Ministry of Business, Innovation & Employment

National Science Challenges

Potential Challenges for Consideration by Peak Panel

Sustaining our Environment and Dealing with a Changing Environment

February 2013

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1 Introduction

The potential challenges in this area cover a wide range of issues related to sustaining our present environment and adapting to environmental change.

Twenty eight submissions were received from the science sector in this domain. These submissions have been grouped as shown in Table 1.

Table 1: Summary of proposed challenges by grouping

Entry Id	Challenge
Describing and Conserving Biodiversity	
137	To improve knowledge of New Zealand's biodiversity through research, maintenance and development of specimen collections and databases, and capacity building. To provide information crucial for the protection of our native biota in a changing world
189	Enhancing bio-diversity in areas where New Zealanders live, work and play
222	Knowing Our Green and Keeping it Clean: New Zealand is famous for its clean natural environment and unique biota. But we understand our biodiversity rather poorly, and our record in preserving this tāonga and keeping it clean is inadequate
284	New Zealand's unique Biodiversity is the renewable resource for our future. Documenting and securing our resources, and knowing the current and future culturally informed capital value of these assets, will permit future proofed sustainable development
388	Smart Green Partnerships to Save New Zealand's Natural Capital: Bringing research from Universities and other research providers to support major community-based and local governmental environmental initiatives
397	To create a network of significant freshwater habitats within and around the production and urban landscape to promote management activities to ensure no net loss of iconic native species living in those habitats
410	For New Zealand to be a global leader in enhancing the social, cultural, environmental, and economic value of terrestrial, freshwater and marine biodiversity. [This was also submitted separately as submission 460]
481	Nurturing Native Ecosystems
Entry Id	**Challenge**
Biosecurity and Pest Management	
62	Reduce the growing and devastating impact of unwanted pests by improving biosecurity and pest management solutions
299	Low levels of small introduced mammals in New Zealand conservation estate
311	Pest Free New Zealand
312	A Pest-Free Aotearoa: Rid New Zealand of its small mammal pests to achieve security of markets for our produce, indigenous biota, and ecosystem services towards social and economic prosperity
399	By 2050 an environment where small mammal pests are no longer a threat to the

Entry Id	Challenge
	security of New Zealand's indigenous biota, or condition of New Zealand's ecosystem services
431	Bio-protection for a small island nation
461	Future Proofing New Zealand Biosecurity. Overall Goal: To halve, by 2030, the rate destructive, exotic organisms establish in New Zealand's terrestrial and aquatic ecosystems, by aligning and boosting national biosecurity effort. This is fundamental to economic growth, environmental quality and public health
462	Protecting New Zealand's Natural Capital from Biological Risks. Overall Goal: The Government's goal for economic growth is underpinned by measures that protect New Zealanders, our unique natural resources, and primary industries from biological risks
37	Revitalise New Zealand native forests
Entry Id	**Challenge**
Climate Change	
65	New Zealand becoming the global leader in climate change solutions [Also submitted as proposal I.D # 58 (I.D #58 Has some slight details added to it but wording is almost exact)]
76	Sustaining New Zealand's environment, economy and society in a world with a changing climate
125	Climate Change - have a proper global assessment and how that applies to New Zealand as an individual country
244	Reducing greenhouse gas emissions from agriculture New Zealand while supporting the sector's prospects for growth and generation of wealth for all New Zealanders
263	Reducing the uncertainty of Antarctica's impact on New Zealand's oceans, climate and ecosystems in a changing global climate. [Also submitted as proposal #389]
361	Better climate change projections for a better prepared New Zealand
381	Minimising global climate change
408	Generating sustainable growth and resilience under a changing climate: Create scientific and technical knowledge to guide adaptation to climate variability and change, reduce greenhouse gas emissions, and engage with all sectors in its application. [Also submitted as proposal #449]
430	Living with climate change in Aotearoa
464	A World-leading Low Carbon Economy. Goal: Develop a world leading low carbon economy that provides energy security, increases access to export markets and reduces greenhouse gas emissions
480	Environmental Change: Preparing New Zealand for the Effects of Environmental and Climate Change

2 Describing and Conserving Biodiversity

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 2: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
Describing and Conserving Biodiversity		
137	To improve knowledge of New Zealand's biodiversity through research, maintenance and development of specimen collections and databases, and capacity building. To provide information crucial for the protection of our native biota in a changing world.	1. Discovery & description 2. Stewardship of collections and databases 3. Analysing data to provide new insights 4. Training and skill development
189	Enhancing bio-diversity in areas where New Zealanders live, work and play	1. Background Research 2. Animal Predators 3. Plant Competition 4. Community Involvement
222	Knowing Our Green and Keeping it Clean: New Zealand is famous for its clean natural environment and unique biota. But we understand our biodiversity rather poorly, and our record in preserving this tāonga and keeping it clean is inadequate.	1. Understanding our Greenness 2. Improving our Cleanness
284	New Zealand's unique Biodiversity is the renewable resource for our future. Documenting and securing our resources, and knowing the current and future culturally informed capital value of these assets, will permit future proofed sustainable development.	1. Complete an inventory and create a National biorepository of New Zealand's native and introduced microbial biodiversity annotated for environmental application and sustainable bioresources development. 2. To complete an inventory and genetic repository, of New Zealand's marine coastal and shelf biodiversity including extreme environments. Utilise the knowledge to substantiate environmental management while also exploring novel bioresource development

Entry Id	Challenge	Themes
Describing and Conserving Biodiversity		
		3. Complete an inventory substantiated by a genetic repository, of New Zealand's terrestrial biodiversity including extreme environments. Utilise the knowledge to substantiate environmental management while also exploring novel bioresource development 4. To complete an inventory and genetic repository, of New Zealand's freshwater and lakes biodiversity including extreme environments. Utilise the knowledge to substantiate environmental management while also exploring novel bioresource development
388	Smart Green Partnerships to Save New Zealand's Natural Capital: Bringing research from Universities and other research providers to support major community-based and local governmental environmental initiatives.	1. Defining Visions and Strategic Targets. 2. New Business Models to Create Employment and Economic Wealth from Environmental Restoration Initiatives 3. Education and National Engagement in Environmental Well-Being as a Foundation for Economic Strength 4. Green Urbanism: Bringing Nature and its Benefits into the Cities
397	To create a network of significant freshwater habitats within and around the production and urban landscape to promote management activities to ensure no net loss of iconic native species living in those habitats.	1. To create a network of significant freshwater habitats within and around the production and urban landscape to promote management activities to ensure no net loss of iconic native species living in those habitats 2. Better tools to measure the effectiveness of freshwater biodiversity protection and enhancement 3. New and better pest management and herbicide tools for freshwater systems 4. Quantify native fish values in lowland habitats
410	For New Zealand to be a global leader in enhancing the social, cultural, environmental, and economic value of terrestrial, freshwater and marine biodiversity. [This was also submitted separately as submission 460].	1. Define and value our distinctive biodiversity 2. Understand the complexity of biodiversity in order to protect its values 3. Reduce the threats and increase the resilience of valued biodiversity 4. Use a robust evidence base to assess biodiversity, its values and services

Entry Id	Challenge	Themes
Describing and Conserving Biodiversity		
481	Nurturing Native Ecosystems	1. Describing our remaining native ecosystems and their value to New Zealand 2. Threats 3. Enhancing Native Ecosystems

Entry ID	**397**
To create a network of significant freshwater habitats within and around the production and urban landscape to promote management activities to ensure no net loss of iconic native species living in those habitats	
Summary	This challenge proposes measures aimed at halting the decline of freshwater biodiversity due to habitat loss/modification. It proposes to develop networks of viable freshwater habitats within urban environments, develop new and improved pest management and herbicide tools for freshwater systems, and develop and improve upon measures used to quantify/assess the state of biodiversity within particular freshwater habitats. These measures will assist in developing better ways to sustainably manage our native freshwater biodiversity.
Theme 1 **To create a network of significant freshwater habitats within and around the production and urban landscape to promote management activities to ensure no net loss of iconic native species living in those habitats**	
Importance to New Zealand	There is a lack of information on freshwater biodiversity to inform policy and management responses. Many native aquatic species are in known states of decline, many other species particularly invertebrates are data deficient. Freshwater biodiversity is in decline due to habitat loss or modification.
Research components	Identify networks of key habitat sites within the production and urban landscape needed to sustain viable populations of key native species.
Theme 2 **Better tools to measure the effectiveness of freshwater biodiversity protection and enhancement**	
Importance to New Zealand	It is very difficult to cost effectively measure the state of native freshwater biodiversity and to detect changes either due to pressures, such as habitat modification, or as the result of management intervention.
Research components	Collating a suite of existing tools for measuring freshwater biodiversity state and change and where necessary develop new tools to fill identified gaps. Developing user friendly strategies and methodologies to apply these tools to cost effectively

	measure state and change at all levels - local, regional, national.
Theme 3 **New and better pest management and herbicide tools for freshwater systems.**	
Importance to New Zealand	Freshwater systems generally have fewer cost effective and long term solutions for the control of key pest fish and aquatic weed species.
Research components	Develop more cost effective tools to protect significant native freshwater habitats from the impacts of introduced pests and weeds. These may need to be highly innovative using state of the art technologies involving deep understanding of ecology, molecular biology and genetics.
Theme 4 **Quantify native fish values in lowland habitats**	
Importance to New Zealand	Current understanding of Taranaki and New Zealand lowland waters is limited. Many aquatic species are threatened but in the absence of information that quantifies native fish values, management agencies cannot adequately maintain and protect those values.
Research components	Fieldwork to quantify fish communities, including spawning and migratory habitat
Research Gaps and Opportunities	In spite of a vast amount of research undertaken in New Zealand on biodiversity protection, most research is site specific and targets terrestrial systems. Freshwater biodiversity has much more significant information gaps which makes it difficult for policy and decision making. In terms of information its applications is limited by its fragmented nature held in many places. In many cases the results of research have not been taken up by potential users. Information is often not readily accessible and there is often and lack of coordination between organisations who have responsibilities for managing biodiversity and with resource users that may be impacting on biodiversity values.
Comments	There are two key elements to this research proposal. The first to plug current information gaps in freshwater biodiversity to ensure significant sites and values are more readily identifiable to decision makers and resource users. The second is to develop strategies and methodologies to cost effectively use all of the available tools to maintain and improve biodiversity outcomes for threatened native freshwater species and associated habitats.

Entry ID	137
To improve knowledge of New Zealand's biodiversity through research, maintenance and development of specimen collections and databases, and capacity building. To provide information crucial for the protection of our native biota in a changing world	
Summary	This challenge proposes to improve knowledge of New Zealand's biodiversity through research, maintenance and development of specimen collections and databases, and capacity building. To provide information crucial for the protection of our native biota in a changing world.
Theme 1 **Discovery & Description**	
Importance to New Zealand	New Zealand's unique biodiversity is part of our national identity. Better knowledge of its components and how they function will enhance New Zealand's well-being by enabling us to steward our living resources sustainably and holistically for the present and future generations. Most of our native fauna and flora is endemic — found nowhere else in the world — with many unique and special attributes deriving from our geography and geological history. As well as providing fascinating insights into life on our planet, biodiversity research focused on biosystematics provides insights into the evolution of our distinctive flora and fauna, underpins biosecurity, identifies plants and animals with useable properties or products, and recognises and protects the ecological services they provide in marine and freshwater environments and on land. In addition it enables reproducible science — science that is based on valid names and vouchered specimens, enabling testable hypotheses. Biodiversity research further supports work in Antarctica, and trade and international relationships.
Research components	Discovery and taxonomic research to describe and document New Zealand flora and fauna, including understanding phylogenetic relationships and evolution, distribution in time and space, and biological characteristics and traits.
Theme 2 **Stewardship of collections and databases**	
Research components	1. Improving long-term care and security of collections and databases and the wealth of knowledge they contain for future generations; 2. Improving accessibility of collections and associated data to enable long-term access for multiple users
Theme 3 **Analysing data to provide new insights**	
Research components	1. Application of new technologies to enhance analysis and interoperability of data sets and collections, enabling improved access within New Zealand and internationally to meet biodiversity and biosecurity requirements; 2. Integrating

	biodiversity datasets with available environmental information, with the aim of improving our knowledge of basic ecological processes affecting biodiversity for more competent stewardship of our globally unique and vulnerable ecosystems
Theme 4 **Training and skill development**	
Research components	1. Training and skill development — to build taxonomic skills: o at tertiary level (no university specialises in this subject area at present) – to address issues of critical national capability and capacity o within Maori communities to enable integration with traditional knowledge and better access and use of indigenous biodiversity o in the community to equip and enhance community knowledge and recognition of biodiversity at all levels for a variety of purposes including monitoring 2. Development of skills in new areas of taxonomic research, such as molecular techniques and barcoding, to improve efficiency in the delivery of taxonomic services.

Entry ID	**189**
Enhancing bio-diversity in areas where New Zealanders live, work and play	
Summary	This challenge proposes to develop research programmes which specifically target individual components of our biodiversity- it is proposed that informed choices should be made regarding specific areas/organisms to focus conservation efforts (such as animals on the DOC list of threatened species- preferably high profile ones with public 'feel good' factor). Other research areas involve targeting introduced predators, or re-establishing native plants in mono-cultural agricultural/forestry land. This challenge aims to utilise a large volunteer base (such as the 70,000 strong 'Forest & Bird' organisation).
Theme 1 **Background Research**	
Importance to New Zealand	In order to develop a research programme specifically targeting the enhancement of individual components of our bio-diversity, it will be necessary to make choices because of the large number of organisms involved Our starting point could be the DOC list of 600 threatened species, but it would be important to ensure a spread across species or we might end up with a list of just lichens and mosses .A selection covering a range of animals, .plants , invertebrates etc is crucial and a considerable amount of background research on their occurrence, current status, basic ecology and potential for recovery will be needed. Much information may already be available, but it will be important to include some “flagship” species to meet and engage public expectations of the challenge.

Theme 2 **Animal Predators**	
Importance to New Zealand	As indicated above much of our bio-diversity is threatened by introduced animal and plant predators .The development of a plan of action by the group of 20 (See themes above) will be an integral part of this challenge. There is still much to learn about many of our predators. For example, the emergence of hedgehogs as a major pest of insects and birds is now recognised, but requires some detailed studies. Domestic and feral cats and dogs can do immense damage in a short time and can pose real difficulties to control .There is work going on in other countries such as the UK and Australia where cats, in particular, are recognised as the next “big thing “ in predator control .
Theme 3 **Plant Competition**	
Importance to New Zealand	Much of our plant bio-diversity has been lost through the widespread planting of exotic, largely monocultural forestry and grassland .This intensification and the application of uniform management practices has eliminated critically important variability in ecological sites ,which have formerly supported a wide range e of native species .The reclaiming of these sites may be more difficult than simply eliminating animal predators .Even when stock are excluded from permanent grassland little natural re-establishment of plant and animal bio-diversity can occur for at least 40 years .Research is needed to speed up this process.
Research components	As discussed earlier much of the huge programmes of restoration plantings which have been carried out throughout the country in recent years have (with a few exceptions) been carried on without specifically targeting individual components of our bio-diversity (apart from plants). At the simplest level it is naïve to expect a large increase in bird life to result from plantings without a concomitant programme of pest control ie “Empty cathedrals”. The importance of the science contribution to this challenge is that it closely define the requirements for the successful enhancement of the selected bio-diversity components .As much of our bio-diversity is unique to New Zealand it follows that the importance of many predators may also have unique features Thus it is envisaged that most of the research will be carried out in New Zealand Exceptions could be in the development of safe poisons and traps for animal predators .Genetic manipulation of fertility in animal predators may also need to draw on basic work carried out internationally
Theme 4 **Community Involvement**	
Importance to New Zealand	An important component of many science programmes is technology transfer to the relevant industry, sector or community .The results of this challenge will be extremely important to the voluntary sector, which has often not taken a strategic approach to targeting individual components of our bio-diversity. These groups vary in size from the 70,000 members of Forest and Bird to thousands of smaller

	organisations and individuals who spend most of their weekends restoring our environment through planting, restoration programmes and pest control throughout New Zealand. This research will make their work more effective and it is therefore very important that they also have an active role in the research and are not just receivers of the technology .Advantages to the challenge are the availability of a very large and often knowledgeable voluntary work force who will not lack motivation .This will pose difficult managerial and logistical issues ,but the rewards will ensure that the challenge has the total commitment of the community
Research components	As discussed earlier much of the huge programmes of restoration plantings which have been carried out throughout the country in recent years have(with a few exceptions) been carried on without specifically targeting individual components of our bio-diversity (apart from plants) .At the simplest level it is naïve to expect a large increase in bird life to result from plantings without a concomitant programme of pest control ie "Empty cathedrals " .The importance of the science contribution to this challenge is that it closely define the requirements for the successful enhancement of the selected bio-diversity components . As much of our bio-diversity is unique to New Zealand it follows that the importance of many predators may also have unique features .Thus it is envisaged that most of the research will be carried out in New Zealand .Exceptions could be in the development of safe poisons and traps for animal predators .Genetic manipulation of fertility in animal predators may also need to draw on basic work carried out internationally
Research Gaps and Opportunities	One of the greatest challenges of this proposal is to effectively utilise the huge "army" of volunteers in this sector .Not just as a workforce but also as a repository of a large bank of valuable observational and anecdotal information.
Comments	The leadership and management of this project will be an enormous challenge. The incorporation of the voluntary sector into the programme will play a key role in its success .Although many of these individuals hold strong opinions they share a passion for restoring our New Zealand environment and bio-diversity. They also have a hunger for information and science which will make their work more effective and satisfying. As most dictionaries will tell you a challenge would not be a challenge if it is not "a difficult and demanding task "

Entry ID	**222**
Knowing Our Green and Keeping it Clean: New Zealand is famous for its clean natural environment and unique biota. But we understand our biodiversity rather poorly, and our record in preserving this tāonga and keeping it clean is inadequate	
Summary	This challenge proposes to initiate on-going study geared towards understanding our biodiversity (and the preservation our high-quality environment). This involves genetic studies of culturally and commercially important species (e.g. paua) to

	facilitate sustainable harvesting, genetic studies of threatened species to best align conservation efforts, and genetic studies to characterise our undiscovered/undocumented biota. Further to this is environmental work which will restore ecosystems and habitats affected by industrial practices. This work is predicted to have environmental, social, and economic benefits (i.e. tourism).
Theme 1 **Understanding our Greenness**	
Importance to New Zealand	Our biota is a fundamental part of what makes New Zealand. Tourists come to see our whales, our birds and our national parks; our natural areas provide ecosystem services worth billions; many of our native species are tāonga to Māori; and the recreational activities of many New Zealanders involve nature. The late Sir Paul Callaghan made explicit the argument that New Zealand's economy depends critically on our high quality environment, in part because it attracts innovators and other high-worth workers who value that aspect of the quality of life. But, in order to fully appreciate what we have, so that we can act as guardians, we need to know much more about it. For example, preserving marine fisheries (especially of culturally important species like pāua) requires we understand the genetic structure of populations, so we know the scale at which protection should be implemented. Highly structured populations necessitate many local no-take areas whereas fewer conservation efforts are needed with highly connected, dispersive taxa. Knowing just how different our fauna is matters too: recent genetic work has shown the stitchbird or hīhī has no close relatives and belongs in its own family. Its conservation, therefore, matters to its guardian iwi, globally in terms of biodiversity and there are immediate economic spinoffs in ecotourism. In short, understanding our greenness matters to us as New Zealanders: there are significant economic, cultural and iwi benefits.
Research components	This work requires scientists adept in field work, as well as those with genetic and bioinformatic skills. Much of our biota is currently undocumented (especially invertebrate animals and micro-organisms) and yet these components are critical to the healthy functioning of our ecosystems. Developing easy-to-use pipelines that enable biodiversity to be reliably measured from carefully taken samples will be critical. Such pipelines are likely to involve new technologies and novel bioinformatics tools. Biologists (ecologists, taxonomists and geneticists), mathematicians and computer scientists will need to work together.
Theme 2 **Improving our Cleanness**	
Importance to New Zealand	New Zealand's clean-green reputation is a major positive for almost every aspect of our economy, from tourism to the quality of our exports. Yet our record here needs improvement: many of our rivers are polluted with farm runoff, large numbers of our treasured species face extinction or being restricted to high-maintenance enclosures and offshore islands.

	Scientific research can often point to solutions for such problems and save many times the cost of the investigation. For example, recent genetic work on strains of campylobacter was instrumental in slashing the incidence of food poisoning from infected chicken. Work on the consequences of inbreeding in endangered species improves their management at no extra cost. In short, improving our greenness will enhance our quality of life, our treasured biodiversity and our international reputation.
Research components	Again, this work requires field-work ecologists, as well as scientists with modern bio-laboratory skills. The volumes of data produced will necessitate carefully planned analyses, underpinned by the latest bio-mathematical research. Experimental investigations of possible solutions to particular problems (e.g., how do we minimize the pathogen content of dairy-farm runoff) will be needed. Critically, the scientists involved need to work with each other and cannot be confined to traditional silo-like disciplines.
Research Gaps and Opportunities	The rate at which our biodiversity is being documented, let alone understood in terms of its ecological and evolutionary relationships, is extremely slow. Indeed, some species are likely to become extinct before their discovery. We need to invest more strategically in how we evaluate our biodiversity. Nevertheless, there are enormous opportunities in this work. Some of the issues we are facing in New Zealand are similar to those faced overseas, although our situation is more urgent (we understand our biota less well and our clean-green reputation is more critical to our economic wellbeing). Consequently, methods developed here are likely to be useful overseas. In the same way that the Department of Conservation's ability to eradicate mammalian pests from conservation hotspots is world-leading, the research proposed above may also lead to world-class innovative methods for analysing and preserving biodiversity.
Comments	The two themes go hand in hand. It is not sufficient to try to improve the quality of our natural environment if we do not understand what is there in the first place. Equally, we are wasting time and money investigating what we have if those elements are about to disappear from our world.

