality, retention, sharing, and publication when planning research activity. Most partner research organisations already have these policies in place, and the DMP should build upon existing practices among the Parties and ensure:

- Data are readily available for future research

- Insofar as practicable, data are in a suitable format for long-term management/curation
- Supporting metadata and other documentation are accurate and comprehensive
- Mechanisms are in place to permit discovery, access to, and reuse of research data
- An accessible repository of research data created or held by the Challenge (*Section 3.10 Programme management)*
- A culture of best-practice data management by researchers participating in the Challenge.

The 'additionality' to be gained by working together in the Challenge extends beyond sharing knowledge (which most agencies do as a matter of course) through to implementing shared policies on research data management, fostering a common data management culture across researchers, and developing shared (federated) infrastructure to support data management and open access.

As Challenge Contractor, Landcare Research is recognised nationally as a leader in open-access data, and will add value by supporting the Challenge to meet open-access standards as set out in *NZGOAL* and the *NZDIMP*. Landcare Research will do so by applying its corporate data management policies across the Challenge and supporting Challenge Parties to implement it via training, guidelines, sharing of best practice and case studies. We also propose to use our Data Management Plan template endorsed in October 2013 by MBIE and the *Open Government Information and Data Programme* (LINZ). Other Challenge Parties are well advanced in open data practices, particularly those with Nationally Significant Databases and Collections, and they will also provide support in this area.

The above policies do not preclude Challenge Parties reserving the right to charge for data and its manipulation, or to recover costs relating to provision of access to data or its interpretation. Similarly, legitimate interests of the subjects of research data must be protected (e.g. anonymised or aggregated), and Privacy Act principles and ethical considerations must be taken into account. Challenge researchers may also restrict data access within the Challenge for a limited period after data collection to enable publication of research findings and appropriate quality assurance.

1.8 Intellectual Property (IP) management

The majority of the research in the Challenge is intended for fully open application to provide greatest public benefit. The expectation is that Māori, key stakeholders, and end-users will be actively involved with the Challenge (often through co-funded projects) and that they will freely engage with, adopt, and make use of research findings for sector, iwi, and community benefit. That said, it is expected some Challenge-funded research may result in commercially applicable IP. A potential example would be novel technologies with offshore commercial application (e.g. novel rodenticides or insecticides).

Intellectual Property will be managed in accordance with the Intellectual Property Management Plan in Schedule 4 of the first Challenge Programme Agreement, and any subsequent Challenge Programme Agreement. Key elements include:

- Challenge Project IP shall be dealt with in the best interests of New Zealand
- Where Challenge Project IP does not have any expected future commercial application, Parties will provide open access to relevant Project information to the public
- Pre-existing IP will remain the property of the owner who shares it for research purposes
- Cultural IP (mātauranga Māori) treated as proprietary, which is contributed or developed as a result of collaboration with Māori, remains, as appropriate, in iwi, hapū, or whānau ownership
- Where a Challenge Project seeks to use such mātauranga Māori, the Parties involved in that Project will consult with relevant iwi, hapū, or whānau to reach kotahitanga (consensus) on how the IP is to be used in the Project
- Challenge Project IP arising from a research project will be owned by the Party or Parties that create(s) it, and they will be responsible for protecting, managing and commercialising that IP
- Jointly-created Challenge Project IP suitable for commercialisation will be assigned to one Managing Party through a process of agreement of all the Parties involved in its creation. The

Managing Party will be responsible for protecting, managing and commercialising that Challenge Project IP and sharing revenue with the joint creators as agreed

- The IP owner of any Challenge Project IP not suitable for commercialisation will provide a non-exclusive, royalty-free licence to other Parties, as relevant, for the purpose of undertaking research or educational purposes related to the Challenge
- All Challenge Project IP will be reported to the Challenge Director, who will keep a record of this for reporting purposes.

1.9 Related activities – public outreach, communication, and education activities

This Challenge seeks to boost the accessibility of science to New Zealanders and reduce barriers to participation in science activities, provide forums for discussion, and leverage the inherent public interest in our biological heritage. The Challenge also aspires to ignite young New Zealanders' passion for biological heritage science.

All Research Programmes in the Challenge will have identified communication and outreach activities that will form part of the annual review process. The Challenge will run outreach and education programmes in collaboration with the Royal Society of New Zealand (RSNZ), New Zealand museums, the Enviroschools Foundation, relevant scientific societies (e.g. NZ Ecological Society), the Science Media Centre (SMC), Learning Experiences Outside the Classroom (LEOTC) providers, with other science Challenges, and the Science Learning Hub (SLH). Details are provided below.

The value of community involvement in achieving long-term sustainable changes in behaviour has been demonstrated by conservation psychologists. Involving community members in designing and implementing environmental programmes heightens a sense of group identity and empowerment (Wiesenfeld & Sanchez 2002). This can, in turn, motivate further actions to protect the local environment, and is a critical ingredient leading to long-term sustainability (Pol 2002).

This step change will be enabled by applying collaborative decision making methodologies in the Challenge that have been successful elsewhere. The Challenge will use these proven approaches to engage communities in sustainable action.

Outreach to public and scientific communities

In the Start-up Phase, we will create a network of communication experts in participating Parties, and develop an Engagement Plan to detail the Challenge's outreach and how it will be delivered. This will use existing networks, but also pilot innovative ways of increasing outreach and impact (*Section 3.12 Indicative budget*). For example, the Science Media Centre website could feature the Challenge and highlight its successes to public audiences. Once a communication network is established, we will implement a two-phase outreach and engagement programme:

- *Networks for exchange* – a series of wānanga will engage experienced scientists with emerging scientists, students, and enthusiasts to explore scientific careers, methodologies, findings, and issues. These will be delivered in marae with iwi partners and facilitated by the proposed museums' programme and RSNZ networks (*Section 1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement* and *3.13 Vision Mātauranga/Māori engagement*). We will use these networks in 'citizen science' projects that extend beyond traditional 'NatureWatch' reporting. In particular, we will engage retired scientists, life-long enthusiasts who have become experts in some aspect of the biota or environment, with citizens who have enquiring minds and an active desire to become involved. Some of these retired scientists are supported by CRIs, universities, and museums, either as emeritus researchers or associates. More could be gained from these experts collaborating with citizen scientists, especially in ecology and the distribution of exotic and native organisms. In the first instance, we will work with relevant organisations, including museums, to create a citizen science network that can be aligned with our Challenge (and possibly others).
- *Outreach to scientific communities* – we will use existing scientific organisations and societies to engage with the wider scientific community via Challenge-sponsored workshops, symposia, and keynote presentations, working with relevant scientific societies. For broader issues of science in the

environmental domain, we will collaborate with other Challenges (*Our Land and Water* and *Sustainable Seas*) and stakeholder organisations (MfE, DOC, MPI, regional councils, PCE, RSNZ, museums, Te Ara, SMC) to coordinate communication quality, reach, and impact.

Education and engagement

Key education partners will be the national museum network, the Enviroschools Foundation, LEOTC providers, and the Science Learning Hub. Other community-initiating opportunities are likely to arise as the Challenge progresses. Our proposed education and engagement programme will involve:

- *Public education programme* – in line with more traditional outreach approaches, and in partnership with the national museum network, we will assist with exhibitions, informal outreach programmes, events, and digital outreach (*Section 3.12 Indicative budget*). These will be delivered initially at Te Papa and the Auckland War Memorial Museum (AWMM), but later will be extended nationally through the network of museums. The museums have significant experience in public education that includes enhancing science literacy, removing barriers to science participation, and providing integrated online information access. Te Papa and AWMM annually total 2 million visitors, of which >100,000 are school students.
- *Schools and education providers* – to engage a broad range of New Zealand students, we will partner with Enviroschools, the SLH, and LEOTC providers to incorporate Challenge-related findings into primary and secondary curriculums and learning experiences. We will work with coordinators from the Enviroschools Foundation to develop new or enhance existing biological heritage lessons and experiences. In partnership with the SLH, we will develop multimedia education resources relating to the Challenge for school teachers of students in Years 2–10. Through the eight university Parties, we will implement a Challenge summer student programme in which promising secondary school students will be engaged in meaningful science tasks connected with the Challenge. We will also evaluate and enhance the alignment of relevant courses at these tertiary institutes with the Challenge and the Skills Development initiatives (*Section 1.3 Research team and skills*).

1.10 Monitoring of performance, evaluation of impact

Quality assessment is outlined in *Section 1.4 Research portfolio and quality*. Programme KPIs are summarised in *Section 1.1 10-year Research Plan* and discussed in more detail in the Research Plan (*Part Two: Research Plan – detailed description*). Performance monitoring will be based on a continuous *plan–monitor–review* cycle, focused on 'what remains to be done' to achieve programme outcomes and the Challenge mission. In practice, this will require close dialogue with end-users (via the EAP) to assess progress at regular (e.g. annual) intervals and identify any changes needed to strengthen impact and hence value.

Implementing the *plan–monitor–review* cycle will be a key accountability for the Challenge Director, supported by the Science Leadership Group (*Section 3.8 Advisory groups*). Investment changes recommended to the Governance Group will be based on this mechanism. Reporting to MBIE will similarly be based on findings from application of this *plan–monitor–review* cycle. This approach is similar to that being implemented for CSIRO Flagships. It addresses many of the inherent difficulties in evaluating economic, environmental and social outcomes from long-term research programmes.

We will also carry out an 'outcome effectiveness' research project as a core component of determining progress towards outcomes and therefore 'what remains to be done'. A portion (up to 3%) of Challenge funding will be allocated for in-depth analysis of the research, collaborative behaviours (between research teams and with end-users) and outcomes. We will engage independent experts to work with the Challenge Director and Programme Leaders, to build up New Zealand expertise in this field of outcome analysis. The analyses will cover:

- Efficiency of use for resources invested, particularly alongside the considerable co-funding invested by Challenge Parties
- Quality and productivity of research activity and outputs, including benchmarking with international groups

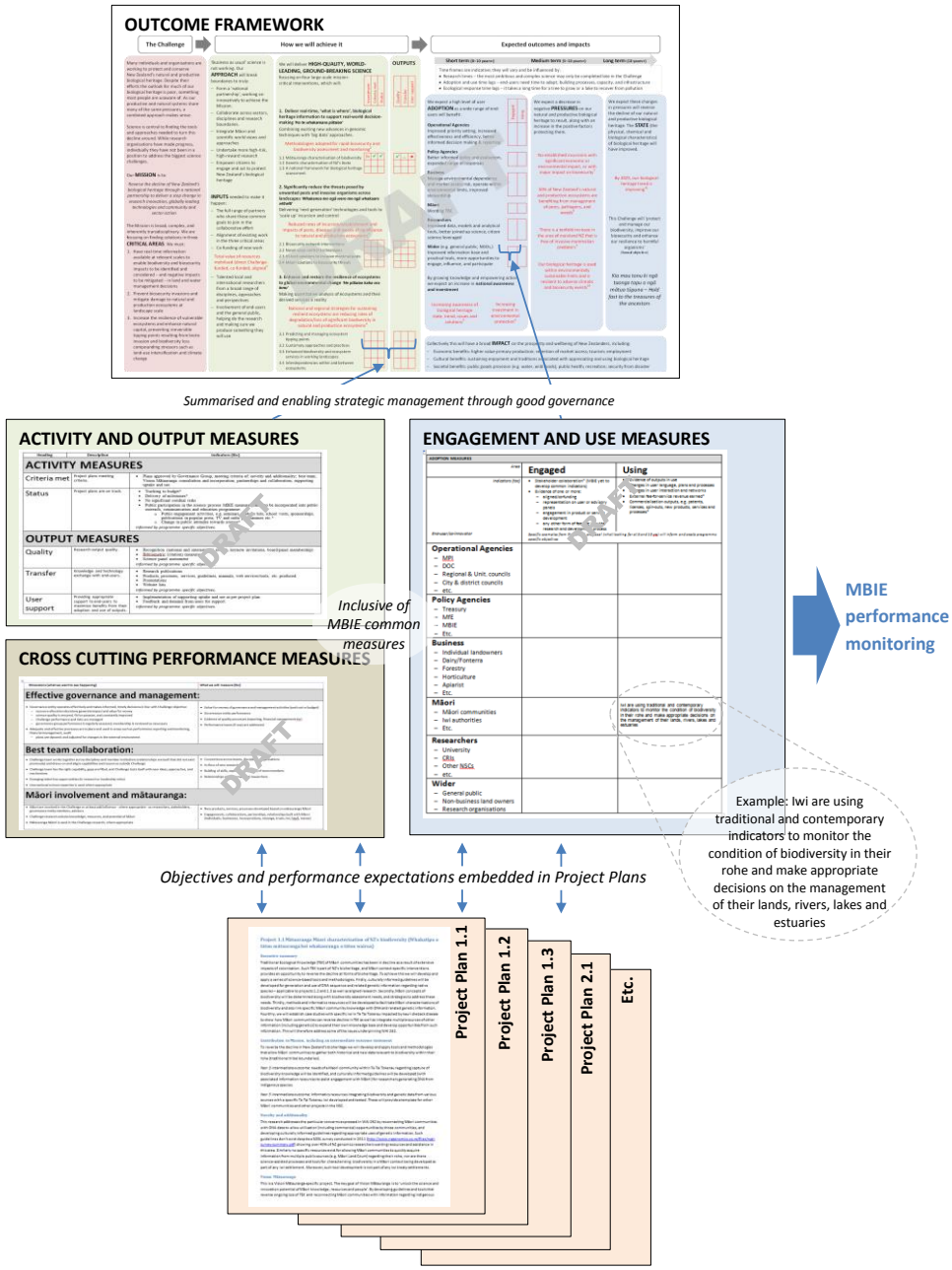
- End-user collaboration, co-investment, uptake and implementation, including identification of barriers to effective implementation and how these may be overcome
- Measures of environmental and socio-economic outcomes.

We will incorporate a specific focus on Vision Mātauranga in all our monitoring work, involving key input of the proposed Kāhui Māori (*Section 3.8 Advisory Groups*, *Section 3.9 Review of governance and management,* and *Section 3.13 Vision Mātauranga/Māori engagement*).

The relationship between the Outcome Framework and evaluation and performance measurement

The *Outcome Framework* provides a means to broadly understand key elements for successful progress relative to the Mission. Within the framework, key performance indicators have been included, allowing high-level reporting on Challenge achievements and supporting strategic management through good governance.

Figure 8: The relationship between the *Outcome Framework* and evaluation and performance measurement



In general, the specific indicators proposed in the *Outcome Framework* will be informed and evidenced by external measures (e.g. from DOC, MPI and national surveys) and where possible are intended to align with the Environmental Reporting Bill and associated reporting framework. Whereas the tables provide a 'traffic light' approach as a means to summarise the more detailed Challenge-specific activity, output, engagement, use and other cross-cutting performance measures. These more detailed measures will comprise a mix of MBIE common indicators and measures specific to the *Biological Heritage* Challenge. *Figure 8* shows this relationship and also how MBIE performance monitoring requirements will be met.

These measures, along with the Framework, link with Programme and Project plans. This is a two-way relationship, for example, while MBIE common indicators may set performance expectations around levels of collaboration, Project plans will set expected end-user adoption outcomes against which progress is tracked.

Relating these documents and associated indicators in such a way enables transparency between Projects and the Mission, and associated performance expectations. It allows the Governance Group and Science Leadership Team to actively manage the Challenge at their respective levels, providing both Project and aggregated activity/process views.

The detail of the indicators will be finalised once the MBIE common indicators are confirmed, the details of Projects solidify, and the feasibility and cost of collecting information on each indicator is assessed.

We are also aware of frameworks and approaches such as Bennett's Hierarchy, 'productive interactions' and 'behavioural additionality', which may be readily applied. It is considered too early to commit to any of these approaches, pending any discussion with MBIE and across Challenges as to which if any may be applicable and useful. It is noted that many of the draft indicators could be used in such frameworks, allowing a good degree of later flexibility.

Part Two: Research Plan – detailed description

The *New Zealand's Biological Heritage* Challenge brief is broad, complex, and inherently transdisciplinary. Five major themes and 23 topics are identified in the RfP. Realistically, the Challenge cannot immediately address all components of the RfP.

Three Research Programmes (*Figure 5*) were arrived at through extensive consultation with researchers, stakeholders, and end-users. Priorities were agreed on the basis of convergence of key elements to achieve the Challenge objectives. Despite the complexity of the task, the overarching goals set by the Challenge are clear: to better understand the distribution and status of New Zealand's introduced and native biota; to improve our ability to detect and eliminate threats; and to ensure ecosystem resilience in the face of increasing global environmental pressures. In delivering these goals we will, for the first time, fully integrate biodiversity and biosecurity research, across productive or natural ecosystems, to the same Mission (*Section 1.1 10-year Research Plan*). Likewise, Māori viewpoints, capabilities, and leadership will be central (*Section 1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement*). Finally, citizen science will take its rightful place in engaging community participation in the Mission (*Section 1.9 Related activities – public outreach, communication, and education activities*).

The Programme structure and timeline is provided in *Table 6*, with six Projects signalled to start in Year 1 and potentially five Projects in Year 2. Nine potential Projects to start after Year 5 are signalled in the narrative for each Programme. Prioritisation processes are outlined in *Section 1.4 Research portfolio and quality*.

While these Projects have all been identified as a priority for the Challenge through discussions with partners, end-users, and researchers, the Challenge's role and funding will vary across Projects according to the strategy adopted to achieve our Mission. For example, lead-off Projects currently proceeding to contract are expected to receive major Challenge funding to ensure the necessary impacts and outcomes. Others may also receive maximum level of support once the research and team are clarified. However, others may require variable types and levels of support – including aligned end-user funding – as objectives become more clearly established through the assessment process established by the Challenge. New Projects of importance may also emerge through ongoing evaluations of the research landscape and biological heritage issues. We envisage some Projects proceeding via the Challenge providing a forum for national level leadership and co-ordination of current efforts, but requiring only limited investment.

Table 6: Programme structure and timeline

Timeline	Yr 1	Yr 2
Programme 1: Real-time biological heritage assessment *'Ko te whakamana pūtaiao'*		
Project 1.1 Mātauranga Māori characterisation of NZ's biodiversity (Whakatipu o tātou mātauranga hei whakaoranga o tātou wairua)		
Project 1.2 Genetic characterisation of NZ's terrestrial and freshwater biota		
Project 1.3 A national framework for biological heritage assessment across natural and production landscapes		
Programme 2: Reducing risks and threats across landscapes *'Whakanoa mo ngā wero me ngā whakaaro witiwiti'*		
Project 2.1 Biosecurity network interventions		
Project 2.2 Novel wasp control technologies		
Project 2.3 Hi-tech solutions to invasive mammal pests		
Project 2.4 Māori solutions to biosecurity threats (Patua riha rāwaho)		
Programme 3: Enhancing and restoring resilient ecosystems *'He pūtaiao kaha ora tonu'*		
Project 3.1 Predicting and managing ecosystem tipping points		
Project 3.2 Customary approaches and practices for optimising cultural and ecological resilience		
Project 3.3 Enhanced biodiversity and ecosystem services in working landscapes		
Project 3.4 Interdependencies within and between ecosystems		

The following section sets out in more detail the Programmes and Projects being considered for the first 5 years of the Challenge. The three lead-off Projects *(Project 1.3 A national framework for biological heritage assessment across natural and production landscapes*; *Project 2.1 Biosecurity network interventions* and *Project 2.2 Novel wasp control technologies*) are currently being further developed by Research Leaders for formal contracting, having been supported by the Kāhui Māori and the End-user Advisory Panel (EAP), and formally approved by the Governance Group to be developed to the contracting stage, when they will be reassessed by peer review.

A further four Projects (*Project 1.1 Mātauranga Māori characterisation of NZ's biodiversity*; *Project 2.3 Hi-tech solutions to invasive mammal pests; Project 3.1 Predicting and managing ecosystem tipping points*; and *Project 3.2 Customary approaches and practices for optimising cultural and ecological resilience*) are well-advanced for consideration by the Governance Group for development to the contracting stage. We anticipate this will be achieved before 1 July 2015 or early in the new financial year. All these Projects are presented in 2-page outlines (appended). The remaining four Projects (*Project 1.2 Genetic characterisation of NZ's terrestrial and freshwater biota*; *2.4 Māori solutions to biosecurity threats*; *3.3 Enhanced biodiversity and ecosystem services in working landscapes*; *3.4 Interdependencies within and between ecosystems*) are at an early phase and require further development and focus through national research and end-user workshops, before being further considered by the Governance Group, EAP, and Kāhui Māori. These are presented as 1-pagers, highlighting the scope of proposed workshops, where they will be considered further.

Research Programme 1: Real-time biological heritage assessment *'Ko te whakamana pūtaiao'*

Purpose and approach

Large-scale data collection and analysis will combine with innovative technologies and science to deliver critical information on the distribution and identity of biota. Stakeholders will be able to make evidence-based, real-time decisions on land and water management.

The Programme integrates two complementary approaches. The first applies new methodologies and technologies for rapid biodiversity and biosecurity assessment and monitoring. New surveillance and assessment methods will gain maximum value from emerging and maturing technologies, including molecular (e.g. full genome sequencing, metagenomics, transcriptomics), remote sensing (e.g. high-resolution aerial spectral analysis in combination with new remote sensing techniques such as LiDAR) and smart sensors (e.g. acoustic monitoring, sensor-nets). Second, existing and new data will be enhanced through improved national e-infrastructure and 'big data' analysis and modelling, making it available in real time. Community understanding of biological heritage will be enhanced through citizen science engagement in biodiversity and biosecurity actions, based on the concept of four million New Zealand scientists.

High-throughput data collection technologies will be implemented by cross-institutional teams. This will provide (1) accessible information on trends in species distributions and abundance at relevant scales and in real time, (2) early warning of new shifts in biosecurity risks or biodiversity loss, (3) recognition of valued biodiversity by the public, including iwi, and (4) state and trend information for national and international (e.g. IPBES, CBD) environmental and natural capital assessment reporting.

Table 7 provides an indicative research roadmap for Programme 1, and outlines intermediate and 10-year outcomes, subject to further refinement as part of the scheduled research planning process. Progress will be assessed against these as part of the annual *plan–monitor–review* cycle.

Table 7: Programme 1 – indicative research roadmap

Programme 1	
Real-time biological heritage assessment 'Ko te whakamana pūtaiao'	
Next-generation technologies and tools for improved biosecurity surveillance/biodiversity assessment	
Outcome: *Biological heritage information is available at relevant scales and in real time to enable biodiversity and biosecurity impacts to be considered in management decisions*	
KPI: *Methodologies adopted for rapid biosecurity and biodiversity assessment and monitoring*	
Project 1.1	
Mātauranga Māori characterisation of NZ's biodiversity (Whakatipu o tātou mātauranga hei whakaoranga o tātou wairua)	
Contribution to Mission: To reverse the decline in New Zealand's biological heritage we will develop and apply tools and methodologies that allow Māori communities to gather both historical and new data relevant to biodiversity within their rohe (traditional tribal boundaries).	
5-year outcome	**10-year outcome**
Needs of a Māori community within Te Tai Tokerau regarding capture of biodiversity knowledge will be identified, and culturally informed guidelines will be developed (with associated information resources to assist engagement with Māori) for researchers generating DNA from indigenous species. Informatics resources integrating biodiversity and genetic data from various sources with a specific Te Tai Tokerau iwi developed and tested. These will provide a template for other Māori communities and other projects in the Challenge.	Māori communities use new tools to manage biodiversity-related mātauranga, identify biosecurity and biodiversity risks, and make informed resource allocation and use decisions (e.g. cultural harvesting)
Project 1.2	
Genetic characterisation of NZ's terrestrial and freshwater biota	
Contribution to Mission: Biosecurity threats assessed and responded to, and biodiversity management strategies improved using large-scale phylogenetic and genomic data	
5-year outcome	**10-year outcome**
Phylogenetic and genomic characterisation of high-priority elements of the biota is underpinning biodiversity and biosecurity responses	Broad-scale phylogenetic and genomic data provide detailed characterisation of NZ's terrestrial, freshwater, and estuarine biota, enabling a step change in biosecurity surveillance, biodiversity assessment, and ecosystems management
Project 1.3	
A national framework for biological heritage assessment across natural and productive landscapes	
Contribution to the Mission: To reverse the decline in New Zealand's biological heritage we require tools to detect incursions, and changes in biodiversity and ecosystem function in order to implement effective mitigation strategies and assess conservation performance. The integration of nationally-consistent eDNA methodologies with existing monitoring programmes will deliver a step change in biodiversity assessment	
5-year outcome	**10-year outcome**
The eDNA platform will underpin measurement of biodiversity in natural and production ecosystems for biodiversity end-users and evaluation of mitigation strategies	Biodiversity and biosecurity impacts are regularly considered in land and water policies, regulations and management decisions, drawing on real-time, comprehensive biodiversity information at relevant scales. The NZ Government can report comprehensively on the state of and trends in NZ's environment – including in international fora

Programme Leader

Thomas Buckley – Landcare Research

Project 1.1 Mātauranga Māori characterisation of NZ's biodiversity (Whakatipu o tātou mātauranga hei whakaoranga o tātou wairua)

Executive summary

Traditional Ecological Knowledge (TEK) of Māori communities has been in decline as a result of extensive impacts of colonisation. Such TEK is part of New Zealand's biological heritage, and Māori context-specific interventions provide an opportunity to reverse the decline in all forms of biological heritage. To achieve this we will develop and apply a series of science-based tools and methodologies. First, culturally informed guidelines will be developed for generation and use of DNA sequence and related genetic information regarding native species – applicable to 1.2 and 1.3 as well as aligned research. Second, Māori concepts of

biodiversity will be determined along with biodiversity assessment needs, and strategies to address these needs. Third, methods and informatics resources will be developed to facilitate Māori characterisations of biodiversity and also link specific Māori community knowledge with DNA and related genetic information. Fourth, we will establish case studies with specific iwi in Te Taitokerau impacted by kauri dieback disease to show how Māori communities can reverse decline in TEK as well as integrate multiple sources of other information (including genetics) to expand their own knowledge base and develop opportunities from such information. This will therefore address some of the issues underpinning WAI 262.

