A. PROJECT TITLE	3.2 Communicating risk and uncertainty to aid decision-making
"SHORT" TITLE	Communicating risk and uncertainty
B. THEME / PROGRAMME	Theme 3: Addressing risk and uncertainty

C. PROJECT KEY RESEARCHERS

Role	Name	Institution / company	Email
Project Leader	Joanne Ellis	University of Waikato	joanne.ellis@waikato.ac.nz
Project Leader	Dr Fabrice Stephenson	NIWA	Fabrice.stephenson@niwa.co.nz
Researcher	Prof Judi Hewitt	NIWA and UoA	
Researcher	Associate Prof Ilze Ziedins	University of Auckland	
Researcher	Dr Maria Armoudian	University of Auckland	
Researcher	Regan Fairlie	Manaaki Te Awanui	
Researcher	Dr Richard Bulmer	NIWA	
Researcher	Ms Dana Clark	Cawthron	

D. CO-DEVELOPED WITH

Name	Role	Organisation / company / agency	Level of partnership
Amanda Leathers	Co-development partner	WWF	Co-development partner
Abbie Bull	Co-development partner	MfE	Watching brief
Alex Rodgers	Co-development partner	Hauraki Gulf Forum	Co-development partner
Becky Focht	Co-development partner	Hawkes Bay Council	Co-development partner
David Taylor	Co-development partner	Aquaculture NZ	Co-development partner
Erica Gregory	Co-development partner	EPA	Watching brief
Eric Jorgensen	Co-development partner	Ocean Bay Farm	Co-development partner
Hannah Jones	Co-development partner	Waikato Regional Council	Co-development researcher
Jack O'Carroll	Co-development partner	EPA	Co-development partner
Kristopher Ramm	Co-development partner	DOC	Co-development partner
Martin Cryer	Co-development partner	MPI	Co-development partner
Megan Carbines	Co-development partner	Auckland Regional Council	Co-development partner
Monique Ladds	Co-development partner	DOC	Co-development partner
Ray Wood	Co-development partner	Chatham Rock Phosphate	Co-development partner
Robin Britton	Co-development partner	Resource Management	Co-development partner
Shane Geange	Co-development partner	DOC	Co-development researcher
Simon Lamping	Co-development partner	MFE	Co-development partner
Stuart Brodie	Co-development partner	MfE	Watching brief
Richard Saunders	Co-development partner	MPI	Co-development partner
Michelle Cherrington	Co-development partner	Moana NZ	Co-development partner
Maru Samuels	Co-development partner	Iwi Collective Partnership	Co-development partner

E. ABSTRACT

A central objective of risk assessments is to characterise uncertainty which can be used to prioritize management interventions and trade-offs and therefore serves as an essential component of EBM. Previously risk assessment focused on single pressure-response relationships. However, recent advances that incorporate risk provide a mechanism for assessing cumulative impacts of multiple pressures on many ecosystem components essential for EBM. Existing risk assessment methods will be evaluated to inform the development of decision-support tools for predicting and managing cumulative stressors. Methods including variance partitioning, conditional probabilities and model simulations will be used to investigate how uncertainty changes moving from single to multiple stressor relationships and with increasing scale. Cumulative pressures arising from both marine and land-based activities, with a focus on sediment, nutrients, bottom disturbance and climate change, identified as New Zealand's main stressors impacting the marine environment will be considered. Scenario testing will then be used to integrate environmental and socio-economic risks into integrated risk analysis frameworks. While many risk assessment methods are available internationally, deficiencies from a mātauranga Māori, an EBM and a marine perspective are apparent. Existing methods and tool development will therefore focus on exploring the variety of analytical approaches available and overview their role as EBM decision-support tools in a New Zealand context. This project aims to develop decision-making practices that are more inclusive and multi-sectorial and that explicitly identify risk and knowledge uncertainty in a way that reduces risks to ecological, social, cultural and economic wellbeing.

