National Science Challenges SUSTAINABLE SEAS Ko ngā moana whakauka

Phase II Project Proposal

A. PROJECT TITLE	1.1 Understanding ecological responses to cumulative effects
"SHORT" TITLE	Ecological responses to cumulative effects
B. THEME / PROGRAMME	Theme 1: Understanding degradation and recovery in social-ecological systems

C. PROJECT KEY RESEARCHERS

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D. CO-DEVELOPED WITH

Name	Role	Organisation / company / agency	Level of partnership
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Caine Taiapa	Māori Researcher	Manaaki te Awanui	T3 Nga tohu o te Ao
Dean Flavell	Chairperson	Te Maru o Kaituna	Watching brief

Additional co-developers, including iwi and hapū groups, have been withheld by request.

E. ABSTRACT

Project *1.1 Understanding ecological responses to cumulative effects* focuses on understanding ecological responses to cumulative effects and the causes of hysteresis in recovery of ecological function. This emphasis on cumulative effects and their management is central to the Challenge objective of enhancing both the ecological health and utilisation of marine ecosystems. The project is co-developed with iwi, stakeholders, and other Challenge projects, and will utilise past data, collect new data and produce new methods, models and tools for assessing cumulative effects.

Consistent with iwi voices this project will work across mātauranga Māori and western science worldviews including the co-development of place-based tohu or traditional indicators of the ecological condition of our estuaries and coasts. It will extend Phase

I research on tipping points caused by sediments and nutrients to include the effects of additional stressors (fishing and climate change) to develop and test rules of when non-linear change to ecosystem functions that underpin services are likely. It will also investigate bottlenecks to recovery of reef and soft-sediment seafloor ecosystems associated with ecological processes such as the abundance and spatial distribution of species and facilitatory interactions among species and the environment, with a specific focus on high value habitat forming species (shellfish and kelp forests). Finally, it will develop new methods to map ecological response footprints of stressors and their impacts on ecosystem services in marine systems.

F. RELEVANCE TO CHALLENGE OBJECTIVE
Current management practice typically fails to cope with: interactions among stressors that generate adverse ecological effects at thresholds well below those anticipated for single stressors; and the consequence of different activities in terms of the potential for ecosystem recovery, due mainly to a lack of essential knowledge. Thus, research that builds understanding of the cumulative effects of multiple stressors on ecological function and the potential and time scales for ecosystem recovery is central to EBM. This new ecological knowledge will inform model development in the Challenge (particularly in projects 1.2 and 3.2) and enhance the development of Tangaroa projects (particularly T1 and T2). Knowledge and tools produced will also underpin other project across the Challenge, e.g., in Blue Economy, which seeks new economies that lead to improved ecological health, and project 4.2 which grapples with the consequences of mismatches between spatial scales of management and ecological scales of degradation and recovery. We will also align the research with case studies particularly in Marlborough Sounds, Bay of Plenty and Hauraki Gulf.

G. OUTPUTS

We deliver specific types of outputs for different purposes. For brevity we define the purpose and nature of different forms of outputs ahead of the detail:
Papers – independent peer reviewed scientific and indigenous publications are essential to build trust in science and Māori worldviews and ensure international credibility. They are critical if we are to use our research findings to inform EBM practices, support high level reports and evidence in Environment Court – scientific papers are intentionally recognised as having tremendous value.
Frameworks – guidelines and tools to support decision making within EBM contexts. These products will be used to synthesise ecological/environmental/cultural knowledge to help EMB practitioners and project partners. They will demonstrate connections and interactions that have important consequences on ecosystem structure, function, resilience and ecosystem services. We will build these models/tools and trial them with project partners and other parties as the project develops. Initial models will be simple, principle-based and graphical. We expect these to evolve within the project and with partner projects.
Education support tools – These will target working with schools, taiohi (tribal youth) and public media to encourage understanding and valuing marine ecosystems.