Contribution to Mission, including intermediate outcome

To reverse the decline in New Zealand's biological heritage we will develop and apply tools and methodologies that allow Māori communities to gather both historical and new data relevant to biodiversity within their rohe (traditional tribal boundaries).

Year 3 intermediate outcome: Needs of a Māori community within Te Tai Tokerau regarding capture of biodiversity knowledge will have been identified, and culturally informed guidelines developed (with associated information resources to assist engagement with Māori) for researchers generating DNA from indigenous species.

Year 5 intermediate outcome: Informatics resources integrating biodiversity and genetic data from various sources with a specific Te Tai Tokerau iwi will have been developed and tested. These will provide a template for other Māori communities and other projects in the NSC.

Novelty and additionality

This research addresses the particular concerns expressed in WAI 262 by reconnecting Māori communities with DNA data for utilisation (including commercial), and developing culturally informed guidelines regarding appropriate uses of genetic information by researchers. Such guidelines don't exist despite an NZGL survey conducted in 2011 (http://www.nzgenomics.co.nz/files/nzgl-survey-summary.pdf) showing over 40% of New Zealand genomics researchers wanting resources and assistance in this area. Similarly no specific resources exist for enabling Māori communities to quickly acquire information from multiple public sources (e.g. Māori Land Court) regarding their rohe, nor are there science-assisted processes and tools for characterising biodiversity in a Māori context being developed as part of any iwi settlement.

Vision Mātauranga

This is a VM-specific project. The key goal of VM is to 'unlock the science and innovation potential of Māori knowledge, resources and people'. By developing guidelines and tools that reverse ongoing loss of TEK and reconnecting Māori communities with information regarding indigenous species within their rohe, these resources and experiences will allow Māori communities to engage with and benefit from science-based tools and more meaningfully add to New Zealand's biological heritage.

Project aim(s)

Key aims are to develop knowledge, mechanisms and tools that enable Māori communities to positively and substantively contribute to the increase in New Zealand's biological heritage by (a) developing strategies, methods and resources to halt the decline in their own TEK, (b) using Western science-derived tools and information to expand and utilise biological diversity knowledge, and (c) learning by applying these tools to a biosecurity-relevant case study that demonstrates contribution potential of Māori communities to New Zealand's biological heritage and post-border biosecurity response.

Key research question(s)

1. How can Māori communities halt the decline of their TEK by reconnecting with their TEK and biodiversity?
2. How do we connect Māori communities with local genotypes and genetic information generated in other projects in this challenge (and elsewhere), and integrate these data with other information sources to reverse TEK decline and enhance biological heritage?

Risk (feasibility and achievability)

The proposed work will require aligned funding. Development of culturally informed guidelines for sequencing and using DNA from indigenous species is de-risked by applying information from a related project aimed at biobanking and human medical genomics.

Management impact

Key changes will be in (a) increased extent of interactions between genomics researchers and Māori communities regarding genomics of indigenous species – with an emphasis on creating benefits and minimising risks for those communities via changes in organisational policies and procedures (noting that the Crown has not officially responded to the WAI 262 report nor is there any official intention to do so); (b) improved access to and integration of rohe-specific public domain information by iwi, and (c) improved collection and curation of biodiversity information by iwi and hapū. These will directly underpin management of natural resources by Māori communities, including co-managed reserves and national parks.

Uptake potential

We envision strong uptake potential for culturally informed guidelines (see NZGL link, above), and these will be applicable to all Programme 1 activities. Māori groups that have been consulted have offered letters of support for this project.

The team

The project will be led by **Dr Phillip Wilcox** (Scion/University of Otago) and involve kaitiaki from various rohe, and Māori with experience in biodiversity assessment in a Māori context as well as experience in developing culturally informed guidelines for other contexts. Although researchers from other areas of the Challenge will also be involved (Projects 1.2 and 1.3), the majority of this research will need to be conducted by Māori in a Māori context, so these activities are proposed as a stand-alone VM project.

Project 1.2 Genetic characterisation of NZ's terrestrial and freshwater biota

Contribution to the Mission, including intermediate outcome

Genomic methods and large-scale phylogenetics are transforming many aspects of biology. We will develop a large-scale genomic and phylogenetic based research project by which we can detect and assess lineages of high biosecurity risk and high biodiversity value. This project will have strong connections to both *Project 1.1 Mātauranga Māori characterisation of NZ's biodiversity* and *Project 1.3 A national framework for biological heritage assessment across natural and productive landscapes.*

Objective

To improve the detection and evaluation of biosecurity threats through the application of phylogenetic information and more effectively target conservation strategies based on phylogenetic distinctiveness across taxonomic and spatial scales.

Research question(s)

We have identified three questions to be refined in a workshop: (1) How can we optimise conservation priorities and management activities by accounting for the phylogenetic structure and distinctiveness of the biota, (2) How do we recognise phylogenetic lineages representing biosecurity risk and address questions of origin, spread, and impact, and (3) How can genomic information enhance the conservation of threatened elements of the biota?

Proposed workshop

The workshop will require that key scientists, iwi and stakeholders are represented. Included in this discussion will be an assessment of how researchers and land managers currently use genomic and phylogenetic information in threat assessment and management strategies. We will explore how a large-scale phylogenetic backbone representing the full breadth of the New Zealand terrestrial and freshwater biota can be used to establish a representative baseline for evaluating biodiversity values and biosecurity risks across all biota and ecosystems. This research will support the improved detection of invasive species, prediction of biosecurity risk, and identification of phylogenetically distinct lineages of high biodiversity value. This approach will prioritise the characterisation of taxonomic groups associated with key productive and natural

ecosystems. The native organisms under study are taonga species and the workshop will include an acknowledgement of WAI 262 and development of a process by which relevant principles can be incorporated into the research plan. This discussion will be led by Programme 1 Kaihautū Phil Wilcox and this project will be dependent on work streams within Project 1.1. The Kāhui Māori will advise and assist with the workshop, including identifying appropriate kaitiaki and iwi representatives to be invited. The initial workshop may well reveal the need for further discussions before research can commence. Citizen science will also be an important component of this Project and a citizen science 'champion' will be included in the workshop.

Stakeholders

The workshop will be a relatively small, focused group, but it will include the Programme 1 Kaihautū as well as appropriate members from Māori communities with expertise in resource management and kaitiakitanga, and experience working with molecular scientists (to be invited by the Kāhui Māori and Kaihautū). Major government stakeholders to be included will be DOC and MPI.

Project 1.3 A national framework for biological heritage assessment across natural and productive landscapes

Executive summary

This project will develop a New Zealand-wide framework and platform for biological heritage measurement and monitoring using environmental DNA (eDNA) data. Existing biodiversity assessment initiatives have separated biosecurity and bio-protection and typically exclude the vast majority of New Zealand's biological heritage, such as fungi, microbes and invertebrates. This is despite the importance of these taxa for ecosystem function. Developing an eDNA framework and platform to measure and monitor biological heritage will allow surveillance of common, endangered, invasive and elusive species and underpin environmental reporting. The eDNA methods will be extended across New Zealand to provide accessible, robust and complete information on biological heritage at different temporal and spatial scales. Methodologies developed here will also contribute to other Projects within the Challenge, and vice versa.

Contribution to Mission, including intermediate outcome

To reverse the decline in New Zealand's biological heritage we require tools to detect incursions and changes in biodiversity and ecosystem function, in order to implement effective mitigation strategies and assess conservation performance. The integration of nationally-consistent eDNA methodologies with existing monitoring programmes will deliver a step change in biodiversity assessment.

Intermediate outcome: By year 5 biosecurity end-users will be using the eDNA platform developed here to detect and monitor incursions, and biodiversity end-users will be using this same platform to monitor state of the environmental and evaluate mitigation strategies.

Novelty and additionality

Currently, several eDNA pilot projects are operating, yet few of these are connected with each other or linked to traditional biological databases. Additionality will be achieved by developing standard methods and infrastructure to facilitate the integration of existing eDNA initiatives and traditional methods currently used to monitor the full spectrum of our biological heritage. Integrating across projects within this framework will facilitate a scaling up of the science questions and applications that can be addressed. Integration will occur across all biodiversity and productive landscape sectors, and across freshwater and terrestrial systems. These connections will make this project globally unique.

Vision Mātauranga

We will develop a case study to work with a single iwi in indigenous biodiversity management (e.g. Cultural Health Indicators (CHI)) for comparison with eDNA data. The eDNA informatics solutions will be designed with the multiple unique needs of Māori communities in mind, in addition to science needs and other stakeholders, as guided by the above case study. An outcome of the research will be to inform researchers of Māori methods of assessment (e.g. CHI), and benchmark potential contribution of CHI to eDNA. This will also improve researchers' understanding of Māori perspectives on genomics to more appropriately conduct research. This Project will also align closely with *Project 1.1 Mātauranga Māori characterisation of NZ's biodiversity*.

Project aim(s)

1. Standardise eDNA data collection and bioinformatics processes across research groups.
2. Establish national eDNA informatics platform for the measurement and monitoring of biological heritage across landscapes and for the detection of incursions.
3. Use eDNA data to address questions on ecological function, biosecurity and biodiversity conservation at the New Zealand-wide scale.

Key research question(s)

1. How does biological heritage scale spatially and temporally, and how does this scaling affect our ability to provide robust biodiversity information?
2. How is biological heritage changing over time, and how will it respond in the future?
3. How well do measures of diversity and function derived from eDNA correlate with traditional measures?
4. How correlated are the community attributes of freshwater systems and the terrestrial catchments they drain?
5. How widespread are invasive pests and diseases and how can eDNA contribute to early detection of new organisms?
6. How do we best extract ecosystem function information from eDNA data?

Risk (feasibility and achievability)

Science excellence will be ensured by strengthening and maintaining relevant international science connections in the eDNA area. The broad team we have assembled is committed to integrating methods in order to achieve the additionality. A barrier to uptake might be created by the regulatory and trade risks caused by the false-positive detection of unwanted organisms in eDNA. We will include a workstream to develop the science required to minimise these risks.

Management impact

There will be two principal impacts. First, there will be improved detection and measurement of incursions both at the border and post-border. Second, there will be improved measurement of biological heritage through broad taxonomic sampling. This second outcome will enable much more efficient assessment of end-user mitigation strategies.

Uptake potential

Through collective action by key stakeholders, our eDNA framework will be implemented throughout New Zealand. Environmental DNA methodologies will be embedded within existing monitoring programmes employed by DOC and regional councils. The project group includes representatives from DOC, MPI, MfE, EPA, and regional councils. Citizen science and outreach will contribute to this project through alignment to the Katoa network (http://katoa.ac.nz/). Integration with Katoa is advantageous, as it already involves nearly 100 high schools across the country in the use of eDNA to understand biodiversity. Culturally informed practices will improve scientists' effectiveness in positively engaging with iwi. Similarly, developing consistent assessment frameworks across natural and productive landscapes will assist Māori in cataloguing biological heritage and helping them understand what they have, and potentially complement Māori methods of assessment.

The team

The Project Leader will be **Dr Robbie Holdaway** (Landcare Research), and the team will include representatives from all institutions engaged in eDNA data collection and analysis. This includes both CRIs and universities. This team has all the expertise required for delivering on the goals of the Project and Challenge Mission, including molecular bioinformatics, data analysis, molecular biology, ecology, and environmental monitoring and reporting.

Major aligned research programmes

MBIE contestable-funded Smart Ideas – Phase 2 *Next-generation biodiversity assessment* project (Landcare Research), CRI core funding (Plant & Food Research, Scion, GNS, Landcare Research, NIWA, ESR), Bio-Protection Research CoRE, and university-funded projects (PBRF).

Potential research directions for Programme 1, Year 5 onwards

Platforms and models for biological heritage 'big data' analysis

The extraordinary increase in information from metagenomic analyses and real-time automated sensors will require new bioinformatic and modelling capacity for mapping, visualisation and forecasting if this information is to provide an effective platform for biodiversity and biosecurity management. We will begin developing this capacity from Year 5 on, taking advantage of the NeSI High Performance Computing Facilities for large-scale data analysis.

Next-generation technologies for moving from point to landscape and from species to function

Emerging technologies such as high-resolution remote sensing, acoustic monitoring, and intelligent detection cameras are already revolutionising the type, amount, and level of biodiversity information we can access. We can go further than this. If whole-genome data are connected with biophysical and functional information (such as nutrients, decomposition, water holding capacity), a mechanistic real-time analysis of total ecosystem functioning is within reach. From Year 5 we will start operationalising new advanced technologies to develop applications that will, for the first time, allow managers to see and respond to ecological pressures and threats as they happen.

Research Programme 2: Reducing risks and threats across landscapes *'Whakanoa mo ngā wero me ngā whakaaro witiwiti'*

Purpose and approach

This Programme combines innovative approaches for the identification and prioritisation of biosecurity risk; new tools for pest control and large-scale management; and improved citizen engagement with biosecurity. It will deliver step changes in biosecurity management and planning, and policy advice and responses for the benefit of all stakeholders.

There are four critical facets to protecting our biological heritage: (1) weeds, vertebrate and invertebrate pests and pathogens already threaten our biological viability, (2) the toll of exotic pests, weeds and pathogens will worsen through border incursions of new threats and post-border outbreaks of current sleeper pests, weeds and pathogens, (3) climate change, trade and tourism, and changed land and water use will create uncertainty as how to manage, and (4) existing toxin and biological control options will be under increasing pressure to conform to environmental and animal welfare regulations. The Programme therefore spans two complementary approaches. First, innovative risk assessment models will be used to predict, with high specificity and sensitivity, the impacts of invasive species threats on economic and cultural biological values (including taonga species). Biosecurity authorities will be able to prioritise their resources. Second, technologies will be developed for the cost-effective delivery of novel, highly-specific and highly-effective strategies for the management of pests. A 'best practice' social engagement and public information process that embraces Māori kaitiakitanga perspectives for New Zealand's biosecurity and biodiversity programmes will support this approach.

Additionalities will come from integrated multidisciplinary research. We have access to expertise from productive and natural systems sectors, addressing different targets (animal, aquatic, plant), and a range of stakeholders (MPI, DOC, etc.). We will link many scientific disciplines (social scientists, veterinarians, epidemiologists, economists, geographers, political scientists, information technologists) to ensure a more informed, consistent and strategic approach.

Table 8 provides an indicative research roadmap for Programme 2.

Table 8: Programme 2 – indicative research roadmap

Programme 2

Reducing risks and threats 'Whakanoa mo ngā wero me ngā whakaaro witiwiti'

Scaled-up detection, eradication, and control of pests across landscapes

Outcome: Prevent biosecurity invasions and mitigate damage to indigenous and managed ecosystems at landscape scale

KPI: Reduced rates of incursion/establishment and impacts of pests, diseases, and weeds of significance to natural and production ecosystems

Project 2.1

Biosecurity network interventions

Contribution to Mission: Entry and spread of pests, weeds, and pathogens into NZ is a major cause of the decline of key components of NZ's biological heritage, including the profitability of agricultural output, access to export markets, and the population viability of native and taonga species

Intermediate outcome: Biosecurity managers will use our next-generation, integrated risk assessment tools to predict post-border pathways, their impacts, and the optimal management for specific pests, weeds, and pathogens affecting production and natural ecosystems. Our quantitative systems approach will enable rapid, accurate assessment of economic and environmental risks of post-border invasion. It will improve targeting of pest surveillance, prioritisation, and management at multiple scales.

5-year outcome	10-year outcome
Biosecurity managers use next-generation, integrated risk assessment tools to predict post-border pathways and optimal management for specific pests, weeds, and pathogens affecting production and natural ecosystems	A quantitative systems approach enables rapid, accurate assessment of post-border invasion risks. This significantly improves the targeting of pest surveillance, prioritisation and management at multiple scales.

Project 2.2

Novel wasp control technologies

Contribution to Mission: By providing end-users with the tools (and deployment strategies) to control current insect pest issues, and to combat new incursions of unwanted insects, this project will help reverse the decline of native biodiversity through a national partnership that moves beyond the current status quo to involve the best researchers and end-users for the task across the country

Intermediate outcome: Socially acceptable, cost-effective, and targeted next-generation technologies, tools, and strategies will be in use at landscape-scale to control wasps in natural and production ecosystems to protect taonga species and minimise cost and risk to agricultural industries

5-year outcome	10-year outcome
Socially acceptable, cost-effective, and targeted next-generation technologies are piloted with the aim of mitigating the impact of wasps in natural/production ecosystems	Socially acceptable, cost-effective, and targeted next-generation technologies, tools, and strategies are in use at landscape-scale to control wasps in natural and production ecosystems to protect taonga species and minimise cost and risk to agricultural and horticultural industries

Project 2.3

Hi-tech solutions to invasive mammal pests

Contribution to Mission: By providing end-users with the tools (and deployment strategies) needed to eliminate small mammal pests across natural and production system through a national partnership that ensures all hurdles to application are recognised and addressed

Intermediate outcome: Production and conservation sectors, iwi, and communities have access to an array of improved tools, methodologies, and strategies for the improved surveillance and threat detection; intervention prioritisation; and eradication/control of small mammal pests

5-year outcome	10-year outcome
NZ production and conservation sectors, iwi, and communities have access to an array of improved tools, methodologies, and strategies for improved surveillance and threat detection, prioritising interventions and threat management, and widespread suppression/eradication of small mammal pests	Socially acceptable, cost-effective, and targeted next-generation technologies, tools and strategies are in use at landscape-scale to suppress and eradicate small mammal pests (possums, rodents, mustelids) and enable landscape-scale protection for native biodiversity and production ecosystems

Project 2.4

Māori solutions to biosecurity threats and incursions to taonga species

Contribution to Mission: Māori solutions to biosecurity threats and incursions to taonga species fundamentally integrates landscapes, mātauranga practices and knowledge to achieve biosecurity outcomes desired by both Māori and non-Māori. By providing *NZ's Biological Heritage* stakeholders with solutions and strategies for restoration and management of taonga species, we can help reverse the decline of our biological heritage. These solutions and strategies will draw from a full suite of interdisciplinary sources, including historical documentation, mātauranga Māori, and experimental science, to combat habitat degradation through an evidence-based approach. This is the only proposal that exclusively considers floral and faunal species of cultural and economic importance to Māori.

Intermediate outcome: To protect taonga species that are culturally and economically important to Māori, from biosecurity threats and incursions (pathogens, pests, and weeds) using a combination of contemporary science and mātauranga Māori

5-year outcome	10-year outcome

Case studies demonstrate how iwi and Māori organisational responses to biosecurity risks and threats can incorporate mātauranga approaches and culturally appropriate solutions, and protect taonga species	Iwi authorities lead regional and national responses and development of solutions to mitigate biosecurity risks/threats with local and central government agencies

Programme Leader

Philip Hulme – Lincoln University

Project 2.1 Biosecurity network interventions

Executive summary

A major biosecurity challenge is the effective containment and management of threats following their establishment in New Zealand. For many biosecurity threats it is recognised that human-assisted dispersal plays a critical role in their spread. There are considerable economic, environmental and social benefits to containing outbreaks and actively slowing pest spread before impacts can be fully realised and widespread management is required. We will bring together different perspectives in network modelling across multiple sectors (e.g. freight movement, nursery trade, livestock movement, recreational travel) in order to identify mitigation checkpoints to contain or slow pest spread.

Contribution to Mission, including intermediate outcome

The entry and spread of pests, weeds, and pathogens into New Zealand presents a major cause of the decline of key components of New Zealand's biological heritage including the profitability of agricultural output, access to export markets, and the population viability of native and taonga species.

Intermediate outcome: Biosecurity managers will use our next-generation, integrated risk assessment tools to predict post-border pathways, their impacts and the optimal management for specific pests, weeds and pathogens affecting productive and natural ecosystems. Our quantitative systems approach will enable rapid, accurate assessment of economic and environmental risks of post-border invasion. This will improve targeting of pest surveillance, prioritisation and management at multiple scales.

Novelty and additionality

Traditional network models have been developed to address New Zealand biosecurity issues such as bovine TB risk, transfer of pests via shipping and in forestry, highlighting the uptake and awareness of these approaches by end-users. However, existing tools are challenged by the 'big data' that better capture the size and complexity of national rather than regional and local networks. The novelty is a step change in the approach that will reduce complex spatiotemporal patterns to simple, homogeneous wave propagation patterns by replacing geographic distance with probabilistic motivated effective distance. The additionality is the choice of large, complex spatiotemporal networks (e.g. freight movement, nursery trade, livestock movement, recreation) to stretch our theoretical understanding and apply these concepts, for the first time, within a biosecurity perspective. We will advance knowledge using the state-of-the-art approach by integrating individual-based models within networks, as well as capturing economic incentives and constraints on network interventions.

Vision Mātauranga

We will work closely with members of the Māori agribusiness sectors, particularly the horticulture industry (e.g. Tāhuri Whenua National Māori Vegetable Growers Collective) and livestock movement (e.g. Parininihi ki Waitotara) networks, to identify vulnerabilities to pest spread and deliver outcomes of relevance to their operations. In recreation and kaitiaki networks, we will engage with trusts and rōpu to examine threats to taonga species in freshwater (e.g. Te Tiaki Mahinga Kai) and terrestrial (e.g. Kia Toitū He Kauri) environments to incorporate Māori principles and perspectives in modelling threats, including the incorporation of mātauranga Māori as early-warning indicators.

Project aim(s)

To develop and implement modelling tools for freight movement, nursery trade, livestock movement, and recreational travel networks to mitigate human-assisted pest spread. These tools will permit:

- Mapping out the generic patterns of likely introduction and spread in New Zealand

- Identification of critical points in networks to target cost-effective intervention and surveillance
- Increased traceability such that an outbreak could be traced back to the supplier or importer.

Key research question(s)

1. What are the attributes of different networks that facilitate invasive species spread and establishment?
2. Do networks span management boundaries such that a multi-stakeholder response is required?
3. How will network structure change over time and what are the consequences for biosecurity?
4. How can an understanding of networks help focus surveillance efforts and intervention strategies?

Risk (feasibility and achievability)

A key step in the Project initiative will be to engage with appropriate data providers regarding data access and confidentiality. However, we have had initial assurances from end-users that data are available and that they would facilitate access.