F. RELEVANCE TO CHALLENGE OBJECTIVE

We lack relevant tools that allow us to understand and communicate the consequences of limited knowledge on the outcomes of the decisions we make about ecological, business, health and social and cultural values. This is particularly true for EBM in the

marine environment where uncertainty levels of direct responses to stressors is often very high. High levels of uncertainty occur primarily due to difficulties in understanding how ecological functioning responds to stressors against a background of natural environmental variability and climate change. This problem is further complicated by a lack of understanding of how direct effects of stressors propagate through to social and ecological systems to create indirect effects on ecological health, economic health and social and cultural values. A central objective of project 3.2 will therefore be to develop decision-making processes that explicitly identify and address both risk and knowledge uncertainty. This knowledge is directly relevant to the challenge in providing multi-sectorial decision-making practices that result in improved marine management practice and policy.

Outputs: Here we describe some of the plans to provide uptake that apply generally to most outputs. Firstly, scientific papers will be used to provide peer review of the knowledge collected and the results of analyses that underpin the development of any models and tools. Peer reviewed articles will be summarised and made accessible for non-scientists (e.g. through press releases) in collaboration with the Challenge communications team and our co-development partners. Secondly, development of cumulative effects assessment into risk and uncertainty frameworks will involve significant on-going co-development with iwi and stakeholder partners and collaboration with Projects 1.1 and 3.1. Thirdly, the format of outputs will also be co-developed with our iwi, stakeholder and research partners.

G. OUTPUTS	This project will produce the following Outputs:	Linked to which Theory of Change Outputs:	Explain briefly your plan to ensure uptake by iwi and stakeholders:
	1) A published review of existing risk assessment frameworks against EBM requirements and providing recommendations of elements that can be successfully integrated in a New Zealand context.	Decision-making guidelines that recognise risk and uncertainty evaluated, developed, demonstrated and made available for iwi and stakeholders.	Early and on-going co-development hui and workshops will evaluate fit for purpose risk assessment methods within a Mātauranga and EBM context. Requirements and adaptations needed will be reported back and likely tools and models to move forwards determined with our co-development partners.
	2) Methods to evaluate how uncertainty changes with cumulative impacts of multiple stressors and with different scales of data have been developed, peer reviewed and published.		The results of this analysis, conducted in conjunction with Project 1.1, will be disseminated through wananga (Project 3.1 and T1), and co-development workshops (3.2 and 1.1). The methods will be incorporated in Outputs 4, 5, 6 and 8, thus ensuring wider dissemination and use.
	3) Development of on-line guidelines that conceptualise risk and uncertainty for their use in decision making including key ecological, business, social and cultural uncertainties in collaboration with 3.1.		Much of the underlying concepts for this output will be derived from our co-development partners. The guidelines and the format in which they are circulated will be decided in conjunction with Project 3.1 and research partners from Projects 1.1, 1.2, T1 and T3. Input will also be sought from the Blue Economy projects.
	4) Report of readily usable models and communication tools that bring together key business-social-cultural- ecological uncertainties in order to predict consequences of decisions published and presented at workshops in collaboration with Project 3.1.		Models and tools will be developed and trialled with iwi and stakeholders through research activities with Project 3.1 including joint workshops, wananga and presentations. Notably project workshops will be used to evaluate fit for purpose and demonstrate how modelling of risks underpin tool development in an iterative process in conjunction with iwi and stakeholders. Final model selection and development (Output 5) will be undertaken with co-development partners of projects 1.1, 3.1 and 3.2.
	5) One scientific paper to evaluate how uncertainty changes with cumulative impacts of multiple		We will also work closely with our institutions' outreach and communications facilities, and those of the Challenge, to engage and reach a wider audience than can be achieved through