Entry ID	**284**
New Zealand's unique Biodiversity is the renewable resource for our future. Documenting and securing our resources, and knowing the current and future culturally informed capital value of these assets, will permit future proofed sustainable development	
Summary	This challenge is aimed at documenting New Zealand's uncharacterised biodiversity, including microbial, marine, and terrestrial species. An electronic repository for this information will be developed which will prove valuable for both

	current and future conservation efforts. In addition, this challenge proposes to develop commercially valuable 'bioproducts' (especially from microbes e.g. using metabolising microbial cultures to produce molecules/ by-products of interest).
Theme 1 **Complete an inventory and create a National biorepository of New Zealand's native and introduced microbial biodiversity annotated for environmental application and sustainable bioresources development**	
Importance to New Zealand	Ninety percent of New Zealands biodiversity, regardless of which habitat it is from, is microbial. This biosphere also makes up over 90% of the biomass in many ecosystems. It is largely undescribed and unexplored with respect to its role in ecosystem functioning and potential for bioresources development. Planning for sustainable ecosystem development, be it on land or in the sea, cannot be realistically accomplished until we understand the microbial realm. For example Tauranga Harbours marine bacteria if filtered and accumulated, would weigh more than 30,000t. The role of this biome is unknown. It is clear that bacteria are a source of enormous bioactive product potential. Given the unique diversity of New Zealand's microbial ecosystem due to our isolation and range of extreme environments, and given the advent of sophisticated technologies for identification and linkage to global bioinformatics networks, now is the time for a stock take and to create a repository for the future. New Zealand is well engaged internationally to explore diverse new bioproduct opportunity where not only discovery but production can be based nationally. Simultaneously we will be much better able to understand the workings of our environment and develop management protocols to optimise sustainable practice in more traditional primary industry.
Research components	Antarctic Microbial Ecology Current Antarctic microbiological programs Coastal Microbial Ecology Biodiversity review of major estuarine and coastal ecosystems around New Zealand with a prioritised focus on estuaries under environmental stress and systems supporting aquaculture. Terrestrial Microbial Ecology Expansion of existing programs examining New Zealand's terrestrial microbial communities in native forests and high altitudes. Focus on ecosystems under stress including intensively farmed lands. Freshwater Microbial Ecology Development of freshwater and lakes microbial environment research with a focus on ecosystems under stress from blue green algal blooms. Extremophilic Microbial Ecology The 1000 Project. Microbial identification, preservation and fermentation are the key areas of research knowledge required. Added to this is a need for cross cutting research expertise to understand the role of microbes as ecosystem drivers and in development of tis understanding (eg quorum sensing), it will be possible to elaborate novel applications for wealth creation in allied fields.

Theme 2 **To complete an inventory and genetic repository, of New Zealand's marine coastal and shelf biodiversity including extreme environments. Utilise the knowledge to substantiate environmental management while also exploring novel bioresource development**	
Importance to New Zealand	New Zealand is listed as a marine biodiversity hotspot as we oversee 1% of the worlds oceans with the 4th largest EEZ, yet have 14% of the globe's species (CoML 2010). On average across marine plant and animal phylogenetic groups, 60% of species are endemic. Only a fraction of our marine species have been fully documented however and yet we are losing species at an alarming rate given the increases in coastal sedimentation and proliferation of invasive species. Added to this is the advent of warming seas with climate change. The south east coast of Australia has for instance seen an increase of around 2-3oC in the past 5 years with substantial change in marine ecosystems with knock on effects in marine based capture industry. We do not know what is happening along our coasts as there is an urgent need to downscale biogeographic boundaries and examine their stability. There is a need to update, with taxonomic detail, the coastal biodiversity inventory of New Zealand. At the same time, given new international alliances in fast track development of known marine natural product leads, it is advantageous to create a national repository to evaluate bioresources for immediate and future development. New Zealand for instance has contributed almost a quarter of the US led international cancer leads from marine resources currently in development or now drugs. We have a significant future in developing novel bioproducts for niche New Zealand agriculture and biofuels industry and to continue to contribute to the globes biomedicinal industry.
Research components	Estuarine Biodiversity Review current inventories of estuarine biodiversity and complete missing components. Develop a bioresources repository with representative samples from throughout New Zealand. Focus on estuaries under threat (Kaipara, Tauranga, Avon Heathcote). Coastal Biodiversity Review and update DoC's coastal marine biodiversity inventory including review of biodiversity in marine reserves building on 30+year datasets in order to track decadel trends. Initiate new research in areas of New Zealand not already covered in biodiversity inventory programs. Focus on areas of known seawater anomalies in order to quantify biodiversity trends over time as the may be influenced by climate change (permanent biodiversity transects representative around New Zealand). Create a bioresources repository. Continental Shelf Biodiversity Integrate NIWA program Invasives Biodiversity Integrate NIWA program The key components of research knowledge required are classical and molecular biosystematics across the full range of marine fauna and flora, marine ecological experience, chemical ecology and bioinformatics expertise.

Theme 3 **Complete an inventory substantiated by a genetic repository, of New Zealand's terrestrial biodiversity including extreme environments. Utilise the knowledge to substantiate environmental management while also exploring novel bioresource development**	
Importance to New Zealand	New Zealand does not have a bio bank of native flora and fauna. If we are to provide secure stewardship of our native terrestrial biodiversity for future generations, such a facility is urgently required. The biorepository will not only serve as a genomic bank for future conservation use, but can fulfil potential as a resources centre for development of new bioproducts. The economic potential for New Zealand in the very fast growing sectors of natural healthcare products alone ($US10b+/yr) is substantial.
Research components	Review habitats at risk and examine major conservation areas to create an biobank of native New Zealand flora and fauna. The key areas of research knowledge required are classical and molecular systematics of terrestrial fauna and flora, together with ecological expertise. Genomics and bioinformatics science would also be required.
Theme 4 **To complete an inventory and genetic repository, of New Zealand's freshwater and lakes biodiversity including extreme environments. Utilise the knowledge to substantiate environmental management while also exploring novel bioresource development**	
Importance to New Zealand	New Zealand freshwater ecosystems are under enormous pressure from expansion of farm land and from degradation of hinterland from forestry and urban development. There is an urgent need for an inventory of our Freshwater ecosystem biodiversity and create a bank of genetic material for future conservation use. There are also emergent sustainable technologies based on freshwater algae in particular for biofuels development that for New Zealand would additionally take advantage of geothermal energy. New technology can add value through carbon sequestration and water quality improvement.
Research components	Review habitats at risk and examine major conservation areas to create an biobank of native New Zealand flora and fauna. Key research knowledge areas are classical and molecular biosystematics, rivers and lakes ecology and bioinformatics.
Research Gaps and Opportunities	New Zealand is unique with regard to our natural resources and also with respect to the way the country sees its future, with full integration of modern and cultural value. Such an approach sets a challenge for planning and indeed expanding the sustainable utilisation of natural resources. There is an urgent need to fill in the knowledge gaps about the diversity and stability of our bioresources and to provide a repository of genetic material for future generations. A component of the inventory is to develop an advanced tool for New Zealand that will permit natural resource valuation against risks to the ecosystem, combined with recognition and valuation of social and cultural heritage. By harnessing the expertise of a multidisciplinary team spanning economics; law; Mātauranga Māori; terrestrial, freshwater and marine science; together with

	modellers and GIS visualisation experts, the world's first Natural Resources Capital Atlas (NRCA) will be created alongside New Zealand's first integrated BioBank. Valuation can be modified by estimation of risks and threats brought about by environmental pressures including downstream knock-on effects in a connected environment. The diversity inventory, repository and atlas will permit transparent public participatory planning for conservation and sustainable resource development. This tool and the biobank that would underpin it, will advance New Zealand's ability to conserve valuable biodiversity while simultaneously facilitating sustainable development of new bioproducts.
Comments	New Zealand is lamentably behind the world in terms of its stewardship of native biodiversity. This is a serious issue for conservation, but also in terms of limiting our ability to sustainably develop novel bioresources. New Zealand is well partnered internationally to take a lead role in development of new bioproducts including biofuels. We have market advantage as our diversity is unique, we remain viewed as clean and green and our primary productivity potential in both terrestrial and marine environments is second to none (nutrient rich soils and seas and high sunlight). With a biodiversity inventory and genomic bank, we will be in a position to explore new as yet untapped resources while securing the biodiverse New Zealand heritage for generations to come.

Entry ID	**388**
Smart Green Partnerships to Save New Zealand's Natural Capital: Bringing research from Universities and other research providers to support major community-based and local governmental environmental initiatives	
Summary	This challenge proposes to review current environmental-restoration programmes, with the goal of identifying and setting achievable, measurable targets. This comes in tandem with the development of new business models which will create jobs and economic benefit from these revised restoration programmes, and harnessing public interest in environmental restorative work- restoring and cementing New Zealand's 'clean green image' as the foundation for our economic future.
Theme 1 **Defining Visions and Strategic Targets**	
Importance to New Zealand	There are literally hundreds of Environmental Restoration (ER) projects nationally. Most local regional councils have ER programmes, and the number of community-based and private ER initiatives continues to grow. The investments into these major initiatives are substantial. For example, fenced sanctuaries like Zealandia and Maungatautari have invested tens of millions of dollars, as has

	Project Janszoon, a $30 million trust to restore Abel Tasman National Park. While most of these ER projects have visions and strategic plans, these would have been developed with limited baseline data linked to achievable restoration targets that allow progress to be measured. Without these, investments are at risk because success cannot be directly measured and 'mid-course' corrections implemented as needed. University-based researchers have the capacity, numbers, and will to engage with local projects throughout the country and provide the needed expertise and manpower to create evidence-based visions, strategic plans, and implementation and monitoring plans. These are essential to ensure that these massive investments are fully realised. Furthermore, the engagement of university researchers and resources can be achieved rapidly and in highly cost-effective ways.
Research components	Pair-wise partnerships can be formed quickly between all universities and local projects in their areas, or where special research expertise exists at a particular university. The relevant expertise may be in obvious areas such as ecological restoration, but equally in social science, education, engineering, and architecture and design faculties. The goal of these partnerships would be to support ER initiatives to review their visions, strategic plans, and implementation plans to ensure that they are realistic and achievable, fit for purpose, and cost-effective. They would ensure that an active research plan underpins each major project as part of its implementation plan. As noted above, few ER initiatives explicitly engage with researchers or have evidence-based plans. This proposed Challenge could promptly provide wide-ranging research foundations for all major ER projects that chose to engage. Each ER initiative will have its own specific requirements, as well as sharing generic goals and challenges that research can address. Part of the Challenge would be to share finds and plans among initiatives. Victoria University of Wellington has initiated workshops and engagement among other Universities to explore (a) the extent of research expertise that could be mobilised on short notice and (b) the appetite among researchers to do so. The enthusiasm of researchers from a wide array of disciplines for this engagement is high, as is interest managers of ER initiatives, whether community-based, private, or local/regional government.
Theme 2 **New Business Models to Create Employment and Economic Wealth from Environmental Restoration Initiatives**	
Importance to New Zealand	As traditional land-based industries have declined, provincial communities have shrunk as jobs have moved to cities. Local communities are often keen to restore local environments and seize on opportunities such as with the fenced sanctuaries or other projects, but almost all of these projects have weak financial foundations and few plans to create meaningful income streams. University business researchers have the capacity to help local communities

	create viable economic futures by creating and supporting local businesses to use the natural environment in new and imaginative ways. The commitment of New Zealanders to a healthy natural environment can be harnessed not only to restore our environmental wellbeing, but equally importantly to use the natural environment to create income streams into the future that will support ER initiatives. In other words, we need to find new ways to sustain the national sustainability movement. Another aspect of success in this theme would be to restore New Zealand's "clean, green" image as the foundation of our national economic future.
Research components	Target outcomes include job creation and retention of young people in their local communities. New Smart Technologies offer pathways to job creation, and these can be supported by university researchers in engineering, design, and humanities faculties working with experts in business creation. Most ER initiatives rely on substantial contributions from volunteers. University expertise in volunteerism can contribute to efficient, effective use of these corps of volunteers. The national appetite for a Pest-Free New Zealand could also contribute to this theme.
Theme 3 **Education and National Engagement in Environmental Well-Being as a Foundation for Economic Strength**	
Importance to New Zealand	New Zealanders have a strong collective commitment to the natural environment. However, historically this has been disconnected from the national agenda for economic development. However, New Zealanders increasingly see the disconnect between our "clean, green" national brand and the reality of our declining environmental quality. University Education Faculties are well placed to undertake research into the benefits and educational methodologies associated with strong environmental understanding. A strong connection to our natural environment is also a key component of national identity – of how we see ourselves as a people and a nation. We are one of the few countries in the world whose citizens label ourselves with an indigenous animal (Kiwi). The values of our indigenous people strongly link themselves to the natural environment as taonga. Finding ways to restore the natural environment is not of itself sufficient. Understanding the psychological benefits and incorporating them into our educational system can help to create a stronger national identity that understands the value of our natural world.
Research components	Research in this area would be contributed by many academic disciplines, including education faculties, but also psychologists and social scientists. Improved understanding of how to incorporate environmental education into our school systems is critical, as is learning how to create a national consensus around major national initiatives such as Pest Free New Zealand. Additionally, national identity draws on our history as a country and people linked closely to the natural world, thus needing to engage historians in this theme.

	Environmental history is a major gap in our educational system, although its significance for most countries is as great as social and political history. The use of the local environment in primary teaching is increasing, but in both primary and secondary teaching further research is required not only to teach students about New Zealand history and environment, but far more importantly to learn how to engage young people (and adults too) in moving from understanding to active commitment to environmental quality that supports economic wellbeing.
Theme 4 **Green Urbanism: Bringing Nature and its Benefits into the Cities**	
Importance to New Zealand	In the past century, New Zealand completed the transition from a primarily rural to a predominantly urban population. In fact, we are one of the most highly urbanised nations in the world. Nonetheless, we remain highly attached to and dependent upon our "clean, green" national brand both for wealth and national identity. Ironically, our young people now grow up with limited connections to the natural world and the many benefits it brings to us as a nation and as individuals. Restoring the links between urban dwellers and the natural world has many benefits and can help to ensure that our dependence on the natural environment is fully understand in ways that enhance our natural environment.
Research components	Traditionally, environmental restoration focuses on natural areas beyond the limits of cities and towns. This theme aims to link cities and towns directly to rural communities and natural areas – to create a seamless link between cities and natural environments. While most communities now aim to be relatively sustainable, this often focuses primarily on recycling, waste management, water and air quality, and renewable energy. However, Green Urbanism has a greater reach, aiming to bring nature directly and tangibly into the urban environment to fully realise its many benefits. This theme aims to engage a wide array of university researchers in partnerships with local authorities as well as community-based restoration projects to create greener cities whose citizens have direct contact on a daily basis with the natural world. Research projects would arise from urban architecture, digital design and other smart technologies, engineering, and traditional sciences such as biology and chemistry.
Research Gaps and Opportunities	The link between economic health and environmental wellbeing is increasingly accepted. Indeed, it was a major theme of the recent Transit of Venus Forum. Nonetheless, like almost all countries New Zealand significantly under-invests in environmental quality and ecosystem protection. This proposal aims to link University research to environmental initiatives to create increased national wealth.
Comments	Environmentalism has often seen economic development as the enemy. Emerging thinking (as evident at the recent Transit of Venus Forum) makes clear the need for environmental restoration to proceed in unison with economic development; in fact, sustaining ER requires a strong economic foundation, and vice versa. University researchers are natural partners in bringing these different modes of

	thinking together. A major theoretical gap also exists in the area of ecosystem services, that is, those economically important contributions that natural ecosystems and species make to human well-being and wealth. Examples include clear air, clean water, and pollination of our crops. Research has yet to succeed in linking ecosystem services and benefits into traditional economic models. Achieving better understanding of the economics of ecosystem services would provide a pathway to realise a unified model of national well-being, with tangible follow on pathways for improved environmental management.

Entry ID	**410**
For New Zealand to be a global leader in enhancing the social, cultural, environmental, and economic value of terrestrial, freshwater and marine biodiversity. [This was also submitted separately as submission 460]	
Summary	This challenge proposes to co-ordinate research that better define/identify New Zealand's richness of biodiversity, including ecologically important species, and which species are most threatened/in decline etc. This may require the development of new methodologies to better assess the state of species populations (i.e. enhanced metrics/algorithms to determine species decline). Public consultation is required to identify species with strong public interest.
Theme 1 **Define and value our distinctive biodiversity**	
Importance to New Zealand	The people of New Zealand value both indigenous and introduced biodiversity, yet there is insufficient comprehensive reliable information to make choices about what biodiversity our lands and water must support. Public and private organisations with biodiversity management, regulatory and policy obligations need to know what they are dealing with. The problem confronting the Environmental Protection Agency is typical. It needs to assess the importation of new organisms, but is challenged when <50% of our indigenous species have been defined. It is also essential to understand how society defines and values biodiversity, and to develop a more complete picture of the full range of services biodiversity can yield, and the risks. For example, 75% of global food crops require pollination by insects, yet the most frequent pollinators, honeybees, are in decline, increasing the reliance on indigenous pollinators. Knowing what New Zealanders care about in terms of biodiversity values is essential for enabling private and public sectors to determine what biodiversity to define, what services it provides, and what trade-offs need to be made in competing values. The benefits from this will be profound. It will provide the focus for biodiversity research as to where society requires science solutions for maximal benefit (setting an agenda for the other themes in this challenge).

	The science will demonstrate where and how to manage biodiversity and its services, thus enabling policy development. This will provide a clearer explanation to 'biodiversity investors' raising the potential for alternative financial mechanisms to support biodiversity protection and restoration. Ultimately this will enhance the value of biodiversity.
Research components	A first research component will define valued biodiversity in terms of species, communities, and ecosystems. Many large yet important groups of organisms (e.g. the soil microbes that underpin agricultural production and govern carbon storage) are poorly known. Critical baseline information currently lacking is essential for distinguishing indigenous, endemic and threatened from introduced, pest or pathogen. The need is particularly acute for marine biota where the origin of many species is unknown and remedial action may or may not be needed depending on the category. Indigenous taxonomic groups must also be thoroughly understood when potential biocontrol efforts are planned. Biodiversity conservation planning needs a better understanding of threatened communities and ecosystems, in particular those without forest cover. There is an important role for discovery in Antarctica and the marine zone, because, for example, of the 4.2 million km^2 in the New Zealand marine zone only 2 km^2 have been scientifically surveyed. A second research component will determine the environmental, social, cultural and economic values aligned to biodiversity. These values differ among societal groups. Different iwi, for example, value bird species very differently. While these values can be based on biodiversity alone, understanding how biodiversity underpins services (e.g. carbon and water) and industries (e.g. tourism), and their trade-offs, is also essential. We need to assemble data for specific biophysical relationships, scale them up to regional and national representations, and then integrate them with social and economic drivers. This represents a shift from only considering intrinsic value to including market valuation considerations. Integration of terrestrial, freshwater, and marine systems into a 'world-view' of biodiversity will challenge our scientific expertise and allow productive conversations.
Theme 2 **Understand the complexity of biodiversity in order to protect its values**	
Importance to New Zealand	Our understanding of the factors that produce and sustain biodiversity is simplistic and unsatisfactory. Of particular importance is how cross-scale interactions (between species, within communities, between communities, across landscapes and waterscapes, and between whole ecosystems) determine the make-up of our natural and anthropogenic environments. Notably, these interactions are deeply intertwined in manners that transcend 'traditional' ecological boundaries in such a way that the whole is truly greater than the sum of its parts.