Management impact

End-users include MPI, DOC, OSPRI, and regional councils. Outputs will provide a robust framework for simulating likely scenarios following the incursion of exotic pests and assist them to target (a) surveillance activities by identifying important highly connected hubs/nodes and (b) control efforts by identifying hubs/nodes and bridges that, if removed from the network by movement restrictions and/or enhanced biosecurity, would limit human-assisted spread of pests. The Project ties closely to the NZ Biosecurity Science Strategy: 'We need a better understanding of the routes and mechanisms by which damaging pests and diseases can disperse within New Zealand, and how this relates to their epidemiology. Tools and methods to trace incursions back to pathways to learn from experience, and forward to better understand how pests and diseases spread, will be very valuable'.

Uptake potential

Several end-users are already familiar with the use of network models to predict risk and conceptually will understand the approach. The involvement of end-users early in the research, a necessary step for data collation, will facilitate regular interaction and feedback on progress. Surveillance and intervention scenarios will be tailored to end-user needs to facilitate uptake. An important citizen science component will be to characterise human movement along these networks, which will require engagement and data gathering through individuals involved in each network.

The team

The team will be led by **Professor Philip Hulme** (Lincoln University), and brings together high-profile university academics (including two FRSNZ) with senior CRI colleagues to integrate fundamental and applied aspects of applying network models in biosecurity across a range of threats. Links will be made to the Bio-Protection as well as Complexity (Te Pūnaha Matatini) CoREs and the Plant Biosecurity CRC.

Major aligned research programmes

The Better Border Biosecurity (B3) surveillance theme will apply our findings to develop knowledge and tools that ensure investment in surveillance provides optimal returns to New Zealand; Bio-Protection CoRE research on natural dispersal of pests will be informed by alternative perspectives arising from our network models.

Project 2.2 Novel wasp control technologies

Executive summary

Wasps are devastating pests that can reduce indigenous fauna by up to 80% in some forests. This Project will develop four state-of-the-art technologies to combat wasps: (1) The Trojan Female Technique is a novel twist on the SMT paradigm, utilising naturally occurring mitochondrial DNA (mtDNA) variation to introduce Trojan females (TFs) into wild populations where they will produce 'sterile male' equivalents across multiple generations, (2) Exploit key pheromones and semiochemicals that could either disrupt mating or act as lures to assist toxin delivery, (3) Such toxins face the challenge of wasp hygiene behaviour and a recently discovered mite on *Vespula* wasps in New Zealand will act as a model system to overcome hygiene

behaviour of social insects, which is a major barrier to delivering pathogens or toxins to nests), and (4) To develop a highly specific control RNAi method that is effective against wasps but has no effect on bees.

Contribution to Mission, including intermediate outcome

By providing end-users with the tools (and deployment strategies) needed to control current insect pest issues, and to combat new incursions of unwanted pest insects, this Project will help reverse the decline of native biodiversity through a national partnership that moves beyond the current status quo to involve the best researchers and end-users for the task across the country.

Intermediate outcome: Socially acceptable, cost-effective and targeted next-generation technologies, tools and strategies will be in use at landscape-scale to control wasps in natural and production ecosystems to protect taonga species and minimise cost and risk to agricultural industries.

Novelty and additionality

The Project recognises that novel technological developments carry the greatest opportunities for generating step changes in pest control. Novelty is delivered through a step change in research innovation, by driving globally-leading technologies such as RNAi and mtDNA mutations, through pathways to application to their in situ use to New Zealand's benefit. The additionality is derived from addressing a single major biosecurity issue in New Zealand from several different perspectives that bring together disparate research excellence spread across multiple institutions into a single, focused project. This will build a consortium of researchers and end-users to scope out new research directions and synergies, for the control of both wasps and other pest invertebrates in New Zealand.

Vision Mātauranga

Wasps are one of the greatest threats to biodiversity and of high relevance to Māori landowners and kaitiaki Māori. The Wasp Tactical Group (WTG) has identified the importance and central role of Māori in wasp management. We will consult iwi, hapū and whānau in relation to the social acceptability of the proposed new technologies, risks to non-target organisms, and the inclusion of mātauranga into possible solutions. We will also work with Te Herenga Māori Network, which brings together Māori resource and environmental managers, to consult on issues relevant to the Environmental Protection Authority. Māori will be engaged in social partnerships that include focal groups to identify the range of opinions across all stakeholders and large-scale surveys of the distribution and abundance of wasps.

Project aim(s)

Co-develop four new technologies for insect control (with appropriate tactical, strategic, and end-user considerations), using the common wasp (*Vespula vulgaris*) as a test species and assess the economic feasibility, social acceptability and practicality of each technology for large-scale deployment.

Key research question(s)

1. Can we develop novel genetic technologies (RNAi and mtDNA) to regulate wasp populations?
2. Can we use 'Trojan mites' to deliver pathogens into wasp nests?
3. Can we use smart dispensers to deliver pheromones or insecticides to wasps?
4. Can we develop wasp eradication strategies?

Risk (feasibility and achievability)

The novel technology components proposed all have achievable outcomes representing the essential next steps towards using them to make potential game-changing advances in wasp control with continuing development via pathways to application, and goals of in situ application within 10 years.

Management impact

Wasps are major pests in New Zealand, having large effects on ecosystems and iconic fauna probably because social insects were not present in the prehuman biota of the country. *Vespula* wasps stand out as the worst intractable pest problem in New Zealand, with massive impacts on indigenous biodiversity and parts of the productive sector, and being a public health and nuisance issue. New tools for wasp control are one of the top ten research priority areas for regional councils. The Department of Conservation supports the current Wasp Tactical Group (WTG), along with community groups, industry groups and regional councils, to whom this project will deliver. The Project ties closely to the NZ Biosecurity Science Strategy: 'Develop

more cost-effective, socially and culturally acceptable, and humane tools and techniques to control, contain and eradicate pests and diseases, where tools are limited. Develop pest and disease management tools that minimise impacts on other species, particularly on threatened and taonga species.'

Uptake potential

This Project will ensure uptake by (1) engaging all relevant stakeholders from an early stage (including the general public, Māori and industry) to ensure all potential hurdles to application are recognised and dealt with, (2) designing for usage across all sectors (from community groups, to industry bodies and regional councils, to central government and border protection), (3) raise awareness and engagement through comprehensive citizen science activities.

The team

This Project will be led by **Professor Phil Lester** (Victoria University of Wellington), and team members include representatives of the WTG, combined with other leading research teams in novel insect control technologies within New Zealand. All CRIs, universities, and the CoRE with wasp research teams are involved. The WTG has incorporated Vision Mātauranga by including iwi from the conceptual stage, and continues to maintain a close working relationship with tangata whenua.

Major aligned research programmes

It will leverage off current CRI core-funded projects on insect eradication, integrated pest management of pipfruit pests using semiochemicals; and integrated pest management for grapevine pests using semiochemicals; current MBIE Smart Ideas funding that address (a) Trojan Female Technique for pest management, and (b) annotation and transcriptomics of social insect genomes for novel insecticides; MPI Sustainable Farming Fund investigating the current impact of a newly discovered mite on wasps; and Marsden Fund identifying potential pathogens of wasps.

Project 2.3 Hi-tech solutions to invasive mammal pests

Executive summary

The ability to cost-effectively keep rats, stoats and possums at zero density will be transformational for New Zealand conservation. The ultimate outcome is to enable scaling-up of current efforts to landscape-scale pest freedom. This Project will accelerate the provision of improved tools, methodologies and strategies for mammal pest control in general and for local elimination in particular. They will be socially acceptable, cost-effective and targeted next-generation technologies that have been proven at pilot scale to effectively eliminate small mammal pests. A step change in research innovation will be achieved by identifying and making the advances necessary to achieve end-users' and stakeholders' desired outcomes from within the fields of 'lures/repellents', 'surveillance/detection/monitoring', 'improved toxins and devices', 'genetic-based tools' and 'landscape-scale strategy (the top five themes identified for progress in the 2012 Pest Summit).

Contribution to Mission, including intermediate outcome

This Project directly and immediately addresses the major decline in native biodiversity through consumption of native plants and animals by possums, rats, and stoats. It will provide the tools (and deployment strategies) needed to eliminate small mammal pests across natural and production systems through a national partnership that ensures all hurdles to application are recognised and addressed.

Intermediate outcome: Production and conservation sectors, iwi and communities have access to an array of improved tools, methodologies and strategies for the improved surveillance and threat detection; prioritising intervention prioritisation; and eradication/control of small mammal pests.

Novelty and additionality

The Project recognises that novel technological developments carry the greatest opportunities for generating step changes in pest control. Novelty is delivered through a step change in research innovation, by driving globally-leading technologies such as genome screening for pest-specific toxin receptor targets, through pathways to application to their in situ use to New Zealand's benefit. The additionality is derived from addressing a single major biosecurity issue in New Zealand from several different perspectives (the five themes noted above), bringing together disparate research excellence spread across multiple institutions into

a single, focused project. This will build a consortium of researchers and end-users to scope out new research directions and synergies, for the control of small mammal pests in New Zealand.

Vision Mātauranga

Māori have strong commitment to the protection of taonga, particularly iconic native birds and the holistic environments they are a part of. Taonga species are under serious threat from animal pests. We will seek technologies and strategies capable of reversing this trend that are not only effective but also satisfy kaitiaki requirements of humaneness that pest management has minimal physical, environmental and spiritual impacts on the wairua of ecosystems.

Project aim(s)

Widespread suppression and eradication of small mammal pests (possums, rodents, mustelids): (1) Novel tools and technologies for cost-effective, landscape-scale control, eradication and surveillance of small mammal pests (e.g. strategy and tools for remote wireless trapping/surveillance systems), (2) Designer lures to increase knockdown efficiency, (3) Tailoring specific lethal control agents (and advanced delivery systems) for priority small mammal /invertebrate pests and pathogens (e.g. via genome mining or molecular approaches for designer toxin receptor targets).

Key research question(s)

1. What are the current, emerging and on-the-horizon technologies nationally and internationally?
2. What are the end-user needs and pathways for novel technologies?
3. What are the new 'product specifications' needed to achieve stakeholder and end-user goals?
4. Are there social hurdles and how can they be overcome?
5. Can we identify synergies between current and developing technologies?

Risk (feasibility and achievability)

The novel-technology components proposed all have achievable outcomes representing the essential next steps to make potential game-changing advances in small mammal control with continuing development via pathways to application, and goals of in situ application within 10 years.

Management impact

One of the greatest threats to native flora and fauna in New Zealand is unarguably the predation and/or browsing impact of introduced small mammals, most notably possums, rats and stoats. Protection and restoration of our indigenous biological heritage is thus dependent on the management of these pests to low levels. In addition, the possum threatens livestock industries through its role as the wildlife reservoir generally responsible for the persistence of bovine tuberculosis. However, at present, much of the current toolbox for small mammal control is still based on technologies and strategies from last century. With the goal of facilitating the extension of small mammal control to the landscape-scale protection of this Project will build a 21st century toolbox that draws on the latest advances in engineering, physiology, ecology, genetics and sociology.

Uptake potential

This project will ensure uptake by (1) engaging all relevant stakeholders from an early stage (including the general public, Māori and industry) to ensure all potential hurdles to application are recognised and dealt with, (2) designing for usage across all sectors (from community groups, to industry bodies and regional councils, to central government and border protection), and (3) raising awareness and engagement through comprehensive citizen science activities.

The team

Development of new toxins, toxin delivery systems, advanced lures, close to real-time monitoring systems, and other novel technologies capable of meeting the requirements of the wide range of stakeholders involved presents a major scientific challenge. This project will be led by **Dr Dan Tompkins**, supported by a new collaborative research leadership team including a wide range of skills, including design, engineering, social science and VM, in addition to the conventionally applied disciplines of wildlife management and pest control.

Major aligned research programmes

Research will be aligned to ongoing projects on small mammal control funded through MBIE Smart Ideas Phase I, current MBIE-funded research mapped to the challenge, CRI core funding, TBfree New Zealand research, co-investment by SMEs and research being led by DOC, Zero Invasive Predators, and the Project Janszoon. A key aim will be to find the best possible balance between providing new tools for delivering continuous improvement within the current 'sustained pest control' paradigm, and the future goal of scaling up to landscape-scale pest elimination on the mainland.

Project 2.4 Māori responses to biosecurity threats (Patua riha rāwaho)

Contribution to Mission, including intermediate outcome

Māori solutions to biosecurity threats and incursions to taonga species fundamentally integrate landscapes, mātauranga practices and knowledge to achieve biosecurity outcomes desired by both Māori and non-Māori. By providing the *New Zealand's Biological Heritage* stakeholders with solutions and strategies for restoration and management of taonga species we can reverse the decline of our biological heritage. These solutions and strategies will draw from a full suite of interdisciplinary sources, including historical documentation, mātauranga Māori, and experimental science, to combat habitat degradation through an evidence-based approach. This is the only proposal that exclusively considers floral and faunal species of cultural and economic importance to Māori.

Intermediate outcome: To protect taonga species which are of culturally and economically important to Māori from biosecurity threats and incursions (pathogens, pests and weeds) using a combination of contemporary science and mātauranga Māori.

Key research question(s)

This proposal focuses on providing integrated solutions to protect our taonga species from biosecurity threats (both pre- and post-border). The key research question is: How do we incorporate mātauranga Māori with contemporary methods to improve pre border biosecurity risk assessment, surveillance of at risk species, and monitoring of plant health, to enable increased bio-protection of taonga species from invasive plants, insects and pathogens?

Proposed workshop

The goal of the workshop (2-day) is to prioritise and focus on 'at-risk' taonga species, as identified by Māori organisations (iwi, hapū, and whānau). Previous hui and discussions in the biosecurity space have prioritised the need for research into the landscape ecology and epidemiology of *Phytophthora* (including PTA); pre border threat of myrtle rust *Puccinia psidii*, to taonga Myrtaceae species (i.e. pōhutukawa); and underpinning knowledge to safeguard the Māori huakiwi (kiwifruit) economy from *Pseudomonas syringae* pv. *actinidiae* – (Psa-V). In addition to work on plant pathogens, this workshop will further focus on threats to taonga species from invasive plants and insect pests, as well as discussion on how to approach potential and known biosecurity issues affecting freshwater ecosystems. Specifically we will produce a list of taonga species considered 'under threat' from invasive plants, pests and diseases and develop a mitigation and protection strategy based on the integration of Māori knowledge with other technologies and knowledge streams.

Stakeholders

Protecting taonga species is a high priority for all Māori as well as a significant number of non-Māori (e.g. Let Kauri Live). There are already several iwi and end-user groups engaged in this space, including:

Key iwi: Ngāti Whātua ō Kaipara, Te Rarawa, Te Kawerau ā Maki, Ngāti Wai, Ngāti Hine, Tainui, Ngāti Rehua, Tūhoe, Ngāti Awa, Ngāi Tahu, Kahungunu and Waikato-Tainui, Maniapoto, Whakatōhea, Te Arawa, Ngā Kete o te Wānanga, Ngāi Tahu rūnaka

Key stakeholders: MPI, DOC, regional councils, Fish & Game, MfE, EPA, Tangata Whenua Forum of BOPRC

Other groups that have signalled their interest include Tirairaka o Ngāti Hine, Te Uri o te Ngāhere Trust, and the Māori Trustees.

Potential research directions for Programme 2, Year 5 onwards

Biosecurity intelligence and FutureWatch

Unprecedented events are by their very nature an existential threat to New Zealand biosecurity. As authorities will lack the practical experience that comes from responding to repeated threats, these pose major issues for the nation's preparedness. We will begin work in Year 5 scanning for global trends, and developing generic and ecosystem-specific scenarios as a basis for preparing for possible biosecurity futures.

New and spatially-dynamic management technologies

Retrospective analysis of past incursions with respect to landscape and connectivity will be used to build predictive models for the persistence and spread of different pest/pathogen types. Research on population dynamics, dispersal, Allee effects, thresholds for local population decline, persistence and rapid range expansion and how these factors interact with local landscapes will underpin these models. Order-of-magnitude increases in the scale of pest exclusion, containment and eradication will be feasible with this model guidance.

The Biosecurity Virtual Laboratory (BVL)

Agencies need to be able to explore 'what-if' questions about how changes in landscapes, activities and climate influence biotic threats and how management may respond. The BVL will provide modelling tools to provide richer '*in silico*' opportunities for understanding and forecasting biosecurity risks.

Research Programme 3: Enhancing and restoring resilient ecosystems *'He pūtaiao kaha ora tonu'*

Purpose and approach

Climate change, biotic invasions and land use intensification are placing pressure on our natural and production ecosystems, but our ability to predict and manage their impacts is weak. Healthy ecosystems are needed for biodiversity conservation and intensive primary production. To sustain healthy ecosystems, resilience to environmental change is needed, here defined as the capacity to absorb disturbance and maintain function. The resilience of many ecosystems has been reduced, inducing state-changes with ecological, economic and cultural loss from which recovery is difficult and costly. We aim to build resilience into New Zealand ecosystems: at multiple scales and where people live. Research will integrate across terrestrial and aquatic ecosystems, across natural and production landscapes, and will build in social and cultural resilience. Using a whole-of-system approach, we will determine how and when environmental change influences resilience and identify management to reinforce positive ecosystem restoration efforts.

Four complementary approaches are used. (1) Demonstration areas transcending disciplinary silos among biologists, social scientists, and modellers, with the aim of generalising results nationally. (2) Experimental manipulations to augment data aimed at quantifying interdependencies among ecosystems. (3) Social research to provide the foundation to transform practice, policies, institutions, and governance systems, and to examine how mātauranga Māori values are incorporated and applied by decision makers. (4) Models to permit quantitative predictions about resilience, to link up previously-disconnected components of ecosystems, and to enhance opportunities for collective critique (peer review), integration across traditional disciplinary boundaries, and synthesis. Combining these four approaches will provide stakeholders with the capacity to: (1) enhance resilience in high-value ecosystems that show signs of failure; (2) restore ecosystems that can be pulled back from a degraded state, and (3) sustain ecosystem services. *Table* 9 provides an indicative research roadmap for Programme 3.

Table 9: programme 3 – indicative research roadmap

Programme 3

Enhancing and restoring resilient ecosystems 'He pūtaiao kaha ora tonu'

A whole-of-system approach to sustaining resilient ecosystems through management at multiple spatial and temporal scales

Outcome: *Resilience to vulnerable ecosystems and is enhanced, preventing irreversible tipping points resulting from biotic invasion and biodiversity loss compounding stressors such as land-use intensification and climate change*

KPI: *National and regional strategies for sustaining resilient ecosystems are reducing rates of degradation/loss of significant biodiversity in natural and production ecosystems*

Project 3.1

Predicting and managing ecosystem tipping points

Contribution to Mission: Understanding the processes leading to rapid, self-reinforcing changes ('tipping points') in social–ecological systems will be used to develop a new framework for detecting, predicting, preventing, and where possible, reversing these declines in NZ's biological heritage

Intermediate outcome: Enhanced resilience of natural and production ecosystems to disturbances such as land-use intensification, ecosystem fragmentation, and climate change

5-year outcome	10-year outcome
Models that predict tipping points in testing phase to detect signals of impending critical transitions, and interdependent ecosystem components that buffer against these transitions Key environmental drivers for ecosystem restoration to enhance resilience are identified at large spatial scales and for at least one production and one natural ecosystem	Policy and operational agencies use new models to provide evidence-based predictions of ecosystem tipping points Regulators and land managers understand how tipping points occur, can identify vulnerable ecosystems, and develop critical actions to reverse ecosystem degradation

Project 3.2

Customary approaches and practices for optimising cultural and ecological resilience

Contribution to Mission: This research will improve how the management of species and ecosystems is prioritised, and deliver new methodologies and legal frameworks that enhance population and ecological resilience in the face of emerging pressures. Co-production of knowledge and multi-evidence-based approaches will provide a step change in the way people perceive, understand, and form responses to protect and manage New Zealand's biological heritage, an endeavour that sits at the heart of the Challenge Mission.

Intermediate outcome: Embedding of a human element within NZ's approach to biodiversity protection, including new governance models, will be routine in National Resources Sector and other strategic policy documents

5-year outcome	10-year outcome
Natural resource decision makers are testing new models to assess how customary practices influence ecosystem and social resilience in the face of ecological stressors	Iwi and Crown authorities adopt customary strategies to co-manage natural resources, and build both social and ecosystem resilience

Project 3.3

Enhanced biodiversity and ecosystem services in working landscapes

Contribution to Mission: Enhancing a full suite of ecosystem services (i.e. benefits to people) from native biodiversity within production landscapes is important to policy design and choice of interventions. Without this research, native biodiversity will continue to decline across much of the NZ land area.

Intermediate outcome: Quantitative tools can evaluate the socio-ecological benefits of strategies to optimise ecosystem services

5-year outcome	10-year outcome
Land owners have new tools to identify threat management interventions that ensure resilience of terrestrial and aquatic biodiversity Demonstration projects will compare the benefits of different spatial landscape arrangements and management interventions on the delivery of key ecosystem services	National and regional strategies for sustaining ecosystem services are reducing rates of degradation/loss of significant biodiversity in natural and production ecosystems Land managers (e.g. farmers, iwi, local/regional authorities etc.) are using spatially explicit, national-scale models to evaluate future scenarios for delivery of ecosystem services, and make informed decisions about which ecosystem components they are prepared to trade off as losses and gains

Project 3.4

Interdependencies within and between ecosystems

Contribution to Mission: Demonstrating the flow of organisms (with both positive and negative effects) within and among the estimated 2 million ha of remnant natural ecosystems embedded within the 14 million ha of production systems will be viewed increasingly as critical to the ongoing success of industry and well-being of the community.

Intermediate outcome: Land managers have new tools to assess the non-target impacts of weed, pest, and pathogen management interventions (from Programme 2), and optimise interdependencies at natural–production sector boundaries

5-year outcome	10-year outcome

Land managers can quantify the role of organism flows in reducing resilience at the natural–production ecosystem boundary, and the influence of remnant native ecosystems on primary production, soil physical properties, water quality, and pollination	Businesses can quantify the ecological impacts of their products and maintain access to high-value offshore markets Land managers are implementing solutions for managing the natural–production sector interface, tailored specifically to NZ conditions Local government and land managers can make informed decisions about management when there is conflict regarding native biodiversity

Programme Leader

Andrea Byrom – Landcare Research

Project 3.1: Predicting and managing ecosystem tipping points

Executive summary

Natural and production ecosystems face continuous challenges that threaten their integrity and value. Indeed, environmental changes can drive ecosystems into alternative, self-reinforcing states. These 'tipping points' (or 'catastrophic regime shifts') are often unpredictable. Also, although the physical and biological components are well understood, these are also affected by social conditions such as management/policy decisions, customary practices, resource use, and anthropogenic changes to the environment. Thus, coupled social–ecological systems have become a focal point for understanding the causes and effects of tipping points, and their relationship with the provision of ecosystem services.

Even if tipping points can be anticipated, there are few actions that could be recommended currently to restore the system and reverse the shift, even though tangible recommendations are much needed by natural resource managers and the production sector. The mechanisms and pathways for restoring an ecosystem by moving it towards a self-reinforcing 'desirable' state remain unclear for many systems. Previous attempts have focused on system-specific research rather than the development of general principles that could be widely applied. This project aims to do just that.

Contribution to Mission, including intermediate outcome

Understanding of the processes leading to rapid, self-reinforcing changes ('tipping points') in social–ecological systems will be used to develop a new framework for detecting, predicting, preventing, and where possible reversing these declines in New Zealand's biological heritage.

Intermediate outcome: Enhanced resilience of natural and production ecosystems to disturbances such as land-use intensification, fragmentation and climate change.

Novelty and additionality

The *novelty* in this project will be provided by the overarching modelling framework, which is a new (and generally applicable) approach to understanding social–ecological systems, characterising early-warning signals, and delivering on such insights at multiple spatial scales and across natural and production systems.

The step change (*additionality*) in this project will be the integration of ecological, cultural, social, and economic drivers, and its application to natural, production, and freshwater ecosystems at multiple scales.