	stressors and with different scales of data.		the workshops and hui alone including the use of audio-visuals, internet platforms and Maori media.
	6) At least one heuristic model/s that can robustly conduct integrated risk analysis for EBM while addressing uncertainty. 7) Definitions of risk and uncertainty in mātauranga Māori and western science terminology provided (in collaboration with Project 3.1). 8) One scientific paper addressing integration of risk and uncertainty into spatial management.	Tools for predicting and managing cumulative and multiple stressors developed, assessed and packaged for iwi and stakeholders.	The models to move forwards will have been identified in co-development workshops (see MS3 and MS7). Scenarios for iterative testing will be co-produced. Project workshops and scenario testing (extending past the co-development partners) will be used to socialise the models. Communication tools will be developed based on workshop responses to facilitate uptake in collaboration with Project 3.1 and the Blue Economy. Definitions will be developed by our Maori communicator in conjunction with Projects 3.1, 1.1, T1 and T3. Maori media, T4 and project dissemination pathways and hui of the contributing projects will be used to disseminate the output. The integration of risk and uncertainty into spatial management will focus on communication and iterative co-development with iwi, DOC, MPI and Regional councils through Project 1.2.
	9) Important knowledge gaps remaining that will strongly affect the ability to predict likely outcomes of decisions identified and published (the nature of output e.g. infographic, opinion piece, on-line report will be determined with our co-development partners).	Remaining knowledge gaps that increase environmental risks of decision making are identified for iwi and stakeholders.	Knowledge gaps and their relative importance will be identified by tools and model development during scenario workshops with iwi and stakeholders.

H. OUTCOMES	This project will contribute to the following Theory of Change Outcomes:
	• Decision-making practices that are more inclusive and multi-sectorial and use predictions of effects from cumulative and multiple activities are adopted. • Decision-making processes explicitly identify and address both risk and knowledge uncertainty in a way that reduces risks to ecological, social, cultural and economic wellbeing. • Knowledge from the Challenge (science and mātauranga) is used in decision making to improve ecological health and influences Aotearoa New Zealand's marine management practice and policy. Researchers and iwi and stakeholders involved during the life of the Challenge continue to actively promote, research in, and use knowledge from the Challenge.

I. INTRODUCTION

Risk assessments quantify the probability of undesirable events along with their consequences (Holsman et al. 2017). The ability to estimate risks associated with actions is necessary for any management regime, whether it be managing the economy, a business or the environment. When managing multiple sectors, having robust methods and understanding both the uncertainties and the effects of those uncertainties increases in importance. This is particularly true for EBM in the marine environment as uncertainty around direct ecological responses to stressors is often very high, mainly due to difficulties in collecting baseline knowledge and in understanding how ecological functioning responds to stressors against a background of environmental variability and climate change. This problem of uncertainty is further extended by a lack of understanding of how direct effects propagate through ecological and social systems to create indirect effects on ecological health, economic health and social and cultural values. A central objective of risk assessments is to characterise uncertainty which can be used to prioritize management interventions and

trade-offs and therefore serves as an essential component of EBM (Holsman et al. 2017). Previously risk assessment focused on single pressure-response relationships. However, recent advances that incorporate risk provide a mechanism for assessing cumulative impacts of multiple pressures on many ecosystem components essential for EBM (Holsman et al. 2017). While many risk assessment methods are available, deficiencies from both a mātauranga Māori and an EBM perspective are apparent. Project 3.2 therefore aims to create guidelines, models and tools that explicitly identify risk and uncertainty and can underpin decision-making practices that are more inclusive and multi-sectorial.

J. AIMS

Our aims address two overarching research questions:

1. What risk assessment tools are available that incorporate uncertainty into their estimates, deal with multiple stressors and are easily communicated to Māori and stakeholders?
2. How do uncertainties, and thus social and ecological risks, accumulate during decision- making? Including the uncertainties inherent in merging data from different scales (e.g., scaling environmental, ecological information and social up or down to match each other or available model types) and the uncertainties and risks at separate stages of assumptions, modelling and decision-making.

These questions have been reframed as five research aims.