	For example, interactions between flowering plants and their pollinators drive key components of our agricultural sector, and this pollination simply wouldn't take place without a viable habitat through which those pollinators could disperse. As such, research in this theme has strong implications for management in productive settings. By identifying the factors and ecological configurations that lead to resilient and stable biodiversity we will be able to employ effective strategies for the protection of biodiversity, its values and services (e.g. pollination, nutrient cycling and erosion prevention). These strategies will enable biodiversity resilience to global change, empower social and cultural benefits, and facilitate agricultural production. By developing programmes aimed at maximising natural resilience, we will also minimise the need for active intervention and the costs associated with them. Furthermore, the synergies that exist within ecology define the very way in which we must approach each potential threat to present-day biodiversity. Without understanding and highlighting the interplays between them, we run the clear risk of heading down a blind alley by maintaining too narrow or too broad a focus for the problem at hand.
Research components	One research component will identify the factors most associated with viable and productive ecological communities. To date, research in this area has focused on ecosystem 'stability'. Research here will also include a clearly-established link between the 'quality' of an ecosystem and its underlying ecological, environmental, social, and economic values as identified in Theme 1. Research will also explicitly test the degree to which ecological outcomes are the consequence of the ecological interconnectedness highlighted above. The end result of this multidisciplinary research component will be to provide a necessary interpretive basis for Themes 3 and 4. A second research component will develop novel methods with which to understand, characterise, and quantify ecological resilience. A growing body of research has demonstrated that many natural communities are inherently resilient, and yet they are simultaneously susceptible to sudden, catastrophic, and irreversible changes when subject to a sufficiently large disturbance. Our ability to maintain ecological resilience goes hand in hand with our ability to prevent, predict, and respond to the threats that could induce ecological tipping points (see Theme 3). A key challenge here is for studies to incorporate field-based, lab-based, and theoretical approaches in a complementary fashion so as to link the empirical and conceptual bases for resilience across land and water. Analytical and computational approaches provide powerful short-term alternatives, and are amenable to particular types of 'virtual' experimentation that are often impossible to conduct in the field (e.g. simulated species extinction). Such theoretical approaches provide the added benefit of improving our ability to make ecological

	predictions or forecasts for incorporation into economic models.
Theme 3 **Reduce the threats and increase the resilience of valued biodiversity**	
Importance to New Zealand	Human activity has wide-ranging effects on species, communities and ecosystems and can threaten biodiversity. Some threats are local or regional, for example fire, damming of rivers or weed introductions. Others are global, for example increasing atmospheric CO_2 concentration. Threats can be catastrophic and short term (e.g. predation of birds by mammals) or progressive and long-term (e.g. rising sea level). Historical impacts, such as fragmentation of landscapes by agriculture, may leave indigenous biodiversity in a permanently threatened state. We need to strategically and effectively mitigate this wide range of threats. Research under this theme will maximise biodiversity gains at minimum cost from determining what threats to manage, where, when and how often. Biodiversity gains affect social well-being through support of our national identity, including kaitiakitanga under the Treaty of Waitangi. Biodiversity gains reinforce community engagement and cohesiveness. Iwi, private individuals and companies directly contribute towards national biodiversity goals on public and private lands, in lakes and rivers, and in coastal waters. Mitigating biodiversity threats will endorse 'brand New Zealand' and improve the marketability of our products, enrich tourism experiences, and support sustainable use of culturally important elements.
Research components	Given the breadth and complexity of threats to New Zealand's biodiversity, we must first understand which impact most on the values identified in Theme 1. For example, while invasive species pose a major threat to biodiversity, many invasive animal, plant and microbial pests interact and substitute for each other. Managing these complex interactions is difficult, but we must reduce uncertainty for effective responses. Understanding potential pest threats improves our ability to stop them at our borders and to prioritise and define management and policy responses (in concert with Theme 4). Second, we need to develop our ability to control or eliminate priority threats. Approaches must be cost-effective, provide a high certainty of success, maximise collateral benefits, and minimise risk to other values. For example, agricultural intensification has greatly increased pressure on some parts of the landscape and waterscape. We need strategies that mitigate threats, for example offsetting, while permitting productivity growth. Third, research will centre on attributes of the threat(s) or species, community, or ecosystem that influence biodiversity resilience and how they affect the timescales over which biodiversity benefits accrue (with input from Theme 2). Removal of a threat alone may not achieve biodiversity gains, and research on restoration and rehabilitation is a major part of this theme.

Theme 4 Use a robust evidence base to assess biodiversity, its values and services	
Importance to New Zealand	The New Zealand Biodiversity Strategy showed our biodiversity is declining. While the strategy has been highly influential, it rests on a rather slim evidential base. Information on declines is most complete for vertebrates but patchy for the rest; for most taxa the evidence is largely anecdotal. Public, governmental, and industry scrutiny of the significant investments in biodiversity is intensifying. New Zealand's claims on environmental performance, identity and image are becoming central to national well-being and trade. Recent initiatives such as biodiversity offsetting and community engagement will need a robust evidential basis for decision making and demonstration of benefits. Biodiversity assessment research will form the evidence base for enhancing biodiversity, its values and services. Proximate benefits include the following: increased cost-effectiveness and better biodiversity outcomes through strategic deployment of methodologies and tools developed in Themes 2 and 3; better decision making by managers as a result of improved knowledge of biodiversity status and trend; superior regulations, policy and ultimately social, cultural and economic value from our investments in biodiversity. More generally, the theme is necessary to obtain the level of environmental stewardship towards which New Zealand aspires, while maintaining our international reputation and standing. One task eagerly faced by this challenge is the optimal integration of research related to this broad biodiversity value-set with other challenges (e.g. on primary production) that require a fit-for-purpose biodiversity perspective. This will facilitate and enhance the use of land and water for other essential services.
Research components	First, improving the evidence base involves developing innovative sampling designs, methodologies, analytical algorithms and representations, as well as data management and synthesis capacities for metrics around values identified in Theme 1. Most biodiversity metrics focus on vertebrates and plants, yet smaller organisms comprise most biodiversity, and have important roles in water quality and other services. The evidence base approach must operate across scales from individual properties to national and global levels. It is no longer acceptable to infer national status and trend from local case studies and ad hoc management regimes. Context-setting research on the complexity and inter-dependence of New Zealand biodiversity (Theme 2) and how these vary along climate, soil and marine gradients is needed to understand biodiversity status and trend. Second, biodiversity metrics are needed to address five issues: national- and organisational-level reporting; prioritisation of management actions and policy instruments; assessment of management impacts; setting the basis for biodiversity offsetting; and the need for an early-warning system for biodiversity threats. Such reasons are the basis for the New Zealand Antarctic Research Institute's priority of developing a terrestrial observation system for Antarctica.

	Application of biodiversity metrics to these five issues in a way that combines point or locally intensive biodiversity data with broader scale spatial representations, while retaining detail and certainty, will be a complex scientific challenge. Finally, an overarching framework for New Zealand is needed in which the benefits and costs of conflicting land and water demands can be optimised for biodiversity, its values and services.
Research Gaps and Opportunities	To meet the challenge, the following gaps need to be addressed: • How can we define and classify biodiversity in a way that links to values and services? • Can we discover cryptic biodiversity and assess little-explained ecological niches (e.g. deep sea, deep underground, air, organic farms)? • What is the link between biodiversity and social health (e.g. taonga, urban 'green space', recreation) and economic wealth (e.g. tourism, use of products, film industry, drug discovery)? • What are the relationships between indigenous biodiversity, the provision of different services, and their legal, social and economic ramifications for society? • How will global change (e.g. climate change, macroeconomics) and management (e.g. intensification, 'sharing' versus 'sparing') influence these ramifications? • How do the costs of various biodiversity management responses relate to the environmental, social, cultural and economic benefits delivered? To meet the challenge, the following opportunities need to be leveraged: • Use next-generation meta-genomic sequencing technology to quantify previously intractable linkages among biota. • Use nationally important biodiversity collections and databases to provide the wealth of complex information needed to safeguard New Zealand's biodiversity against potential and existing threats. • Use modern advances in information and diagnostic technology to facilitate rapid and effective accessibility and application of information systems for border protection and market access. To meet the challenge, the following gaps need to be addressed: • What is the degree of interconnectedness of New Zealand's ecosystems, focusing on interactions between species, interactions within communities, interactions between communities, and interactions across land and water? • What factors contribute to ecosystem stability and resilience and how can these be managed to minimise the vulnerability and fragility of ecosystems in the face of increasing threats (see Theme 3)? • How can the stability and resilience of biodiversity be enhanced to benefit environmental, social, cultural and economic values? To meet the challenge, the following opportunities need to be leveraged: • Use novel approaches to understand ecological resilience in terms of both short-term mitigation and long-term viability and quality, including analytical and computational approaches, long-term empirical studies and ecological prediction and forecasting. • Use the enhanced abilities available through super-computing. • How can we control multiple invasive species on the land and in the water,

	across many different environments, in sustainable ways ('predator free' or 'pest free' New Zealand)? • How can we remove threats to taonga species, and manage, access, and utilise indigenous biodiversity through Māori capabilities and frameworks developed with mātauranga Māori and pan-Māori engagement? • How can we maintain biodiversity in the face of an increasing risk to threatened species and ecosystems (defined in Theme 1) from land-use intensification? To meet the challenge, the following opportunities need to be leveraged: • Use the ecosystem-level perspective (Theme 2) necessary to understand the resilience of ecosystems to biodiversity threats. Short-term mitigation of direct threats to species and communities needs to be balanced by an understanding of long-term viability. • Use modern technological advances in biology and engineering. • Use increased engagement with business and society on the critical environmental, social, cultural, and economic constraints to the restoration of threatened biodiversity, to identify the most enduring approaches to threat management.
Comments	The late Sir Paul Callaghan supported a challenge of making New Zealand 'pest free'. One of the benefits from being 'pest free' would be enhanced biodiversity, although there are many issues and alternative perspectives around the pest issue. An evidence base is required for international (Intergovernmental Panel on Biodiversity and Ecosystem Services, Convention on Biological Diversity and Montreal Process) and national (e.g. Natural Heritage Management System) biodiversity reporting. This theme will establish New Zealand as a global exemplar in credible stewardship of biodiversity for economic, social, and cultural values. There will be opportunities to internationalise developments. Essential to this will be the biodiversity-related nationally significant collections and databases. The advanced informatics requirements of research in this theme will be supported through existing partnerships in the National e-Science Infrastructure. Additional existing necessary infrastructure includes a network of field stations that cover the mountaintops to the marine environment, with some bridging the land and water interface. Knowledge as to where terrestrial biodiversity is now, and where it once was, is embedded in nationally significant collections and databases of plants, invertebrates, and fungi, and in living collections of plants, fungi and bacteria. There are also large national databases for fish, water quality and stream health. Our thinking around biodiversity values has recently undergone considerable evolution including a much stronger linking of biodiversity and prosperity by the Department of Conservation. This evolution poses challenges for biodiversity research, which must now markedly increase our understanding of what New Zealanders care about to achieve societal benefits.

Entry ID	481
Nurturing Native Ecosystems	
Summary	This challenge proposes to carry out robust descriptions of New Zealand's remaining native ecosystems, to determine processes, components, etc. that are related to their viability and sustainability. This will involve identifying and defining current threats to these ecosystems (such as pests, climate change, industrial activity), and establishing measurements which allow progress/improvement to be measured over time. This will eventually lead to the enhancement of oru native ecosystems.
Theme 1 **Describing our remaining native ecosystems and their value to New Zealand**	
Importance to New Zealand	Establish measures of economic, social and cultural value provided by our remaining native ecosystems and maintain or improve against these baseline levels over time
Research components	9.1.1 Describing the nature and function of components of native ecosystems, conceptualizing and investigating processes, thresholds and limits that describe viability and sustainability 9.1.2 Describing the extent, network and linkages of native ecosystems on land coastal interface and in the ocean required to provide for the sustainable existence of undisturbed native ecosystems
Theme 2 **Threats**	
Importance to New Zealand	Define the current pest and other threat landscape to New Zealand's native ecosystems, use to establish baseline measures and maintain or improve these over time
Research components	Defining processes, implications and consequence of non-human invasions within and across species, ecosystem components and environments Defining processes, implications and consequences of physical, biological, chemical and climatic change at broad and local scales on native ecosystems including the spectrum of catastrophic, major and incremental disturbance. Defining processes, implications and consequences of changes in culturally determined responses and expectations of the natural environment on native ecosystems.
Theme 3 **Enhancing Native Ecosystems**	
Importance to New Zealand	As above – set targets for specific improvements in measures of ecological wellbeing or reduction in threats over time
Research components	Defining, building, monitoring and adjusting integrated societal, cultural, physical and biological mechanisms which extend richness and productivity of native

	ecosystems
Research Gaps and Opportunities	Undisturbed or lightly disturbed native ecosystems are becoming increasingly rare in New Zealand through human activities including tourism, agriculture, fishing and the introduction of invasive species. A concerted effort to describe these remaining systems including components, functions and interactions is critically important before they are irrevocably modified and will provide the basis for their future management to ensure ongoing value to New Zealand.

3 Biosecurity and Pest Management

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 3: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
Biosecurity and Pest Management		
37	Revitalise New Zealand native forests	1. Forest diversity 2. Carbon sequestration 3. Water Quality 4. Local employment
62	Reduce the growing and devastating impact of unwanted pests by improving biosecurity and pest management solutions	1. Terrestrial 2. Fresh water 3. Marine 4. Risk assessment
299	Low levels of small introduced mammals in New Zealand conservation estate	1. More effective elimination of small mammal pests 2. Real time monitoring of pest load for optimal intervention
311	Pest Free New Zealand	1. Pest Eradication. Finding technology that can actually eradicate pests, with an initial focus on rats, stoats and possums 2. Measurement and Detection - being able to detect and measure the numbers of pests in different areas 3. Public Demand - a pest free New Zealand requires acceptance of the methods used and desire for the outcome
312	A Pest-Free Aotearoa: Rid New Zealand of its small mammal pests to achieve security of markets for our produce, indigenous biota, and ecosystem services towards social and economic prosperity.	1. Identify Research Priorities Towards Greatest Possible Progress 2. Generate Innovations in Soft (socio-psychological science) and Hard (life and physical science) Technologies for Pest-animal Eradication 3. Trial and Refinement of New Technologies Towards Proof-of-Concept and -Principle and their Independent Evaluation

Entry Id	Challenge	Themes
Biosecurity and Pest Management		
		4. Implementation and Commercialisation: The Nation-wide Coordinated 'roll-out' of New Technologies Towards Pest Eradication and International Economic Returns on Investment
399	By 2050 an environment where small mammal pests are no longer a threat to the security of New Zealand's indigenous biota, or condition of New Zealand's ecosystem services	1. Tools and strategies that will enable suppression of small mammal pest populations to ultra low levels, below which they no longer pose a threat 2. New Zealanders are engaged in the ongoing effort to protect New Zealand's indigenous biodiversity and ecosystem services
431	Bio-protection for a small island nation	1. Increased biosecurity for public health 2. Increased biosecurity for our primary industries & environment
461	Future Proofing New Zealand Biosecurity. Overall Goal: To halve, by 2030, the rate destructive, exotic organisms establish in New Zealand's terrestrial and aquatic ecosystems, by aligning and boosting national biosecurity effort. This is fundamental to economic growth, environmental quality and public health.	1. Futurewatch - to identify emerging and future biosecurity 2. Detection and Identification of Threat Organisms 3. Strengthening Biosecurity Response Capacity and Capability
462	Protecting New Zealand's Natural Capital from Biological Risks. Overall Goal: The Government's goal for economic growth is underpinned by measures that protect New Zealanders, our unique natural resources, and primary industries from biological risks.	1. Forecasting the biosecurity landscape 2. Detecting and identifying pests and diseases 3. Managing pests and pathways

Entry ID	62
Reduce the growing and devastating impact of unwanted pests by improving biosecurity and pest management solutions	
Summary	By improving methods of pest surveillance/eradication, including border control, this challenge aims to reduce/better manage the negative impacts of terrestrial, freshwater, and marine pest invasion.
Theme 1 **Terrestrial**	
Importance to New Zealand	Productive sectors can be devastated (Psa, Psyllid) so the benefit is maintaining the opportunity to expand in future without hindrance, no opportunity cost.
Research components	Surveillance and eradication
Theme 2 **Fresh water**	
Importance to New Zealand	Tourism and water protected
Research components	Surveillance and eradication
Theme 3 **Marine**	
Importance to New Zealand	Aquaculture, the sea
Research components	Surveillance and eradication
Theme 4 **Risk assessment**	
Importance to New Zealand	prioritisation
Research components	invasive species risk assessment
Research Gaps and Opportunities	better quality information from MPI would help to quantify slippage and other border issues

Entry ID	299
Low levels of small introduced mammals in New Zealand conservation estate	
Summary	This challenge focuses on control of small mammalian pests (i.e. possums), and includes development and implementation of new technologies for monitoring pest loads/population sizes in real time. This will allow cost effective strategies to be implemented at optimal stages of pest life/reproductive cycles.
Theme 1 **More effective elimination of small mammal pests**	
Importance to New Zealand	A very large part of the DoC and private conservation group effort is expended in slow, labour intensive, and unsustainable or enduring pest control
Research components	Develop innovative means of mammal control not limited by current bait and trap methods Cost effective and sustainable delivery mechanisms
Theme 2 **Real time monitoring of pest load for optimal intervention**	
Importance to New Zealand	Recognition of pest load and reproductive success signals early intervention and optimal timing of control measures
Research components	Development and implementation of new technologies for detection and monitoring of pest load and behaviour Cost effective knowledge of developing threat to conservation effort and species recovery
Research Gaps and Opportunities	Current methods are expensive, repetitive, require human intervention. There is opportunity to access knowledge in disciplines other than biology or animal behaviour.

Entry ID	311
Pest Free New Zealand	
Summary	This challenge proposes to develop new technologies such as toxins, lures, trap, etc., that will allow efficient eradication of New Zealand's pests. In order to successfully implement these, public engagement is needed to gauge acceptance/reaction to any new methods.
Theme 1 **Pest Eradication. Finding technology that can actually eradicate pests, with an initial focus on rats, stoats and possums**	
Importance to New Zealand	There are considerable benefits to primary production, tourism and our conservation goals from the eradication of pests in New Zealand. Native bird life would be able to flourish once again.
Research components	Finding more cost effective toxins, bio-controls, lures, traps and other delivery

	methodologies that can help reduce and, in particular, eradicate pests from New Zealand.
Theme 2 **Measurement and Detection - being able to detect and measure the numbers of pests in different areas**	
Importance to New Zealand	There are considerable benefits to primary production, tourism and our conservation goals from the eradication of pests in New Zealand. Native bird life would be able to flourish once again. Detection and management of pests is necessary to focus and prioritise efforts.
Research components	Better detection of pests both remotely and harnessing the efforts of the public. Ways to share and showcase data to raise the profile of pest eradication in New Zealand and help communities measure their progress.
Theme 3 **Public Demand - a pest free New Zealand requires acceptance of the methods used and desire for the outcome**	
Importance to New Zealand	There are considerable benefits to primary production, tourism and our conservation goals from the eradication of pests in New Zealand. Native bird life would be able to flourish once again. Given most of New Zealand's land is inhabited and private property, the buy in of the public is crucial.
Research components	We need to understand New Zealander's attitudes to eradication of pests and the methods used, and understand under what circumstances will eradication be seen as more acceptable. It would also be useful to know what is driving certain communities that are demanding eradication.
Research Gaps and Opportunities	Super lures that can attract pests from great distances would help cut down on the amount of traps needed.

Entry ID	**312**
A Pest-Free Aotearoa: Rid New Zealand of its small mammal pests to achieve security of markets for our produce, indigenous biota, and ecosystem services towards social and economic prosperity	
Summary	This challenge proposes to develop pest control methods with the greatest potential for advance. This will involve commitment and co-ordination across all potential research providers (via nationwide workshops) to develop appropriate research priorities. Such technologies should provide rapid results in pest eradication, and might include enhanced baits, traps, lures, bio-control etc.

Theme 1 Identify Research Priorities Towards Greatest Possible Progress.	
Importance to New Zealand	There are many possible ways of making progress but not all approaches, techniques, or technologies are likely to result in rapid and transformational improvements in our capacity to suppress and eradicate pest populations. Moreover, some approaches, techniques and technologies need to be developed concurrently because they are complementary and depend on other coordinated advances. The goal of this theme is to make sure we target effort and investment where the potential for greatest advance is most likely. Priority research topics should be those that are most likely to deliver rapid, transformational improvements in our ability to eradicate pests but pest-animal control and eradication is the responsibility of a large number of separate organisations and workforces with individual objectives and priorities. Rapid and transformational advances require a coordinating and synthesis of effort across institutions. Work towards this theme should allow research providers to deliver greater service and outcomes for New Zealand and deliver economic efficiencies by reducing costs and accelerating outcomes.
Research components	Key to identifying and coordinating research priorities for national action is to commit all potential research providers to identifying where research can make the most rapid and greatest advances. A series of nationwide workshops which utilise modern socio-psychological techniques to facilitate the creativity, innovation and engagement of research providers. The workshops will qualify and quantify future research priorities, the engagement (buy-in) of research providers, encourage inter-institutional collaboration, and actions towards the development of a national 'pest-free' research agenda. The workshops will bring local and international expertise together from universities, research institutes, businesses and government (providers and beneficiaries of research) to achieve synthesis. The synthesis will describe a research agenda for the future and what resources are required to action it. Research gaps and opportunities? The purpose of research components in Theme 1 is to achieve a stronger understanding of research gaps towards research prioritisation. The research components are also themselves a useful, potentially experimental, exercises in behavioural and institutional change. If conducted with an explicit implementation and evaluation framework, the research process might be used as a case-study to inform future efforts that require large-scale engagement and collaboration towards problem solving. More ‘wicked’ problems than pest-eradication are likely to require solutions in the future and progress towards their solution would benefit from the experience of inter-institutional, nation-wide synthesis like that described here. Other comments: there is widespread support for this approach as evidenced by the recent Pest Summit held by the Department of Conservation (3-4 December, 2012) in Wellington.