Vision Mātauranga

In order to ensure that we have full iwi/hapū/whānau engagement in the projects, and because published material on Māori relevance of tipping points is not available for synthesis via workshops, we will use a parallel sub-project to develop a Māori-centred methodology and research model (He korowai mātauranga) that wraps around the project. This will ensure full utilisation of mātauranga Māori aspects across the 'tipping points' research. It is envisaged that this sub-project will begin early in Year 1 so that a model of best practice (mātauranga Māori) can be incorporated within the wider project. This sub-project will ensure that all aspects of the project will meet the needs and aspirations of specific iwi (relative to the planned research geographic areas); ensures a research partnership that utilises both mātauranga-a-iwi and non-Māori knowledge frameworks for mutually beneficial outcomes; and ensures the mana whenua kaitiaki responsibilities are fully realised.

Project aim(s)

To provide the knowledge necessary to predict and prevent the approach of rapid, difficult-to-reverse changes (tipping points) in social–ecological systems, and to remove barriers to restoration of altered ecosystems, under current and future environmental conditions.

Key research question(s)

We will synthesise knowledge, including mātauranga-a-iwi, to derive cross-system generalities and answers to the following questions: (1) Which stressors are important across different systems for driving tipping points? (2) Which ecosystems show tipping points versus gradual change? (3) Within each ecosystem, what early warning of impending regime shifts could be detected by monitoring programmes?

Second, we will use the syntheses in a modelling framework, combined with case studies, to answer the following questions: Are the same variables (e.g. connectedness of agents) important for controlling tipping points in both social and ecological systems? In highly-connected social–ecological systems, can social groups be monitored for early-warning signals? At what scales do stressors driving tipping points occur, and are management interventions feasible at the appropriate scales? How can we identify individuals who, via their social connections, are likely to spread the uptake of new approaches that positively or negatively impact landscape structure and environmental outcomes?

Risk (feasibility and achievability)

There is a risk that data will not be available for synthesis into the overarching framework. We have mitigated against this risk by putting together a comprehensive project team, which brings a substantial body of existing data to the project. Moreover, case studies like the DOC/Fonterra Living Waters partnership have clear examples of tipping points (in that example, non-regenerating native forest remnants), caused by past human activities (altering flooding regimes via a stop bank and introducing *Tradescantia*). In such examples, there are several options for management to reverse the shift, and there are social factors associated with the potential success of these options (e.g. farmer behaviour, including fencing, and movement of the stop bank). A second risk is that, while the concept of 'tipping points' is conceptually easy to understand, the problem is regarded as being too complex to solve. We have mitigated against this risk by building experienced social researchers into the project team, who bring a wide range of established stakeholder collaborations.

Management impact

Presently, methods for achieving the elusive goal of managing for tipping points in land and water ecosystems are unavailable. Clear recommendations are needed to guide optimal management. This project will provide such fundamental recommendations to a wide variety of stakeholders including iwi. Working closely with project teams collecting primary data as part of Programme 1, the team will deliver joint protocols for monitoring and assessment, work closely with partners to inform on restoration activities including for post-Treaty settlements and co-governance arrangements, and help determine 'bottom lines' for protecting significant natural values.

Uptake potential

We will use the Natural Resources Sector as one focal point for adoption and uptake of the research findings. Through the End-user Advisory Panel for the Challenge, we will also broaden and deepen linkages with the primary sector including Beef + Lamb NZ and OSPRI/TBfree New Zealand (whose wider remit now includes conservation goals). The Dairy Sector also has a keen interest in this project: at the time of writing we are working to understand their needs. One obvious example is likely to be avoiding degradation of soil in high-intensity dairy systems, and remediating soils where productivity has already declined. The team will work alongside both the NRS and the Primary Sector in order to to ensure that research findings are written into natural resource policy and adopted by industry.

The team

The research team has been assembled with the complexity of both the biophysical and social–ecological nature of 'tipping points' in mind. **Professor Jason Tylianakis** (University of Canterbury) will lead the team.

Major aligned research programmes

'Cumulative effects' MBIE programme (NIWA); 'Restoring wetland ecosystem functioning' MBIE programme (Landcare Research); Aquatic rehabilitation programme (NIWA); Core funding in 'Managing Invasives' and 'Enhancing Biodiversity' portfolios (Landcare Research); Core funding in 'Sustainable flows' programme (NIWA); DOC/Fonterra Living Water initiatives (potential initial focus on Hikurangi catchment (Northland)). Through aligned projects, the team works with a wide range of stakeholders including DOC, regional councils and unitary authorities, MfE, MPI, Fish & Game, commercial companies, numerous iwi, community, and restoration trusts, and the QEII National Trust, at a range of scales from local to national.

Project 3.2: Customary approaches and practices for optimising cultural and ecological resilience

Executive summary

Human activities worldwide have caused unprecedented declines in biodiversity and associated ecosystem services, particularly in the past 60 years. In response to this global biodiversity crisis, greater emphasis has been placed on engaging indigenous and local knowledge systems to inform responses for sustaining or restoring biodiversity. In many instances, these relationships are characterised by harvest or use, with contact between the user, the harvested species and its environment guided by customary values, cosmologies, approaches, practices and ethics.

Māori maintain a strong environmental guardianship ethic (kaitiakitanga) integral to their relationship with terrestrial, freshwater, and marine resources. The vision for this project is to understand how Māori customary approaches and practices influence and interact with plant and animal populations and ecosystem composition and processes. Integral to engaging Māori customary approaches and practices will be an appreciation of the cross-cultural legal and societal institutions required to implement these culturally-based interventions and restore ecosystem and whānau health and function.

Contribution to Mission, including intermediate outcome

Our research will innovate the governance and management of New Zealand's biodiversity using Māori customary methodologies within adaptive legal frameworks and greater societal understanding and acceptance. Insights into the mechanics of how customary approaches and practices function will enhance ecosystem resilience in the face of emerging new environmental and climatic pressures. Co-production of knowledge and multi-evidence based approaches will provide a step change in the way Māori communities, local and central government, and wider society prioritise, understand and deliver strategies for protecting and restoring our biological heritage. Pivotal to our research ethos will be the fundamental role the human element plays within the ecosystem.

Intermediate outcome: New Zealand's biodiversity is protected, restored and used through the implementation of Māori customary environmental approaches and practices.

Novelty and additionality

The *novelty* in this project lies in predicting how different biotic and abiotic conditions will alter both ecological and cultural outcomes achieved by implementing various customary approaches.

The *additionality* in this project is captured by the unique blend of skill sets in the project team, including biophysical, social, legal, and mātauranga production of knowledge that will be provided by researchers, iwi and stakeholders from a wide range of organisations in New Zealand.

Vision Mātauranga

This project is the 'flagship' VM project in Programme 3, and mātauranga approaches are embedded throughout.

Project aim(s)

1. Identification of customary approaches and practices used by Māori and the current cultural, ecological, legal, political and socio-economic conditions under which they are implemented.
2. Understanding of the influence of customary approaches and practices on demographic processes of focal populations and subsequent flow-on effects to ecosystems.

3. Assessment of the effectiveness of customary approaches and practices in protecting and/or restoring populations or ecosystems.
4. Understanding Māori and non-Māori attitudes to engaging customary approaches and practices for protection and management of New Zealand's biological heritage.

Key research question(s)

There is a risk that kaitiakitanga-based approaches and practices, which may include harvest, will not be adopted due to uncertainty within Māoridom and wider society about how these cultural mechanisms function, and what effect they might have on biodiversity and species survival in a dramatically altered ecological, cultural and social environment. Understanding the drivers of Māori, public and institutional member attitudes towards customary practices allows for the development of effective policy to overcome this risk. Our proposed approach will provide a system of cross-checking of information and mechanism for uptake.

Risk (feasibility and achievability)

There is a risk that kaitiakitanga-based approaches and practices, which may include harvest, will not be adopted due to uncertainty within Māoridom and wider society about how these cultural mechanisms function, and what effect they might have on biodiversity and species survival in a dramatically altered ecological, cultural and social environment. Understanding the drivers of Māori, public and institutional member attitudes towards customary practices allows for the development of effective policy to overcome this risk. Our proposed approach will provide a system of cross-checking of information and mechanism for uptake.

Management impact

Historical factors (e.g. colonialisation process) have constrained opportunities and influenced the capacity of Māori to contribute to biodiversity conservation and protection in New Zealand. The settlement of Treaty of Waitangi claims, however, has provided the political and legal platform for iwi to gain increasing autonomy over their lands. Whānau, hapū and iwi will therefore have a lead role in defining, measuring, and forming culturally appropriate solutions to New Zealand's biodiversity crisis.

Uptake potential

Initial workshops with iwi and relevant sections within DOC, MPI, MfE, and regional councils will be used to present concepts and potential case studies and gauge levels of interest and potential contributions that these agencies might make to the project. Continual engagement with iwi and central and local government will facilitate the uptake of findings within pre- and post-Treaty Settlement environmental policy and planning. These processes will provide mechanisms for implementing our results and facilitating outcomes, for example by making key recommendations to manage protected areas.

The team

This team was put together to cover the range of biophysical, social, legal, and cultural research approaches required to address the research questions. Key researchers, iwi, and stakeholders provide the blend of skills required to deliver both science excellence and a clear pathway to adoption, in order to deliver on the Challenge Mission. Key iwi: participating iwi will be identified through current relationships, a hui-a-tau consultation process, and a process of scoping the applicability of potential case studies. Key stakeholders: DOC, regional councils, MPI, MfE, Ngā Whenua Rāhui. The lead researcher, **Dr Phil Lyver**, has a strong track record of collaboration with iwi.

Major aligned research programmes

Ngā Pae o Māramatanga Centre of Research Excellence (University of Auckland); Core funding in the 'Enhancing Biodiversity' portfolio (LCR).

Project 3.3: Enhanced biodiversity and ecosystem services in working landscapes

Contribution to the Mission

Working lands comprise two thirds of the New Zealand land area so to effectively meet our vision for reversing the decline of native biodiversity we will require concerted efforts to maintain, enhance and restore

native biodiversity across working landscapes. Demonstrating the flow of the full suite of ecosystem services (i.e. benefits to people) from native biodiversity within these landscapes is important to policy design, choice of interventions and to demonstrate the importance of native biodiversity to the 57,000+ individual landowners/managers whose collective actions will make the real difference. Without this research, native biodiversity will continue to decline across much of the New Zealand land area.

Objective

To enhance native biodiversity and the ecosystem services that result from this in terrestrial and freshwater ecosystems across working landscapes through application by stakeholders of targeted multipurpose management interventions.

Research question(s)

This proposal focuses on the use of management interventions to enhance native biodiversity and the ecosystem services that result from this. The key research question is: how do we design policy, choose effective interventions and achieve implementation to reverse the decline of native biodiversity and enhance the flow of ecosystem services that arise from native biodiversity within working landscapes, and demonstrate the success of these interventions?

Proposed workshop

The goal of the first workshop (two days) is to collate what is already known about native biodiversity in working landscapes (especially patterns of biodiversity distribution and the types of species present), the range of ecosystem services that are derived from this biodiversity (including key indicators/measures of ecosystem services that can be used to quantify these), and management interventions that are available to help sustain native biodiversity (i.e. interventions aimed at mitigating threats to native biodiversity and the ecosystem services it delivers). Specifically we will develop frameworks for quantifying these factors across different types of working landscapes, with the results of the review written up for publication.

The workshop will include key stakeholders to foster active collaboration and ensure that the choice of management intervention(s) and indicators are relevant for their needs. The workshop will also consider criteria for selecting experimental site(s) and an initial short-listing of candidate site(s) will be developed to enable us to focus in on case studies to experimentally quantify the ecosystem services that native biodiversity provides at the scale of a farm, catchment, or region.

Stakeholders

The issue of sustaining native biodiversity in working landscapes is a key issue for district and regional councils, and increasingly for primary producer sector groups and corporates (e.g. Beef + Lamb, DairyNZ, Foundation for Arable Research, Horticulture™ NZ, Fonterra, Zespri) including farmer groups such as Federated Farmers. We will work closely with these groups. MfE, DOC, and QEII National Trust also have strong interests in this area, as do various environmental NGOs (e.g. Forest & Bird, Fish & Game, WWF) and we will also work closely with them. In addition to involving Māori researchers in the project, iwi will be consulted as key stakeholders/end-users.

Project 3.4: Interdependencies within and between ecosystems

Contribution to the Mission

The estimated 2 million ha of remnant natural ecosystems embedded within the 14 million ha of production systems will be view increasingly as critical to the ongoing success of industry and well-being of the community. The spillover will be an acceleration in biodiversity gains and a decline in pest outbreaks throughout the country.

Objective

Improved biodiversity and resilience of ecosystems at the natural–productive landscape interface.

Research question(s)

Neighbouring land-use and quality (or more generally, context) is often thought to affect the resistance and resilience of a system through interconnections. However, the conceptual basis and information knowledge on when and where these interrelationships between systems occur, or have a meaningful impact, is poorly

characterised for many New Zealand systems. This project develops the conceptual basis, and empirical tests, for understanding when and where interdependencies among ecosystems contribute to their (1) resistance and resilience against disturbance; and (2) to the provision of key ecosystem services such as pest control and pollination.

Proposed workshop

The first goal of the workshop (two days) will be to collate what is already known about independencies within and between ecosystems and will include the following (1) describe and provide an indication of the size and extent of the potential range of ecosystems of interest including existing native ecosystems (e.g. native forest, wetlands, shrublands, etc.) and production systems (e.g. planted forest, pasture or horticulture) (2) list and describe the range of independencies (including critical) within and between ecosystems, approaches for quantifying these independencies and their possible importance, (3) identify any links between biodiversity (species richness) and condition of native and the adjoining ecosystem and the flow of organisms and (4) list the influence of current management practices and potential interventions that are available to alter the flow of organisms between ecosystems.

Stakeholders

There is growing interest in two key concepts amongst our stakeholders: (1) as managers, they do not manage natural resources in isolation, so their actions relate to a wider landscape context; and therefore (2) in order to manage resources more effectively, managers need to understand how adjacent land uses may influence ecosystem productivity and function in 'their' patch. In this project, we have had extensive input by Pipfruit NZ, the QEII National Trust, and Beef + Lamb New Zealand.

With the wider project team we intend to bring an extensive stakeholder network to the table: possibly unprecedented in New Zealand. We framed our project around the issues our stakeholders are currently grappling with, such as: (1) How do attributes of the donor and receiving environments influence the flow of organisms between adjacent land uses, and alter the resistance or invasibility or particular land use types? (2) What are the spatial scale over which these flows occur, and the types of edges that facilitate or resist beneficial and detrimental movements?

Potential research directions for Programme 3, Year 5 onwards

Breaking feedbacks that reinforce state changes in degraded ecosystems

Degraded ecosystems are difficult to restore. Pressures that drove degradation (e.g. nutrient load to a lake, invasive predators, or altered soil hydrology due to loss of vegetation cover) need to be reduced to well below the level that caused degradation before ecosystems can improve. This Project will be designed to break feedback cycles that maintain undesirable states, by using keystone species, communities and ecosystem processes as indicators.

People and ecosystem services

To 'close the loop' on the provisioning, regulating and supporting services we identify in *Projects 3.2* (*Customary approaches and practices for optimising cultural and ecological resilience*) and *3.3* (*Enhanced biodiversity and ecosystem services in working landscapes*), we will link back to community well-being and livelihoods by explicitly measuring a range of cultural ecosystem services identified as important for both Māori and Pākehā (e.g. spiritual values and knowledge systems, 'green credentials' for the production sector). Social research methods will be used to quantify changes in awareness. The ultimate aim will be to enhance social–ecological resilience for communities with connection to production system resources.

Connectivity as a driver of ecosystem resilience

The rates at which organisms and nutrients move among ecosystems vary with connectivity. Land–water ecotones (e.g. riparian zones, wetlands) are dynamic environments; and native terrestrial ecosystems frequently exchange mobile species. However, human-imposed boundaries (e.g. property boundaries, land-use contrasts) are now superimposed upon this connectivity. Boundaries can enhance connectivity for some

taxa while preventing the passage of others. We will determine how to enhance the resilience of adjacent ecosystems by building refuges, manipulating connectivity, and constructing meta-communities while minimising loss of primary production and spread of invasives.

Part Three: Business Plan

3.1 Introduction

The governance and management arrangements for the *New Zealand's Biological Heritage* Challenge aim to ensure the Challenge can deliver additionality (*Section 1.1 10-year Research Plan*) in several functional areas:

- **Research impact** – by 'scaling up' mission-critical research; incentivising 'best teams' and interdisciplinary collaborations; and novel mechanisms to drive science excellence (*Section 1.1 10-year Research Plan)*
- **Strategic alignment** – via clearer articulation of outcomes and impacts; targeting resources to strategic priorities; more systematic coordination of research effort via planning and review processes; and enhanced cost-effectiveness via shared services/infrastructure (*Section 1.2 The research landscape* and *Section 1.4 Research portfolio and quality)*
- **Adoption/user impact** – by 'embedding' end-users in the Challenge to test prototypes and new approaches; enhance pathways to adoption; provide real-time feedback loops to measure Challenge impacts, and communicate Challenge outcomes to the wider community (*Section 1.6 Impact*)
- **Research career pathways** – by growing our top talent via targeted early-career, postgraduate and practitioner programmes; supporting Māori research capability; and capitalising on the Challenge's scale and opportunities to attract/retain top-flight researchers *(Section 1.3 Research teams and skills* and *1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement)*
- **Public engagement with science** – by embedding significant strands of public outreach, education, communication and citizen science in the Challenge (*Section 1.7 Open data* and *Section 1.9 Related activities – public outreach, communication, and education activities)*

Our proposed design for the Challenge also gives due recognition to its defining features:

- **The Challenge has a broad scope and scale** – almost all national research providers and a large number of productive, conservation, Māori and natural resource sector agencies have an interest in the Challenge. It is the second largest Challenge in terms of mapped funding.
- **It has special relevance and interest to Māori.** As a Treaty partner and co-generators of knowledge, Māori can contribute to the Challenge in multiple ways, i.e. through Vision Mātauranga approaches and considering implications of the WAI 262 report on indigenous knowledge (*Section 1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement).*
- **High public interest in the Challenge**, as shown in the *Great NZ Science Project*. Outreach, communication, and engagement will be integral to the Challenge's success *(Section 1.9 Related activities – public outreach, communication, and education activities)*
- **Stakeholders have a key role:** We are committed to meaningfully involving key stakeholders and Māori in the Challenge design and implementation to improve societal engagement, and 'licence to operate' for Challenge outputs (e.g. new technologies) (*Section 3.3 Investment strategy and prioritisation* and *Section 3.8 Advisory groups).*

3.2 Design principles

The objectives of the proposed governance and management arrangements are to:

- Minimise new structures/complexity (workability/cost-effectiveness)
- Reflect co-funder, end-user, Māori and other stakeholder interests (inclusiveness)
- Ensure contestability of advice and avoid capture (checks and balances)
- Enable the involvement of new agencies/stakeholders (dynamism/level playing field)
- Incentivise excellence and facilitate innovation (contestability of ideas)

- Ensure decision making at the right level (appropriate delegation).

Other principles – additionality, cost-effectiveness, and 'getting it right' – are worth further clarification.

Additionality

A key characteristic of the Challenge influencing its design is the proportionally large ($200m+) 'aligned' investment from co-funding compared with the Challenge Funding Envelope ($63.7m) (*Figure 3*). The Challenge Funding Envelope can be used to increase the effectiveness of aligned research and catalyse any desired change in its focus. This potential to leverage the Challenge Funding Envelope to deliver more effectively on the Challenge Mission is a key additionality from the Challenge. In other words, the Challenge's overall success rests on the interaction and alignment between the two funding envelopes (*Section 1.1 10-year Research Plan*). Accordingly, the governance and management arrangements must enable 'active management' of the Challenge Funding Envelope and 'direction' for the aligned research. This will require regular engagement across agencies. If the national research effort related to this Challenge is to operate optimally, without duplication, then the governance must facilitate an effective overview of research effort across the country.

Cost-effectiveness

The proposed design aims to be cost-effective and pragmatic, making use of members of existing panels and self-funded advisory groups, and sharing back-office support. That said, the Challenge is a new, larger-scale collaboration than previously, with high complexity and a large set of collaborators. This will add to costs. In time, the Challenge may reach $25m p.a. in research and related activity, so scale is a critical consideration in how we govern and manage it.

'Getting it right' (Challenge phasing plan)

To date, this Challenge has proceeded in three phases. Three further phases are planned.

Phase 1: Proposal phase (mid-2013 – April 2014)

During this Proposal Phase, the Challenge built on a platform co-sponsored by Landcare Research and Plant & Food Research. The development process included key steps to build a collaborative culture to underpin subsequent implementation and delivery of the Challenge:

- **Researchers *and* end-users worked together to design the Challenge**. As the national leaders for biosecurity and biodiversity, MPI and DOC helped ensure the Challenge will deliver on both *science* and *societal* goals. Three Māori scientists/managers from Landcare Research, Plant & Food Research, and Lincoln University helped embed VM concepts and interests in the proposal.
- **A Facilitation Group**, comprising researchers from CRIs, universities, and independent providers, and across relevant disciplines, enabled researchers to contribute to research priorities and peer review research stretch at early stages of the proposal development
- **We engaged with a wide set of stakeholders** through a series of workshops and a Stakeholder Reference Panel to understand the research landscape and strategic policy, management, and operational context in which the Challenge will operate. As an early signal of transparency, we provided online updates (http://www.biologicalheritage.nz/home). One outcome was the establishment of the End-user Advisory Panel, linking for the first time end-users with an interest in both production and natural ecosystems.
- **We ran a series of hui and consulted Māori researchers and authorities directly** about the research and business plans to integrate Māori perspectives into the Challenge. This included establishing the Kāhui Māori to effectively represent the Challenge partnership with Māori.

Phase 2: Start-up Phase (1 October 2014 – 9 April 2015)

The Start-up Phase has focused on establishing partnerships and collaborations among Challenge Partners; deciding on systems and processes; finalising strategy; clarifying impacts and expected outcomes and confirming prioritisation and investment mechanisms; and embedding the new cultural approach. We have progressed work on aligning research from all Challenge Parties to the Challenge Programmes. During this Start-up Phase the Challenge aimed to build effective and enduring structures and processes.

In the Start-up Phase, researchers and stakeholders from all Challenge Parties developed Project briefs within each of the three Programmes. Three Projects *(Project 1.3 A national framework for biological heritage assessment across natural and production landscapes*; *Project 2.1 Biosecurity network interventions* and *Project 2.2 Novel wasp control technologies*) have so far met the criteria developed by the EAP and Kāhui Māori. These were assessed to deliver on the key parameters in the *Investment Strategy* (*Section 3.3 Investment strategy and prioritisation*), and have received formal approval from the Governance Group. These are now termed 'lead-off' Projects. Further details of prioritisation processes are outlined in *Section 1.4 Research portfolio and quality*. These lead-off Projects will now proceed to Phase 3 (Contracting Phase; see below). A further four Projects were sent back to the researchers to address specific points raised by the EAP, Kāhui Māori, and Governance Group (see Phase 4).

Finally, during the Start-up Phase we have refined the Research Plan and Business Plan (this document), which addresses the requirements of MBIE and the Science Board set out in a letter to the Challenge Contractor on 4 August 2014.

Phase 3: Contracting the three Start-up Projects (9 April – 30 June 2015)

The first set of three lead-off Projects will now proceed to formal contracting stage during this three-month period.

Phase 4: Refinement and contracting of further Start-up Projects (1 July – 30 December 2015)

The aim in this Phase is to take further Projects (*Project 1.1 Mātauranga Māori characterisation of NZ's biodiversity; Project 2.3 Hi-tech solutions to invasive mammal pests; Project 3.1 Predicting and managing ecosystem tipping points*; *Project 3.2 Customary approaches and practices for optimising cultural and ecological resilience*) to contracting phase. This will entail getting them to the same standard as the three lead-off Projects. All seven Projects in Phases 3 and 4 are presented in 2-page outlines in the *Research Plan*.

During this Phase we will also hold a series of workshops for Year 2 Projects (*Project 1.2 Genetic characterisation of NZ's terrestrial and freshwater biota*; *Project 2.4 Māori solutions to biosecurity threats*; *Project 3.3 Enhanced biodiversity and ecosystem services in working landscapes*; *Project 3.4 Interdependencies within and between ecosystems; Table 6*) with the aim of getting the best national teams working on these Projects, supported by international experts to further scope the research activities proposed. These are presented as 1-page outlines in the *Research Plan*, highlighting the scope of proposed workshops.