RA 1. Review of presently used, well-documented risk assessment procedures to determine whether they are fit for EBM. In particular, whether they deal with complex social and ecological processes, direct and indirect effects and the type of data commonly available and are able to produce the types of outputs required. During the review, adaptations that would be required to become fit-for-purpose will be identified and an initial work programme for use in RA 4 developed.
RA2: Analysis of cumulative effects and scaling on uncertainty. This aim focuses on collating and analysing data used in Project 1.1 to understand how cumulative effects of multiple stressors occurring across scales affects our uncertainty about ecological risks and the degree to which uncertainty is driven by data limitations and the need to merge data collected at different scales.
RA3: Development of scenarios to be used to test tools and understand how uncertainties and risks accumulate. This aim will iteratively develop scenarios that will be used to test the utility of tools suggested by RA 1 to explore how different management decisions may affect risks and how uncertainties are understood and dealt with by iwi and stakeholders. It will integrate scenarios suggested by work from RA2.
RA4: Building/adapting tools based on models that bring together key business/environmental/biophysical uncertainties and incorporate definitions and perceptions of risks. This aim deals with the iterative testing of scenarios developed in RA3 to create risk assessment models that incorporate uncertainty and best underpin EBM decision-making in Aotearoa-New Zealand.
RA5: Communicating and socialising tools. This aim will investigate whether the RA4 models are easily usable by decision-makers as they are, or whether interfaces need to be built. It will also create guidelines and ensure that model outputs can be used by project 1.2.

K. PROPOSED RESEARCH

Decision-making tools that can communicate the degree of uncertainty associated with risk predictions and the potential consequences of specific decisions to the environment and society are needed. Within Project 3.2 five core Research Areas (RA) have been identified as part of a co-development process, which align closely with Project 3.1. The initial co-development process involved all identified partners however a next step will be to identify a smaller subset of participants who prefer to remain involved in all on-going meetings, versus participants with focused interests who would prefer to be part of a larger group that receive regular updates yet provide input on specific tasks. The five RAs identified from our initial co-development process include:

RA1: Review of present well documented procedures.

Risk assessment frameworks quantify the probability of undesirable events occurring, along with the consequences of those events should they occur (Burgman 2005, Holsman et al. 2017). Risk assessments have been used in marine resource management to help evaluate the risk of environmental and social pressures on species and habitats including the probability of extinction for species of concern (Mace and Lande 1991), risk associated with climate change (Hare et al. 2016), and management of data-poor fisheries (e.g. Patrick et al. 2010). RA1 will review existing methods exploring the variety of analytical approaches available and overview their role as EBM decision-support tools. Methods reviewed will include fisheries management strategy evaluation, biosecurity, business, Productivity Susceptibility Analysis (PSA), Residual Risk Analysis (RRA), Ecological Risk Assessment for Effects of Fishing (ERAEF), Spatially Explicit Fisheries Risk Assessment (SEFRA), Generalized Likelihood Consequences as used by ecological risk assessment and business, spatially explicit risk assessment and Bayesian Networks (BNs) to assess fit-for-purpose methods and selection of elements that can be successfully integrated in a New Zealand context. Outputs from this review will be summarised and communicated at joint stakeholder and Iwi meetings organised through Project 3.1 *Perceptions of risk and uncertainty*. Gaps and challenges will be noted and appropriate tools identified for scenario testing and development of case studies (RA3-4).

RA2: Spatial data collation and simulation testing for analysis of cumulative effects and scaling on uncertainty.

Traditionally, marine risk assessment focused on the direct effects of single pressure-response relationships. Only recently have advances included the use of risk assessment in an EBM context, where new methods provide a way to evaluate the cumulative impacts of multiple pressures on multiple ecosystem components (Holsman et al. 2017). Cumulative effects are generally not additive, or simply the sum of individual stressor effects, therefore understanding ecological responses to multiple stressors is needed to underpin both the quantification of error and the development of tools that can express the risks associated with cumulative effects (CE). Here we are particularly interested in how data limitations and the scales at which data needs to be merged to understand CE affects uncertainty. Stressors considered in RA2 will include those arising from both marine and land-based activities that impact on the marine environment and will focus on those assessed in Project 1.1 and defined by Environment Aotearoa 2019 as the major stressors in the NZ marine environment (sediment, nutrients, bottom disturbance and climate change). Research from Phase I (Tipping Points) provides a mechanistic understanding of how elevated turbidity and nutrient stress impact soft-sediment habitats. Building on these models we will collaborate with Project 1.1 where additional stressors such as physical disturbance will be tested to further develop our understanding of how cumulative effects arise. Methods including variance partitioning, conditional probabilities and model simulations will be used to investigate how uncertainty changes moving from single to multiple stressor relationships (Legendre 2008) and across scales of data. Using a precautionary approach RA2 aims to identify stressor interactions that have the potential to result in synergistic effects and how variance changes with increasing scale (Hewitt et al. 2016; Ellis et al. 2019). Structural Equation Modelling (SEMs) can also be used to identify the role of direct and indirect drivers of change and can enable feedbacks between abiotic and biotic components to be empirically tested. Regional councils, DOC and the EPA have expressed interest in better understanding CEs and a desire to develop a regional case study working for example in the Hawkes Bay or Hauraki Gulf areas (TBD). This case study data will also likely be used in RA4 in the development of decision-support tools such as BNs.