In the broader context of Phase II of Sustainable Seas it is important to remember that 1.1 is the only project developing new knowledge on ecosystem processes – this is fundamental to effective EBM as recognised in the **Theory of Change Output a**. The information generated and the knowledge stored in this project will inform the design, parametrisation and implementation of models developed in the Challenge.

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. Two scientific papers on the development of ecological footprint analysis in the context of cumulative effects and the footprint of specific stressors (habitat disturbance, sediments, nutrient inputs, changes in turbidity). 2. Two scientific papers detailing the development of new applications of satellite data with the aim of creating a national scale indicator of sediment/turbidity in New Zealand's harbours and estuaries. 3. Five scientific papers addressing ecological recovery and the role of key species in influencing recovery dynamics in soft-sediments and rocky reef ecosystems.	**a** Biophysical and social-cultural-ecological knowledge that supports the development of understanding and tools that underpin EBM---developed and accessibly packaged	All papers will provide peer review of the knowledge that will inform the development of the EBM tools, models and other outputs listed below that will be co-developed with identified stakeholders. In the case of the framework (Output 6) there will be an emphasis on DOC, MPI, Regional Councils and kaitiaki. Models and tools will be discussed, developed and trialled with iwi though joint research activities, harbour hīkoi and wānanga, hui-a-iwi and co-management forum presentations, as proposed with T1 in the Bay of Plenty and in case study areas (Hauraki Gulf and Marlborough). Project workshop/hui will be used to demonstrate how ecological results underpin

4. A tool based on ecological footprint analysis that is focussed on engaging the public in recognising how footprints are assessed, how effects accumulate with additional stressors and summarising the cost-of-use against multiple environmental benefits and services 5. At least one model of ecosystem recovery that allows key species to influence recovery dynamics, can be used in seafloor (soft-sediments and rocky reef) ecosystems and can be run to generate the relative success of management actions to enhance recovery. 6. A framework to support decision making in the context marine protected area implementation and design and; management interventions to 'improve ecological status and restore mauri and managing habitat disturbance in fisheries. 7. A list of practical steps to enhance seafloor recovery rates that can be used by research managers, kaitiaki and community groups 8. An educational resource for local kaitiaki, community, Rūnanga and schools addressing the links and overlap between mātaranga and ecology. This will be co-developed and is envisioned being delivered in the form of an infographic.		tool and model applications and values. In particular these will be used in case study areas to demonstrate the steps that may be useful when recovery faces bottlenecks and determine which of these are practical from a management/ kaitiaki/ citizen science perspective Trials for education resources will be undertaken in communities, Rūnanga and schools involved in the research (e.g., Ōhiwa, Marlborough Girls). Media presentations
9. A framework for developing methods that incorporate mātauranga Māori and western science knowledge of coastal ecosystems. 10. A research paper containing definitions of degradation and recovery of rohe moana in mātauranga Māori and western science terminology. 11. A co-developed marine management tool/kete mātauranga for kaitiaki, Rūnanga, community and schools, that focusses on preventing degradation and enhancing recovery of rohe moana	**b** Traditional, local and other cultural knowledge that supports EBM is captured/ understood/recognised	These methods, narrative and tools will be co-developed through joint research activities, harbour hikoi, wānanga, hui-a-iwi and community presentations with T1 (BOP) and in the Hauraki and Marlborough case studies. This includes collection of information and method trials. Workshops will be held in conjunction with project 3.1 and 3.2 to increase the data and perspectives gathered and extend communication of the tools and narrative into marine spatial planning and risk assessment. Capability field workshops will be held with hapū/iwi and case study partners with T1 (BOP), Marlborough Sounds and Hauraki Gulf
12. Five papers addressing the mechanistic assessment of cumulative effects in soft-sediments and reef communities. 13. A set of guidelines about the nature of interactions between stress/disturbance and ecosystem interactions. 14. A decision-making framework to assess the risk of cumulative effects will be developed based on	**f** Tools for predicting and managing cumulative and multiple stressors developed, assessed and demonstrated	All papers will provide peer review of the knowledge that will inform the development of the guidelines and framework outputs The guidelines and framework will be co-developed with identified stakeholders in case study areas and projects 1.2, 3.1, 3.2 and T1. Engagement in case studies will be used to trial the use and applicability of the framework. In particular, in partnership with T1. This test will

the above guidelines and able to incorporate the potential for non-linear change		be used to adapt the guidelines such that they include Mātauranga Māori and the framework such that it links with Output 8 Outputs and the data collected will be used in projects 1.2 and 3.2 to inform risk assessments and marine spatial planning. Media presentations