Phase 5: First Challenge Funding Envelope (1 July 2015 – 30 June 2019)

In this Phase we envisage that new Project phasing will occur following the processes outlined in Phases 2–4 above.

Overall, these five Phases summarise activity to date (Phases 1–3) or activity that is imminent (Phases 4 and 5). As other Challenges develop research plans we will work with them to identify and implement mutually beneficial collaborative projects and activities (*Section 1.2 The research landscape*). Phases 1–5 will complete the first Challenge Funding Envelope.

Phase 6 will be the second Challenge Funding Envelope (1 July 2019 to 30 June 2024):

We have not scoped any detail for research directions in Phase 6 at this stage.

3.3 Investment strategy and prioritisation

Key parameters

The investment strategy for allocating Challenge Envelope funding is based on the following key parameters:

- **Mission-led** – all Challenge projects must set out explicitly the intended contribution to the Challenge Mission, including the likely pathway for these contributions to be realised. In practice, this will require a 'line-of-sight' from each project to the Challenge Mission.
- **Focused on outcomes** – the intended contributions to the Challenge Mission need to be expressed objectively, in terms of science impacts for the respective Challenge Programme, and aligned to intermediate outcomes for the Challenge as a whole. This will require a focus on knowledge exchange and transfer with end-users, as part of the design and delivery of each Project.
- **Additionality** – Challenge Projects need to deliver additionality, i.e. impacts that are materially greater (and more valuable) than those that would be achieved in the absence of the Challenge (and the additional funding provided through the Challenge Envelope). This will require a combination of high-quality, world-leading, ground-breaking science, as well as strategic national interventions to enhance impacts and outcomes including from aligned research programmes.
- **Vision Mātauranga** – Challenge projects should include clear commitments to giving effect to Vision Mātauranga and, through that, to the Treaty of Waitangi. This should normally reflect Kaihautū working in partnership with Programme Leaders.

Negotiated and contestable allocations

Challenge funding will be allocated to:

- **Negotiated projects** – 80% of project funding. Negotiated projects will be developed through participative and collaborative processes, led actively by the Science Leadership Group, to address the goals for each of the three Challenge Programmes. A set of 'lead-off' Projects will be initiated in the first year of the Challenge, with further Projects established to link with stakeholder and end-user strategies and to complement aligned research by Challenge Parties. The criteria for these negotiated projects will be:
    - Alignment to key investment strategy parameters (as set out above)
    - Establishment and maintenance of a Project Portfolio, balanced across Challenge Programmes, consistent with relevant sector and research strategies, and complementing aligned research by Challenge Parties (as set out below).
- **Contestable projects** – 20% of project funding. Calls will be made from time to time for new targeted research projects, inviting researchers to put forward new research initiatives. The criteria for these contestable funding events will be set by the Governance Group, following assessment of gaps and priorities in the entire Challenge Portfolio (i.e. Challenge Envelope plus aligned research).

Challenge Envelope Project Portfolio

Over time, funding allocations to establish and implement the Portfolio of Challenge Envelope Projects will take into consideration the following prioritisation parameters:

- The balance of investment across the three Challenge Programmes must reflect the scale of impact each Programme is likely to make to achieve the Challenge Mission. In general terms, Programme 2 (*Reducing risks and threats*) will have the greatest direct impact on the Mission, and should therefore attract more investment than Programmes 1 and 3.
- Investment in any Project must be sufficient to enable high-quality, world-leading, ground-breaking science, and hence additionality for the Challenge. Funding must not be spread too thinly across a large number of Projects.

- Achieving ground-breaking results will take time, so multi-year support for negotiated Projects will be required. Over time, funding required for any negotiated Project may increase or decrease, in relation to progress and achievements being realised, as well as the impact of aligned research by Challenge Parties and related investments by end-users. Annual reviews of progress will therefore consider the need and opportunity to change the level of funding allocated to long-term, negotiated Projects.
- The initial focus (e.g. for lead-off Projects) concentrates on establishing critical momentum for long-term Projects that will be pivotal for achieving the overall Mission (*Reversing the decline of New Zealand's biological heritage*). The importance of Programme 2 (*Reducing risks and threats*) to achieving the overall Mission implies a priority for lead-off Projects for this Programme.
- Meeting the Vision Mātauranga priorities for the Challenge will involve a balance of embedding VM in Challenge Projects and investing directly in 'Vision Mātauranga-specific' Projects. Two-way interaction between Programme Leaders and Kaihautū will be essential. In practice, this will mean some Projects led by Programme Leaders with support from Kaihautū, and some Projects led by Kaihautū with support from Programme Leaders.
- Over time, as the Challenge provides direction for aligned research, priorities, and funding, allocations for Challenge Envelope Research Projects should be refined, to optimise the complementarity of Challenge Envelope and aligned research. The overall Challenge Portfolio must be 'complete', integrated across the Challenge Programmes and addressing all the components/steps required to achieve the Challenge Mission. This may require staging Challenge Envelope Projects over a longer time-frame to ensure no critical gaps.
- Some latitude to fund new Project options at later stages must be retained. This means not all of the funding available for negotiated Projects can be committed at the outset.

Lead-off Projects

The Governance Group has identified three 'lead-off' Projects, intended to build critical momentum while also reflecting overall governance processes for the Challenge. These lead-off Projects are:

- *A national framework for biological heritage assessment across natural and production landscapes* – this project, contributing to Programme 1 (*Real-time biological heritage assessment*), will develop a New Zealand-wide framework and platform for biological heritage measurement and monitoring using environmental DNA (eDNA) data. It will in turn allow accurate detection and monitoring of biosecurity incursions while also underpinning environmental monitoring and reporting at different scales.
- *Biosecurity network interventions* – this project, contributing to Programme 2 (*Reducing risks and threats*), will combine network modelling across multiple sectors to identify opportunities for interventions to contain or slow the spread of invasive organisms. It will in turn help biosecurity managers use integrated risk assessment tools to predict post-border pathways, impacts, and optimal management for specific pests, weeds, and pathogens affecting production and natural ecosystems.
- *Novel wasp control technologies* – this project, also contributing to Programme 2 (*Reducing risks and threats*), will develop a suite of new technologies to combat wasps: Trojan Female Technique, pheromones and semiochemicals, mites to facilitate delivery of pathogens or toxins to nests, RNAi control specific to wasps (but with no effect on bees). It will lead to socially acceptable, cost-effective and targeted technologies, tools, and strategies for use at landscape-scale to control wasps in natural and production landscapes.

The selection of these lead-off Projects reflects application of the investment and prioritisation parameters set out above. In particular, commitment to these lead-off Projects reflects a focus on creating momentum for some Projects that will be critical to achieving the overall Mission, establishing a 'high bar' (in relation to high-quality, world-leading, ground-breaking science) for allocating Challenge Envelope funding, and reinforcing the importance of embedding VM and integrating diverse skills in Challenge Envelope Projects.

Once detailed work plans and budgets for each of these lead-off Projects have been confirmed (as part of contracting research activity to Challenge Parties), the Governance Group will consider further Projects. By

then, the Governance Group will also be informed by an initial assessment of aligned research for Challenge Parties.

Aligned research

The integration of aligned research by Challenge Parties will be critical for achieving the ambitious vision set of this Challenge.

Challenge Parties have agreed to align research (and related activities) funded from non-Challenge sources to the Challenge Programmes to complement research and related activities funded directly by the Challenge. This alignment will expand the scale and/or scope of total activity supporting the Challenge Programmes and Mission.

Research aligned by Challenge Parties will remain under the authority of those Challenge Parties (and the obligations they may have to the funding sources that support such aligned research). Over time, aligned research should contribute to priorities set by the Governance Group. The Governance Group will provide all Challenge Parties with such priorities from time to time so Challenge Parties can in turn strengthen the effectiveness (and hence value) of their aligned research. Challenge Parties will report their aligned research contributions to the Challenge, for the purposes of optimising the integration of Challenge Envelope and aligned research, and in turn reporting progress and achievements from the Challenge as a whole.

In practice, statements from Challenge Parties regarding their research aligned to each of the Challenge Programmes will inform the Governance Group's decisions about allocation of Challenge Envelope funding and assessment/revision of priorities for aligned research. This will enable regular optimisation of the overall Portfolio of Challenge Envelope and aligned research, to maintain their contribution towards the goals of each Challenge Programme to the overall Mission.

Fit with sector and research strategies

The pathway-to-impact from Challenge Envelope research will be strengthened where there is close linkage to key sector and research strategies – especially the national Biodiversity Strategy and Biosecurity Strategy. Fit with other key strategies – including the Government's Business Growth Agenda and specific sector strategies (e.g. industry sector biosecurity readiness and response initiatives, community-led biodiversity and ecosystem restoration initiatives) – will also be important.

Intermediate outcomes defined in the outcome framework for this Challenge are developed to relate directly to such sector strategies. This immediately provides a strategic focus for Challenge Envelope Projects. Intended research impacts for each Challenge Programme represent a critical link between Challenge Envelope Projects and these intermediate outcomes.

Over time, continuing and active engagement with sector groups will further sharpen the definition of both the intended research impacts for each Challenge Programme and the pathway linking these to intermediate outcomes. This active engagement will be a key focus for the Science Leadership Group.

Building the 'best team'

The 'best team' brought together for each Challenge Envelope Project will reflect the following:

- Complementary skills – this will be especially important for Projects requiring integrated multi- and/or inter-disciplinary research. Depending on the project, this could include integrating economic and social science with traditional biophysical science, or basic and applied research, or integration with knowledge transfer and exchange with end-users. Where key skills needed for 'best teams' are not immediately available, Challenge Projects must include plans for incorporating such skills in time.
- Capability development – will include opportunities to develop new skills and facilitate succession in key areas. While Challenge Parties (individually and collectively) are responsible for managing research capability, funding allocation to Challenge Envelope Projects should facilitate support by Challenge Parties for such capability development.

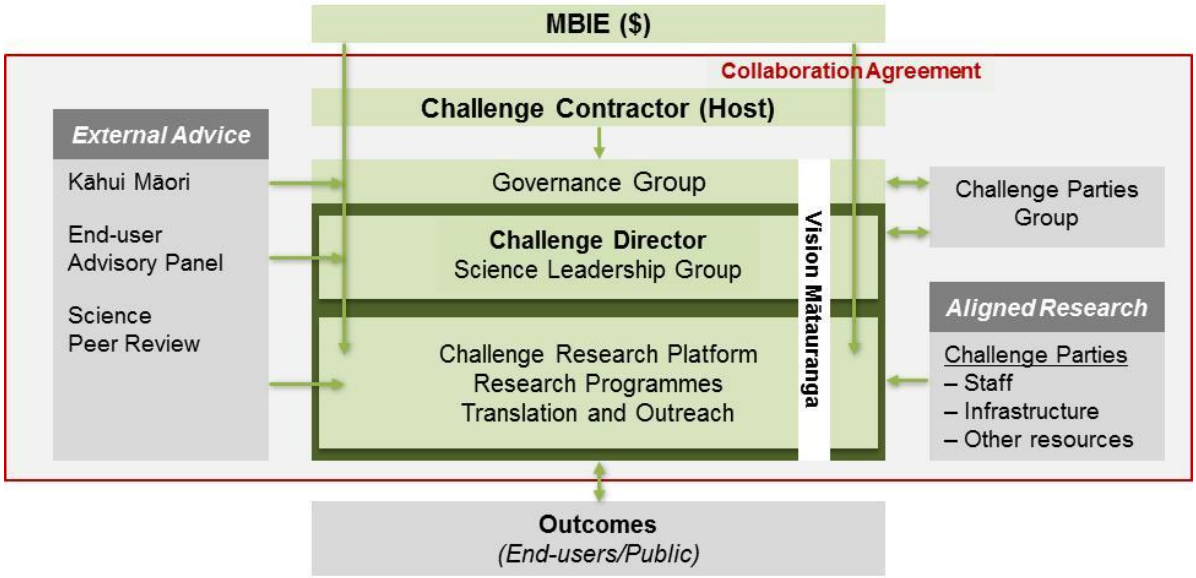
- Institutional support – so Challenge Parties can provide access to critical research infrastructure (e.g. genomic sequencing, databases and collections, large-scale field research sites).
- International linkages – the Challenge Parties will ensure that there are opportunities for incorporating international researchers in Programmes and Projects, including sabbatical placements, international collaborations, and visiting fellowships.

In practice, Challenge Envelope funding will support only part of the 'best teams' required for the Challenge. Integration of Challenge Envelope Projects and research aligned by Challenge Parties will therefore be important for building the best teams for the Challenge as a whole. Researchers involved in these wider Challenge 'teams' will therefore need to appreciate the value – to them individually and to their institutions – of being part of Challenge Programmes, whether or not they are engaged directly in Challenge Envelope Projects. Building these Challenge teams, integrating Challenge Envelope and aligned research, will be an important leadership focus for the Science Leadership Group.

3.4 Challenge structure

The Challenge is *governed* by a small, independent, skills-based Governance Group, providing experienced strategic oversight. It is *managed* by a Science Leadership Group with leadership, global networks, and programme management skills, supported by a Support Unit (*Figure 9*).

Figure 9: Governance and management structure



Note: Māori and other stakeholder participation occurs at all levels: governance, management and through the Research Platform

The proposed structure aims to minimise cost and complexity by using existing Challenge Contractor systems, engaging existing advisory group members as appropriate, and sharing back-office support. The structure supports regular engagement by governance and management with Challenge Parties and Advisory Groups to ensure Challenge decisions consider end-user and Challenge Party needs, while ensuring independent decision making and dynamism (*Section 1.4 Research portfolio and quality*) through the life of the Challenge.

The Governance Group and Science Leadership Group started operating immediately after the Science Board decision to support this Challenge, in August 2014.

3.5 Participants (Challenge Parties)

Challenge Parties will comprise research providers, end-users, and other stakeholders who have signed a Collaboration Agreement and committed to align research (and related activities) to the goals of the three

Challenge Programmes. Seventeen agencies have signed a Collaboration Agreement to collaborate in the Challenge. The Collaboration Agreement sets out in detail the terms for participating in the Challenge (and consistent with terms set out in the Heads of Agreement included with the proposal submitted in April 2014).

As the Challenge Contractor, Landcare Research brings demonstrated financial controls; robust monitoring, reporting and evaluation processes; HR; IT, communications and other support systems to the Challenge. It also brings a collaborative ethos as the 'integrating and transdisciplinary CRI' working across multiple agencies and sectors. Headquartered at Lincoln, Landcare Research ensures linkages between this Challenge, the *Our Land and Water* Challenge, and the Lincoln Hub.

Other agencies may join the Challenge in time, should it demonstrate value and alignment to their interests, and should their research align with the priorities and needs of the Challenge. Similarly, when a Challenge Party's priorities no longer align with those of the Challenge, the Party may leave the Challenge in line with the terms of the Collaboration Agreement.

3.6 Governance

Challenge Contractor

The Board of the Challenge Contractor (Landcare Research) is accountable for overall delivery of the Challenge goals through its investment contract with MBIE. However, as stated in the Collaboration Agreement, this will confer no advantage or disadvantage to Landcare Research in the operation of the Challenge.

Governance Group

The Contractor Board has delegated a set of functions to the Governance Group. The Governance Group is responsible for approval and oversight of the strategic development, risk management, and delivery of the Challenge. While the Governance Group remains accountable to the Challenge Contractor, its focus will be on ensuring the Challenge achieves its stated objectives in line with the MBIE Investment contract.

The Governance Group comprises six members:

- **Dr James Buwalda** (Independent Chair)
- **Devon McLean** (Director, Project Janszoon)
- **Dr Barry O'Neil** (CEO, Kiwifruit Vine Health)
- **Rob Phillips** (CEO, Environment Southland)
- **Dr Gail Tipa** (Tipa & Associates, and recently Trustee of Te Rūnanga o Ngāi Tahu)
- **Dr Daniel Walker** (Research Director, Agriculture & Global Change, CSIRO Agriculture, Australia)

The members were selected for the expertise needed to deliver Challenge objectives, including:

- Governance/financial management
- Knowledge of national and regional policy and primary sector priorities
- Understanding of the principles of the Treaty of Waitangi, WAI 262, and mātauranga Māori
- Research leadership and knowledge of the research and innovation landscape
- Understanding of the application of research innovations
- Evaluation/impact assessment.

We have considered the merit of adding other skills and expertise to the Governance Group, such as Māori business expertise. On balance, we have concluded that the immediate priority is for the Challenge (Governance and Science Leadership) to engage actively with key stakeholder groups (e.g. Federation of Māori Authorities) to underpin future collaboration and partnership. In this way, the need for and value of

additional skills and expertise on the Governance Group will become clearer. Decisions about changing the composition of the Governance Group accordingly can be made at the time of the scheduled review of governance and management, in 2016.

Governance Group members are independent of executive roles in Challenge Parties. While members will contribute relevant perspectives based on their professional and leadership roles and experiences, they will not act as 'representatives' of any agency, sector, or interest. We have an independent Governance Group to ensure the interests of the Challenge remain the focus of decision making. For the same reason, the Chair will be independent of research provider, stakeholder, or end-user affiliation. Members have been appointed until 30 June 2016, which aligns with a review of governance arrangements (*Section 3.9 Review of governance and management*). We would then expect to stagger changes to the composition of the Governance Group to ensure gains are made through the introduction of new skills and experience, supported by continuity and coherence through the retention of critical skills and experience over time.

Three non-voting observers will participate in the Governance Group: two rotating representatives of the Challenge Parties Group, and one representative of the Challenge Contractor (*Appendix 2: Governance and Management Positions*). The term of rotation for Challenge Party representatives will be 12 months, with DOC and MPI taking up the initial 12-month term (2014–2015). The Chair of the Governance Group reserves the right to invite other observers and has accordingly invited a university and a CRI observer to participate in Governance Group meetings.

The key responsibilities of the Governance Group (*Appendix 3: End-user Advisory Panel – Terms of Reference*) are to:

- Approve the Challenge's strategic direction and oversee strategy and performance reviews
- Allocate resources to support the Challenge Mission
- Ensure VM is embedded appropriately in the Challenge
- Oversee the appointment of a permanent Director, subject to Challenge Contractor approval
- Approve the final design of contestable and collaborative investment mechanisms
- Regularly brief the Challenge Contractor Board and MBIE on Challenge performance/strategic direction
- Ensure financial and other accountabilities operate effectively for the Challenge
- Manage risks and constraints to Challenge delivery
- Manage the performance of the Director.

The Governance Group will meet bi-monthly (videoconferencing or teleconferencing may be used by exception) or as required (e.g. monthly during the Start-up Phase). The independent Chair will engage regularly with the Challenge Director to ensure governance and management approaches are complementary and mutually reinforcing. To ensure effective links between Challenge Advisory Groups and Challenge governance, the Chair will meet at least annually with the Chairs of the Challenge Parties Group, Kāhui Māori, and End-user Advisory Panel (EAP) and, as needed, with science advisory groups convened to undertake specific functions within the Challenge.

3.7 Management arrangements

The Science Leadership Group (*Appendix 2: Governance and Management Positions*) comprises the following members:

- Interim Challenge Director: **Professor Bruce Clarkson** (University of Waikato)
- Programme 1 Leader: **Associate Professor Thomas Buckley** (Landcare Research)
- Programme 2 Leader: **Professor Philip Hulme (**Lincoln University)
- Programme 3 Leader: **Dr Andrea Byrom** (Landcare Research)

- Māori Kaihautū**: Dr Phil Wilcox** (Scion/University of Otago), **Dr Nick Waipara** (Auckland Council), **Dr Amanda Black** (Lincoln University), **Dr Phil Lyver** (Landcare Research)
- Māori Manager: **Melanie Mark-Shadbolt** (Lincoln University) will provide overall coordination for VM perspectives in the Challenge

The Interim Director is a pragmatic science leader who commands the respect of the Science Leadership Group and can establish the Challenge effectively.

A process for recruiting a permanent Director is underway, with an appointment expected by June 2015. The permanent Director will be a Challenge Contractor employee or secondee, appointed on recommendation of the Governance Group, and accountable for overall Challenge performance. Other staff in Challenge roles will continue to be employed by their originating organisations. The Programme Leaders led the development of the Research Plan and are well placed to ensure continuity as the Challenge is implemented. The Challenge Contractor will approve any changes to Programme Leader appointments on recommendation of the Governance Group, based on research leadership credentials and an ability to take a Challenge-wide perspective.

Science Leadership Group

The permanent Science Leadership Group will comprise 2.1 FTEs:

- Challenge Director (Chair) (0.7 FTE permanent)
- Research Programme Leaders (3 × 0.33 FTEs)
- Four Māori Kaihautū (2 × 0.1 FTEs + 2 × 0.05 FTEs) and one Māori Leader (0.1 FTE) (*Section 1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement* and *Section 3.8 Advisory groups*).

The Science Leadership Group will:

- Oversee the strategic planning process in the Start-up Phase
- Drive the delivery of high-value, high-impact research, and promote relevant research linkages
- Set strategic priorities for the Research Platform and allocate resources accordingly
- Monitor and report regularly on performance against the terms of the MBIE contract
- Embed the principles of the Treaty of Waitangi, WAI 262, and VM in the Challenge
- Identify issues/risks (constraints to delivery, high-risk research) and mitigations
- Facilitate internal and external communication, engagement and public outreach.

Challenge Director

The Challenge Director will provide overall leadership to the Challenge, with the support of the Science Leadership Group. Given the scale and complexity of the Challenge, the Director must demonstrate exceptional science leadership; sector knowledge; and programme, project, financial, and relationship management skills. The role has a focus on external collaboration in view of the criticality of aligned and related research to the overall success of the Challenge.

The Challenge Director will also be responsible for:

- Facilitating collaboration among Challenge Parties to support delivery of the research programmes and achievement of the Challenge goals
- Facilitating engagement with Māori, stakeholders, and end-users to ensure the Challenge remains Mission-focused, and support the uptake and application of research results
- Ensuring reporting research progress and achievements from the Challenge
- Informing the Governance Group appropriately so it can fulfil its governance accountabilities

- Acting as the primary commentator externally on the Challenge and its work
- Liaising with directors of other relevant Challenges (*Section 1.2 The research landscape*)
- Managing conflicts of interest/disputes appropriately

Support Unit

A small, efficient unit will provide effective administrative support to the Challenge. We propose to share a unit with the *Our Land and Water* Challenge to minimise costs, ensure reliability of support, and build a 'Centre of Excellence' for research investment processes. We propose a unit of 4 FTEs (an amalgam of different functions) with costs shared by the two Challenges on a pro-rated basis. We are proposing this resource to ensure the Challenge can run transparent, equitable, high-quality investment processes in line with investor expectations. In the meantime the Challenge Contractor has set up a small unit to establish the Challenge. In the Start-up Phase significant resources were needed, and the skill set will change once we move out of this phase. Some functions may also be 'outsourced' (e.g. via Contractor charge-back), if this creates efficiencies/better delivery.

For budgeting purposes and in line with MBIE guidelines, we propose approximately 2.1 FTEs in the Support Unit; indicative functions and responsibilities include:

- Establishing Challenge support processes, derived largely from Contractor processes
- Implementing trustworthy financial management, subcontracting, monitoring, and evaluation
- Running investment and associated peer review and evaluation processes
- Coordinating internal and external outreach and communication functions (*Section 3.10 Programme management* and *Section 3.14 Stakeholder engagement*)

3.8 Advisory groups

We propose three (largely self-funding) structures to support *whole-of-Challenge* decision making, while recognising that specialist engagement at Programme and Project level will continue, using existing structures in the first instance. This reflects the principles of workability and cost-effectiveness and ensures appropriate contestability of advice to the Challenge.

Challenge Parties Group

The Challenge Parties Group is a self-funded group to ensure regular dialogue between Challenge Parties and governance and management (*Section 3.5 Participants (Challenge Parties)).* As parties aligning research to the Challenge, the Challenge Parties have a shared interest in its success. The Challenge Parties Group provides advice relevant to how they can participate effectively in the Challenge at the time strategic priorities are set for the Challenge, and ensures there is dialogue on potential alignment of research and related activities to the priorities.