RA3: Development of scenarios to be used to test tools and understand how uncertainties and risks accumulate.

EBM aims to manage resources within environmental limits while enabling socio-economic development from utilization of the marine environment. In this project we will use scenarios to adapt risk assessment tools and test, validate and communicate these tools. RA3 will iteratively develop scenarios in conjunction with Project 3.1 through jointly organised workshops (and with additional linkages to Projects 1.1, 1.2, 4.2, the Blue economy and Tangaroa). These scenarios will cover a range of activities and objectives of varying complexity, across a range of scales, in order to fully test the approaches identified by RA1 as useful. Scenarios will also include “tipping points” building on Phase I research in order to assess the ability of tools to cope with rapid transformations and ecosystems with a lost capacity to cope with stress. Potential case studies that evaluate the effects of multiple stressors on socio-ecological systems, the implications and risks to various stakeholders and iwi will be selected in collaboration with other projects (3.1, 1.1, 1,2 and/ or T1). This will include exploration of how different management decisions may reduce these risks and integration of how the uncertainties are understood and dealt with by iwi and stakeholders will be assessed and fed back to stakeholders and Iwi through appropriate communication led by project 3.1. The scenarios will be used to determine appropriate tool development in RA4.

RA4: Building/adapting tools based on models that bring together key business/environmental/biophysical uncertainties and incorporate definitions and perceptions of risks.

Social-ecological data sets are difficult to combine and analyse because the data may be more or less extensive, are often collected at different scales and in different formats (Andersen et al., 2012). Yet understanding social, economic, technological, cultural and ecological drivers of marine ecosystems as well as associated uncertainties is crucial for successful EBM. Research from RA1 and the scenarios to be tested will inform which tools will be trialled in RA4. However, it is likely that we will trial two approaches. Firstly, linking biological and socio-economic systems will be investigated by conducting ecological risk assessment for a case study along with a sequential socio-economic risk assessment. The respective ecological and social (including cultural and economic, Project 3.1) risk assessments would be considered individually and then the joint risk to human and natural components of the system evaluated (Holsman et al. 2017). This approach has recently been applied to evaluate climate change vulnerability of species and the dependent human communities living in the NW Atlantic (Colburn et al. 2016). Consideration of both ecological and socio-economic components, or integrated risk analysis, is critical because risk is not distributed equitably, there is often asymmetry in both the benefits and costs between different stakeholders and community as well as risk to the environment (Cook and Heinen 2005). This approach will complement and interact with the management-ecological modelling undertaken in Project 4.2. Secondly, a potentially promising method identified by co-development meetings that enables social-ecological data to be combined is Bayesian Networks (BNs). BNs are a heuristic model which consist of a graphical representation of the causal relationships (links) between the variables (nodes) in a network, with connections created by conditional probabilities. BNs enable flexible modelling where empirical evidence-based data and expert or traditional knowledge (Naranjo-Madrigal et al. 2015) (comprising quantitative and qualitative information) can be simultaneously used to investigate links between variables and processes and investigate scenarios (Stephenson et al. 2018). These models can be built in an iterative and modular fashion, and the links between variables can be updated as new data becomes available, facilitating their use in adaptive management (Landuyt et al. 2013; Gonzalez-Redin et al. 2016). A recent extension of BNs enables the incorporation of spatial information to investigate spatially explicit scenarios. For example, the drivers and effects of cumulative stressors (sedimentation & harvesting) on marine