Theme 2 Generate Innovations in Soft (socio-psychological science) and Hard (life and physical science) Technologies for Pest-animal Eradication	
Importance to New Zealand	Pest animals in New Zealand pose an $840 million liability to the New Zealand economy in terms of the costs of pest control. The wider economic, environmental, and social costs are larger still – estimated to be around $2.5 billion to the productive sector alone. New technologies and approaches to reducing this liability are currently slow to develop or be adopted for pest-animal control. We still largely depend on old technologies or their modification in minor, incremental ways. Research resources need to be focussed to simplify and engage in the search for transformational technologies and techniques for more rapid progress. More rapid advances in pest-control technologies will feedback positively towards greater progress and efficiencies for primary producers, businesses, and communities dependent on natural resources. More rapid progress will positively feed-back into greater support and sill further progress toward the ultimate goal – eradication and a social and economic return on the investment.
Research components	The research agenda described from Theme 1 will be prescribed to research providers with over-sight and feedback from research beneficiaries (businesses, communities, government). Objectives for inter-institutional, multi-disciplinary teams will be set, committed to milestones, and resourced for development. Several such projects should run concurrently to optimise the trade-off between aspirational risk and reward in innovation. Technologies and approaches likely to be considered may include (but will not be restricted to): • Automated, potentially mobile, surveillance and communication devices to detect and coordinate the targeting of efforts to eradicate invasive animals • Development of super-lures to increase the attractiveness of surveillance and killing technologies like traps and poison baits. • Better baits and poisons which kill selectively and more humanely to mitigate social risk. • Biological-control technologies which impact on pest animal reproduction or survival. • Control and deployment technologies which optimise the timing and density of bait or trap delivery over heterogeneous landscapes • Developments in the application of socio-psychological (soft) techniques in social campaigns to facilitate support and mobilise a wider populace towards eradication goals. Research gaps and opportunities? Many existing or developing engineering, telecommunications, biological, chemical and socio-psychological technologies might be modified and adopted for pest-animal eradication:

	e.g., robotics, artificial intelligence, chemical 'nose', image recognition. The opportunity exists to bring that expertise to bear on the problem. Other science still needs to be developed in ways that can be expected to achieve sustained pest eradication: e.g., nanotechnology, olfactory signalling and lethal genes.
Theme 3 **Trial and Refinement of New Technologies Towards Proof-of-Concept and -Principle and their Independent Evaluation**	
Importance to New Zealand	Very large uncertainties will exist about what novel solutions are actually feasible, applicable and effective. Great inefficiencies and delays to progress occur when research outcomes are not immediately trialled and the outcomes fed-back into refinements, improvements, or the reallocation of resources to other potential solutions. The theme is important because progress is more rapid when potential solutions receive intense evaluation towards proof-of concept as a guide to further research or investment elsewhere. When financial support for research is limited, as is the case in New Zealand, waste of granted funds and effort can be addressed by more closely integrating research and trial mechanisms.
Research components	Replicated trials of new technologies that capture the diversity of contexts, applications and implementation strategies should be conducted to provide confidence towards further investment in the developed technology. Negative outcomes should quickly result in the reallocation of investment to other potential solutions. Positive outcomes should progress quickly to being scaled up, implemented, and commercialised, where possible (Theme 4). The evaluation of replicated trials should be by a group who are independent of research project groups. An umbrella group for evaluation should be established which coordinates the evaluation of all resourced projects. Research gaps and opportunities? Evaluation is critical to gap-filling and opportunism in research. An explicit proof-of-concept mechanism and its oversight by an independent umbrella organisation strategises investment and delivery where outcomes are most likely. The research components and their oversight and evaluation by a national, independent group is a structure that would be of benefit to a number of other research agendas. The experience during this Science Challenge may inform progress on other future challenges.
Theme 4 **Implementation and Commercialisation: The Nation-wide Coordinated 'roll-out' of New Technologies Towards Pest Eradication and International Economic Returns on Investment**	
Importance to New Zealand	Progressing from science research to solutions depends on New Zealand driving the application of new technologies to its own problems and in its own context. We cannot rely on others to maintain priorities similar to ours where the eradication is the ultimate goal – failure to eradicate generates on-going future costs to us. The investment in research must generate returns in terms of pest-animal eradication. New Zealand leads the world in some aspects of pest-animal management: e.g.

	island pest eradication. It might turn this technical advantage into greater economic advantage if we progress new solutions through to international commercialisation. Pest-animal control has often been regarded as a cost to the nation, but experience shows that where New Zealand has developed world-leading expertise those skills are sought-out for conservation projects across the globe. If we meet our Science Challenge in the way described we could turn our investment in a pest-free New Zealand into profit and economic advantage – selling products, techniques and expertise to the world – because many of our pests are managed as exotic pests (e.g. rats) or indigenous biodiversity (e.g. Australian brushtail possum) elsewhere.
Research components	The ecological, economic and social challenges of implementation will need to be addressed due to the scale of a national pest-eradication program. Soft-technologies (socio-psychological techniques) to ensure mass public support will be particularly necessary and must begin before, and be sustained throughout, implementation. Early research to identify likely social and cultural barriers to support should be conducted and campaigns designed to address those. Early research to understand the most tractable motivations of public support should be conducted to also assist in campaign design. Patents will need to be researched, lodged, and defended. Legal expertise and business models should be applied during product development to protect the nation's intellectual property, defend it, and move the product into mass production appropriate to market size. We should adopt local expertise in production to design, build and maintain industries for product manufacture. Research gaps and opportunities? There has not yet been a nationally coordinated effort to identify how New Zealand might benefit economically from advances in its pest eradication capacity. What pest-animal technologies and techniques might be saleable to the rest of the world? What pest-animal services and expertise might be saleable to the rest of the world? The process of pest-eradication is, in itself, a nation-wide socio-psychological and ecological experiment from which the world might learn. Indeed, its attainment is a remarkable marketing tool reinforcing brands or creating new brands for other aspects of the New Zealand economy e.g. 100% Pure, 100% Pest Free.
Research Gaps and Opportunities	We have addressed research gaps and opportunities for individual themes where we have described research components.
Comments	There is widespread support for the approach to New Zealand's pest-animal problem described here as evidenced by the recent Pest Summit held by the Department of Conservation (3-4 December, 2012) in Wellington.

Entry ID	399
By 2050 an environment where small mammal pests are no longer a threat to the security of New Zealand's indigenous biota, or condition of New Zealand's ecosystem services	
Summary	This challenge proposes to develop new, socially acceptable, sustainable technologies for pest control, allowing us to protect our distinct biodiversity. Tools such as genetic modification or synthetic biology should be investigated. Implementation will involve fostering strong and on-going public participation, and such any new methodologies will need to possess strong public approval.
Theme 1 **Tools and strategies that will enable suppression of small mammal pest populations to ultra low levels, below which they no longer pose a threat**	
Importance to New Zealand	Pest mammals are a threat to New Zealand's biodiversity, forestry (both native forest habitats and exotic crops), and carry diseases that may threaten our primary industries. New Zealanders value highly our indigenous wildlife and flora, in particular indigenous forest habitats. Our biodiversity and wild places attract tourism, and our indigenous species offer potential future benefits in terms of bioprospectivity. There are economic and values-based reasons why New Zealanders should place importance on protecting our country from the threats of mammal pest populations.
Research components	1) Create a landscape-scale schematic that integrates the full suite of control options utilising the full range of applications. 2) Assess new and potentially innovative small mammal pest control tools and strategies that are socially acceptable for use until 2050. 3) see research component of next theme.
Theme 2 **New Zealanders are engaged in the ongoing effort to protect New Zealand's indigenous biodiversity and ecosystem services**	
Importance to New Zealand	Protecting our environment from pests is not solely the role of government, but requires the mandate and effort of individuals and the collective population to support these efforts. People make a huge impact on replanting of indigenous flora, protecting habitats for native animals, and defending the processes needed to protect our unique biodiversity. New Zealand's biodiversity is unique internationally, both as an island recently colonised by humans (and therefore with significant proportion of natural habitats remaining intact); but also as a remnant of Gondwanaland from which certain predators never arrived. Our isolation enabled divergence of many species and diversity of other flora and fauna and habitats that are unequalled elsewhere in the world. It is the people of New Zealand and the world who value this diversity and the people who will support (or not) the efforts to control pests to maintain its protection.

Research components	Assess the likelihood of future adoption of novel approaches to control or eradicate pests - using tools such as genetic modifications and synthetic biology. The goal of this theme would be to develop novel approaches within the context of social acceptability.
Comments	This challenge was used in the Cabinet paper.

Entry ID	**431**
Bio-protection for a small island nation	
Summary	Current border-patrol standards render New Zealand susceptible to biosecurity threats (such as emerging infectious diseases). Improvement in border security will result in benefits for public health, primary industries, and our environment. Such improvements will involve detection of incoming diseases at our borders, or developing techniques for eradication of pests which have already crossed our borders.
Theme 1 **Increased biosecurity for public health**	
Importance to New Zealand	Like all countries, New Zealand is vulnerable to emerging infectious diseases, such as pandemic influenza and new respiratory diseases such as SARS. They have the ability to cause very disruptive and unpredictable threats to public health such as global pandemics of influenza and SARS. Although our relative isolation gives us the potential to protect our population through highly effective border security measures, the available screening methods are not very effective at detecting infected travellers at the borders.
Research components	New Zealand therefore needs to better protect its population from imported pandemic infectious diseases. One key step in this process is a large study led by the University of Otago looking at border security, including screening arriving passengers using questionnaires, throat swabs, and thermal scanning.
Theme 2 **Increased biosecurity for our primary industries & environment**	
Research components	The University of Otago has widespread expertise in the causes of biosecurity issues (i.e., pest/pathogen understanding) and their likely impact (conservation research to protect and preserve New Zealand's wildlife (including threatened birds, marine mammals, frogs and reptiles) that could support wider work within this theme area. Otago also carries out applied research focuses on factors such as pest eradication, predator-free islands, the role of mainland eco-sanctuaries, reserve design, and translocation/restoration genetics. These can play important mechanisms in managing and mitigating the negative consequences of biosecurity incursions.

Comments	Biosecurity is a critical issue that impacts significantly on: 1. Socio-economic outcomes — i.e., a human infectious disease outbreak would have significant public health implications and knock-on impacts on tourism; a similar livestock or plant based incursion would cause direct loss in primary sector productivity (e.g. as with Psa) and potentially knock-on impacts on market access (e.g. as with BSE abroad); and 2. Environmental outcomes — i.e., loss of biodiversity and/or ecosystem services (e.g. Varroa mite impact on feral bee populations and pollination services).

Entry ID	**461**
Future Proofing New Zealand Biosecurity. Overall Goal : To halve, by 2030, the rate destructive, exotic organisms establish in New Zealand's terrestrial and aquatic ecosystems, by aligning and boosting national biosecurity effort. This is fundamental to economic growth, environmental quality and public health	
Summary	It is predicted that in the future New Zealand will face a growing range of biosecurity threats, requiring pre-emptive biosecurity planning and policy advice. By analysing historical data for past biosecurity invasions, predictive models can be built which identify which factors are most important in predicting the effects and preventing the outbreak of such threats. Further to this, resilience of the biosecurity network needs to be strengthened, via interactions between scientists, public, and industry to increase surveillance capabilities.
Theme 1 Futurewatch - to identify emerging and future biosecurity. This theme aims to provide strategic foresight via innovative tools to identify emerging and future biosecurity threats. It will combine robust and resilient analysis with scenario development to optimise intervention options, planning and policy advice	
Importance to New Zealand	This theme will advance the biosecurity planning, readiness, policy advice and responses so seriously needed to off-set the inexorable growth of biosecurity threats. This requires better understanding of the risk characteristics (genetic, demographic and environmental) of potential threat organisms and pathways through which they are introduced. A sound 'futurewatch' capability is therefore fundamental to biosecurity readiness and will provide a platform for minimising future impact, through better methods for assessing and prioritising threat organisms and for predicting their impacts. This is critical given the inherent vulnerability of New Zealand's ecosystems to biosecurity threats. New Zealand's geographic isolation from many potential threats, coupled with the species-sparse assemblage of mainly exotic economic plants and animals in many

	terrestrial ecosystems, means there has been little co-evolution with potential threat organisms. This results in extreme vulnerability.
Research components	The dynamic nature of the biosecurity risks faced by New Zealand over the medium- to long-term requires access to advanced foresighting capability that will lead to the prompt identification of emerging biosecurity threats – staying one step ahead of potential threats. This theme will fulfil such a need by integrating novel future-orientated methodologies to deliver a comprehensive foresight toolkit. This will draw on historical data to identify the likely driving variables and forecast future trends for potential biosecurity threats involving terrestrial and aquatic pathways as well as vectors (notably including marine vessels) through which such threat organisms arrive in New Zealand. Such information will then be coupled with sophisticated trend/impact analysis methodologies, so that it will be possible to develop 'surprise-free' forecasts of future biosecurity risks. Such 'no-surprises' forecasts, based on elapsed events, would then be linked to likely future climate, economic, demographic, agricultural and trade developments in order to anticipate events that might cause deviations from the surprise-free extrapolation. In this way responses to likely biosecurity impacts can be suitably planned for and accommodated. Overall such methodology will become the foundation for developing a whole series of scenarios chosen to identify major future biosecurity uncertainties and responses. Outcomes of this horizon-scanning process will then be available to be fed back into ongoing planning, thereby providing the basis for ongoing reviews that will establish detailed biosecurity futures for New Zealand.
Theme 2 **Detection and Identification of Threat Organisms: develop and apply network models and information covering terrestrial and aquatic environments, to engage public (citizen scientists), industry and science communities in surveillance, strengthening resilience of the biosecurity network**	
Importance to New Zealand	A strong biosecurity system demands substantial investment in capability across the continuum from the border to boardroom, with effective action depending on access to information and surveillance systems. Work in these areas can be aligned and accelerated. Vote Biosecurity amounts to $200 million p.a. yet this is a fraction of public funds expended on biosecurity by other government agencies (e.g. regional and local councils, CRIs and Universities). Industry invests heavily through import and export compliance as well as pest management. No biosecurity system can be perfect and recent pest incursions have highlighted New Zealand's continued vulnerability. Science is needed to develop and evaluate novel tools allowing timely detection and identification of priority organisms at low densities when the chance of successful eradication or control is highest. This applies especially in marine environments and pathways where current surveillance systems are expensive and difficult to implement. To date, responses to biosecurity breaches have been reactive, rather than pro-

	active, focusing on single incursion events rather than potential weaknesses in the biosecurity system itself. As multiple organisations engage in biosecurity readiness (e.g. government-industry agreements, shared surveillance responsibilities), the dynamics of the biosecurity system are changing from a largely centralised, government responsibility to a more dispersed network of stakeholder bodies. Questions emerge around network robustness including effectiveness of information flows and feedbacks. Evaluating emerging properties of this system will help ensure they do not impede biosecurity management. Opportunities to optimise networks and build contingency plans and structures that minimise adverse outcomes will be highlighted.
Research components	This theme will catalyse data collation and information access, drawing on information from distributed sources to improve the capacity to detect and respond to biosecurity threats. Indeed a significant opportunity exists here to develop ways to harness 'citizen scientists' to maintain widespread and continuous biosecurity vigilance, complementing existing surveillance capacity. This opportunity to harness the good-will of New Zealanders and their commitment to protecting the New Zealand environment should also increase awareness, thereby strengthening day-to-day surveillance. 'Filters' will need to be developed to handle the large volume of disparate information that an expanded surveillance capacity will generate. Related to this, new tools will be developed. These will include inventories, compliance monitoring, early detection, delimitation and proof of freedom from infestation. Additionally surveillance methodologies and diagnostic tools will be developed to improve both sampling/monitoring efficacy and identification of threat organisms. In this vein it will be necessary to develop a federated data system using consistent open-source standards for data capture and delivery. Ultimately this will provide the public, researchers, industry and government agencies with better access to large, complex, and interrelated datasets, allowing comprehensive analysis of the manner in which components of New Zealand's biosecurity system interact. By exploring how all components work together, the theme will reveal organising principles and emergent properties, thereby strengthening the effectiveness of the biosecurity information and surveillance network. This will help to identify the optimal network architecture, including definition of roles of stakeholders, pivotal information nodes and communication routes.
Theme 3 **Strengthening Biosecurity Response Capacity and Capability to respond promptly and accurately to incursions, with effective and socially acceptable tools for disinfestation of risk goods, as well as for eradication and control of the spread of threat organisms**	
Importance to New Zealand	Biosecurity incursions significantly impact the viability of productive ecosystems and their economic value. Preventative measures addressing the risks pre-border and/or surveillance and interceptions at the border are widely accepted as the most cost-effective approach to manage future threats. However, border control

	can never be perfect and indeed, some low densities of future risk organisms are likely to be already established in New Zealand's landscapes and waterways. Post-border invasive behaviour is therefore important and can be significantly affected by contemporary evolution, changes in agricultural practice and/or relaxation of environmental constraints as a result of climate change. Considerable economic, environmental and social benefits will arise from identifying and characterising future post-border threats early, thereby containing outbreaks and/or actively slowing invasive species spread before their impacts are fully realised and widespread pest management is required.
Research components	This theme focuses on understanding, predicting and preventing founder population increase, spread and ultimately, impacts. An integrative framework will be developed using input by stakeholders for handling biosecurity threats post-border. Threat species surveys, population dynamics and definition of impact thresholds will be integrated, to develop models of invasion-based interactions with various ecosystems and climate change. These will provide the basis for socially acceptable control and eradication technologies. This will rely on understanding of pest and disease biology and epidemiology. Such activity will include new/improved treatments for biofouling on vessels (including complex structures such as mobile drilling rigs), treatment technologies for the inside and outside of sea containers, and the identification of safe fumigants (including replacement(s) for methyl bromide). Further, research is needed on the potential threat organisms not yet confronting New Zealand's ecosystems to enable more timely and effective response should such threats materialise. A 'model systems' approach will allow rapid extrapolation and application of such knowledge to new threat organisms, e.g. infectious salmon anaemia. The combination of invasion models and pest/disease biology will in turn underpin the development of robust decision tools, for more effective response capacity and capability. Overall, this theme will develop new technologies for controlling or eradicating threat organisms in ways to balance genetic diversity with the productive capacity of New Zealand ecosystems (often monocultures). This will include bioprotection technologies integrated with biology, epidemiology and landscape ecology. New response capacity and capability developed through this theme will be incorporated into an enhanced national biosecurity capability network.
Research Gaps and Opportunities	New Zealand already invests significantly in biosecurity science and the aim of the Future Proofing Biosecurity Challenge is not to duplicate such activity but act as a platform to integrate and align this towards more robust long-term national outcomes. Nevertheless, there are several research gaps that exist in the biosecurity system. Firstly, research is often sector/ecosystem specific (e.g. marine, agricultural, forestry, freshwater, natural environment), it addresses different targets (e.g. human, animal, aquatic or plant health) and largely based within the natural sciences. These groupings currently do not communicate effectively with each

	other and often approach biosecurity from different perspectives using different emphases and tools. The Future Proofing Biosecurity Challenge will bring these communities, including the public, together to facilitate cross-fertilisation of ideas ensuring a more consistent approach. Secondly, much of the research undertaken is reductionist and focused on only one aspect of the biosecurity system (e.g. pre- or post-border). Urgently needed is an holistic perspective bridging gaps between the various research activities and draws the different elements together, thereby co-ordinating the overall thrust of New Zealand's biosecurity research portfolio is. Third, biosecurity is an interdisciplinary topic yet the involvement of social scientists, veterinarians, medics, epidemiologists, economists, geographers, political scientists, information technologists in the research agenda has been weak to date. Each theme within this challenge is interdisciplinary and seeks to bring together the widest set of expertise, links with stakeholders and policymakers. Ultimately they seek to and deliver scientific insights that are understandable to the wider public.
Comments	By absolute necessity New Zealand must invest heavily and effectively in biosecurity activities to protect its economy, environment and people from the risks associated with invasive and damaging organisms. Such organisms already inflict billions of dollars' worth of damage to the country's ecosystems (terrestrial and aquatic), crops, livestock, waterways, public health and ultimately, the economy. Approximately $3-4 billion (~ 2% of GDP) is already being lost directly to introduced risk organisms each year and accelerating global trade and travel has the potential to double this by 2030. Similarly, these incursions cause irreversible damage to the country's unique natural heritage. Climate change, increasing trade and travel, intensifying agricultural practice, population growth, urbanisation and exploitation of terrestrial and aquatic resources can only exacerbate the biosecurity threats to the nation. In fact, these factors are already challenging this country's favourable biosecurity status that has permitted its peerless reputation for food safety and reliability of supply. New and nationally integrated approaches to biosecurity must be developed to off-set these dangers. While there is already considerable public, community and industry awareness of the importance of biosecurity to the New Zealand's well-being, the country's readiness and response capability is limited and fragmented. This challenge is designed to align and boost this capability, particularly by integrating research effort across multiple sectors and creating opportunities for much greater public participation in biosecurity readiness and response. Of the approach discussed in this analysis, perhaps the biggest opportunity least exploited is how to garner the enormous potential value of New Zealand citizen science in protecting New Zealand's unique productive and indigenous ecosystems. This mobilisation of growing public interest in science will require close and multidisciplinary attention. More broadly this challenge which covers terrestrial and aquatic ecosystems

	includes the Bio-Protection Research Centre (Lincoln University), four Crown Research Institutes (NIWA, SCION, AgResearch, and Plant and Food Research) and three key biosecurity stakeholders (the Ministry for Primary Industries, the Department of Conservation and the Forest Owners Association). This proposal will complement four other national science challenges, these being: 'Benefiting from biodiversity' proposed by Landcare Research and the Department of Conservation, 'Sustainable agriculture: Ensuring food production for the next 1000 years' proposed by Lincoln University, AgResearch's 'Increasing Sustainable Productivity' challenge and NIWA's 'Increased Wealth from and Stewardship of our Oceans'. Note: NIWA supports the submission of a biosecurity National Science Challenge, including that listed above. As a result of time constraints, however, there were elements that NIWA felt could take a slightly different approach. To ensure that MBIE has a diversity of ideas being submitted, NIWA has included a slightly different version of a biosecurity Challenge to be considered alongside the above challenge.