The Challenge Parties Group is open to all agencies that have signed the Collaboration Agreement. The Parties will nominate representatives, but we envisage they will elect a senior leader (Tier 1–2) to engage with the Governance Group, and a relevant manager to engage with the Science Leadership Group. Two members of the Challenge Parties Group will be non-voting observers at Governance Group meetings to ensure Parties' views are considered as strategic priorities are set. The Collaboration Agreement provides more detail on the Group's functions.

End-user Advisory Panel

The EAP provides advice to governance and management to ensure the Challenge sets its strategic direction and priorities in line with end-user priorities. The EAP will provide advice on progress towards delivering on KPIs and the Mission, and adoption pathways to maximise uptake of Challenge outputs. The EAP will work directly with the Director and Programme Leaders to ensure there is adequate focus on the delivery of sector-

relevant research. The EAP will also contribute to reviews convened to assess the Challenge's performance, with a focus on progress towards the Mission and effectiveness of the adoption pathway to end-users.

The EAP will comprise up to 20 members of relevance to Challenge outcomes, including a balance of agencies from production and conservation sectors. The current membership is given in *Appendix 2: Governance and Management Positions*. The EAP will be self-funded. The Terms of Reference, developed by the End-user Advisory Panel and approved by the Governance Group (*Appendix 3: End-user Advisory Panel – Terms of Reference*), provide more detail on the proposed functions of the EAP.

The Kāhui Māori

The Kāhui Māori's role will be to provide advice to the Challenge on implementation of Vision Mātauranga and wider cultural matters, including intellectual property issues, where relevant to Māori as specified in the Intellectual Property Management Plan. It will advise the Director, Governance, and Science Leadership Groups on events in Te Ao Māori that may affect the Challenge. The Kāhui Māori may also facilitate engagement with Māori stakeholders and support consultation between the Challenge and Māori interests. A Terms of Reference for the Kāhui Māori will be developed in consultation with Māori and approved by the Governance Group (refer to *Appendix 5: Kāhui Māori – draft Terms of Reference*).

Science advice and review

During the Start-up Phase the Science Leadership Group ran a strategic planning process (that included the EAP and Kāhui Māori) to develop a set of initial Projects. A further priority for the remainder of the Start-up Phase will be to develop a monitoring and evaluation framework to ensure activity is well aligned to the Mission.

Given the breadth of the Challenge and expected dynamism of the research over 10 years, we do not propose to establish a static Science Advisory Group. Instead, the Challenge will, as needed, convene review panels to ensure targeted review over several funding cycles, drawing on relevant skills and expertise.

Panel membership will be drawn from global/national experts, Challenge Party Science Panels, or from Challenge participants. Panels may assist periodic reviews, the annual strategic planning process, or proposal assessment in support of investment processes (*Section 1.4 Research portfolio and quality* and *Section 1.10 Monitoring of performance, evaluation of impact).*

The Panel advice will support decisions on stage-gating, scaling up or tapering work depending on maturity, performance, and relevance to Challenge goals (*Section1.1 10-year Research Plan*). Panels will provide advice on:

- Strategic and research priorities in view of new international initiatives, emerging research directions, new techniques, technologies, and approaches
- Opportunities to link the Challenge more effectively with global initiatives of relevance
- How the Challenge compares in terms of international standards for science excellence, relevance, engagement, and commercialisation
- Transdisciplinary and integration activities within the Challenge.

Although informed by external advice, decisions on the content, scale, and portfolio mix for the Challenge research will be taken by the Governance Group, on recommendation from management, following an annual review and planning process (*Section 1.4 Research portfolio and quality*).

3.9 Review of Governance and Science Leadership

We propose to run an internal review of Governance and Science Leadership arrangements for the Challenge before 30 June 2016, in a process led by the Challenge Parties. The Challenge Contractor Board will approve the Terms of Reference for the review. MBIE, the Challenge Contractor, Governance and Science Leadership Groups, EAP, and Kāhui Māori will contribute to the review. The Challenge Parties will produce a consensus report following the review, with any recommendations to improve Governance or Science Leadership submitted to the Challenge Contractor Board for discussion with MBIE. The agreed

recommendations, if accepted by MBIE, will be implemented within a year and formalised via a contract variation.

An independent review of the Challenge is proposed early in Year 5, focusing on achievements and impacts and progress toward KPIs. The review team will engage with the EAP, Kāhui Māori, Challenge Parties and other stakeholders, and incorporate reports from science advisory processes (*Section 1.10 Monitoring of performance, evaluation of impact* and *Section 3.8 Advisory groups).* This review will inform the investment proposal for Phase 2 of the Challenge.

The three advisory bodies will self-review annually for discussion with Governance and Science Leadership.

3.10 Programme management

The Challenge Contractor will apply its corporate protocols for Programme and Project management, budgeting, auditing, subcontracting, invoicing, QA, reporting, and forecasting. The Challenge Contractor will translate its experience in successfully managing large-scale, long-term research platforms (e.g. Backbone contracts and Core funding), employing demonstrated programme management approaches such as centralised project information storage, regular 'dashboard' reporting on KPIs, 'red flags', and standardised approaches to managing projects not meeting milestones.

In consultation with the Science Leadership Group, the Challenge Contractor will review (and if necessary revise) its risk management framework for application in the Challenge. A risk register and management plan in response has been developed (*Section 1.6 Impact*). Detail on how the Challenge proposes to make allocation decisions, set priorities, and undertake planning, review, and evaluation processes, is provided in *Section 1.4 Research portfolio and quality* and *Section 1.10 Monitoring of performance, evaluation of impact*.

The Challenge Contractor will apply learnings from leading large, multidisciplinary research initiatives (e.g. OBIs, MBIE 'Sandpit' projects) that require active transfer of information across providers. Building on the existing webpages, Facebook site, and newsletters, we propose to establish an internal communications platform to facilitate regular exchange of research results and early-stage data to all Challenge Parties. This will enable updates on investment processes, visits by relevant experts, evaluations and reviews, awards, outreach and engagement. We propose to develop a restricted-access, log-on 'wall' on which researchers can 'post' material for discussion or peer review before release.

In Year 2, the Challenge Contractor will explore applying its unique data identification system to enable ready access to information on data provenance, versioning, metadata, and access.

3.11 Investment and financial management

The Challenge Contractor and other Parties are significant organisations with a track record of financial stability and annual audits of public funding by the Office of the Auditor General (OAG). Challenge funds will be managed on behalf of the Parties by the Challenge Contractor, which has extensive experience in managing large-scale research programmes and public research funds. In 2013, OAG commended Landcare Research on its national leadership in financial and impacts reporting.

Challenge funds will be managed in accordance with the Challenge Contractor's procurement policies and delegations. The Challenge Contractor will regularly monitor and audit funds for unusual expenditure, and provide financial reporting on use of Challenge funds, to the Challenge Director and Governance Group. The Challenge Contractor will maintain discrete accounts for Challenge funds within its financial system. Funds may be transferred from these accounts to Challenge Parties in line with researcher participation in Challenge Programmes, as defined in subcontracts between the Challenge Contractor and respective Challenge Parties. This approach retains flexibility to integrate aligned/co-funded work with Challenge-funded work, and supports the Challenge's focus on achieving outcomes (not outputs).

The Challenge Director and Programme Leaders will have responsibility for managing research funded through the Challenge Envelope. In practice, this will involve leading teams of researchers drawn from multiple Challenge Parties, as specified in subcontracts between the Challenge Contractor and respective Challenge Parties. Integrating aligned research from the various Challenge Parties will be a critical feature of this research leadership.

3.12 Indicative budget

We have confirmed the Challenge scope via a planning process in the Start-up Phase, including a staged approach for investing in new Challenge Envelope Projects (as illustrated by initial decisions on 'lead-off' Projects). This in turn has informed our indicative budget in *Table 10*, to be confirmed as Projects are contracted over time.

Table 10: Indicative budget for New Zealand's Biological Heritage National Science Challenge

	Start-up phase	Phase I				Phase II
	1 Oct 14–30 Jun 15	*1 Jul 15–30 Jun 19*				*1 Jul 19–30 Jun 24*
	Year 1 ($m)	**Year 2 ($m)**	**Year 3 ($m)**	**Year 4 ($m)**	**Year 5 ($m)**	**Years 6–10 ($m pa)**
Research Programme 1	0.18	0.72	1.26	1.61	1.61	1.62
Research Programme 2	0.18	0.97	1.70	2.14	2.14	2.17
Research Programme 3	0.18	0.72	1.26	1.61	1.61	1.62
Targeted Contestable	0.00	0.51	1.05	1.34	1.34	1.35
Sub-total	0.53	2.93	5.26	6.72	6.72	6.75
Knowledge Transfer/Outreach	0.00	0.35	0.45	0.45	0.45	0.45
Governance	0.17	0.17	0.16	0.16	0.16	0.17
Management	0.27	0.21	0.21	0.21	0.21	0.22
Sub-total	0.43	0.38	0.37	0.38	0.38	0.38
Yearly Total	0.96	3.66	6.08	7.54	7.54	7.58
Governance & Management % of Challenge Funding Envelope	45%	10%	6%	5%	5%	5%

	BH NSC incl. Contestable
Years 1–5	25.80
Years 6–10	37.90
10 Year Total	63.70

Vision Mātauranga (VM) – relevant research and related activity occurs within the programmes. Therefore there is no separate line for VM.
Research administration support is included within the programmes.
Governance and Management costs are in accordance with MBIE guidelines.

The budget is based on a start date of 4 August 2014 (when MBIE provided formal advice regarding the Science Board's approval for this Challenge) and sets out an expenditure profile totalling $25.8m in the first contract period (to 30 June 2019). We anticipate an expenditure profile totalling $37.9m in the second contract period (to 30 June 2024). Indicative budgets for the lead-off projects approved to proceed to contract development are $350–$650k p.a. per project for up to five years.

The budgeted Governance and Science Leadership costs recognise the significant effort needed to establish the Challenge, as well as the significant effort required to achieve effective alignment of research by 17 Challenge Parties (CRIs, universities, government departments). While Governance and Science Leadership costs make up a relatively large portion of the small level of expenditure in the first year (to design and implement start-up processes, such as setting up management systems and planning for lead-off Projects), this proportion will fall rapidly as the Challenge Envelope Research Projects are implemented, and will be sustained at 5% once the Challenge Research Programme is fully up and running.

The Mission for this Challenge cannot be achieved through the Challenge Envelope funding alone. Indeed, research aligned to the Challenge (by Challenge parties) and related activities for uptake and application of Challenge research (by next- and end-users) together represent a much larger scale of activity than that funded directly by the Challenge Envelope. In short, the investment in Governance and Science Leadership must be sufficient to achieve and sustain the strategic coherence required across the range of parties and stakeholders involved in this Challenge. The proposed cost structure applies learnings from other large-scale, multiparty research platforms led by the Challenge Contractor and Challenge Parties (*Better Border Biosecurity* collaboration, Natural Hazards Research Platform, Bio-Protection Research Centre). In accordance, the Challenge will recognise the (real) cost of running investment processes, proposing a quantum of support that will provide credible assurance to MBIE, co-funders, and stakeholders that public funds invested in the Challenge are well managed and accounted for, and transparently monitored.

Aligned research

The value of aligned research from Challenge Party research organisations – e.g. CRI Core funding (potentially up to $14.87m), MBIE contestable funds ($3.73m), Marsden funding ($8.6m), university funding (PBRF, scholarships, fellowships) – and from DOC and MPI – is not included in the budget table. Challenge Parties have agreed (as set out in the Collaboration Agreement) to align research to the Challenge and to report annually on the nature of such research. Challenge Parties may vary in the way they value such aligned research. Our focus is principally on understanding and influencing the contribution of this aligned research to the goals of each Challenge Programme and to the overall Challenge Mission, rather than simply measuring the level of expenditure by Challenge Parties on aligned research.

We expect significant co-funding investment opportunities to arise during Phase 1 of the Challenge, once the research priorities have been refined and specific opportunities are more visible for potential external co-funders. This is likely to include parties involved in community and business initiatives consistent with the Challenge Mission (e.g. industry groups involved in biosecurity readiness and response, groups involved in eradicating small-mammal predators from specific landscapes), as well as Parties promoting engagement by New Zealanders in such initiatives (e.g. government departments, museums). We aim to secure $8m p.a. in new cash or in-kind co-funding by the end of Phase 1 (June 2019). This highlights the significant leverage potential of this Challenge.

We will work with key stakeholders and global collaborators (*Section 1.2 The research landscape*) through the Challenge to secure new co-funding, including by using the Challenge 'brand' to access international funding.

We will regularly (at least annually) review the budget, as funding commitments to Challenge Envelope projects are confirmed. This will enable us in turn to ensure investment continues to conform to the investment strategy and prioritisation processes set out above (*Section 3.3 Investment strategy and prioritisation*). Annual budgets for the Challenge will be developed by the Science Leadership Group for consideration and endorsement by the Governance Group, and final approval by the Challenge Contractor.

3.13 Vision Mātauranga/Māori engagement

Vision Mātauranga is woven through the structure and function of this Challenge (*Section 1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement).* As noted earlier, Māori researchers/managers contributed to the Oversight Group to shape this Challenge proposal. We ran a series of hui and consulted Māori researchers and authorities about the research and business plans to engage Māori perspectives within the Challenge.

We have appointed to the Science Leadership Group a Māori Manager with VM and tikanga expertise (*Appendix 2: Governance and management positions*), as well as four Kaihautū, to provide advice and support to the Challenge on VM principles and concepts, Māori world views, tikanga, mātauranga, language, research priorities, and methodologies (*Section 3.8 Advisory groups*). The Kaihautū, supported by the Kāhui Māori, will help ensure the Challenge operates in accordance with the VM principles set out in the Collaboration Agreement. As noted in *Section 3.8 Advisory groups*, a Kāhui Māori may serve as a conduit to engage with iwi and Māori organisations on the Challenge as a whole and provide input on Māori research priorities and delivery of outcomes (*Appendix 5: Kāhui Māori – proposed Terms of Reference*). In addition, while all three research Programmes include Māori-centred research, we propose an integrated Māori Research Programme, led by the Kaihautū, to ensure coherence of approach across the Challenge and provide a pathway to build VM expertise among the Programme Leaders and other senior staff.

The proposed researcher development Programmes (*Section 3.3 Investment strategy and prioritisation)* and engagement with wānanga, universities (*Section 1.9 Related activities – public outreach, communication, and education activities)*, and iwi will support development of Māori researchers/managers *(Section 1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement)*, grow a cohort of emerging Māori research leaders, and inspire young Māori to take science, technology, engineering, and mathematics (STEM subjects). Te Ātiawa and the Palmerston North Māori Reserve Trust are part of the museum proposal (*Section 1.9 Related activities – public outreach, communication, and education activities).*

3.14 Stakeholder engagement

As noted earlier, a key design principle for the Challenge is to 'embed' Māori and other key stakeholders and actively involve them in Challenge delivery. As the Challenge evolves, we will work closely with key stakeholders via the EAP, the Kāhui Māori, and the Challenge Parties Group to ensure the Challenge can meet its goals (*Section 3.8 Advisory groups*). The Science Leadership Group will also engage regularly with these groups and other stakeholder networks (*Section 1.5 Vision Mātauranga – principles for Te Tiriti of Waitangi and Māori engagement* and *Section 3.7 Management arrangements*). This will include consulting on research direction and priorities, providing updates on key initiatives, and presenting research findings in a variety of ways to meet end-user needs. Stakeholder networks will be critical to the adoption of Challenge outputs in society. Key stakeholders will work closely with us to develop and implement 'pathways to adoption' for priority sectors and boost the uptake and application of Challenge outputs. End-users will also provide important feedback on Challenge delivery and improve our ability to measure the real-world outcomes and impacts from the Challenge, including progress towards KPIs. We will involve key stakeholders actively in monitoring, review, and evaluation activities.

A priority in the Start-up Phase will be to develop an engagement strategy to maximise impact with end-users. As a first step, we propose to expand the Challenge web pages, employing social media techniques to provide regular, accessible updates on Challenge Programmes and the difference they make, profile key staff and their work, and showcase successes. We also propose to develop interactive functionality (e.g. posting comments, Q&As, and details of public events and outreach).

3.15 Commercialising IP

Intellectual Property will be managed in accordance with the Intellectual Property Management Plan as detailed in Appendix B of the Collaboration Agreement. All Parties conducting research have established procedures for identifying IP that has commercial potential. Where the IP is jointly owned it will be assigned to a Managing Party. All Parties will report opportunities to the Challenge Director as part of subcontract reporting.

All Parties conducting research utilise either the Kiwi Innovation Network (KiwiNet), a consortium of universities and Crown Research Institutes and entities who are dedicated to taking a collaborative approach to research commercialisation or expertise on the Return on Science, a national research commercialisation programme that delivers new research to market from universities, research institutions, and private companies. Parties are experienced in using the MBIE Pre-Seed (PSAF) Accelerator Fund to assist in commercialisation of products and services.

Through these two commercialisation partner networks and PSAF we expect to empower Challenge Party scientists by helping them to access the tools, connections, investment and support they need. Some Parties already have a strong track record in commercialising, such as pest control tools, and the Challenge expects to build upon that experience to take advantage of opportunities across all three programmes.

3.16 Leveraging off industry structures

The implementation of this Challenge coincides with the establishment of 'Government Industry Agreements' (GIAs) for readiness and response to biosecurity incursions. The GIAs will set out co-funding commitments for readiness and response, including industry responsibilities.

The implementation of GIAs effectively increases the responsibility of industry for managing readiness and response, in return for helping define priorities for managing biosecurity incursion risks. This increased responsibility is likely – over time – to include an increasing need for underpinning research, which may in turn involve Challenge Parties as providers. Through the industry linkages of Challenge Parties, the Challenge will align research to these emerging industry needs of biosecurity readiness and response.

Glossary

Additionality: additional benefits to New Zealand to be gained through the Challenge over and above the benefits from business-as-usual activity.

Adoption: uptake of research-based technologies and knowledge by end-users to create change.

Biocultural: (biological + cultural) a stewardship framework that integrates restoration and enhancement of the environment and culture through recognition and respect for traditional ecological knowledge (*Caston D 2013. Minding Nature 6: 22–32*).

Biodiversity: biological diversity of organisms (genes, species and ecosystems) in our terrestrial, aquatic (freshwater) and estuarine environments. It includes both native and introduced biota.

Biological heritage: the native and introduced biodiversity that underpins economic and social well-being and cultural identity that will be passed on to future generations.

Biosecurity: detection, prevention, and management of threats to our native and introduced biodiversity caused by unwanted, invasive organisms.

Biota: the life-forms (flora, fauna, fungi) that reside in a particular region or period.

Citizen science: (*also known as crowd science or crowd-sourced science*) scientific research conducted in whole or in part by amateur or non-professional scientists.

Co-funding: funding of commercial or non-commercial stakeholders or end-users for research projects or other activities within the Challenge.

Core funding: government funding for the Crown Research Institutes (CRIs). Part of this Core funding might be aligned to a Challenge for which CRI Boards remain responsible.

Ecosystem: community of living organisms in conjunction with the non-living components of their environment (such as air, water and mineral soil) interacting as a system.

Ecosystem services: benefits people obtain from ecosystems, supporting, provisioning, regulating, and cultural services. An Ecosystem Services Approach provides a framework by which ecosystem services are integrated into public and private decision making.

End-user: person or organisation who benefits from research.

Impact: direct effect of an end-user applying a finished product, process or piece of knowledge.

Natural capital: extension of the economic notion of capital to goods and services relating to the natural environment.

Organism: an individual animal, plant or single-celled life form.

Outcome: a consequence resulting from the transfer of technology and knowledge from research.

Social science: perspectives and viewpoints of individuals, communities, and businesses being considered.

Species: group of living organisms consisting of similar individuals capable of exchanging genes or interbreeding.

Stakeholder: person, group or agency who affects or can be affected by an agency's actions.

Step change: a significant change achieved by technology and knowledge transfer

Systems approach: in a holistic, integrated way considers a system as a dynamic and complex whole, interacting as a structured functional unit; does not look solely at its components.

Technology and knowledge transfer: process of transferring skills, knowledge, technologies and methods to ensure scientific and technological developments are accessible to a wide range of users who can further develop and apply what is transferred to achieve benefit.

Vision Mātauranga (VM): government initiative aimed at unlocking the innovation potential of Māori through knowledge, resources, and people. Mātauranga is the knowledge system that embodies the Māori world view.

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Appendix 1: Governance Group – Terms of Reference

1. Governance Group Terms of Reference

1.1 The Governance Group will provide effective oversight and governance of the performance of the Challenge.

1.2 The Governance Group's primary role is to aid the Challenge to achieve its stated objectives through regular oversight of strategic direction, Challenge performance and delivery of the Research Plan work programme in accordance with the NSC Investment Contract.

1.3 The Governance Group will be accountable to the Challenge Contractor, acting on behalf of the Parties, for this Challenge.

1.4 The Governance Group's accountabilities will include:

a. Ensuring that the Challenge meets the terms of the NSC Investment contract through professional oversight, the probity of processes and decision making and a high standard of compliance with the regulatory framework and reporting requirements;

b. Fulfilling fiduciary duty to act in the best interests of the Challenge, including achievement of Challenge objectives and associated KPIs, rather than in the interests of any individual parties;

c. Facilitating and overseeing regular reviews of Challenge strategy, including deciding changes within the parameters of the NSC Investment Contract and/or recommending to the Challenge Contractor desired changes to the NSC Investment Contract to be negotiated with the Ministry;

d. Facilitating and overseeing regular reviews of Challenge performance, including deciding corrective actions within the parameters of the NSC Investment Contract and/or recommending to the Challenge Contractor desired changes to the NSC Investment Contract to be negotiated with the Ministry;

e. Providing advice to the Challenge Contractor on negotiation of this Collaboration Agreement with Challenge parties;

f. Ensuring the Challenge operates in alignment with Vision Mātauranga and the principles of the Treaty of Waitangi;

g. Ensuring the Challenge operates in alignment with the Principles embodied throughout the Challenge, including maintaining effective relationships with Challenge Parties and securing co-funding for Challenge programmes;

h. Ensuring that no one Party unduly dominates the Challenge;

i. Maintaining effective relationships with the Kāhui Māori and End-User Advisory Group, consistent with the mission focus and Principles embodied throughout the Challenge;

j. Approving funding mechanisms within the Challenge (including 'collaborative' and 'contestable' allocation mechanisms), including the way these mechanisms will align the Ministry funding (the 'Challenge Funding Envelope') and co-funding to Challenge programmes;

k. Recommending (to the Challenge Contractor) the appointment of a Challenge Director;

l. Overseeing (on behalf of the Challenge Contractor) the performance of the Challenge Director, including holding the Challenge Director to account for delivering the Challenge objectives and adhering to Principles defined in this Collaboration Agreement;

m. Managing conflicts of interest in a way that is consistent with good governance practice and with the Principles defined in this Collaboration Agreement.

2. Governance Group Membership

2.1 The Governance Group will initially comprise six members, selected for their skills and expertise relevant to the science-based collaboration for delivering outcomes and impacts for New Zealand's biological heritage.

2.2 Key skills required include knowledge of national and regional policy and sector priorities, understanding of mātauranga Māori and Treaty of Waitangi principles, understanding of the New Zealand research and innovation landscape, science leadership, application of research innovations, impact assessment, finance and governance in relation to this Challenge. Members will bring relevant perspectives based on their professional and leadership roles and experiences. The Governance Group will have a Chair who is independent of direct research provider, stakeholder or end-user responsibilities and who must be approved by the Ministry.

2.3 Any changes in the composition of the Governance Group will be notified to the Parties in accordance with clause 29(a) concerning notices and notified to the Ministry as required under the NSC Investment Contract.

3. Overarching Governance Group Framework

3.1 Governance Group members will be required to act in the best interests of the Challenge and not in the interests of a particular Challenge Party or stakeholder. It is acknowledged that the interests of the Challenge Parties are legitimate concerns for the Challenge and Governance Group members may legitimately raise them for consideration by the Governance Group.

3.2 The Governance Group will work within, and where relevant give effect to, this Collaboration Agreement and the NSC Investment Contract.

3.3 The Governance Group is required to have consideration to upholding the reputation of the Challenge and all Parties to this Collaboration Agreement.