social-ecological systems and the effectiveness of various management interventions in reducing the risk of hysteresis and ecosystem collapse could be investigated in a spatially explicit manner (e.g. including probability maps) using BN. While feedback loops cannot be incorporated in a single BN, iterative and hierarchical models can overcome this problem. Given stakeholder interest in this tool, RA4 will therefore likely apply BNs in a specific case study to evaluate its utility at synthesising business, environmental and socio-economic data along with other methods. RA4 will therefore iteratively test methods that bring together key business-social-cultural and ecological uncertainties that can be used in predicting consequences of decisions with Māori and stakeholders. This RA will integrate closely with Project 3.1 *Perceptions of risk and uncertainty* on testing tools that fit within EBM frameworks and mātauranga (as well as Projects 1.1, 1.2 and Tangaroa projects). A range of categories that conceptualize risk and uncertainty and their use in decision making will be trialled, including but not limited to, the use of at least two heuristic models including BN's. It is important to note that these tools can also be used to demonstrate critical knowledge gaps.

RA5: Testing and socialising tools with Māori and stakeholders.

The model/s that proved most fit for purpose in RA4 will be brought forward into RA5 which will focus on socialising these tool/s. Professional development/design will be undertaken to refine the tools and ensure they are 'easily usable' for end users, as well as communication for socialisation. The graphical nature of BN models conveys complex information (probability of outcomes – explicitly incorporating uncertainty in the outputs) in an intuitive manner that is easily interpreted by non-technical managers (Choy et al. 2009). Hence these modelling tools can be used to effectively bridge the gap between scientific investigation and management implementation (Fulton et al. 2007; Choy et al. 2009). Outputs from any spatial decision support tools could be communicated in the spirit of Kaitiaki where risks, uncertainty and trade-offs could be described *in-situ* in the landscape by appropriate Māori communicators. We will also trial online tools where scenarios can be tested and visualised interactively (e.g. as for 'Assessing Estuary Trophic State', https://shiny.niwa.co.nz/Estuaries-Screening-Tool-3/). RA5 will work with Māori and stakeholders through Project 3.1 to determine the most useful tools such as production of videos, stories, and maps and ensure translation of scientific risk terminology into Te Reo and non-technical language. Likely outputs from RA5 include: a) guidelines around categories of risk and uncertainty and their use in decision making that would inform local and central governmental processes, and b) production of easily usable models and communication tools that bring together key business-social-cultural-ecological uncertainties in predicting consequences of decisions.

L. LINKS TO PHASE I RESEARCH

1.2.2 Navigating marine socio-ecological systems & IF1.3.2 Navigating the implementation impasse: enabling interagency collaboration on cumulative effects – building on best practice guidelines and collaborations formed in cross-institutional and cross-cultural workshops to address decision making issues raised by cumulative effects

4.2.1 Tipping points in ecosystem structure, function & services – availability of datasets for robust scenario testing of risk tools in the context of 'tipping points' (e.g. when rapid transformations occur, and an ecosystem loses its capacity to cope with change).

5.1.2 Spatially explicit decision support tools – Availability of spatial biodiversity datasets & lessons learnt using decision support models. Further developments of these tools to assess climate change mitigation measures.

5.1.4 Interactive tools for enabling participation and knowledge exchange – adaptation of a Bayesian Network to inform management decisions affecting the marine environment and the scallop fishery. Further development of these tools for spatial risk assessment.

5.1.3 Novel risk assessment tools for EBM – Building on literature review of methods for risk assessment to see if they can be applied to ecosystem-based management of marine areas.