Entry ID	**462**
Protecting New Zealand's Natural Capital from Biological Risks. Overall Goal: The Government's goal for economic growth is underpinned by measures that protect New Zealanders, our unique natural resources, and primary industries from biological risks	
Summary	This challenge proposes to develop better methods to assess risky organisms and predict their potential impact on economically, socially, and environmentally important resources. E.g. identifying what determines the success of an invading foreign organism. This will draw on and integrate existing, disparate info sources, such as trade/population forecasts, border interceptions, and will requiring novel computational tools. For those organisms that escape this developed first line of defence, effective surveillance (both aquatic and terrestrial) is needed to detect and prevent these organisms from establishing within the environment.
Theme 1 **Forecasting the biosecurity landscape**	
Importance to New Zealand	Better forecasts of emerging threats allow intervention options and contingency plans to be developed to protect New Zealand's borders. The volume of trade goods and number of visitors to New Zealand have been rising rapidly and their points of origin becoming more diverse as our national economy grows. Our increased connectedness to the global community brings with it new and emerging risk organisms, some of which will represent significant threats to the sustainability of New Zealand's natural resources. Our biosecurity system needs to be able to identify and respond to changing global threats with

	agility and speed. This will require better methods to understand and forecast changes in global trade and travel and better information networks with prospective trading partners to identify emerging threats. Better methods are needed to assess and prioritise organisms and to predict their impacts on valued economic, environmental, social and cultural resources within New Zealand. This includes better knowledge of the determinants of success of foreign organisms and their impacts in New Zealand ecosystems.
Research components	1. Forecasting emerging threats. Staying one step ahead of potential threats is critical. We need to know what organisms to look out for and how they might arrive. We need to develop better ways to identify, assess and prioritise organisms that are most likely to emerge as pests and diseases in all ecosystems. Novel methods are needed to account for changing climate, land and water use, trade and tourism patterns, industry and social dynamics. These should draw on existing disparate information sources such as trade and population forecasts, global alert notifications and border interceptions. New data mining tools offer great promise for harvesting existing data and integrating it with future forecasts to develop predictions of future events. 2. High risk aquatic organisms. Global information networks are well-established for pests of agriculture and horticulture, but are much less well developed for environmental and aquatic (marine & freshwater) risk organisms. A consequence is that few pests of these environments have established “track records” of harm and their impacts are difficult to forecast. Because the global pool of potential threats is large, novel methods are needed to predict the organisms of most concern to New Zealand ecosystems. 3. Pathways and vectors. Managing the pathways by which high priority organisms enter New Zealand and spread is the most cost-effective methods of reducing risk. We need improved methods to assess pathway risks and mitigate them. This is particularly critical for marine pathways which are subject to rapid and dramatic change in response to global changes in trade.
Theme 2 **Detecting and identifying pests and diseases**	
Importance to New Zealand	Effective tools for surveillance and border compliance have significantly reduced the number of unwanted species crossing New Zealand’s borders, and those that do are detected early to maximise success of eradication and control measures. Even with the best pre-border intervention strategies, unwanted organisms will continue to reach New Zealand, breach the border and some will become pests. Effective surveillance to detect them early is an essential second line of defence. The biggest challenge is to detect them when they are at low prevalence or density, when the chance of successful intervention is greatest. Science is needed to develop and evaluate novel tools that allow more rapid, accurate identification and detection of priority organisms at low densities, especially in marine environments and pathways (particularly biofouling and ballast water) where current surveillance systems are expensive and lag behind what is available for terrestrial pests

Research components	1. Optimum detection tools for all environments. Design and trial new sampling schemes for different surveillance activities (e.g., inventory, compliance monitoring, early detection, delimitation and proof of freedom from infestation) and develop methods to evaluate and optimise their efficacy. 2. Aquatic surveillance tools. Develop better tools for surveillance of aquatic pests, diseases and pathogens. 3. Rapid identification of aquatic pests and diseases. Development of diagnostic tools, and aligned taxonomic research, to enable rapid identification of aquatic risk organisms. 4. Accessible surveillance data. Contribute to development of a federated data system (using consistent open-source standards for data capture and delivery) to allow end-users and stakeholders greater access to surveillance data and to contribute to their collection. Research components 2 and 3 relate specifically to marine and freshwater environments, where there is an identified lag behind related science in terrestrial environments
Theme 3 **Managing pests and pathways**	
Importance to New Zealand	Methods to treat risk goods at or before the border are effective and socially acceptable, and a suite of options are available to manage established pests (including marine) to mitigate their impacts on valued economic, environmental and social resources. The impacts of risk organisms can be reduced by preventing their establishment in the environment, containing their spread and abundance, and by undertaking activities that protect valued resources at particular places. Amendments to the Biosecurity Act will provide greater clarity around the roles and responsibilities for managing existing pests, but there is a limited arsenal of acceptable options available for pest management (particularly for marine pests). A tool box of fully-developed treatment, control and management strategies is needed for rapid responses to new incursions and to manage established populations. When attempts to eradicate or control pests and diseases fail, strategies to manage and contain pests need to be available to the expanding network of agencies and stakeholders involved.
Research components	1. Treatment technologies for risk goods. Development of more cost-effective, safer and environmentally acceptable treatment technologies for risk goods. With the current development of an Import Health Standard for biofouling on vessels, there is an urgent need for new/improved treatments for biofouling on vessels (including complex structures such as mobile drilling rigs). Other priorities for treatment technology developments include the inside and outside of sea containers, and safe fumigants (including replacement(s) for methyl bromide). 2. Readiness to respond. Incursion response models need to be adaptive and they must have the ability to capture and integrate existing scientific and other

	information from varied sources in real-time during different stages of response activities. Dynamic decision-support tools are needed to provide rapid access to the diverse array of scientific information required to inform response decisions. 3. Aquatic pest management tools. Develop control, eradication and containment methods for potential and established pests and diseases that have public acceptance for use. While there have been significant gains made in the past 20 years in the development of terrestrial pest management tools, significant challenges remain in aquatic environments where existing tools for eradication or control are very limited and very basic (e.g. wrapping techniques and physical removal). Recent disease outbreaks (e.g. kauri dieback, Psa in kiwifruit, infectious salmon anaemia in Chilean salmon farms, and viral ganglioneuritis in Australian abalone) highlight the importance of developing tools and strategies to manage disease outbreaks alongside those for larger pests.
Research Gaps and Opportunities	The three themes discussed in this National Challenge cross the biosecurity system incorporating all environments (terrestrial, freshwater and marine) from pre-border forecasting and interventions to post-border eradication, control and management of established pests. However, only those areas where there are significant research gaps or inadequate resourcing are listed in the Research Components in each theme; in essence these represent the key research gaps and opportunities where science can make a major contribution to the issues. The government's goal of doubling the value of New Zealand's exports by 2025 will be associated with a significant increase in the volume of trade between New Zealand and other countries, mostly by maritime shipping. Despite recent measures, our marine borders still have an unacceptably high rate of intrusion by risk organisms, with maritime shipping (ballast water & biofouling) being the principal pathway through which these species reach New Zealand. The science to manage these threats is the least developed and resourced of all biosecurity sectors. Plans to increase the export value of aquaculture, fisheries and offshore mineral and petroleum resources will bring with them new biological risks to our natural marine resources and biodiversity. There is a strong need for better understanding of how we can forecast and reduce the risks from foreign marine organisms to protect our marine ecosystems from biological risk.
Comments	Growth in New Zealand's economy, including increased and diversified primary production and expanded global trade and travel will increase our exposure to potentially damaging pests and diseases. Foreign organisms already cause billions of dollars of damage to New Zealand's natural resources and the industries they support. The direct output losses caused by pest impacts on primary production in New Zealand have been estimated at $1.15 billion per year. This does not take into account the additional environmental and social impacts, which are difficult to estimate, but expected to be orders of magnitude larger. Costs for compliance with protective biosecurity measures can also be very high. For example, a 1 day delay to a single container vessel caused by non-compliance with the proposed biofouling Import Health Standard could cost the ship operator >$200k and have direct impacts to New Zealand cargo owners and indirect consequences for our global reputation in freight handling productivity.

	Growing our economy, and protecting our natural resources from the risks associated with damaging foreign and endemic organisms, are critical for New Zealand. The government's commitment to a strong biosecurity system recognises the key role that science has in meeting our future growth challenge. The themes identified in this Challenge reflect the science priorities identified by the Ministry for Primary Industries and its expert advisory panels in the New Zealand Biosecurity Science Strategy. The maturity of and funding for biosecurity science in New Zealand differs across sectors and ecosystems and, as a result, so do the issues that need to be addressed to strengthen our biosecurity system. These varied needs are reflected in the Research Components identified under each theme, some of which relate to all environments, others to marine and freshwater only. This proposal complements two other national science challenges: 'Future Proofing New Zealand Biosecurity' proposed by the Better Border Biosecurity terrestrial research collaboration (B3) and 'Enhancing the value of New Zealand's biodiversity' proposed by Landcare Research.

Entry ID	**37**
Revitalise New Zealand native forests	
Summary	This challenge proposes to revitalise New Zealand's declining' native forests. Revitalising our native forests through a range of actions including the control of exotic animals and pests, provide environmental/climatic benefits such as improved waterway health and carbon sequestration, whilst also providing social benefits such as job creation.
Theme 1 **Forest diversity**	
Importance to New Zealand	Our native forests are decadent and being degraded by exotic animals and plants. Healthy forests are a climatic buffer and environmentally attractive.
Research components	Identifying both climax species and undesirable exotics in various forest communities and taking corrective action. Developing new techniques to revitalise forests and ensure exotic plants and animals do not overcome native trees.
Theme 2 **Carbon sequestration**	
Importance to New Zealand	Healthy forests naturally absorb carbon and release oxygen: decadent forests release carbon. New Zealand needs help with the carbon balance.
Research components	Techniques to reverse forest ageing and ensure vital plant communities in perpetuity. This could include replacement of old stems in some areas.

Theme 3 Water Quality	
Importance to New Zealand	Forests naturally cleanse the water entering waterways. New Zealand water quality is deteriorating, and use of natural forests to filter supplies in good ecology. Native trees along streams and rivers should be maintained to enhance both water quality and environmental aspects.
Research components	Focus forest management initially along major water catchments, and extend along rivers and streams with locally-adapted native species.
Theme 4 **Local employment**	
Importance to New Zealand	Regions are becoming depopulated. Some communities have close contacts to forests and could be supported in improving forest vitality, both by manipulation of species mix, removal of exotics and in small-scale wood processing.
Research components	Establishing natural climax ecology and quantify the threats by exotic animals and plants. Improve non-invasive harvest of selected mature stems and improve wood processing techniques for native timbers.
Research Gaps and Opportunities	We no longer undertake scientific studies in the natural forests which cover about 25% of our country. The challenge is to intervene non-invasively to ensure the health of this resource, improve local employment and engagement with forests in the first instance. This would have natural flow-on to healthier ecosystems, waterways, and improved national carbon balance.
Comments	The decadence of New Zealand forests is a "smoking gun" which if not addressed could have unforeseen consequences down the track (such as reduced tourism and huge carbon commitments). There would be a huge "feel-good" factor in improving the natural environment as well as the well-being of local communities.

4 Climate Change

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 4: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
Climate Change		
65	New Zealand becoming the global leader in climate change solutions	1. Phase out fossil fuels from electricity generation in order to reduce CO_2 emissions 2. Phase out fossil fuel use in transport in order to reduce CO_2 emissions) 3. Mitigate the effects climate change
76	Sustaining New Zealand's environment, economy and society in a world with a changing climate	1. Quantify the impact of current and projected future global climate change on New Zealand's agricultural productivity, renewable energy capacity, fisheries, and foreign trade 2. Develop greenhouse gas emissions reduction technologies to mitigate the impacts of climate change globally and to ensure that New Zealand plays its role in climate change mitigation 3. Equip those sectors of New Zealand society most susceptible to the effects of climate change with the tools required to adapt to the future changes in climate identified in theme 1 4. Validate New Zealand's international reputation as an environmentally responsible global citizen contributing to an international research effort to address the threat of climate change
125	Climate Change - have a proper global assessment and how that applies to New Zealand as an individual country	Ultimate goal is to reduce the effects of climate change but that can only be done by proper global assessment
244	Reducing greenhouse gas emissions from agriculture New Zealand while supporting the sector's prospects for growth and generation of wealth for all New Zealanders	1. Reducing methane emissions from enteric fermentation and manure 2. Reducing nitrous oxide emissions from urine and fertiliser application 3. Increasing soil carbon storage including mixed agro-forestry systems 4. Farm system models and decision-support tools that minimise the net emission of greenhouse gases while supporting a healthy and vibrant farming sector

Entry Id	Challenge	Themes
Climate Change		
263	Reducing the uncertainty of Antarctica's impact on New Zealand's oceans, climate and ecosystems in a changing global climate. [Also submitted as proposal #389]	1. Predicting non-linear behaviour and tipping points in Antarctica's natural systems 2. Tracking the impacts of change in Antarctica and predicting the response in "our far south" and across wider New Zealand 3. Assessing the consequences of change for, and the resilience of Antarctic and Southern Ocean ecosystems
361	Better Climate Projections for a Better Prepared New Zealand.	1. To provide detailed reconstructions of ocean/climate change during past warm periods as realistic and relevant analogues of projected change. 2. To determine the processes and impacts of modern ocean/climate change on New Zealand. 3. Generation of improved, evidence-based projections for improved knowledge regarding New Zealand's adaptation to a warmer world. 4. To translate results from science research into information that is "user friendly" and relevant for government, industry and New Zealand society overall.
381	Minimising global climate change	To minimise the effect that global climate change has on New Zealand and other countries
408	Generating sustainable growth and resilience under a changing climate: Create scientific and technical knowledge to guide adaptation to climate variability and change, reduce greenhouse gas emissions, and engage with all sectors in its application. [Also submitted as proposal #449]	1. Observe and understand changes in climate (atmosphere, hydrosphere, ocean, cryosphere) in our region (New Zealand, South Pacific and Southern Oceans, Antarctica). Estimate potential future changes for plausible emissions scenarios from the IPCC's Fifth Assessment 2. Identify present and predicted climatic impacts on our ecosystems and their services, health, primary production, industries and society; determine adaptation options and opportunities; understand and enable mechanisms to support adaptive decision-making 3. This theme will provide information for New Zealand policymakers and industry on the potential, costs and implications for New Zealand of various mitigation options 4. Synthesis, policy development, communications, implementation: Understand interaction between science and society, local and global issues,

Entry Id	Challenge	Themes
Climate Change		
		adaptation and mitigation, communication and engagement, and how these influence policy development and its uptake
430	Living with climate change in Aotearoa	
464	A World-leading Low Carbon Economy. Goal: Develop a world leading low carbon economy that provides energy security, increases access to export markets and reduces greenhouse gas emissions.	1. Reducing Greenhouse Gas Emissions from Agriculture 2. Increasing Renewable Energy 3. Improved energy efficiency 4. Developing a sustainable transport system
480	Environmental Change Preparing New Zealand for the Effects of Environmental and Climate Change	1. Change and Variation In and Across Geographic Areas 2. Land-Freshwater-Marine Continuum 3. Major Agents of Change and Culturally-Determined Behaviour 4. Adapting to Climate Change within a Global Context

Entry ID	65
New Zealand becoming the global leader in climate change solutions	
Summary	This challenge proposes to phase out fossil fuels from electricity generation and transport, which will have benefits such as limiting climate change, decreasing reliance on fossil fuels, and safeguarding New Zealand's 'clean, green' image. This goal works in tandem with the aim of mitigating the on-going effects of climate change i.e. reducing the impact on crop growth by breeding crops resistant to higher temperatures, reducing the effects of ocean acidification on fisheries species. Further opportunity exists in the development of low cost renewable energy generation, and the exporting of these technologies offshore.
Theme 1 **Phase out fossil fuels from electricity generation in order to reduce CO_2 emissions**	
Importance to New Zealand	Doing our part to stop dangerous climate change and prevent its economic, ecological and social impacts. - Meeting international obligations for reducing CO_2 emissions. - Safeguarding New Zealand's clean green image which is a huge marketing asset both for New Zealand exports such as dairy products and for tourism. - Opportunity to export new technologies

Research components	Lowering the cost of renewable energy generation (wind, solar, tidal, biomass). Distributed small scale generation and its integration into the national grid. Energy storage and demand management (to maximise the benefits of fluctuating generation such as solar).
Theme 2 **Phase out fossil fuel use in transport in order to reduce CO_2 emissions**	
Importance to New Zealand	Similarly to phasing out fossil fuels from electricity generation, there are many benefits: - Doing our part to stop dangerous climate change and prevent its economic, ecological and social impacts. - Meeting international obligations for reducing CO_2 emissions. - Decreasing and eventually removing the need to import fossil fuels. - Reducing and eventually eliminating the environmental impacts from fossil fuel production (e.g. deep sea oil drilling and fracking). - Safeguarding New Zealand's clean green image which is a huge marketing asset both for New Zealand exports such as dairy products and for tourism. - Opportunity to export new technologies
Research components	More effective public transport solutions and their integration into existing cities. Safe & efficient energy storage alternatives to fossil fuels for vehicles. - Urban design to enhance the usability of public transport and minimise required travel distances. This research can have immediate practical applications in the context of Christchurch rebuild.
Theme 3 **Mitigate the effects climate change**	
Importance to New Zealand	Like every other country, New Zealand needs to mitigate the effects of climate change. Due to inertia of the climate system and the still increasing global emissions, climate change will continue. Regardless of the local effects of climate change in New Zealand, it's important to keep in mind that New Zealand imports many products from global markets and participates in the global economy. Therefore, finding solutions to mitigate climate change effects around the world is important for preserving the standard of living for New Zealanders. It also presents huge opportunities for exporting solutions
Research components	Breeding crops which are resistant to higher temperatures. Breeding drought resistant crops. Mitigation of other effects of droughts and floods on agriculture. Flood mitigation, changes to buildings and infrastructure design for flood resilience, and cost effective methods of retrofitting existing buildings and infrastructure for flood resilience. Prediction and mitigation of the effects of rising sea level, including erosion and coastal flooding. Mitigation of the effects of ocean acidification on fisheries and aquaculture.
Research Gaps and	I have selected research themes and listed the areas of research in each theme

Opportunities	which are going to have the most impact and can produce the most practical solutions. I have not included other areas which in my view aren't going to have sufficient impact on CO_2 emissions such as research into energy efficiency or carbon capture and storage.
Comments	We need to recognise climate change as the most urgent and important issue facing humanity. It is important to direct research funding in accordance with that view. Given the unwillingness of governments worldwide to price and regulate CO_2 emissions effectively, we need to make alternative energy generation solutions cheaper, so that they are able to displace fossil fuels even on a non-level playing field where CO_2 emissions aren't priced appropriately. The climate is changing and will continue to change for a long time. In addition to phasing out fossil fuels, we need solutions to mitigate the impact of change, both domestically and globally. This problem is urgent and critical to solve because of its enormous economic, ecological and social impacts. However, it can also be a huge opportunity for New Zealand to be a leader in finding solutions. It has the potential to boost New Zealand's exports and international reputation.