3.4 The Governance Group will be responsible for those matters set out in Clause 10.3 and such related matters as are reasonably required to give effect to those matters and to perform any other activities or roles of the Governance Group as described within this Collaboration Agreement.

3.5 To avoid doubt, the Governance Group will have no powers or authority in relation to co-funding nor such matters as financial processing and administration of funds, health and safety, ethics, infrastructure, staff employment/HR/misconduct and individual performance management.

3.6 The Governance Group will adopt and give effect to the Conflicts of Interest Policy as described in Schedule 5 of this Collaboration Agreement.

Appendix 2: Governance and Management Positions

Governance Group	Independent Chair	Dr James Buwalda (Independent Director)
	Independent Members	Devon McLean (Director, Project Janszoon; Chair, Project Crimson Trust) Dr Barry O'Neil (CEO, Kiwifruit Vine Health) Rob Phillips (CEO, Southland Regional Council) Dr Gail Tipa (Tipa & Associates, Ngāi Tahu) Dr Daniel Walker, Chief of Ecosystems, CSIRO, Australia
	Non-voting Observers	Contractor Board: Professor Emily Parker (University of Canterbury; Director, Biomolecular Interaction Centre) Rotating representatives from two Challenge Party members initially DOC and MPI
Science Leadership Group	Interim Challenge Director	Professor Bruce Clarkson (Dean of Science and Engineering, University of Waikato)
	Real-time biological heritage assessment Research Programme Leader	Associate Professor Thomas Buckley (Research Leader, Landcare Research)
	Reducing risks and threats across landscapes Research Programme Leader	Professor Phil Hulme (Professor of Plant Biosecurity, Lincoln University)
	Enhancing and restoring resilient ecosystems Research Programme Leader	Dr Andrea Byrom (Landcare Research and Theme Leader, Incursions & Outbreaks, Invasive Animals CRC, Australia)
	Māori Manager	Melanie Mark-Shadbolt (Lincoln University) will provide overall coordination for Vision Mātauranga perspectives in the Challenge
	Māori Kaihautū *(the Kaihautū will also sit on the Kāhui Māori)*	Dr Phil Wilcox (Ngāti Rakaipaaka, Ngāti Kahungunu; Project Leader, Virtual Institute of Statistical Genetics, Scion/Senior Research Fellow, Department of Biochemistry, University of Otago) *Real-time biological heritage assessment – He pūtaiao kaha ora tonu* Dr Nick Waipara (Ngāti Porou, Rongowhakaata; Principal Advisor Biosecurity, Auckland Council) *Reducing risks and threats across landscapes – Whakanoa mo ngā wero me ngā whakaaro witiwiti* Dr Amanda Black (Tūhoe, Whānau-a-apanui; Lecturer in Bio-protection, Lincoln University) *Reducing risks and threats across landscapes – Whakanoa mo ngā wero me ngā whakaaro witiwiti* Dr Phil Lyver (Ngāti Toarangatira; Kaihautū Vision Mātauranga – Senior Researcher, Landcare Research) *Enhancing and restoring resilient ecosystems 'Ko te whakamana pūtaiao'*
End-user Advisory Panel	End-user Advisory Panel membership	Beef + Lamb New Zealand, DairyNZ, Department of Conservation, Fonterra, Forest Owners Association, Kiwifruit Vine Health, Ministry for Primary Industries, Ministry for the Environment, Predator Free NZ, QEII National Trust, Sanctuaries of New Zealand, Sustainable Business Council, TBfree New Zealand, regional councils
Kāhui Māori	Kāhui Māori membership	Kevin Prime – Chair (Ngāti Hine, Ngāti Whātua, Tainui) Garry Watson (Tainui, Tūhoe) Dr Jamie Ataria (Rongomaiwahine, Ngāti Kahungunu, Ngāti Tūwharetoa) Cheri van Schravendijk-Goodman (Te Atihaunui-a-Paapaarangi, Ngāti Apa, Ngāti Rangi) Dr Sharon Henare (Ngā Pui, Ngāti Whātua)

Appendix 3: End-user Advisory Panel – Terms of Reference

The End-user Advisory Panel (EAP) is one of three advisory groups that will be set up to support the *New Zealand's Biological Heritage– Ngā koiora tuku iho* National Science Challenge. The role of the End-user Advisory Panel is to provide advice on:

1. Progress of the Challenge towards delivering impacts set out in its mission;
2. Adoption pathways to maximise uptake of Challenge outputs.

- The EAP will work directly with the Challenge Director and Programme Leaders within the Science Leadership Group to ensure that there is a focus on the delivery of useable high-value, high-impact research.
- The EAP will directly contribute to decision making undertaken by the Science Leadership Group, to ensure a continued focus on the mission and effective adoption pathways. This will include clear articulation of end-user priorities of relevance to the Challenge Mission.
- The EAP will also directly contribute to review of progress towards impact targets for each Programme, with a focus on the effectiveness of the implementation pathway through to end-user.
- The scope of the Panel will be the Challenge Funding Envelope ($25.8m till 30 June 2018 confirmed) which is actively governed/managed by the Challenge and the aligned research (expected to be at least $143.4m over 10 years) which is subject to 'direction' by the Challenge.
    - End-user contribution to decision making will be embedded in both the negotiated portion of the Challenge Funding Envelope (80%) and the contestable portion of the Challenge Funding Envelope (20%). During proposal assessment, the End-user Advisory Panel will make recommendations on the ranking of proposals.
    - End-user advice will also extend to recommending priorities for the aligned research (i.e. co-funding such as CRI co-funding). However, it is recognised that CRIs and other co-funding parties will also have their own mechanisms for setting priorities in line with expectations in their respective Statements of Core Purpose or equivalent strategic imperatives.
- The focus of the EAP will be strategic, complementing the tactical interests of end-users involved with individual research projects. The EAP will comprise up to 20 members, selected for their skills and expertise relevant to the outcomes being sought through the science being developed within the Challenge. Membership may change from time to time to incorporate specific perspectives deemed relevant to the work of the Panel. It is accepted that members of the Panel represent interests in outcomes accruing through implementation. The Panel may elect a Chair and/or Co-chairs who will have a direct link to the Governance Group.
- The EAP will meet quarterly in the Start-up Phase of the Challenge (nominally 1 October 2014 – 30 June 2015) and at least twice annually thereafter (30 June 2015 – 30 June 2024). Meetings will be convened by the Challenge Director.
- Costs to attend the EAP will be borne by the members and regarded as in-kind co-funding.
- The EAP will undertake a review and self-evaluation annually and may recommend changes to the Terms of Reference accordingly.
- Administrative support will be provided by the admin assistant from the Management Unit.

Membership of the EAP: The scope of this challenge includes biodiversity/biosecurity of plants and animals in terrestrial, estuarine and freshwater environments so membership of the EAP needs to include individuals with operational responsibility for biosecurity and biodiversity impacts in the indigenous estate and productive sectors. It is proposed that the Stakeholder Reference Group established to support the development of this proposal serves as an interim EAP.

The initial composition of the End-user Advisory Panel is:

Andrew Harrison: Kiwifruit Vine Health – Co-chair
Geoff Hicks: Department of Conservation – Co-chair
Alison Stringer: Ministry for the Environment
Bill Dyck: Forest Owners Association
Bridget MacLean, Sean Goddard: Fonterra
Bruce Thorrold: DairyNZ
Geoff Ridley: Beef + Lamb New Zealand
Matt Maitland: Sanctuaries of New Zealand
Mike Jebson: QEII National Trust
Naomi Parker: Ministry for Primary Industries
Paul Livingstone: TBfree New Zealand
Penny Nelson: Sustainable Business Council
Richard Bowman: Regional councils
Rob Fenwick: Predator Free New Zealand

Appendix 4 – End-user Advisory Panel Assessment Process

The assessment process

The assessment process followed a discussion on the EAP Terms of Reference to ensure the panel had a common understanding of their role and the criteria being used. A 4-point scale was agreed on as several members felt it 'forced' avoidance of a middle grade, e.g. 3 in a typical 5-point scale. An initial set of criteria was reviewed to produce the table of criteria below. The Panel recognised that they would not have primacy for assessing Vision Mātauranga (VM) projects but considered nevertheless that they would score all projects and expected that the Kāhui Māori would to do the same.

The Director gave an introduction to the process that had led to the development of the project briefs, focusing on their connection to the funded proposal. The Panel sought clarification on aspects of the process from the Director and Programme Leaders, including the difference between proposed lead-off projects and projects identified for further development via workshops.

Each project was introduced by the Director, and Programme Leaders responded to questions from the Panel. The VM Leader provided comment on VM projects and other aspects of VM. Project-level scores were applied by group consensus, i.e. individuals did not score each project; each project was considered by the Panel members, discussed and consensus reached on the scores. The scores were used to guide later discussion and decision making rather than used to rigidly characterise each project. Portfolio-level criteria were considered after all the potential lead-off projects had been scored.

Feedback on each project was recorded to be passed back to project teams to enable revision of the project briefs.

A threshold for a recommendation for 'in-principle' support by the EAP was determined; all projects except two were recommended to proceed: *Project 1.1 Mātauranga Māori characterisation of NZ's biodiversity* and *Project 2.3 Hi-tech solutions to invasive mammal pests*. The first is the domain of the Kāhui, and the second was referred back for revision to ensure novelty/additionality is maximised and to clarify its connection to the NEXT-funded ZIP project.

Assessment criteria applied

Criterion	Explanation
Project level	
Contribution to the Mission	How strongly does the proposal align with the Challenge Mission?
Feasibility	Is the proposal achievable and what is its expected contribution to outcomes?
Novelty and additionality	How new and innovative is the proposal; what does it add to current ways of doing things; what's the 'stretch' in it?
Management impact	Is it relevant and will it make a direct difference; what is the likely benefit to users?
Uptake potential	How clear is the pathway to adoption; are mechanisms for science transfer/communication evident in the proposal?
Portfolio level	
Drawing on the best team	Are the right people involved with complementary mix of skills, expertise and capacity? Does the proposal clearly articulate leverage opportunities (e.g. specialised people and co-funding; collaboration)?
Balance	How does the proposal fit within a portfolio that is appropriately balanced; in terms of applied/fundamental science, short/long term deliverables or 'wins', biodiversity/biosecurity, conservation/production?

Assessment results

Proposal	Mission	Feasibility	Novelty	Management Impact	Uptake	Total
Project 1.1 Mātauranga Māori characterisation of NZ's biodiversity	1	2	3	2	3	11
Project 1.3 A national framework for biological heritage assessment across natural and productive landscapes	3	3	4	3	3	16
Project 2.1 Biosecurity network interventions	3	3	2	3	2	13
Project 2.2 Novel wasp control technologies	4	2	4	3	4	17
Project 3.1 Predicting and managing ecosystem tipping points	3	2	4	3	2	14
Project 3.2 Customary approaches and practices for optimising cultural and ecological resilience	3	3	1	3	3	13
Project 2.3 Hi-tech solutions to invasive mammal pests	NS*	NS	NS	NS	NS	NS

* Not scored

Appendix 5: Kāhui Māori – draft Terms of Reference

The Kāhui Māori is one of three advisory groups that will be set up to support the *New Zealand's Biological Heritage– Ngā koiora tuku iho* National Science Challenge. The role of the Kāhui Māori is:

- To ensure the Challenge recognises the principles of Te Tiriti o Waitangi.
- To ensure meaningful involvement of Māori in decision making, planning, implementation, evaluation, and dissemination of the Challenge research.
- To understand and support the role of Māori as tangata whenua of Aotearoa.
- To understand and foster the economic, environmental, social and cultural aspirations of iwi, hapū and whānau.
- To provide advice to aid the Challenge to achieve its stated mission, objectives and outcomes through regular input and review of strategic direction, prioritisation of Research Programmes and the pathway to implementation, especially as they relate to Māori.
- To regularly report to interested Māori stakeholders the progress and outcomes of Challenge activities.

The Kāhui Māori will:

- Work directly with the Challenge Director, Programme Leaders and Māori Kaihautū to drive the delivery of high-value, high-impact research of interest and benefit to Māori.
- Directly contribute to decision making undertaken by the Science Leadership Group, to ensure a continued focus on the Mission and effective adoption pathways. This will include clear articulation of stakeholder priorities of relevance to the Challenge Mission.
- Also directly contribute to review of progress towards impact targets for each Programme, with a focus on the effectiveness of the implementation pathway through to end-user.
- Review Challenge documents that are of particular interest to or have a direct impact on outcomes and benefits for Māori (e.g. IP and WAI 262).

The scope of the Kāhui Māori will be the Challenge Funding Envelope ($63.7m over 10 years) which is actively governed/managed by the Challenge *and* the aligned research (expected to be at least $143.4m over 10 years) which is subject to 'direction' by the Challenge:

- Kāhui Māori contribution to decision making will be embedded in both the negotiated portion of the Challenge Funding Envelope (80%) and the contestable portion of the Challenge Funding Envelope (20%). During proposal assessment, the Kāhui Māori will make recommendations on the ranking of proposals especially those which include Vision Mātauranga-based elements.
- Kāhui Māori advice will also extend to recommending priorities for the aligned research (i.e. co-funding such as CRI co-funding). Where possible, integration of Vision Mātauranga-based research programmes will be encouraged. However, it is recognised that CRIs and other co-funding Parties will also have their own mechanisms for setting priorities in line with expectations in their respective Statements of Core Purpose or equivalent strategic imperatives.
- The Kāhui Māori will meet quarterly. Meetings will be convened by a Chair elected from among the Kāhui Māori at the first convened meeting after establishment. The Māori Kaihautū will attend and act as observers to the Kāhui Māori but cannot be elected Chair or vote.
- It is expected that where possible costs for the Kāhui Māori will be borne by the members and regarded as in-kind co-funding. However, travel and incidental expense costs will be met (where necessary) by the Challenge administration for iwi/hapū/whānau and Māori organisation/stakeholder participants.
- Administrative support will be provided by the Admin Assistant from the Management Unit.

Scope and membership of the Kāhui Māori

The scope of this challenge includes biodiversity/biosecurity of plants and animals in terrestrial and freshwater environments. Both indigenous and introduced biodiversity are important so membership of the Kāhui Māori needs to include individuals with not only an interest in both these aspects (i.e. indigenous estate and productive sectors) but should include individuals with a developed understanding of biodiversity and biosecurity from a context of kaitiakitanga, manaakitanga and tohungatanga and their unique cultural alignment to respective iwi, hapū, and whānau throughout Aotearoa.

The Kāhui Māori will comprise up to 12 members with three non-voting members, selected for their skills and expertise as relevant to the outcomes being sought through the science being developed within the Challenge. It is accepted that members of the Kāhui Māori are representatives of organisations with an interest in the implementation of the Challenge outputs and so delegates are also acceptable for the meetings. One of the members of the Panel will act as Chair. The Kāhui Māori Chair will meet regularly with the Chair of the Governance Group and may also meet with the Māori representative on the Governance Group. On occasion, the Māori representative on the Governance Group may also be invited to meet with the full membership of the Kāhui Māori via a meeting of the Kāhui Māori.

Membership of the Kāhui Māori will include the following, a maximum of:

- Four iwi/hapū/whānau representatives
- Two Māori stakeholder/government agency representatives
- Two Māori regional council representatives
- Two Māori organisation representatives
- Two CRI/university representatives, and
- Four Challenge Kaihautū (non-voting members).

Kevin Prime – Chair (Ngāti Hine, Ngāti Whātua, Tainui), Garry Watson (Tainui, Tūhoe), Dr Jamie Ataria (Rongomaiwahine, Ngāti Kahungunu, Ngāti Tūwharetoa), Cheri van Schravendijk-Goodman (Te Atihaunui-a-Paapaarangi, Ngāti Apa, Ngāti Rangi), and Dr Sharon Henare (Ngā Pui, Ngāti Whātua) will form the interim Kāhui Māori while the permanent Kāhui Māori is being established. The Kāhui Māori will then be responsible for ensuring that it has a mandate to act on behalf of Māori for this Challenge.

Review

The Kāhui Māori will be expected to self-review annually assessing their membership make-up, terms of reference and performance. Recommendations for changes shall be made to the Challenge Director and noted by the Māori representative on the Governance Group.

Appendix 6: Draft principles – Te Tiriti o Waitangi/Māori engagement

Introduction

Te Tiriti o Waitangi is about mutual relationships, responsibilities and accountabilities. The *New Zealand's Biological Heritage– Ngā koiora tuku iho* National Science Challenge is committed to respectful, collaborative relationships and approaches on Te Tiriti o Waitangi. The Challenge will incorporate MBIE's Vision Mātauranga objectives to perform high-quality research that will improve and protect Aotearoa New Zealand's biosecurity and biodiversity for Māori and all New Zealanders. We acknowledge the worldviews, skills and experiences of the team and the accountabilities each brings to the Challenge.

The principles below are a set of guiding statements intended to support VM Policy objectives whilst meeting the needs of all New Zealanders, but especially Māori.

Principles

The Biological Heritage National Science Challenge will commit to:

- Creating a research plan in which Māori and the Crown recognise each other as full Treaty partners, and in which all cultures are valued for the contributions they bring to the Challenge (*partnership*).
- Māori inclusion at the governance level, consistent with the spirit of Te Tiriti o Waitangi which promotes participation and partnership.
- Recognising and protecting the inclusion of Māori worldviews, tikanga, kawa, mātauranga, taonga, culture, and Te Reo Māori (*active protection*).
- Meaningful involvement of Māori in decision making, planning, implementation, evaluation and dissemination of the Challenge research (*duty to consult*).
- Building enduring relationships based on trust, integrity and honesty and supported by a process of engagement and consultation, as appropriate, with Māori stakeholders, end-users and communities (iwi, hapū and whānau) (partnership).
- Promoting the inclusion of Māori research methodologies and the need to protect and enhance Māori knowledge of biodiversity and biosecurity (*active protection*).
- Undertaking future-focused interdisciplinary research that will inform equitable transformation of the environment, education (science) and the well-being of Māori and all New Zealanders.
- Helping to build Māori research leadership through capacity and capability development by identifying rangatahi and emerging Māori researchers and scientists (*participation*).
- Increasing the knowledge and capability of all Challenge members to engage as appropriate with Māori interests (*inclusion*).

Engagement

This Challenge aims to ensure that engagement with Māori is meaningful, appropriate and leads to positive outcomes for all of Aotearoa/New Zealand. The Challenge has a responsibility to foster healthy relationships with Māori based on the principles of tika (*the right way to do things, respect*), pono (*honesty and integrity*) and aroha (*compassion, empathy, sharing*).

The Kāhui Māori will confirm the Māori engagement policy and develop a plan that is based on a spectrum of Māori participation as adapted from the IAP2s Public Participation Spectrum (see www.iap2.org.au).

Whakamōhio Inform	Whakauiuia Consult	Whakaura Involve	Mahi Ngātahi Collaborate	Whakamanahia Empower
MĀORI PARTICIPATION GOAL				
To provide Māori (whānau, hapū, iwi) with balanced and objective information to assist them in understanding and contributing to the Challenge	To actively seek Māori (whānau, hapū, iwi) feedback on the Challenge and its research, direction etc.	To ensure Māori (whānau, hapū, iwi) are an integral part of the Challenge process so that issues and concerns are consistently understood and considered	To foster an inclusive philosophy incorporating Māori (hapū, iwi) in each aspect of the decision making, development, and implementation of the Challenge	To implement a decision-making process for Māori (hapū, iwi) by Māori
PROMISE TO MĀORI				
The Challenge will keep Māori (whānau, hapū, iwi) informed	The Challenge will keep Māori (whānau, hapū, iwi) informed and will listen to and acknowledge concerns and provide feedback on how Māori input has influenced the Challenge and its decisions	The Challenge will work with Māori (whānau, hapū, iwi) to ensure that their concerns and aspirations are directly reflected in the Challenge and its research, and provide feedback on how Māori input influenced the Challenge's decisions	The Challenge will ensure Māori (hapū, iwi) are consulted with for direct advice and innovation in formulating solutions, and will incorporate their advice and recommendations into the Challenge decisions to the maximum extent possible	The Challenge will implement what Māori (hapū, iwi) agree to
EXAMPLE TOOLS				
• Open days (via Research Programmes) • Fact sheets • Media releases • Websites • Hui	• Focus groups • Surveys/response requests • Hui	• Interviews • Wānanga • Workshops • Fieldwork • Hīkoi • Kaihautū • Kāhui Māori • Hui	• Co-governance • Co-management • Kāhui Māori • Kaihautū • Hui	• Treaty Settlement legislation • WAI 262 • Conservation and natural resource policy • Guiding principles of engagement through the recognition of tikanga and kawa

Review

This document will be reviewed annually by the Kāhui Māori and adjusted accordingly.

Appendix 7: Data Management Plan

Data Management Plan

Research project title: High-level Data Management Plan for Biological Heritage NSC

Job code(s): N/A

Project duration: __/__/____ *to* __/__/____

Project/Job leader: N/A

Team: BH NSC Challenge Parties

Data custodian(s): N/A

Funding agency(ies): MBIE (NSC)

Research area

Short (2-3 lines) description of the project's fundamental aims and purpose.

A Data Management Plan (DMP) is a living document that should be revisited and updated throughout the duration of the research, and it is not possible to precisely document all aspects of data management on Day 1. Nor is it appropriate to have a single data management plan (DMP) for the whole Challenge. This DMP outlines high-level principles and intentions at the outset of the Challenge. Individual research projects will (and have already begun) to complete and maintain specific DMPs.

The nature of your data

What data is being generated or reused in this research?

A wide range of environmental data will be reused (existing data from NZ and/or overseas) and collected during the Challenge. The few research projects that have been initiated have identified the following types of data:

- DNA sequence data sourced from environmental samples ('eDNA'). Associated data will include information on samples, locality, and various environmental measurements
- Experimental, genomic, and transcriptomic data
- Spatiotemporal information describing flows between different network nodes and the attributes of those nodes, the links between then and the character of items (livestock, containers, people, boats etc.) moving between them

More generally data we expect to generate and/or re-use includes, for example:

- Sample collection data from a wide range of biological material
- Re-use of data from CRI/museum biological collections
- Re-use of DNA data on international databases (e.g. GenBank®)
- List of taxonomic assignments, identifications, and names
- Information from monitoring of native biodiversity and key threats (e.g. pests and weeds)
- Citizen science data
- Quantification of the flow of organisms within and between ecosystems

In what file format(s), will you store your data after acquisition (consider if one of New Zealand's Nationally Significant Databases is a suitable repository, and any data format's this may require)?

- Various DNA sequence formats, as required by international databases such as GenBank®, Short Read Archive, etc.
- .csv, MS Excel, and MS Access

Who owns the data and intellectual property rights arising from your research?

Intellectual Property ownership needs to be determined on a case-by-case basis

Data descriptions (metadata, 'data about data')

What metadata will be created or captured and published with the data to make them interpretable and reusable?

Basic descriptive and specific data field (e.g. spreadsheet column) metadata will be recorded/defined. Where possible, data descriptions will be stored electronically alongside the data.

Note any supporting information/documentation that will enhance understanding of the data.

Links to any reports and publications related to the data

Data access and sharing

Will your data be made publicly accessible? If not what restrictions will be imposed, and why?

Bearing in mind issues of sensitivity, as much as possible data will be made publicly accessible. Details on accessibility and the conditions imposed on access need to be considered at the specific project and dataset level.

How will you resolve any data sensitivity (e.g. ethical/privacy/confidentiality) issues that may prohibit sharing some or all of the dataset(s)?

Where appropriate, we will use aggregation and/or anonymisation of data before any public release of data. We will hold discussions with relevant landowners and iwi prior to or at the time of sampling to ensure expectations around both privacy/ethical issues and IP are clearly understood and documented. We recognise that some data may not be able to be made publicly accessible and release of data will need to be considered on a case-by-case basis.

Will your research data be embargoed for any reason? If yes, provide details.

Some data may be embargoed until publication. Where data are suitable for public release, provision of access will not be unreasonably delayed.

What data sharing license do you think is appropriate for this research data?

Licensing needs to be considered on a case-by-case basis for each project and dataset. Where appropriate, we will adopt an open access approach as mandated by NZGOAL (which uses the creative commons licensing).

Short-term data storage and backup

Where will you store the data during the project's lifetime? If large data files are anticipated please estimate total size.