M. LINKS TO & INTERDEPENDENCIES WITH PHASE II RESEARCH PROJECTS

The research must be highly integrative with key projects in the challenge to be successful. In particular, information on cumulative effects and recovery pathways from Project 1.1 *Understanding ecological responses to cumulative effects* will be needed to underpin both the development of understandings of perceptions of risk and uncertainty and tools that can express the risks associated with cumulative effects – or uncertainties around predicting these effects. Stressors considered will include those arising from both marine and land-based activities that impact on the marine environment from estuaries to the deep sea. Other key projects include Projects 1.2 *Tools for incorporating ecological responses to cumulative effects into management action*, Blue economy, and Tangaroa projects, and the regional case studies that will be completed under the Programme "EBM and blue economy in action". Because the Blue Economy projects have not been identified yet we will work closely with the theme leader to ensure linkages between the programs. The risk assessment models produced and the understanding of differences in how risks and uncertainties are perceived will inform development of EBM policies and practices at different scales and will be particularly important in defining when and where the precautionary principle should be invoked. Specifically, scenario testing will be investigated in conjunction with proposed Projects 3.1 *Perceptions of risk and uncertainty*, 1.2 *Tools for incorporating ecological responses to cumulative effects into management action,* 4.2 *Options for policy and legislative change for EBM at difference scales,* T1 *Awhi Mai Awhi Atu*, T2 *Huatuakina o hapū e!* and T5 *He Kāinga Taurikura ō Tangitū as* well as any case studies that Project 1.1 *Understanding ecological responses to cumulative effects* is using. Models and tools will be developed with integration from proposed Project 3.1 *Perceptions of risk and uncertainty*, to assess risks to indicators used in 1.1 *Understanding ecological responses to cumulative effects* and 1.2 *Tools for incorporating ecological responses to cumulative effects into management action*. Studies conducted under the Blue economy Theme should be utilised and projects in this theme will be encouraged to participate in TA1, RA3 and RA4. The tools should provide outputs that can be used by proposed Projects 1.2 and the Blue economy Theme for EBM risk assessments.

N. VISION MĀTAURANGA (VM)

Coastal Māori entities are actively seeking mātauranga Māori and western science advice to address aspirations in halting ecosystem degradation and supporting improved marine ecosystem recovery, mitigation and adaptive management strategies, inclusive of both traditional and contemporary forms of kaitiakitanga (MPI, 2017). Co-developed decision-making tools that are informed by mātauranga Māori and EBM frameworks will be trialled in a case study area providing considerable scope to co-create models and tools by working with Māori researchers in T1 *Awhi Mai Awhi Atu: Enacting a kaitiakitanga based approach to EBM* and Project 3.1 *Perceptions of risk and uncertainty*. Wānanga/workshops with local kaitiaki will provide opportunities to evaluate appropriate communication tools and methods that bring together cultural and business-social-ecological uncertainties that can be used in predicting consequences of decisions with, for and by Māori. Within the tool's development we will be guided by our research partners to ensure that the expression of kaitiakitanga (active guardianship) is respectful, relevant and responsive to the needs, issues and priorities of iwi kaitiaki. It is intended that the co-developed outputs from the spatial decision support tools will be communicated in the spirit of Kaitiaki; where risks, uncertainty and trade-offs could be described *in-situ* in the landscape by appropriate Māori communicators. Regan Fairlie will work closely with Projects 3.1 and 3.2 to evaluate appropriate communication tools.

Vision Mātauranga Deliverables

Partnerships:

VM P1. We have newly established relationships with Maru Samuels and collaborations with Dr Kura Paul-Burke and the EPA Māori National Network who will assist with the co-development process. Maru is a newly developed relationship representing commercial perspectives whilst challenge researcher Dr Paul-Burke and the EPA Māori National Network provide kaitiaki perspectives and cross project linkages.

VM P2. Wānanga/workshops with local kaitiaki will provide opportunities to evaluate appropriate communication tools and methods that bring together cultural and business-social-ecological uncertainties that can be used in predicting consequences of decisions with, for and by Māori. We will ensure early co-development Wananga to select appropriate tools and case studies.

Distinctive Contribution:

VM D1. Early and ongoing co-development processes will be run to ensure the contribution of Mātauranga Māori to the design, development and testing of project outputs (Critical steps 1.1 and 3.1 represent important co-development Wananga).

VM D2. Scenario development workshops held jointly with Project 3.1 will involve iwi stakeholders and iwi researchers (SA, RF) to ensure that project outputs are specifically tailored to supporting Māori needs, interests and aspirations (Critical steps 3.1)

Meaningful Outcomes:

VM M1. Iwi researchers within Projects 3.1 and 3.2 (RF, SA) will facilitate the appropriate delivery and dissemination of research outputs including understanding perceptions and definitions of risk and uncertainty from Mātauranga Māori perspectives.