Entry ID	**76**
Sustaining New Zealand's environment, economy and society in a world with a changing climate	
Summary	This challenge proposes to conduct research to identify the current and predicted effects of climate change in New Zealand, and how these affect/will affect agricultural productivity, commercial fisheries, etc. Technology that reduces greenhouse gas emissions will proactively offset the effects of $C0_2$ production, whilst other avenues such as methane reduction should also be explored. Some sectors will inevitably be affected by climate change (such as agriculture) and so infrastructure and research is needed to improve and sustain productivity in the face of a changing climate.
Theme 1 **Quantify the impact of current and projected future global climate change on New Zealand's agricultural productivity, renewable energy capacity, fisheries, and foreign trade**	
Importance to New Zealand	New Zealand's environment, economy and society will all be affected by climate change to varying degrees. The robustness of predicted changes in climate will affect both our willingness to mitigate anthropogenic climate change, and our capacity to adapt to inevitable impacts. While New Zealand agricultural productivity may benefit from a regional increase in temperatures, changes in the frequency of extreme events such as floods and droughts will harm agricultural productivity. With ~70% of New Zealand's electricity being generated from renewable resources, and with further increase expected to come from wind energy, New

	Zealand is susceptible to climate-induced changes in these resources. Changes in fish stocks within our economic exclusion zone are also likely to be affected by changes in climate. Economic returns from agricultural productivity will depend, in large part, on our international trade of that produce. This trade, in turn, will be affected by the agricultural productivity of our primary trading partners (who are also affected by climate) and the 'climate awareness' of consumers of our agricultural produce in overseas markets (for example the 'food miles' issue). Growing New Zealand's economy has been identified as a key goal of the current government. However, if that growth comes at a significant cost to the New Zealand environment it will be unsustainable due to increasing appreciation internationally of the value of environmental protection. Therefore, balancing the needs for economic growth against environmental protection is essential for the sustainability of New Zealand's environment, economy and society.
Research components	• Strategy: Develop a national strategy that defines the needs and priorities for New Zealand-based climate research. • Measurements: Conduct measurement programmes of essential climate variables required to provide the scientific basis for addressing the goal of this theme. • Analysis: Advance understanding of key components of the global climate system and the processes that connect anthropogenic emissions of greenhouse gases (GHGs) and changes in land use to changes in climate. Research outcomes will improve the performance of prognostic climate models. • Extreme climate: Provide robust and validated scenarios of potential future changes in regional extreme climate events. • Agriculture: Generate scenarios of likely future changes in surface climate important to agricultural productivity, in particular likely changes in growing-degree-days and water availability (floods and droughts). • Energy: Quantify the impacts of potential future changes in cloud cover and atmospheric aerosol loading on solar energy, changes in precipitation on hydropower generation, and changes in surface winds on wind power generation. • Carbon footprint: Conduct research to allow producers to quantify and label the total carbon footprint of New Zealand agricultural produce from source to shelf. • Antarctica: Contribute to the international effort to better understand the effects of climate change on the Antarctic physical environment and on Antarctic ecosystems. • Sustainability: Determine the safe limits that ensure that the economic exploitation of New Zealand's environment remains sustainable on intergenerational time periods. Determine and optimize the factors that affect the balance between the need to grow the New Zealand economy with the imperatives arising from climate protection.

Theme 2 **Develop greenhouse gas emissions reduction technologies to mitigate the impacts of climate change globally and to ensure that New Zealand plays its role in climate change mitigation**	
Importance to New Zealand	Of all the developed countries, New Zealand is the most dependent on the natural environment for earning a living. It is therefore appropriate that New Zealand leads the way in GHG emissions reduction. An effective national climate response policy drives technological change that makes our economy more competitive, not less competitive. Furthermore, if New Zealand is not seen to be implementing effective methods and policies to reduce its GHG emissions, this will not go unnoticed by the international community. New Zealand's image as a tourist destination and as a provider of agricultural produce is founded on the perception of New Zealand as a clean, green and environmentally responsible country. Compromising on environmental protection will affect the international reputation of New Zealand and in turn the income potential from overseas tourism and trade. The consequences for failing to restrict increases in global mean surface temperatures to less than 2°C above preindustrial levels, as agreed to at the UN COP17/CMP7 meeting in Durban in late 2011, are outlined in detail in the IPCC assessment reports; for example sea-level rise, food and water shortages, and increased frequency of extreme weather events. As a country with one of the highest per capita GHG emissions, New Zealand has an obligation to those countries that are particularly susceptible to the impacts of climate change, as well as to future generations of New Zealanders, to play its part in the global GHG emissions reduction effort.
Research components	• ETS: Address the effectiveness of the current Emissions Trading Scheme (ETS) in reducing New Zealand's GHG emissions to date and any adjustments that may be required to improve the effectiveness of the ETS. • Agriculture: Accelerate the development of agricultural methane and nitrous oxide emission reduction technologies. Agricultural methane and nitrous oxide emissions contribute substantially to New Zealand's GHG emissions profile. Because methane is a short-lived GHG, reductions in its emissions in the near future will play a significant role in limiting global temperature increases over the following 30 years. • Geoengineering: Conduct research to better understand the potential consequences of geoengineering (the intentional modification of the global climate system) for the New Zealand environment and agricultural productivity, and to underpin New Zealand's international policy position on geoengineering. • Hurdles: Identify the hurdles to the uptake of renewable energy technologies in New Zealand. Determine the economic discount rates that New Zealand society applies (even if subconsciously) when making decisions related to future savings achieved when implementing renewable energy technologies. Identify economically viable (in terms of return on investment) government incentives to increase the use of green energy technologies.

	• Education: Develop an educational programme for the New Zealand public on the scientific evidence for anthropogenic influence on climate change to create the political support for New Zealand to implement climate change mitigation strategies.
Theme 3 **Equip those sectors of New Zealand society most susceptible to the effects of climate change with the tools required to adapt to the future changes in climate identified in theme 1**	
Importance to New Zealand	Given that the world is already committed to a certain level of climate change as a result of GHG emissions to date, some degree of adaptation to future changes in climate will be essential and needs careful consideration. Costs associated with adaptation are likely to be high. Therefore sound science-based advice on the magnitude of adaptation required can be highly economically beneficial. The sectors of New Zealand society most susceptible to the effects of climate change are unlikely to be able to develop this science-based advice themselves.
Research components	• Agriculture: Conduct research to improve sub-seasonal to seasonal predictability in the climate system, and especially in New Zealand climate, to provide the information required by New Zealand farmers to mitigate the effects of expected changes in extreme climate (especially droughts and floods) on New Zealand agricultural productivity. • Infrastructure: Based on the climate extremes research outcomes from theme 1, develop guidelines for infrastructure development that are cognizant of potential future changes in climate, including changes in sea-level. • Water security: Based on projections of changes in precipitation from theme 1, provide guidelines for development programmes to ensure security of water availability to all relevant stakeholders. • Health: Use scenarios of projected surface temperature increases for New Zealand to investigate the impacts on human and livestock health, for example in relation to outbreaks of diseases that do not spread in the current climate. • Energy security: Based on the outcomes from themes 1 and 2, provide guidelines for the strategic development of renewable energy sources. In particular, based on projections of changes in regional weather patterns from theme 1, develop guidelines for the selection of locations for energy generation using wind farms.
Theme 4 **Validate New Zealand's international reputation as an environmentally responsible global citizen contributing to an international research effort to address the threat of climate change**	
Importance to New Zealand	As a small island nation, the New Zealand economy is critically dependent on foreign income, in particular that from tourism and trade of agricultural produce. The success of both of these is highly dependent on New Zealand's international image as a responsible and leading global citizen in its response to climate change. New Zealand therefore needs to both be, and seen to be, a world leader

	in responding to the threat of climate change. With New Zealand's long history of leadership on environmental protection (e.g. its anti-nuclear stance), taking a global stand on important environmental issues is part of its social fabric. Adopting a leading position in the international effort to address the threat of climate change is therefore important to reaffirm the moral integrity of New Zealand's public, and to assure New Zealand's continued economic prosperity from agriculture and tourism.
Research components	• International research: Ensure that our national climate research strategy is well aligned with the needs of international organisations such as the World Climate Research Programme, the World Meteorological Organization, and the United Nations Framework Convention on Climate Change (UNFCCC). • Policy: Develop an effective national climate response policy that is well aligned with international policy. • Emissions targets: Determine GHG emissions reduction targets for New Zealand for each year that are appropriate for a UNFCCC Annex 1 country to achieve the goal of limiting increases in global mean surface temperatures to less than 2°C above preindustrial levels. • GCOS contribution: In addition to the measurement programmes of theme 1, measure essential climate variables in support of the Global Climate Observing System (GCOS). New Zealand occupies a data sparse but climatically important region of the globe. Measurements of certain climate variables, while perhaps not nationally important, make a vital contribution to the global effort to quantify the extent and rate of climate change. • Antarctica: Contribute to the international effort to better understand the effects of climate change on the Antarctic physical environment and on Antarctic ecosystems. • Trade: Develop a quantitative understanding of the effects of climate change, and New Zealand's policy response, on the international trade of New Zealand's agricultural produce. Use economic modelling to determine what climate change policies adopted by New Zealand would maximize returns on international trade of New Zealand agricultural produce – noting clearly that this policy almost certainly affects the international perception of New Zealand as a trading partner.
Research Gaps and Opportunities	There are many gaps in the current portfolio of climate research in New Zealand that, if filled, would make a significant contribution to sustaining New Zealand's environment, economy and society in a world with a changing climate. The current biggest impediment to filling those gaps is the lack of a national strategy to coordinate climate research and thereby identify the gaps. Individual organisations (CRIs and universities) may have developed their own research strategies, but these are internal documents, not publicly available, and generally tend to play to the strengths of the owner organisations rather than consider the research that needs to be done for the good of the country as a whole. Until a national climate research strategy is developed, with widespread stakeholder involvement, climate research in New Zealand will continue to be conducted in a piecemeal fashion that does not lead to an optimal outcome for the

	country. This National Science Challenge presents an opportunity to achieve a coordinated programme of research across multiple research providers that addresses the many current gaps in climate change research in New Zealand.

Entry ID	125
Climate Change - have a proper global assessment and how that applies to New Zealand as an individual country	
Summary	This challenge proposes to assess the global impact of climate change, and use this to specifically identify how this might affect New Zealand. Research is proposed to examine the Northern hemisphere first (as this is where the majority of people live), and extrapolate this information and apply it to the Southern Hemisphere/ New Zealand.
Theme 1 **Ultimate goal is to reduce the effects of climate change but that can only be done by proper global assessment**	
Importance to New Zealand	We all live on the same planet and need to act as one body to ensure its' survival due to the release of billions of tonnes of fossil fuels, that took millions of years to create, in less than 150 years
Research components	Assess Northern Hemisphere first, as that is where the bulk of the population and land masses are. How does that then impact on the Southern Hemisphere
Research Gaps and Opportunities	As there is extreme mis-information depending upon ones' point of view, there needs to be an independent global assessment. Several have been tried but human prejudices and nationalistic barriers are an impediment to a proper assessment.
Comments	If we don't, life as we know it will change forever for those that remain

Entry ID	244
Reducing greenhouse gas emissions from agriculture New Zealand while supporting the sector's prospects for growth and generation of wealth for all New Zealanders	
Summary	The goal is to reduce greenhouse gas emissions from agriculture. Themes include reducing emissions of methane from enteric fermentation and manure at lowest possible cost while total production increases, reducing nitrous oxide emissions from urine and fertiliser application in New Zealand pastures, enabling farmers to increase the amount of carbon stored in pastures, providing farmers with models and decision support tools to minimise the net emission of greenhouse gases

Theme 1 Reducing methane emissions from enteric fermentation and manure	
Importance to New Zealand	This theme aims to significantly reduce emissions of methane from enteric fermentation and manure at lowest possible cost even while total production increases. Methane from enteric fermentation currently makes a bigger contribution to New Zealand's total greenhouse gas emissions than fossil-fuel power generation or transport. At a carbon price of $25/tCO$_2$-eq, methane emissions constitute an opportunity cost to the nation of more than $500 million per year (based on 2010 emissions). Methane from manure is a minor contributor to overall emissions but is an important part of demonstrating effective on-farm management options to reduce emissions and obtain co-benefits from nutrient management. Reducing these emissions would reduce costs to the New Zealand tax payer and/or to New Zealand farmers (depending on climate policy choices). Demonstrable emission reductions would help position New Zealand as environmentally responsible producer of clean and healthy foods, demonstrate its commitment to reducing the effects of climate change, and assist in maintaining and increasing market access where environmental concerns can act as constraints.
Research components	Research would proceed along three main lines of enquiry: 1) Modifying the rumen microbiome to suppress and/or replace methanogenic microbes via vaccines, inhibitors, or changing feed composition including through plant breeding 2) Selecting and breeding naturally low-emitting animals 3) Developing options to minimise methane emissions from manure management. In all three components, consistency with New Zealand farm systems, sizes and management styles would be critical to ensure applicability and widespread adoption.
Theme 2 **Reducing nitrous oxide emissions from urine and fertiliser application**	
Importance to New Zealand	This theme aims to reduce nitrous oxide emissions from New Zealand pastures arising from the deposition of urine and manure and the application of fertilisers. This goal is strongly linked to other objectives, which may be covered in other challenges, relating to managing freshwater resources and reducing the environmental foot print of agricultural production. Nitrous oxide from agricultural soils currently makes a bigger contribution to New Zealand's total greenhouse gas emissions than fossil-fuel power generation or industry. It is the second most important source of emissions from agriculture in New Zealand, and at a carbon price of $25/tCO$_2$-eq, these emissions constitute an opportunity cost to the nation of almost $250 million per year (based on 2010 emissions). Apart from greenhouse gas emissions, leaching of nitrate from agricultural soils contributes to water pollution, which is presenting significant management challenges in some parts of New Zealand. Addressing both freshwater and

	greenhouse gas concerns through an integrated set of tools, technologies and practices would increase their adoption and acceptance by farmers. Reducing greenhouse gas emissions would reduce costs to the New Zealand tax payer and/or to New Zealand farmers (depending on climate policy choices). Demonstrable emission reductions would help position New Zealand as environmentally responsible producer of clean and healthy foods, demonstrate its commitment to reducing the effects of climate change, and assist in maintaining and increasing market access where environmental concerns can act as constraints.
Research components	Research would proceed along three main lines of enquiry: 1) Increasing dry matter production without increasing plant nitrogen content 2) Reducing nitrification of urea from urine and fertilisers into nitrate, with the co-benefit of reducing nitrogen leaching into water ways, via improvement of existing nitrification inhibitors and discovery and development of new inhibitors 3) Accelerating the denitrification of nitrate into nitrogen gas (rather than nitrous oxide), via modifying soil microbial processes and/or altering management practices.
Theme 3 **Increasing soil carbon storage including mixed agro-forestry systems**	
Importance to New Zealand	This theme aims to enable farmers to increase the amount of carbon stored in pastures and reduce any losses and to ensure robust monitoring and verification mechanisms. It has strong links with broader benefits of maintaining productive soils that are resilient to climate change. Emissions or removals of carbon dioxide resulting from changes in soil carbon have the potential to be of a similar importance as direct emissions of methane and nitrous oxide combined from agriculture. However, there is much greater uncertainty regarding observed changes in soil carbon, the effect of different management practices and histories on such changes, and the reliability and sustainability of practices that could increase soil carbon storage. While New Zealand currently does not account for changes in soil carbon and related emissions or removals of carbon dioxide, this may become a future requirement as part of international agreements, or become an expectation as part of good environmental management. The economic value of increasing soil carbon levels, if they can be monitored and verified, could compensate for some if not all of the cost associated with emissions of methane and nitrous oxide. On the other hand, soil carbon losses could further add to the net economic costs associated with agricultural greenhouse gas emissions. Better understanding and managing soil carbon levels would also contribute to ensuring the long-term productivity of New Zealand agricultural land, including in the context of climate change.
Research components	Research would proceed along two main lines of enquiry: 1) Quantifying and understanding the reasons for current levels of soil carbon storage in pastures,

	including the effect of land-use changes 2) Developing tools that allow the prediction of future changes in soil carbon storage under different climatic and soil conditions, farm systems and management styles.
Theme 4 **Farm system models and decision-support tools that minimise the net emission of greenhouse gases while supporting a healthy and vibrant farming sector**	
Importance to New Zealand	This theme aims to provide models and decision-support tools to New Zealand farmers and farm advisers that enable them to take greenhouse gas emissions associated with their operations into account in their day-to-day and strategic management decisions, and help them achieve desired outcomes within any given set of economic, environmental and social objectives. Reducing greenhouse gas emissions associated with agricultural activities requires farmers (including farm managers, advisers and other decision-making bodies) to have access to models and tools that are relevant to best management practice for enhanced productivity into the future. Effective, reliable and relevant farm models and their use by farmers in actual decisions, which enable them to capture the consequences of different management decisions, underpins mitigation objectives as well as other objectives such as managing freshwater quality, reducing soil erosion and maximising productivity. In the absence of adequate decision-support tools, technological and management-based mitigation options may remain under-utilised in practice and hence result in unnecessary costs to farmers and/or the country as a whole. At the same time, effective monitoring and reporting tools can support voluntary actions and reporting of mitigation activities not only for national climate policy and inventory purposes but also in support of international branding and market access.
Research components	Research would proceed along three main lines of enquiry: 1) Improving the representation of greenhouse gas emissions for different farm systems and management interventions, including novel mitigation options, for New Zealand farms, with a capability to be customised and scaled to the farm business unit 2) Improving the understanding of drivers and barriers to farmers making decisions with regard to climate change mitigation objectives 3) Development of decision-support tools that integrate farm management decisions with climatic, soil and other environmental variables to allow farmers to achieve multiple objectives of maximising productivity while minimising environmental externalities.
Research Gaps and Opportunities	Work under these four themes would build on and where possible extend existing work conducted and/or funded by the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC), the Pastoral Greenhouse Gas Research Consortium, the Sustainable Land Management Plan of Action for Climate Change, the Sustainable Farming Fund, industry-led technology transfer and capacity building programmes, and New Zealand's contribution to the Global Research Alliance on

	Agricultural Greenhouse Gases, as part of a coordinated and coherent integrated strategy. Work under theme 4 in particular would also build on livestock industry activities enhancing the productivity of ruminant farm systems. Additional research capacity, activities and expertise reside in universities and CRIs supported by core and commercial funding as well as a range of industry organisations. Maximising the effectiveness of this research will require the full description and understanding of the land and water resources that are utilised in the livestock industry so that objective information and understanding can be interpreted to the base farm units. Currently this ability is not uniform across New Zealand. If this was achieved then the opportunity to farm all our lands with the best possible economic, environmental and social outcomes would be enhanced.
Comments	The NZAGRC is a collaborative organisation comprising major New Zealand institutions and organisations engaged in conducting and funding research into the mitigation of agricultural greenhouse gases. Its members are: AgResearch, DairyNZ, Landcare Research, Lincoln University, Massey University, NIWA, Plant and Food Research, the Pastoral Greenhouse Gas Research Consortium, and Scion. All NZAGRC partners support this submission. The NZAGRC recognises that while mitigation of agricultural greenhouse gases is clearly a national challenge, it has a very specific focus. Other national science challenges may have a broader focus, such as sustainable agricultural growth within environmental limits (following a short-hand description of “green land, clear water, blue skies”). If such a broader challenge were accepted as part of the overall suite of national science challenges, it could incorporate the specific goal of mitigating agricultural greenhouse gas emissions as a major and important research theme, and the research themes proposed here would become research components within the theme of mitigating agricultural emissions. Other challenges relevant to agricultural GHG mitigation could include climate change, managing freshwater resources, and managing natural hazards including erosion. Thought needs to be given on how interactions and synergies between challenges will be handled to maximise their benefits and effectiveness for New Zealand. Even though there are multiple ways in which agricultural greenhouse gases could intersect with and be part of other national science challenges, we submit that turning the goal of reducing agricultural greenhouse gas emissions into a stand-alone national science challenge would help give coordination and draw on synergies between relevant existing and potential additional research strands. The existing NZAGRC partners would be well suited to assist with this integration and its implementation.