Initially data collected by individual researchers will be held on local machines at relevant organisations. Project specific DMPs will identify where individual datasets will be stored (and these plans are subject to review and update during the project). As the Challenge gets underway, needs and opportunities for shared/centralised storage and/or cross-institutional access to existing storage solutions will be investigated and implemented as appropriate.

How (who, where, and how often) will the data be backed-up during the project's lifetime?

Data should be stored on organisations' networks or shared centralised storage, which is regularly backed up. If data are such that they cannot be stored on the network (e.g. due to size/volume, or technical aspects), a specific backup strategy for that project/data should be discussed with the Challenge Party's computer support team.

How will you manage access restrictions and data security during the project's lifetime?

Networks of the Challenge Parties are secured and accessible only by authorised users. We will need to investigate more cross-organisational access arrangements to facilitate collaboration.

Data archiving/longer-term storage

How long will or should the data be kept beyond the life of the project?

The nature of environmental information is that it is often a unique and unrepeatable record of data at a specific point in time, and as such grows in value as time progresses. This means that most data collected in the Challenge may have value in being retained indefinitely. However, an assessment of each dataset needs to be undertaken at the time. Partner obligations under the Public Records Act will be part of such assessments.

Where will your research data be deposited for long-term preservation and publication? Who is responsible for this?

Subject to sensitivity/IP considerations, data will be deposited to a data repository appropriate to each specific dataset. Projects initiated to date have identified the GenBank® Short Read Archive as one such repository. The Panel referred to several other international repositories in their feedback. We are aware of these, and where appropriate will use these established domain repositories. However, we also note that New Zealand has a number of well-established and internationally recognised databases in the biological heritage sphere, and also that there are complexities to be considered before defaulting to an international repository, e.g. issues of licensing and the legal jurisdiction the data would fall under, particularly considerations around Vision Mātauranga knowledge/data and deposit of data offshore, and that some of the repositories referred to are in fact federations of disparately held data collections, e.g. DataONE, which we might consider connecting to as a New Zealand Node. Where each dataset is ultimately preserved/published will need consideration in each project's specific DMP; however, the challenge as a whole acknowledges the need to provide guidance to the research teams, and to identify what solutions exist in-house/in New Zealand (to which access might be facilitated across the Challenge partners) and internationally. For example, Landcare Research has established a data repository and is able to issue DOIs for published datasets to meet journal requirements. This facility could readily be made available to partner organisation researchers, or a dedicated Challenge data repository established. However, whether this is an appropriate course of action needs careful consideration by the Challenge partners within the context of other data repository options in New Zealand and internationally.

When will your research data be moved to a secure archive for long-term preservation and publication?

To be considered project by project, but typically at the conclusion of research/at the point of publication of the results.

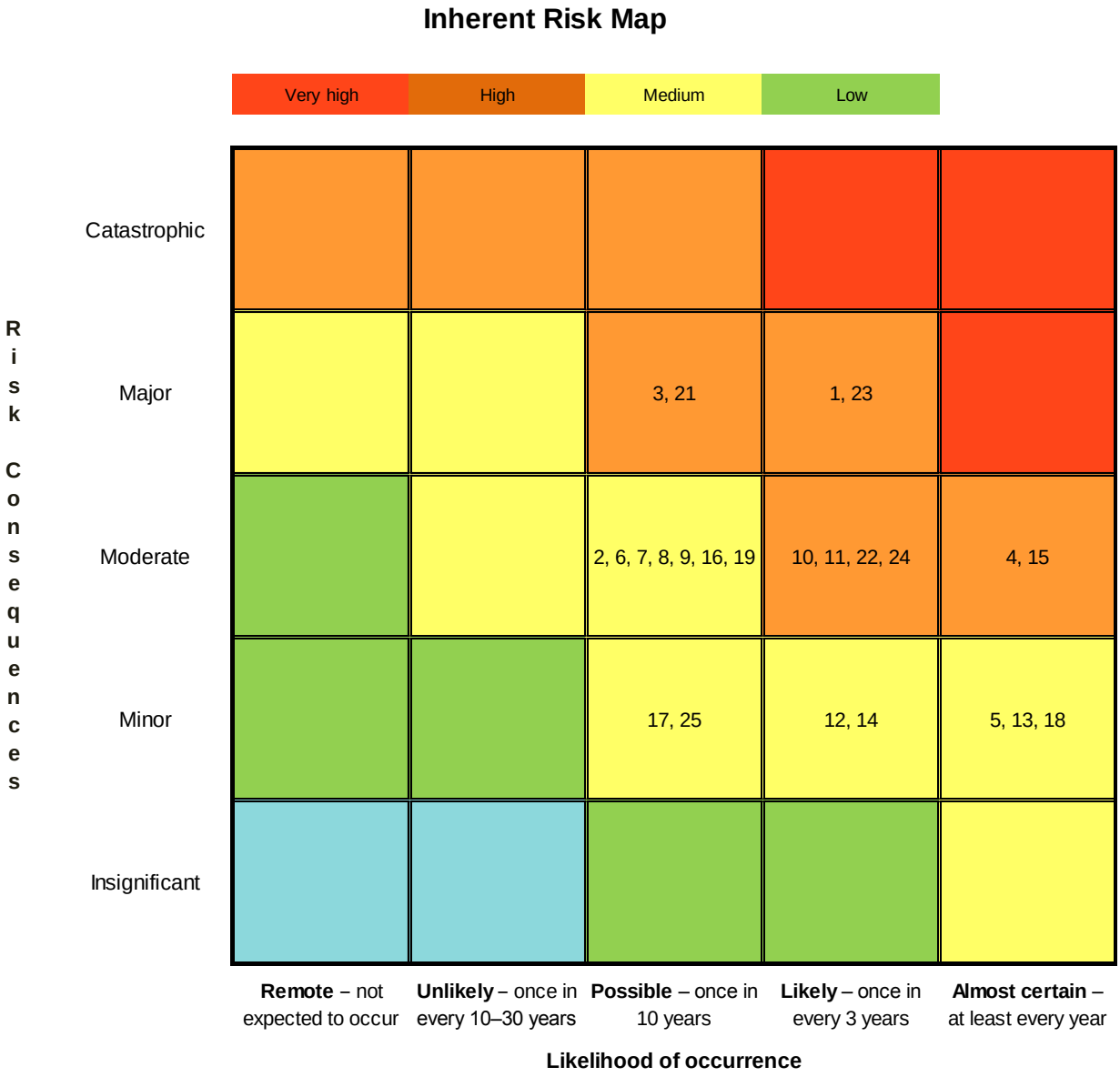
What physical samples/records associated with the electronic data should or will be stored beyond project completion?

To be considered project by project.

Who will be responsible for your data, once you have left your research group?

To be considered project by project.

Appendix 8: Risk Register



Risk		Risk Classification	Consequence Category
1	Poor uptake of outputs. Great research progress, but fail to lead to measurable improvements in the state of New Zealand's biological heritage.	Strategic	Reputational
2	Governance and Science Leadership arrangements do not allow 'active management' of research envelope, thereby losing the ability to leverage Challenge funding	Strategic	0
3	Diversion to a new immediate issue, such as a new nationally-significant biosecurity invasion or widespread novel threat to indigenous species or ecosystem	Strategic	Legislation/ contractual breach
4	Lack of external organisational resources/infrastructure to take up new Challenge research discoveries and/or capture full benefit	Strategic	Reputational
5	Challenge viewed negatively due to conflict arising between different parts of the community with respect to receiving benefits or incurring costs (i.e. trade-offs) from biological heritage outcomes	Strategic	Reputational
6	The scale of the work needed to understand ecosystems and establish databases, compromises the ability to develop new management tools	Operational	Legislation/ contractual breach
7	The public does not engage with the goal of this Challenge due to the increasing urbanisation of New Zealand and disengagement with nature	Strategic	Client/ Stakeholder
8	Insufficient leadership (at multiple levels) undermines effective operations and therefore progress towards the Challenge objective	Operational	People
9	'Silo' behaviours constrain effective interaction across programmes. The limited availability of some key skills (e.g. social science) may be significant in this regard.	Operational	People
10	Insufficiently wide support due to an unbalanced (or missing) mix of stakeholders, including economic/business perspectives; e.g. The Treasury, Sustainable Business Council, Pure Advantage.	Strategic	Client/ Stakeholder
11	Loss of reputation and political risk due to slow traction and no 'runs on the board'	Strategic	Reputational
12	Inability to demonstrate progress towards long-term outcomes along implementation pathways; this is likely to be complex and challenging	Strategic	Reputational
13	Perceptions around high management and governance costs	Strategic	Reputational
14	Monitoring and reporting could generate a large workload with relatively little marginal benefit	Operational	0
15	Limited resources compromise the ability to communicate the coherence and impact of the integrated Challenge approach, which will require sophisticated communication	Strategic	Client/ Stakeholder
16	Poor alignment to national policy processes. The value perceived by Government agencies may depend strongly on how well the Challenge contributes to national policy objectives, such as environmental monitoring and standards	Strategic	Client/ Stakeholder
17	The commitment of all Challenge Parties may be compromised if there are perceptions of privilege/advantage for the Challenge Contractor	Strategic	Client/ Stakeholder
18	Overuse of PhD students in order to work within budget, compromising credibility and/or quality of outputs	Operational	0
19	Only incremental science comes through, not creating an environment for the innovation required	Operational	0
20	WAI 262	Strategic	Legislation/ contractual breach
21	What if the theory of change (intervention logic is flawed), meaning outputs do not alter impacts and outcomes?	Strategic	Legislation/ contractual breach
22	Risk of 'brown boxing' (Vision Mātauranga not integral)	Operational	Legislation/ contractual breach
23	Insufficient incentives for research organisations to participate in the Challenge	Strategic	Client/ Stakeholder
24	Inadequate internal and external communication creates a loss of momentum, particularly during early stages of the Challenge	Strategic	Client/ Stakeholder
25	Research/outputs are superseded or 'leap-frogged' by a third party delivering a similar or better product	Strategic	Reputational

Biological Heritage National Science Challenge Governance Group Risk Register

	Risk Name	Risk Classification	Risk Direction	Inherent Risk	Likelihood of Occurrence	Actions to Manage	Residual Risk	Consequence Category	Target Risk
1	Poor uptake of outputs. Great research progress, but fail to lead to measurable improvements in the state of New Zealand's biological heritage.	Strategic	→	High	Likely	4	High	Reputational	Medium
2	Governance and Science Leadership arrangements do not allow 'active management' of research envelope, thereby losing the ability to leverage Challenge funding	Strategic	→	Medium	Possible	3	Medium		Low
3	Diversion to a new immediate issue, such as a new nationally-significant biosecurity invasion or widespread novel threat to indigenous species or ecosystem	Strategic	→	Medium	Possible	4	Medium	Legislation/ contractual breach	Low
4	Lack of external organisational resources/infrastructure to take up new Challenge research discoveries and/or capture full benefit	Strategic	→	High	Almost certain	4	High	Reputational	Medium
5	Challenge viewed negatively due to conflict arising between different parts of the community with respect to receiving benefits or incurring costs (i.e. trade-offs) from biological heritage outcomes	Strategic	→	Medium	Almost certain	6	High	Reputational	Low
6	The scale of the work needed to understand ecosystems and establish databases, compromises the ability to develop new management tools	Operational	→	Medium	Possible	3	Medium	Legislation/ contractual breach	Low
7	The public does not engage with the goal of this Challenge due to the increasing urbanisation of New Zealand and disengagement with nature	Strategic	→	Medium	Possible	6	Medium	Client/ Stakeholder	Low
8	Insufficient leadership (at multiple levels) undermines effective operations and therefore progress towards the Challenge objective	Operational	→	Medium	Possible	3	Medium	People	Low
9	'Silo' behaviours constrain effective interaction across programmes. The limited availability of some key skills (e.g. social science) may be significant in this regard.	Operational	→	Medium	Possible	3	Low	People	Low
10	Insufficiently wide support due to an unbalanced (or missing) mix of stakeholders, including economic/business perspectives; e.g. The Treasury, Sustainable Business Council, Pure Advantage.	Strategic		Medium	Likely	4	High	Client/ Stakeholder	Low
11	Loss of reputation and political risk due to slow traction and no 'runs on the board'	Strategic	→	High	Likely	4	High	Reputational	Low
12	Inability to demonstrate progress towards long-term outcomes along implementation pathways; this is likely to be complex and challenging	Strategic	→	Medium	Likely	4	Medium	Reputational	Low
13	Perceptions around high management and governance costs	Strategic	→	Medium	Almost certain	4	High	Reputational	Low
14	Monitoring and reporting could generate a large workload with relatively little marginal benefit	Operational	→	Medium	Likely	6	High		Low
15	Limited resources compromise the ability to communicate the coherence and impact of the integrated Challenge approach, which will require sophisticated communication	Strategic	→	High	Almost certain	6	High	Client/ Stakeholder	Low
16	Poor alignment to national policy processes. The value perceived by Government agencies may depend strongly on how well the Challenge contributes to national policy objectives, such as environmental monitoring and standards	Strategic	→	Medium	Possible	6	High	Client/ Stakeholder	Low
17	The commitment of all Challenge Parties may be compromised if there are perceptions of privilege/advantage for the Challenge Contractor	Strategic	→	Medium	Possible	4	Low	Client/ Stakeholder	Low
18	Overuse of PhD students in order to work within budget, compromising credibility and/or quality of outputs	Operational		Medium	Almost certain	6	High		Low
19	Only incremental science comes through, not creating an environment for the innovation required	Operational	→	Medium	Possible	4	Medium		Low
20	WAI 262	Strategic	→		?	6	Medium	Legislation/ contractual breach	Low
21	What if the theory of change (intervention logic is flawed), meaning outputs do not alter impacts and outcomes?	Strategic	→	Medium	Possible	4	Medium	Legislation/ contractual breach	Low
22	Risk of 'brown boxing' (Vision Mātauranga not integral)	Operational	→	Medium	Likely	4	Medium	Legislation/ contractual breach	Low
23	Insufficient incentives for research organisations to participate in the Challenge	Strategic		High	Likely	4	High	Client/ Stakeholder	Low
24	Inadequate internal and external communication creates a loss of momentum, particularly during early stages of the Challenge	Strategic	↑	Medium	Likely	5	High	Client/ Stakeholder	Low
25	Research/outputs are superseded or 'leap-frogged' by a third party delivering a similar or better product	Strategic	→	Low	Possible	6	Medium	Reputational	Low

Risk direction

- → No change in risk direction
- ↓ Risk is decreasing
- ↑ Risk is increasing

Inherent / Residual / Target Risk

- Very high
- High
- Medium
- Low

Likelihood of occurrence

- Almost certain – at least every year
- Likely – once in every 3 years
- Possible – once in 10 years
- Unlikely – once in every 10–30 years
- Remote – not expected to occur

Assessment of actions to manage risk

1. Exceed requirement – the risk management processes have been over-engineered for the level of risk involved
2. Meet requirement – the risk management processes are appropriate for the level of risk identified
3. Need strengthening (minor) – minor improvements in the risk management processes are necessary to reach 'meet requirement'
4. Need strengthening (important) – risk management processes need to be strengthened in important ways to reach 'meet requirement
5. Need strengthening (critical) – risk management processes are clearly deficient in critical ways
6. Unestablished – risk management processes have not yet been established. This will most likely be the situation in the case of a ne

Consequence category (potential)

- Financial
- Reputational
- Legislation/contractual breach
- People
- Client/Stakeholder

Key to Status	
⇔	Progressing or monitoring in place
✔	Completed
✖	Not started, or issues

	Risk Name	Actions	GG/SLG Responsibility	Responsibility	Status	Comments
1	Poor uptake of outputs. Great research progress, but fail to lead to measurable improvements in the state of New Zealand's biological heritage.	Early and on-going engagement with end-users with a view to ensuring outputs are 'fit-for-purpose' and can realistically be implemented. Understand and plan for user implementation pathways and ensure projects plan for and resource user support – 'planning for impacts'. Where appropriate, support end-users in developing internal or external cases for funds.	Director	Science Leadership Group and Project Leaders	⇔	
2	Governance and Science Leadership arrangements do not allow 'active management' of research envelope, thereby losing the ability to leverage Challenge funding	Clear understanding of spans of control and principles/flexibility around opportunities, in doing so ensuring scope exists to leverage funds. RASCI should reflect.	Governance Group		⇔	
3	Diversion to a new immediate issue, such as a new nationally-significant biosecurity invasion or widespread novel threat to indigenous species or ecosystem	Clear description of Challenge focus, what is in and out of scope. If risk eventuates, the response will have to be considered and managed at the time through the Governance structures and in accordance with the nature of the issue, being very clear on the benefits lost through the trade off.	Governance Group		⇔	
4	Lack of external organisational resources/infrastructure to take up new Challenge research discoveries and/or capture full benefit	Early and on-going engagement with end-users with a view to ensuring outputs are 'fit-for-purpose' and can realistically be implemented. Understand and plan for user implementation pathways and ensure projects plan for and resource user support – 'planning for impacts'. Where appropriate, support end-users in developing internal or external cases for funds. In some cases this may be overcome by sharing platforms and having a lead-agency adopt the necessary technology, and then make this available to others.	Director	Science Leadership Group and Project Leaders	⇔	
5	Challenge viewed negatively due to conflict arising between different parts of the community with respect to receiving benefits or incurring costs (i.e. trade-offs) from biological heritage outcomes	Evidence-based approaches will improve transparency of risks and benefits across all stakeholders. Be clear of the separation of the Challenge presenting the knowledge and tools, from that of the decision making body in relation to the conflict (i.e. provision of objective information). Approach and communication around the Challenge should be on the basis of non-bias towards any sector group. Be wary of being seen to have a particularly close relationship with any group that may threaten impartiality, real or perceived – achieved by ensuring all key stakeholders are engaged.	Director	Science Leadership Group and Project Leaders	✖	
6	The scale of the work needed to understand ecosystems and establish databases, compromises the ability to develop new management tools	Ensure programmes of work are balanced during the planning stage, with managers being cognisant of diversion of funds. Be prepared to state limitations of outputs in light of need for improved underlying data and the subsequent degree of uncertainty. It will be necessary to ensure a continual focus on impact at the governance and management levels, and ensure ongoing engagement of end-users.	Director	Science Leadership Group and Project Leaders	⇔	
7	The public does not engage with the goal of this Challenge due to the increasing urbanisation of New Zealand and disengagement with nature	The community engagement/outreach parts of this proposal are expected to build engagement. Monitor as part of outreach plan, considering existing information sources (e.g. DOC and Lincoln University surveys) and any survey as part of that plan. If risk grows, consider further action at that time.	Director	Communications and Outreach Managers	✖	
8	Insufficient leadership (at multiple levels) undermines effective operations and therefore progress towards the Challenge objective	Appointment of appropriate leaders, being patient in the selection process. Create processes and culture for the leadership values sought.	Governance Group	Director	⇔	
9	'Silo' behaviours constrain effective interaction across programmes. The limited availability of some key skills (e.g. social science) may be significant in this regard.	Appointment of appropriate leaders. Create processes and culture to ensure silos do not arise, for example make a project assessment criteria. Ensure opportunities for interaction are not constrained (for example by time and/or resourcing). Internal communication plan should also address, e.g. via messages and stories in newsletters.	Director	Science Leadership Group and Project Leaders	⇔	
10	Insufficiently wide support due to an unbalanced (or missing) mix of stakeholders, including economic/business perspectives; e.g. The Treasury, Sustainable Business Council, Pure Advantage.	Key part of Director role, ensure sufficent time is allocated. Creation of a stakeholder plan. Adequate resources (time in particular) are dedicated to stakeholder engagement. If and as they arise, raise the absence of each key stakeholders as a separate risk.	Director	Science Leadership Group	⇔	Director current focus, need to develop systems etc.
11	Loss of reputation and political risk due to slow traction and no 'runs on the board'	Focus hard on gaining traction quickly and delivering some quick 'runs' that demonstrate the added value possible through the Challenge structure and processes; the 'threats–risk' focus in Programme 2 may be particularly important in this regard. At the same time manage expectations around the nature of the work, the size of the issues, the process and work required to address them and the time lags involved. The communications plan should include such messaging.	Director	Science Leadership Group	⇔	
12	Inability to demonstrate progress towards long-term outcomes along implementation pathways; this is likely to be complex and challenging	Ensure the *Outcome Framework* clearly states the theory of change (intervention logic) and this is told in an accessible way. Careful consideration of associated KPIs. Clarity around expected time lags and what is and is not in control of the Challenge (it cannot force users to adopt outputs for example). Up to 3% of budget earmarked in the proposal for an 'outcomes effectiveness project', ensure this happens.	Director	Framework/KPI lead and Science Leadership Group	⇔	
13	Perceptions around high management and governance costs	The Science Board expects a critical review of such costs before the revised Business Plan in submitted in April 2015. Work with MBIE, clarifying what is in and out of scope (i.e. definition of management and governance as opposed to research costs). Understand risks generated from any under-investment in Governance and Science Leadership. Manage expectations.	Governance Group	Director	⇔	
14	Monitoring and reporting could generate a large workload with relatively little marginal benefit	The design and implementation of monitoring and reporting will need to pay careful attention to efficiency and minimising duplication (especially for co-funded/aligned research). Ensuring each measure is passed though assessment criteria that includes 'resourcing'. Be clear of expected resources required during process design, internal to the Challenge, and the burden on external parties with aligned funding.	Director	Support Team Lead	✖	
15	Limited resources compromise the ability to communicate the coherence and impact of the integrated Challenge approach, which will require sophisticated communication	Communication plan to leverage off co-funding Parties where possible. Consider novel approaches.	Director	Communications Manager	✖	In reference to long-term communications plan
16	Poor alignment to national policy processes. The value perceived by Government agencies may depend strongly on how well the Challenge contributes to national policy objectives, such as environmental monitoring and standards	Cognisance with relevant policies and initiatives is expected from Programme and Project Leaders. Ongoing engagement with relevant stakeholders over the life of the Challenge. Consider a brief exercise of listing key processes and objectives and assessing Challenge alignment against each.	Director	Science Leadership Group and Project Leaders	✖	
17	The commitment of all Challenge Parties may be compromised if there are perceptions of privilege/advantage for the Challenge Contractor	Separate Challenge identity and clear delineation from the Challenge Contractor. Care that all communication comes from the Challenge. Processes are consistent. Conflicts of interest, perceived as well as real, are managed.	Governance Group		⇔	
18	Overuse of PhD students in order to work within budget, compromising credibility and/or quality of outputs	Monitor the use at Project, Programme, and whole-of-Challenge level.	Director	Science Leadership Group and Project Leaders	✖	
19	Only incremental science comes through, not creating an environment for the innovation required	Make a Project criteria in approval process. Also do assessment at aggregated Programme and Challenge levels. Pose this specific question to Science Advisory Panel.	Director	Science Leadership Group and Project Leaders	⇔	
21	What if the theory of change (intervention logic is flawed), meaning outputs do not alter impacts and outcomes?	Ensure the *Outcome Framework* clearly states the theory of change (intervention logic). Ensure the mid-point review covers this.	Director	Framework/KPI lead	⇔	
22	Risk of 'brown boxing' (Vision Mātauranga not integral)	Follow through on intent and approach of the Proposal. Reliance on Māori Kaihautū and the Kāhui Māori, in particular ensuring they are fully involved in early design and planning stages in all Projects.	Director	Science Leadership Group	⇔	
23	Insufficient incentives for research organisations to participate in the Challenge	Develop key messages to promote benefits and alignment. Deliver these messages through multiple channels. Approach key decision makers on an individual basis. Elevate concerns around key partners to Governance Group.	Director	Science Leadership Group	⇔	
24	Inadequate internal and external communication creates a loss of momentum, particularly during early stages of the Challenge	Engage Communications Leader as soon as possible and support development and implement of strategy. Governance and Science Leadership to prioritise communication needs.	Director	Communications lead	⇔	
25	Research/outputs are superseded or 'leap-frogged' by a third party delivering a similar or better product	Researchers and Leaders stay nationally and internationally current, tracking research Projects with similar goals. Be prepared to adapt/adopt if this best contributes to the Mission.	Director	Science Leadership Group and Project Leaders	✖	