VM M2: Co-developed outputs from the decision support tools will be communicated in the spirit of Kaitiaki; where risks, uncertainty and trade-offs could be described *in-situ* in the landscape by appropriate Māori communicators.

O. ENGAGEMENT REQUIRED WITH IWI AND STAKEHOLDERS

Two co-development workshops were organised (one hosted in Hamilton and one in Wellington) to engage with a wide range of stakeholders, end-users, iwi and decision makers operating at a variety of management scales. Both workshops were well attended, and productive discussions ensued on the aims and scope of the project, possible tools that may be fit for purpose and the types of outputs required by stakeholders and Iwi for decision making. Ideas generated in the workshops were integrated into a draft proposal which was circulated to all co-developers for feedback. Comments and suggestions were integrated into the submitted proposal within the constraints of the project. This research will continue to engage with the wide range of co-developers identified. This broad engagement will be facilitated through several workshops organised in conjunction with Project 3.1 *Perceptions of risk and uncertainty* and bi-annual e-mail updates. These workshops will provide an opportunity to develop and undertake scenario testing in our case study areas and will provide an important forum for tools development communication and co-learning. We will engage directly with iwi, stakeholders, investors, managers and policy makers to ensure scientific findings are translated and considered in the context of co-development of tools and communication methods that are most accessible for stakeholders. Notably RA5 will test communication tools and methods that bring together key business-social-cultural and ecological uncertainties that can be used in predicting consequences of decisions with Māori and stakeholders. This RA will integrate closely with Project 3.1 on testing tools that fit within EBM frameworks and mātauranga (as well as Projects 1.1, 1.2 and Tangaroa projects). Notably we will work with Project 3.1 dissemination pathways and hui to extend the people involved in the co-development process and in developing and communication of tools and narratives around risk and uncertainty.

P. PROJECT COMMUNICATIONS

Project 3.2 will engage with a wide range of stakeholders, iwi and decision makers generating communication and outreach opportunities for the project and for the Sustainable Seas Challenge during our workshops and hui (co-led with Project 3.1 – see milestones and outputs). We have also dedicated funding to work with Dr Maria Armoudian who will assist in the early phases of the project with communications platforms providing a vehicle for ongoing outreach and connectivity across New Zealand and

internationally. Drawing from the literature on science communication, media, psychology and framing, we will pursue and test communication tools to engage stakeholders, including the written word, audio-visuals, internet platforms and social media. We will also work closely with our institutions outreach and communications facilities (as well as that of the Challenge) to engage and reach a wider audience than can be achieved through the workshops and hui alone. We anticipate using combinations of methods including producing and disseminating audio-visuals, written materials, and editorials through social media networks, internet platforms, Maori media, and when appropriate, traditional media. This will enable us to communicate directly with communities of interest and stakeholders while reaching more general audiences through mainstream channels, the latter by framing in newsworthy ways.

Q. RISK & MITIGATION

A number of risks are associated with Project 3.2 that relate to obtaining necessary data for simulation testing of cumulative effects and scaling on uncertainty estimates and inherent risks associated with developing suitable tools for communicating risk and uncertainty. We have minimized these risks as follows. Firstly, within RA2 we have identified existing data sources for model development including; existing "tipping points" data collected in Phase I of the Challenge, national estuarine datasets collected by councils and EEZ scale data available through collaborations with DOC and MfE. Working with existing data as well as research generated in Phase II of the challenge ensures we have the necessary information to support tool development. To mitigate risks associated with tool development in an EBM and mātauranga context we will ensure co-development of tools with iwi and stakeholders. Early co-develop of the proposal has already occurred and will continue throughout the life of the program via workshops, hui and associated scenario development research projects.

R. CONSENTS & APPROVAL required to undertake research	• Ethics approval will be required for the stakeholder workshops and hui. We will work closely with Project 3.1 to ensure ethics approvals are obtained for these workshops. • We do not require consents for experimental work as this program will utilise existing data or data generated from other projects within the challenge.

S. REFERENCES

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