Entry ID	263
Reducing the uncertainty of Antarctica's impact on New Zealand's oceans, climate and ecosystems in a changing global climate [Also submitted as proposal #389]	
Summary	This challenge proposes to perform research which is focused primarily on Antarctica, aiming to determine how climate change impacts in Antarctica will affect New Zealand (as the New Zealand oceanic/climactic system is strongly influence by Antarctic events). This will involve collecting data to build predictive models of climate.
Theme 1 **Predicting non-linear behaviour and tipping points in Antarctica's natural systems**	
Importance to New Zealand	For New Zealand, the biggest impacts of a changing global climate are likely to come from beyond our shores. New Zealand sits astride an ocean and climate system that is strongly influenced by Antarctica via the Southern Ocean. Yet, we have insufficient knowledge of how Antarctica's natural systems will behave in a changing climate. What we do know is that any change will have profound downstream effects for New Zealand. Melting ice will raise sea level around our coasts and increased temperatures in Antarctica will change ocean and atmospheric circulation, the very nature of which, as an island nation, we rely on for our primary food sources, energy and tourism. Even small changes in the position and strength of ocean fronts and currents will impact New Zealand's productive seas and primary production. Whereas most climate models, including those used by the Intergovernmental Panel on Climate Change, are based on a linear sequence of progressive and predictable changes, the melting of polar ice is the result of complex interactions that have resulted in non-linear, even runaway rates of melting during times of past warming. Antarctic ice melt may result in sea levels rising by up to 5 metres and as fast as 4 cm per year. Even with the most optimistic scenarios for stabilizing atmospheric carbon-dioxide concentrations, the world can no longer avoid 2°C of warming by 2100, meaning we are already committed to irreversible meltdown of Greenland and West Antarctica. The questions is when, how much and how fast!
Research components	While global ocean and climate change is complex, two components are critical for New Zealand; sea level rise and ocean temperature as controlled by ocean current strength and position. The critical elements controlling this are ice shelves and sea ice as they provide the buffer between the atmosphere, ice sheets and ocean. Research, therefore, needs to focus on: 1. Ice shelf stability and its role in future sea-level change 2. Ice-ocean interaction and implications for global heat transport 3. When and how fast will Antarctica warm New Zealand's stewardship of the Ross Sea sector of the Antarctica provides a critical research opportunity to address this based on the following features and components:

	1. The Ross Ice Shelf, the largest ice shelf in Antarctica and a significant buffer between the vulnerable West Antarctic Ice Sheet and the warming Southern Ocean. 2. The most extensive ice-free areas of land that support ecosystems, which are extremely sensitive to change and hence obvious targets for monitoring change. 3. The least disturbed marine environment remaining – the Ross Sea is perennially covered by sea ice, which links marine, atmospheric and ecosystem processes. 4. One of 3 Antarctic zones where deep bottom water is produced to help drive the global ocean circulation transporting heat around the planet. New Zealand researchers and their international collaborators have pioneered new technologies and approaches to undertaking research in each of these areas and they are now well positioned to determine thresholds, rates of change, and codependencies in these complex systems.
Theme 2 **Tracking the impacts of change in Antarctica and predicting the response in "our far south" and across wider New Zealand**	
Importance to New Zealand	New Zealand's ocean and climate system is sandwiched between the world's biggest current – the Antarctic Circumpolar Current - in the south and the South Pacific Subtropical Gyre from the north. We are thus a nation influenced by the pole and equator. The Southern Ocean includes some of the Earth's most productive and unique marine ecosystems. Yet, the research in determining the impact of a warming world on our vast Exclusive Economic Zone and adjacent Antarctic Treaty sector is almost non-existent despite it supporting key fishing grounds, tourism opportunities, regulating our climate and being designated world heritage site. Only within the last decade have scientists fully realized the role of the Southern Annular Mode, an Antarctic driven ring of climate variability, on the westerly wind system on New Zealand winds, rainfall and temperatures. Even more recently models project that the westerly wind circulation and Antarctic circumpolar current will differentially shift as the Earth warms potentially changing fundamental interactions of the ocean and atmosphere with impacts on the uptake of heat and carbon. And all of this happens on our own southern "back yard" and within our EEZ. Any change will have significant implications for sustainable fisheries as well as the protection of iconic species and biodiversity that underpin tourism opportunities and designation of the islands within the area as a world heritage site.
Research components	By virtue of its location between the pole and equator, political presence via its EEZ and Antarctic Treaty claim, New Zealand is ideally placed to contribute knowledge and understanding of Antarctica and the Southern Ocean. A global and local perspective is essential. The Antarctic Circumpolar Current, for example, sweeps through our EEZ, but it is driven by Southern Hemisphere wind patterns

	that are in turn affected by the polar and equatorial atmospheric temperatures. In that context, the following main goals are germane: 1. To evaluate how changes in the temperature and circulation of the Southern Ocean affect the stability of the Ross Ice Shelf and regional sea ice. 2. To determine the effects of changing westerly winds on the Antarctic Circumpolar Current and its influence on local ocean temperatures, turbulence and production of plankton that underpin the marine food chain. 3. To determine the impacts of changes in Antarctica and the Southern Ocean on New Zealand's climate bearing in mind those impacts will be modulated by influences from the equator. Three linked approaches are required: [1] knowledge of the modern atmosphere/ocean/ice system to identify the physical processes that make the system function. [2] Detailed reconstructions of changes of past warm periods. Such observations unravel natural cycles of change, the long term response to change and the "end-game" i.e. what happens to the system after prolonged warming, e.g. change in ocean plankton. [3] Integration of modern and past observations to calibrate models and verify their simulations.
Theme 3 **Assessing the consequences of change for, and the resilience of Antarctic and Southern Ocean ecosystems**	
Importance to New Zealand	By international agreements, Antarctica is designated as a Natural Reserve devoted to peaceful use and scientific research. And yet, Antarctic ecosystems are under increasing pressure from environmental change and increased human activity. Worldwide, there is growing recognition of the threats to our oceanic and terrestrial systems, with compelling evidence that rates of change are most rapid in the Polar Regions. Currently, we know little of how these fragile high latitude ecosystems will respond. Recent studies suggest that even subtle changes in the environment may induce significant community level shifts, resulting in major, irreversible loss of biodiversity. This interdisciplinary programme aims to investigate and determine the resilience of Antarctica's marine and terrestrial ecosystems to the multiple pressures of climate variability, ocean change including acidification, and other human-induced impacts such as fishing. The research results from this programme that brings together a wide range of disciplines will enable robust predictions of the consequences of environmental change and fishing to ecosystems of the Ross Sea, and the wider Antarctic and Southern Ocean. Through New Zealand's leadership role within the Antarctic Treaty System, this will foster more informed management actions to enhance ecosystem resilience. The programme will enhance New Zealand's high profile in Antarctic ecosystem research through continuation of high quality science, and improved integration of disciplines, by being closely aligned to the newly proposed Scientific Committee

	on Antarctic Research (SCAR) biology programmes AntETR and AntECO, and through strong collaborative links with international partners (including the US, Italy, UK, Spain, Brazil, Germany and Korea)
Research components	The key question to be addressed by this research is: How will Ross Sea marine and terrestrial ecosystems be affected by environmental change and fishing? In answering this question we will contribute more generally to (i) knowledge of environmental change on a global as well as national scale, and (ii) the greater sustainability of the Antarctic and Southern Ocean ecosystem through research informed wise management of the Marine Living Resources. To help address this issue, this science theme will build on the excellent research previously conducted by New Zealand researchers to provide: • Improved knowledge of species, population, community and ecosystem diversity, distributions and processes; • An increased understanding of fundamental biological processes from the organism to community level, present day and under future climate change scenarios • Clear definition and understanding of the multiple, interacting drivers of ecosystem structure and function. A particular focus will be the action of multiple stressors including the ocean and atmosphere, that may have both positive and negative effects on the present ecosystem state; • Improved knowledge of the degree to which Ross Sea ecosystems are interconnected (marine, coastal, terrestrial, and links within and between these realms). Studies will encompass multiple disciplines (biological, physical, geochemical) and scales (from micro to macro), and incorporate a range of approaches (experimental, observational, long term studies, modelling) to define and understand processes under existing and future conditions.
Research Gaps and Opportunities	Even though 80% of the heat from global warming has gone into the Southern Ocean, the international community is only now focusing attention on the important role of the water mass beneath ice-shelves contributing to ice shelf disintegration. We still have very few measurements of the water mass beneath an ice shelf, let alone an understanding of how changing ocean currents around Antarctic will destabilise the ice shelves. New Zealand is well placed to lead an international initiative to obtain the first transect of data from beneath the Ross Ice Shelf. The international research community is establishing terrestrial observing systems through the Scientific Committee on Antarctic Research and New Zealand has already taken the lead in developing the Antarctic Environments Portal to ensure policy ready Antarctic research knowledge is made immediately available to national and international decision makers. Success of the research goals requires an increase in capability around integrated computer simulations and models to help with the predictive requirements. While New Zealand has core strength in data integration with the models it

	requires a boost in the modelling capability and development. Research success requires investment in infrastructure and access to regions with increased sensitivity through marine access/expeditions and the development of global scale ecosystem modelling capability with integrated data/model capability. New Zealand hosts some of the most important climate reservoirs in its oceans and lakes, but accessing these along with simply measuring the current situation is challenging. A nationally coordinated deployment of resources will facilitate better access, opportunities for measurement and analysis of findings. New Zealand already hosts world-class capability in ocean and climate analysis.
Comments	The New Zealand Antarctic Research Institute (NZARI) was launched by the Rt Hon John Key, Prime Minister of New Zealand on 20 August 2012 to advance our knowledge and understanding of Antarctica's impacts and vulnerabilities in a changing climate. NZARI is partnering with New Zealand universities and Crown Research Institutes to assist industry, government and the New Zealand community to plan for the impacts of climate change. NZARI has already attracted significant support from external non-government agencies and high profile individuals who recognize the need to understand Antarctica's influence on the global and national climate, ocean and ecosystems. In February 2012, Dr Gareth Morgan led an expedition "Our Far South" to New Zealand's sub-Antarctic and treaty sector of Antarctica to raise New Zealanders' awareness of the importance and vulnerability of their own "southern back yard". New Zealand is a claimant nation in Antarctica and an original signatory to the Antarctic Treaty. New Zealand has developed significant diplomatic credibility through its longstanding commitment and leadership within the Antarctic Treaty's Committee for Environmental Protection and the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). New Zealand's sovereignty interests in Antarctica are best preserved through a strong and effective Antarctic Treaty System, which in turn demands wise management based on the best available research. Failure to manage the Antarctic environment has the potential to call into question the effectiveness of the Antarctic Treaty System and undermine New Zealand's territorial interests. Leadership in this area also provides the basis for wider engagement with key strategic trading partners and alliances such as the United States, Korea and Australia.

Entry ID	**361**
Better Climate Projections for a Better Prepared New Zealand.	
Summary	The goal of this proposal is to provide detailed reconstructions of ocean/climate change during past warm periods, as a means to gain realistic and relevant analogues of projected change. By reconstructing the response of New Zealand and its oceans to past warm climates, we derive the natural cycles of change that

	help identify the effects of human influenced climate. Research will require the analysis of geochemical, climactic, oceanographic, and geologic data and collaboration with leading climate-change modelling groups.
Theme 1 **To provide detailed reconstructions of ocean/climate change during past warm periods as realistic and relevant analogues of projected change.**	
Importance to New Zealand	By reconstructing the response of New Zealand and its oceans to past warm climates, we derive the natural cycles of change that help identify the effects of human influenced climate. Such reconstructions also yield data on [i] the ultimate impact of change i.e. the end game, that is undetected by models; [ii] the duration and nature of change such as rising sea level and [iii] "out of the blue" catastrophic events that, again cannot be readily predicted by models, e.g. losses of the West Antarctic and Greenland Ice Sheets. Such data underpins improved short- and long-term planning for improved adaptation for a resilient society. Data from reconstructions provide additional observational perspectives to model output thereby markedly improving the quality of simulation. An example is the biological response to ocean warming. A recently completed VUW-GNS-NIWA study shows that 125,000 years ago, the SW Pacific Ocean off eastern New Zealand was 2-6°C warmer than now. This caused a major switch in the marine food chain from animal-based plankton to plant-based plankton. That change appears to be underway as revealed by satellite imagery off eastern South Island, but is not captured by numerical models. Even though the data show a marked swing in the food chain, there is no knowledge of its potential impact on fisheries including the Southern Blue Whiting fishery, which has an export value exceeding NZ$50 million.
Research components	Apply state-of-the-art geochemical and more traditional data, to well-dated ice cores and sediment cores to reconstruct past changes in Antarctica (a major driver of climate) and the NZ region. These components take advantage of New Zealand's participation in major international programmes (Integrated Ocean Drilling Program, ANDRILL, INTIMATE, etc.) and with leading modelling groups (U Pennsylvania, U. Massachusetts, Los Alamos). It will also utilise the considerable capability developed at the ARC/VUW together with GNS Science and NIWA, to create a research team that is undeniably world class. Three subcomponents are envisaged using the capability outlined above. Each subcomponent covers a time period that is highly relevant for the theme. I. Warm Pliocene (4-3.5 million years ago). This was the last time atmospheric concentrations of carbon dioxide were 400 parts per million - a concentration that will be reached in the year 2014 judging by current trends. Pliocene reconstructions for the Ross Dependency indicate the loss of the West Antarctic Ice Sheet, which contributed to 3.5m of sea level rise. Determining the timing and rates of change of this event are critical. II. Last Million Years. Some interglacial periods reached temperatures projected

	for the next century. Determination of New Zealand's response to past warming provides an observational perspective of the future. III. Last Ten Thousand Years. The Holocene has the most accurate and best dated information on past changes including a warming of 1-1.5°C. It will allow a reliable extension of existing historical climate/ocean records back through the Holocene to unravel natural cycles.
Theme 2 **To determine the processes and impacts of modern ocean/climate change on New Zealand.**	
Importance to New Zealand	Whether past reconstructions or numerical models, it is critical to have a comprehensive overview of modern ocean/climate processes operating in the SW Pacific to Antarctica under the present phase of warming. Surprisingly, such an overview is unavailable although excellent studies have been made of isolated sectors or particular aspects of the NZ environment, e.g. sea level. This contrasts with Australia, which is leading us in observations on ocean-Antarctic change since reliable instrumented records began, e.g. last 50-150 years. By synthesising modern ocean/climate change and concomitant biological responses we will be able to: I. Determine the ocean/climate variations at national and local levels the latter acknowledging NZ's great variability in response to active tectonic plates, equatorial to polar climate drivers, sub Antarctic to subtropical ocean waters, two of the largest ocean currents and volcanic activity. II. Identify "hot spots' where major changes are underway. III. Determine the potential processes and drivers that affect present change. This will involve analysis of the equatorial and polar climate drivers that dominate our environment, e.g. a 1.7°C warming off eastern Australia and accompanying invasion of subtropical species since 1944 is driven by a southward expansion of subtropical water under enhanced S. Pacific winds. IV. Use the set of observations to underpin model and past reconstruction scenarios by providing knowledge regarding actual changes and importantly the processes behind changes.
Research components	By its very nature Theme 2 will require a strong multidisciplinary approach that involves local university and CRI groups together with international collaborators. Being a synthesis, a core team with climatic, oceanographic, biologic and geologic expertise will assemble and synthesise the data along the lines of the Intergovernmental Panel on Climate Change (IPCC). The synthesis will then be circulated amongst the science community for factual verification to provide an evidence-based status report of the NZ sector of the Pacific that embraces the Ross Dependency including the adjacent Southern Ocean and the vast oceanic tract of NZ's Exclusive Economic Zone and extended Legal Continental Shelf. That peer-reviewed analysis with be "translated" into non-technical language for end-users.

Theme 3 Generation of Improved, Evidence-based Projections for Improved Knowledge Regarding New Zealand's Adaptation to a Warmer World.	
Importance to New Zealand	To improve projections of ocean/climate in New Zealand, a three pronged approach is proposed that incorporates (i) past reconstructions (Theme 1,) (ii) the modern processes affecting change (Theme 2) and (iii) the integration of that observational information with numerical model simulations. The current tendency is to rely on models, and there is absolutely no doubt that simulations are an essential tool. But as noted previously models, especially coupled systems involving ocean/atmosphere/ice elements, do not capture all aspects of change especially biological responses. In essence models are encyclopaedias of what we know. By substantially improving that encyclopaedic knowledge base with quality observations, more realistic simulations can be made.
Research components	Earth System models that realistically capture the full spectrum of physical, biological and chemical processes affecting the planet are rare and extraordinarily expensive to run. A more pragmatic and perhaps more realistic approach is to use established and verified physical-based models (e.g. coupled ocean/ ice/ atmosphere systems run by U. Pennsylvania; atmosphere/ice models of the NZ Southern Alps operated by VUW and GNS Science) and extend the output to known biological responses as derived from the modern and reconstructed observations, for example, numerical models are projecting decreased winds and warmer waters off the eastern South Island, which the past reconstructions reveal are accompanied by a switch in marine plankton from animal- to plant-based organisms.
Theme 4 **To translate results from science research into information that is "user friendly" and relevant for government, industry and New Zealand society overall.**	
Importance to NZ	Effective dissemination of research results to the wide range of actual and potential users is paramount for society. This proposed outreach initiative will cater to the specific needs of end-users as well as highlighting discoveries of interest and relevance to all. The foundation of this initiative is "user friendly" non-technical documents summarising research output together with improved access to scientists with good communication skills. Non-technical documents should stem from quality, peer-reviewed publications that are "gold-standard" of research. This quality control is essential. The following "products" are envisaged based on previously successful FRST/MSI programmes (e.g. see http://www.andrill.org/static/index.html http://www.victoria.ac.nz/antarctic/research/research-prog/anzice/policy) I. A website that is accessible, informative and up-to-date, e.g., http://www.victoria.ac.nz/antarctic/research/research-prog/anzice II. Evidence-based information for policy for use by national and local governments and their departments.

	III. Relevant data for industry. IV. Science information for international policy via our participation on the Intergovernmental Panel on Climate Change (IPCC) and the Antarctic Treaty System. V. Regular articles/interviews/YouTube clips/films in the local and international media. VI. Participation with high-profile New Zealanders such as Dr Gareth Morgan and his foundation. [This collaborative venture regarding environmental change has contributed to 3 books, media articles, a documentary and public speaking to a total audience exceeding 20,000.] VII. Presentations to professional and community groups.
Research components	The main component of this outreach initiative is to establish a formal science dissemination plan (i.e. Theme IV) that centres on established scientist communicators who link with communication centres in their respective institutions to optimise the outreach effort. That will be concomitant with improved networking with local and national governmental departments, again taking advantage of existing institutional contacts. Continuation of science at the international level is essential. Major initiatives such as ANDRILL, Integrated Ocean Drilling Program (IODP), MARGINS, INTIMATE, four international ice coring projects, bring large quantifiable benefits to NZ through staff training, contributed ship/equipment time, new knowledge and general operations, e.g. an IODP voyage typically drills 6 holes at c. $US1.5 million each (helping to define NZ's subsea geology and resources) whereas a port call by the drill ship injects over $US1.5 million into the local economy.
Research Gaps and Opportunities	A major gap concerns NZ's and Antarctica's response to modern warming. This may seem surprising but while there have been high quality work undertaken on specialised topics such as retreat of South Island glaciers; an Earth-system-type overview of NZ-Antarctica has yet to be made. IPCC reports provide a cursory summary of the region in a few pages by fails to capture the marked variability of NZ. The best-available information is needed to (i) determine the status of our environmental estate as a reference for further change, (ii) Identify recent changes (last 50-150yr) for a region that has its own response to warming that is not captured by global averages, e.g., the global average sea level rise is 3.1mm/year whereas NZ sea level rise is 1.4mm/year and will vary across our region under different climate/tectonic regimes and (iii) Identify "hot spots" of rapid change and their impact on the general environment including living marine resources and infrastructure. The challenge provides an opportunity to galvanise the environmental community to undertake relevant research of direct benefit to NZ's future especially with respect to providing knowledge for improved adaptation. The community is highly skilled, experienced, well connected and is supported by a substantial infrastructure that includes isotope laboratories (GNS, NIWA), modern geochemical facilities (VUW,

	Otago), ice core drilling and laboratories (VUW, GNS), ocean surveys and coring (NIWA), Antarctic drilling (ANDRILL), numerical models of ice (VUW, GNS), ocean (NIWA) and atmosphere (NIWA, VUW). That is a substantial capability that NZ should fully utilise.
Comments	While this proposal is written as a National Science Challenge, it is more likely to be a theme or themes in other potential challenges centred on Climate Change, Natural Hazards, Antarctica or the Exclusive Economic Zone resources. However, this does not diminish its value. International experience has shown conclusively that accurate reconstructions of recent and distant past environmental change are key for evidence-based adaptation strategies.

Entry ID	**381**
Minimising global climate change	
Summary	This challenge proposes to focus on reducing greenhouse gas emissions, and developing ways for New Zealand to adapt to climate-change effects.
Theme 1 **To minimise the effect that global climate change has on New Zealand and other countries**	
Importance to New Zealand	A large proportion of our population lives in low-lying areas and we cannot afford to risk the climate change that is expected to raise sea levels, increase severe weather events and cause large numbers of climate 'refugees', especially in the pacific
Research components	How can New Zealand reduce our GHG emissions. How do we adapt to climate change? How do we support our neighbouring countries to adapt to climate change
Research Gaps and Opportunities	Making GHG emissions reduction good business Educating the New Zealand public on how to reduce their emissions

Entry ID	**408**
Generating sustainable growth and resilience under a changing climate: Create scientific and technical knowledge to guide adaptation to climate variability and change, reduce greenhouse gas emissions, and engage with all sectors in its application [Also submitted as proposal #449]	
Summary	By studying past and continuing changes in climate this challenge proposes to improve understanding of phenomena that influence climate, and therefore test and improve model predictions. This can aid in predictions of how climate change is likely to affect New Zealand's ecosystems, primary production etc., and enable mechanisms to support adaptive decision making. Other proactive measures include R & D to identify technologies to reduce greenhouse gas emissions.

Theme 1 **Observe and understand changes in climate (atmosphere, hydrosphere, ocean, cryosphere) in our region (New Zealand, South Pacific and Southern Oceans, Antarctica). Estimate potential future changes for plausible emissions scenarios from the IPCC's Fifth Assessment**	
Importance to New Zealand	Many countries agree constraining global warming to no more than 2°C is desirable, but recent growth in greenhouse gas emissions suggests the world might experience 4°C or more of warming. Even climate changes at the lower end of the projection range would have consequences for New Zealand. Downscaled projections are required for our region based on the new global scenarios being assessed by the IPCC, which cover the range from about 2°C to more than 5°C of global warming. These projections will support regional identification (themes 2 and 3) of impacts, adaptation options and global greenhouse gas emissions reductions associated with these global scenarios, and will inform national policy choices and regional and local adaptation. Analysis of past changes and continuing observations of climate, will improve our knowledge of natural climate variability and extremes, improve understanding of phenomena that influence climate (including sea-level) on timescales from weeks to centuries, and test and improve model predictions. This will assist with quantifying year-to-year variations in magnitude and frequency of extreme events such as droughts and floods, and developing seasonal projections, for organisations ranging from councils planning and managing land use and water allocation, to farmers making management decisions. Measuring and understanding changes in ocean chemistry and pH will inform assessment of risks to our coastal and ocean ecosystems, aquaculture, and fisheries from ocean acidification. New Zealand has commitments under the UNFCCC and other treaties to support research and observations, especially in developing country regions like Pacific small island states, and in Antarctica.
Research components	• Climate monitoring and analysis to support research, test predictions, and inform adaptive management: o Includes regular observations of atmosphere, hydrosphere, cryosphere, and ocean conditions, and production and analysis of key climate indices • Regional climate process research to support interpretation of observed trends and support projections from seasonal to century timescales. Includes: o Detection and attribution of past changes to underpin our understanding of how sensitive New Zealand systems and sectors are to climate variations and trends o Determining predictability of New Zealand climate on all time scales, given the interactions of natural climate variability and climate change o Understanding key processes in the Southern oceans and Antarctic sea ice and ice sheets which influence climate, sea level and ocean productivity o Paleoclimate data acquisition, analysis and modelling • The future: Modelling, downscaling and climate projections: o Validation against past and present data o Improving regional climate modelling and empirical downscaling techniques o Techniques for seasonal climate prediction

	o Producing future regional climate scenarios consistent with scenarios of global change, including new scenarios to become available from the IPCC's Fifth Assessment, and the influence of stratospheric ozone recovery o Improve methods to predict direct changes in physical systems including river flows, sea level, snow and ice o Providing information on uncertainty ranges in climate projections for given scenarios, suitable for use in risk assessment and management • Regional changes in ocean chemistry and pH, needed to understand risks to ocean ecosystems, fisheries and aquaculture.
Theme 2 **Identify present and predicted climatic impacts on our ecosystems and their services, health, primary production, industries and society; determine adaptation options and opportunities; understand and enable mechanisms to support adaptive decision-making**	
Importance to New Zealand	This theme develops information stakeholders need to support management of New Zealand's natural ecosystems and resources, support development of key economic sectors, and manage risks to communities and individuals, under a changing climate. Climate extremes and changes affect many communities, activities and assets including pastoral agriculture, horticulture, fisheries and aquaculture, built infrastructure, coastal development, tourism, health, biosecurity and forestry. The huge social and economic impacts of climate driven events, including droughts, floods and storm surges, graphically illustrate why stakeholders need the best possible information on likely hazard magnitude and frequency, on exposure and vulnerability of people and their assets, and on managing and minimising climate risk based on such information. They also illustrate the importance of identifying and addressing social and governance issues that help or hinder the uptake and application of such knowledge, especially where public and private interests intersect. Social science research and engagement with organisations such as councils, that will drive adaptation is therefore a vital part of this theme. Understanding climatic impacts, identifying opportunities for productive new activities matched to local climates and microclimates, and managing transformational changes will foster sustainable growth and management of climate risks under our present climate as well as in the future. This is also the case for the small island nations to our north with which New Zealand has strong relationships. The need for improved information to identify potential impacts and support adaptation decision-making is illustrated by the continuing requests for information and support from councils, industries and other organisations.
Research components	• Identifying climate change impacts, adaptation options and opportunities under a range of future climate scenarios for: o water resources o shorelines and coastal erosion o coastal zones and estuaries o ecosystems and their services

	o farming systems, including pastoral agriculture, horticulture, cropping o forestry o fisheries and aquaculture o health o Maori communities, taonga and assets o Infrastructure and communities • Ocean acidification: Impacts on ocean ecosystems, fisheries and aquaculture • Research to support uptake and implementation of adaptation measures including: o The nature and role of social and cultural values in shaping perceptions of climate change, and in enabling or constraining adaptation o Successful approaches to resolving conflicting interests and engaging communities in adaptation planning and decision-making o Beyond risk: Dealing with unexpected climate change impacts.
Theme 3 **Advancing a low-carbon economy by: identifying options for progressively reducing New Zealand net greenhouse gas emissions; undertaking R&D on appropriate options; identifying associated social, environmental and economic constraints and opportunities**	
Importance to New Zealand	This theme will provide information for New Zealand policymakers and industry on the potential, costs and implications for New Zealand of various mitigation options. This will inform development of policies, and development and application of new technologies and practices to reduce New Zealand's net greenhouse gas emissions. Information about relative costs and benefits of various emissions reduction options and technologies will guide investment, and policies to stimulate such investment, towards the most effective and productive options. New Zealand has greenhouse gas reporting obligations under the UNFCCC, and ongoing research to better determine and specify our emissions and to monitor, report and verify mitigation outcomes will build credibility in our national reporting and targets. Investment in technology trials and development could seed commercial opportunities (e.g., if technologies to significantly reduce methane emissions from ruminant animals are identified and developed). It will also assist selection by the commercial sector of appropriate technologies from overseas (e.g. for producing transport fuels from forest waste or tree crops). Co-benefits from this theme extend well beyond climate change – for example renewable energy developments and more energy efficient buildings would reduce dependence on overseas sources of fossil fuels. Social science will play a vital role in this theme, since international and domestic decisions about mitigation depend on individual and collective values, assessments of economic potential, legal frameworks, and international norms.
Research components	• Agriculture and forestry: Improve emissions inventory methodology, and determine emissions reduction potential and options, in addition to work on ruminant animal methane emissions, including: o Predicting changes in soil carbon

	o Use of LiDar to predict carbon stocks in forests and assist agricultural emissions reductions o Using forest soils to reduce atmospheric methane levels • Fossil fuels and renewables: Determine emissions reduction potentials, and undertake technology transfer from overseas and local technology development associated with the energy sector, including: o Transportation options, biofuels and electric vehicles o Energy efficiency for infrastructure, buildings and homes o Renewable energy including geothermal, hydro, wind, solar, tidal and wave power o New Zealand options for carbon capture and storage • Improve New Zealand's emissions and mitigation data through o Analysis of relative costs and benefits of mitigation options and technologies in New Zealand o Verifying CO2 and other emissions inventories through atmospheric measurements o Statistical design of monitoring, assessment and reporting frameworks • Metrics for emissions: Treatment of non-CO_2 gases in emissions reporting and accounting schemes • Integrated analysis of economic, environmental and social implications of mitigation choices, including realistic costs in "second-best" scenarios • Understanding societal processes and drivers underpinning mitigation actions, and the potential and mechanisms to support strategic transformational choices
Theme 4 **Synthesis, policy development, communications, implementation: Understand interaction between science and society, local and global issues, adaptation and mitigation, communication and engagement, and how these influence policy development and its uptake**	
Importance to New Zealand	Effective communications, knowledge sharing and engagement with public and stakeholders are key requirements for applying the knowledge from themes 1 to 3 to policy development and planning, and to implementing adaptation options and mitigation technology. This theme will develop understanding of successful and less successful ways of bringing this about, and help bridge gaps between science, policy and practice. It will also aim to assist those undertaking domestic actions to recognise the many ways in which New Zealand is connected with the rest of the world in the context of climate change. Assessment of how overseas developments could affect New Zealand (e.g. through international policies, technological changes, social and population changes, or consumer preferences on food miles or embedded carbon) will help government and industry consider such flow-on effects in their domestic responses. This theme will also support integrated assessments drawing on results from the first three themes. This will assist policy development through coordinated provision, for example, of climate projections, impact and adaptation option analysis, and assessment of mitigation requirements and options, and develop frameworks that help assess synergies and trade-offs that may occur at various

	levels between different responses, and facilitate the mainstreaming of this understanding into planning and decision-making processes.
Research components	• Communication and engagement with public and stakeholders; improved understanding of their role and potential to achieve adaptation and mitigation outcomes • Cross-cutting synthesis including: o Integrated assessment for New Zealand that helps link assessments of domestic impacts of climate change, adaptation and mitigation with the flow-on effects from global climate and socio-economic changes o Modelling the economics of climate change adaptation and mitigation within a changing global environment, including in “second-best” worlds of imperfect actions and participation o Integrating climate change adaptation and mitigation with other environmental decision-making, at various scales of governance • Analysis of the strategic dimensions of climate change, in conjunction with overseas experts, to inform current and future international climate change negotiations, including: o Research into credible unilateral policy in a variety of second-best international regimes o Research into how New Zealand might seek to engage with plausible future international frameworks • Frameworks, motivations and measures including: o Decision-making frameworks to deal with changing risks and manage potential transformation of systems o Design and assessment of policies and measures to support mitigation outcomes, including price-based, regulatory and voluntary measures based on marketing and information o Improved understanding of individual and collective motivations and constraints regarding adaptation and mitigation • Analysis of the strategic dimensions of climate change, in conjunction with overseas experts, to inform current and future international climate change negotiations, including: o Research into credible unilateral policy in a variety of second-best international regimes o Research into how New Zealand might seek to engage with plausible future international frameworks
Research Gaps and Opportunities	Opportunity - The IPCC’s upcoming (2014) Fifth Assessment: Modelling groups are producing global projections for four new RCPs (Representative Concentration Pathways), ranging from one which might hold global temperature rises to around 2°C, to one which could lead to 5°C warming or more. The IPCC is assessing emissions pathways consistent with each RCP. NIWA will produce regional climate projections for New Zealand corresponding to these four RCPs, which will be available for updated impact and adaptation option studies. Resulting information could be synthesised to produce integrated assessments of the changes, impacts, adaptation options, economics, and likely global greenhouse gas reduction targets for each RCP, to inform New Zealand policy development

	and adaptation planning. Gap 1: An integrated economic modelling framework, and limited New Zealand integration of qualitative social science research with bio-physical and economic modelling of future changes. This limits confidence in understanding which aspects of society and managed systems are most vulnerable to climate change in the context of broader global changes, and which might most require targeted support. Gap 2: Underdeveloped New Zealand research on governance and the role of institutions in managing climate risks through adaptation and mitigation. Such work is needed if on-going incremental and especially transformative changes are to be effective and supported by robust scientific analysis and advice. Gap 3: International policy options: Research to understand what sort of international arrangements are being discussed, which of these are plausible, and how New Zealand could engage constructively with these in a manner that will maximise benefits to New Zealand.
Comments	The New Zealand Climate Change Centre (NZCCC), which has prepared this Challenge, is a joint initiative between all of New Zealand's Crown Research Institutes and three Universities (www.New Zealandclimatechangecentre.org). Its vision is to enhance the capability of New Zealand, both domestically and in partnership with other countries, to anticipate, mitigate and adapt to climate change. The members comprise AgResearch, Canterbury University, ESR, GNS Science, IRL, Landcare Research, Massey University, NIWA, Plant and Food Research, Scion and Victoria University of Wellington. Many of the research components and needs outlined in this challenge require collaboration between research providers and with stakeholders, and collaboration across disciplines including social science, economics, natural sciences, and engineering. The NZCCC member organisations cover a comprehensive range of disciplines and experience, and have strong relations with stakeholders. Thus the NZCCC is well placed to foster the necessary collaboration on climate change across the science sector and with stakeholders, which in fact forms part of its mandate. The NZCCC organises conferences, workshops, round-tables and produces written material to facilitate communication and engagement between its members and the organisations which undertake the policy development, planning and adaptation actions discussed in this challenge. Such communication, outreach and engagement are essential for uptake and implementation of the knowledge to be developed through this challenge.

Entry ID	**430**
Living with climate change in aotearoa	
Summary	This challenge proposes to study the interactions between a rapidly changing

	planet and the social, economic, legal and political systems that are at the same time the source of change and the mechanisms available to moderate — and adapt to — its progression. Key elements include continually monitoring the progression of climate change (and other relevant measures i.e. $C0_2$ emissions), and evaluating the social, political, and economic consequences of these changes. New technologies will need to be developed in order to promote human activity that is less damaging to the climate.

Entry ID	464
A World-leading Low Carbon Economy. Goal: Develop a world leading low carbon economy that provides energy security, increases access to export markets and reduces greenhouse gas emissions	
Summary	This proposal has a goal of developing leading technologies in the reduction of agricultural greenhouse gas emissions. The proposed programmes of research includes the following themes: (1)Reducing Greenhouse Gas Emissions from Agriculture – research to reduce the level of agricultural GHG emissions (e.g. animal-based mitigation strategies, technologies and tools for validating emissions and mitigation strategies etc. (2) Increasing Renewable Energy: research of significant "frontier" issues where the technology is still developing and the cost per unit energy is very high compared with other sources etc. (3) Improved energy efficiency - quantify risks associated with its weather-driven variability etc. (4) Developing a sustainable transport system -
Theme 1 **Reducing Greenhouse Gas Emissions from Agriculture**	
Importance to New Zealand	Reducing the level of greenhouse gas emissions arising from the agricultural sector will increase New Zealand's trade advantage for its primary sector products. New Zealand has a unique signature for greenhouse gas emissions, in that the major proportion comes from agricultural emissions, both from animals directly and indirectly through their waste and other agricultural practices. In order for New Zealand to maintain a credible international position, adhere to international agreements, and overcome the growing trend to international non-tariff trade barriers, it is necessary to recognise the problem with agricultural emissions and take strong action to reduce those emissions to the greatest possible extent. In addition, the government has set a target for a 50% reduction in New Zealand's greenhouse gas emissions from 1990 levels by 2050, of which agricultural emissions will have to be a significant component. New Zealand has the potential to develop leading technologies in this area.

Research components	• Development of animal-based mitigation strategies, e.g. genetic manipulation; • Technologies and tools for validating emissions and mitigation strategies; • Determination of factors influencing emissions; • Techniques for determining key sources and fine-scale source distributions; • Targeted technology developments
Theme 2 **Increasing Renewable Energy**	
Importance to New Zealand	Increasing the proportion of energy generation and use, coming from renewable sources, would decrease the carbon footprint of the economy. There are strong societal drivers for increasing the level of renewable energy generation, particularly in how New Zealanders view their environmental responsibilities. In addition, the government has set a target of 90% renewable electricity generation by 2025, and the energy strategy states that the government will prioritise research funding to areas based on New Zealand's resource strengths and unique characteristics, and where there is commercial potential. It outlines that Government priorities for renewable energy research, development, and deployment support are with bioenergy, marine and geothermal. According to the latest statistics, New Zealand currently has 77% of its electricity generated from renewable sources (over 17% from geothermal and wind), with considerable potential for further growth. Our hydro and geothermal developments are well developed, and we are rapidly developing expertise in wind energy. In addition, the country has real opportunities in newer, emerging technologies, such as marine, solar and biofuels, the development of which will provide father diversity in the country's portfolio of renewable resources, thus reducing risk.
Research components	In the areas of priority for renewable energy, there are significant "frontier" issues, in that the technology is still developing and the cost per unit energy is very high compared with other sources such as gas. This is particularly true for marine energy and deep geothermal energy. While significant potential resources are proved and available, there are significant science challenges still to overcome. There are also social research issues to which research can contribute here, especially in decision-making under a complex environment where there are what often appear to be mutually opposing outcomes (e.g., hydro development vs. protection of in-stream values).
Theme 3 **Improved energy efficiency**	
Importance to New Zealand	Significantly improve efficiencies in all aspects of energy production, distribution and use in New Zealand. Aside from replacement of fossil fuels by renewable energy sources, strategies for sustainable energy development typically involve two major technological changes: energy savings on the demand side, and efficiency improvements in the energy production. Savings garnered through

	increased efficiencies have the potential to significantly reduce the carbon cost per unit of economic production (e.g., GDP). It is necessary, therefore, to have strategies for integrating intermittent renewable sources into coherent energy systems that are improving through energy savings and efficiency measures. The government's targets for a low-carbon economy (expressed, for example, in the goal of a 50% reduction in GHG emissions by 2050 and 90% renewable-sourced electricity by 2025), require a variety of tools and mechanisms that allow for integration of intermittent and variable generation electricity sources. Information and tools that take account of variability will enable planning of New Zealand's future electricity infrastructure, and determination of the optimum configuration of the electricity grid to best harness (regionally specific) renewables. The government also has specific aims to prioritise energy research and development funding toward developing renewable energy and demand side management technologies that improve energy security, and efficient and affordable energy use. Specific priorities include an emphasis on smart electricity network technologies and energy efficiency (at all levels of supply, infrastructure and demand).
Research components	The variable nature and specific locations of most renewable sources (e.g. hydro, wind, wave, tidal) means that their integration into any transmission system poses questions around meeting demand and system stability. Uptake and installation of new renewable electricity generation requires the risks associated with its weather-driven variability to be quantified.
Theme 4 **Developing a sustainable transport system**	
Importance to New Zealand	To develop a transport system that facilitates efficient and effective movement of people and goods, while reducing the carbon footprint of the transport sector. Transportation is a critical component of society and is fundamental to the economic flow of goods and services. At present the transport sector is a growing source of greenhouse gas emissions, which is becoming detrimental to New Zealand's position on reducing such emissions in line with international agreements. This growth in GHG reflects the coupling between the level of transport activity and economic growth, but this coupling cannot continue while expecting reductions in atmospheric greenhouse gases. Aside from reducing greenhouse gases, a number of other factors are driving a push to low-carbon transport, including the need to increase energy security (reduced dependence on oil), reduce air and noise pollution, increase economic competitiveness of New Zealand, improve the liveability of cities, and improve human health. Low carbon transport strategies are being developed in many countries around the world, e.g., USA, UK, India, Germany, Korea etc. In 2008 the New Zealand government set specific targets related to low-carbon transport, e.g. halving the per capita GHG emissions from domestic transport by

	2040, and, most recently, has confirmed a commitment to continued reduction in emissions of CO_2 from land transport over time. The need is to move to a low-carbon transport system that is affordable, and does not adversely affect economic growth or participation in society.
Research components	Research can contribute to overcoming several key barriers towards achieving sustainable low-carbon transport goals, including development of knowledge on individual and societal choices with respect to transport decisions, and facilitation of integrated decision-making (given the cross-cutting nature of transport). It can also provide: • Investigation of international technological developments that are then adapted to New Zealand circumstances; • Factoring transportation energy use in a renewable energy context.
Comments	Importance (of challenge): The Government's overarching goal is to grow the New Zealand economy to deliver greater prosperity, security and opportunities for all New Zealanders. Fundamental to this is how we react to the global challenge of carbon management, including how we utilise our energy sources and potential, as energy is a critical component of all economic and social activity. All nations, including New Zealand, are facing challenges in how they use energy now and in the future, and have a focus on striving to improve energy security, reduce pressure on the environment and reduce greenhouse gas emissions. The current energy strategy outlines how the Government's goal is for New Zealand to make the most of its abundant energy potential, for the benefit of all New Zealanders. This will be achieved through the environmentally responsible development and efficient use of the country's diverse energy resources, so that the economy grows, powered by secure, competitively-priced energy, and energy exports increase, with the environment recognised for its importance to the New Zealand way of life. A major focus area in achieving these goals is through the development of renewable energy sources. A number of powerful drivers dictate a need to develop a low-carbon economy. In the future, the cost of greenhouse gas emissions will be increasingly factored into world markets; this is critical for New Zealand because of the distance to market for our export products. In addition, the price of oil will rise and become more volatile, and significant technological advances and change will drive the adoption of new technologies. New Zealand has a number of specific competitive advantages, including an ability to adopt new technologies quickly and develop new opportunities. Developing a low-carbon economy is a significant challenge, which requires a reduction in emissions from agriculture (the predominant source of greenhouse gases in New Zealand), further development of renewable energy sources, increased efficiencies at all stages of energy production, distribution and use, and development of a low-carbon transportation system.

Entry ID	480
Environmental Change **Preparing New Zealand for the Effects of Environmental and Climate Change**	
Theme 1 **Change and Variation In and Across Geographic Areas**	
Importance to New Zealand	Accepted measures of ecosystem health and biodiversity show no net decline from 2012 levels and a trend to improvement across New Zealand.
Research components	Nutrient, soil quality, vegetation cover and soil loss measures show no net decline from 2012 levels and a trend to improvement.
Theme 2 **Land-Freshwater-Marine Continuum**	
Importance to New Zealand	Nutrient, sediment and other measures of the continuum viability or "health" show no net decline in terms of quality from 2012 levels and trend to improvement. >25% improvement in rivers safe for swimming by 2025.
Research components	Defining and understanding the interfaces, transfer processes, thresholds and indices that are inherent in the continuum and evaluate the importance of these to function and human use Developing tools for monitoring and improving water quality in our rural and urban catchments. Identifying critical threshold levels for maintaining continuum viability and interventions to prevent further deterioration Developing a systems science model and capability to monitor, improve and optimize our use of coastal marine environments (potentially using the Hauraki Gulf as an exemplar)
Theme 3 **Major Agents of Change and Culturally-Determined Behaviour**	
Importance to New Zealand	Rate of behavioural change and community composition effectively modelled and incorporated into regional and national planning processes
Research components	Determining behaviour and tolerances (Global Context, Techno-logical Platforms, Ethnic Diversity) and understanding environmental histories Developing predictive methodologies based on social measures for directing development and defining risk to existing or proposed activities and conservation areas
Theme 4 **Adapting to Climate Change within a Global Context**	
Importance to New Zealand	Predicted global impacts understood and incorporated into regional and national adaptation strategies and related planning processes

Research components	Understanding the factors (such as population displacement, migration, food security and water security) predicted to occur in other parts of the world as a result of climate change that are likely to directly and indirectly impact on New Zealand. Developing predictive methodologies for defining risk to New Zealand and developing social, technical and scientific response strategies
Research Gaps and Opportunities	In the last 50 years New Zealand has been subject to a period of rapid change – in climate, land-use, economic opportunities and demographics. With the world's climate projected to change substantially over the next century developing a stronger knowledge base of (1) the nature, rate and directions of change, and (2) effective adaptation and intervention strategies (that are synergistic to those of global partners), is critical to charting a high quality, economically sustainable future within our unique landscapes and ecosystems and changing world climate