H. OUTCOMES	This project will contribute to the following Theory of Change Outcomes:
	• 2. Decision making practices that are more inclusive, multi-sectorial and account for the effects from cumulative and multiple activities are adopted
	• 3. Knowledge form the Challenge (science and mātauranga) is used in decision making to improve ecological health and influences marine management and policy
	• 5. 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
	• 1. The value of blue economy business models is recognised and adapted by Aotearoa New Zealand businesses
	• 8. 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

This project represents the Challenge's focus on key ecological questions to provide the evidence needed to underpin models, decision-making processes and understanding necessary to implement EBM. Working with our team of co-developers and Challenge partner projects we will investigate the ecological responses of soft-sediment and rocky reef habitats to multiple stressors. Our engagement across society and with the international science community has allowed us to identified key issues and knowledge gaps that we urgently need to address in a world where we desperately need to implement EBM.

Building on Phase 1 research and the Challenge's request for proposals for Phase 2 we will:

- develop ecological footprints analysis to support improved decision-making, investment and knowledge of how activities and stressors impact on biodiversity and ecosystem services.
- provide a cumulative effects assessment framework that is based on understanding of interactions between ecosystem components to inform marine spatial planning and risk assessment.
- identify the constraints on ecosystem recovery to better manage risk and expectations of the time-scale of responses to management/iwi/community interventions to maintain healthy and functioning ecosystems
- on the basis of an assessment of cumulative effects and environmental degradation develop indicators/tohu that facilitate engagement in EBM and assess effectiveness of actions and provide for accountability to decision- and policy makers.

To achieve this research project, we will engage in field studies, develop models and work with broader environmental initiatives across New Zealand proposed by iwi community groups, central or regional government that support EBM developments. This includes:

- Hauraki Gulf Seas Change process (inc reef and seafloor ecosystems)
- Maketū estuary and Ōhiwa harbour in light of actions to improve biodiversity and ecosystem function
- Marlborough Sounds with multi-sector interests in trailing EBM (inc reef and seafloor ecosystems)
- Southland estuaries with interests in enhancing the removal of nitrogen from the coastal ecosystem

In the context of each of these initiatives we will be working with key species that play important roles in marine ecosystem processes and thus recovery from major stressors. For example, we will work with the potential for shellfish populations to enhance the ecosystem recovery of estuaries and ameliorate negative effects of sediments and nutrients. We will also use the protection to the seafloor provided by marine protected areas to assess the loss of ecosystem function across strong gradients of habitat disturbance and address the loss of kelps forests from our coasts its impact on culturally important food resources and to help us tease out the implications of other stressors (over fishing, climate change and increased turbidity) on ecosystem health and function.

These studies will allow us to use identified concerns as a way of developing frameworks to improve the way we make decisions about the risks posed by different activities in the marine environment and the opportunities we have to improve the ecological health and mauri of our coasts and estuaries.

J. AIMS

Please note this is a coherent and interconnected project with information and synergies occurring across research aims and activities but for clarity have provided indicative funding percentages to indicate the scale of the different components.

1. To develop the concept of ecological footprints for marine ecosystems focusing on importance stressors that produce cumulative effects that challenge management practice (20%).
2. To develop a framework that assess cumulative effects based on the mechanisms of ecosystem functions and potential delivery of ecosystem services (45%).
3. Assess the rate and likelihood of degraded ecosystem recovery, addressing the causes of hysteresis in the recovery of key habitat forming species, to improve risk assessment and help manage societal expectations post recovery-positive interventions (35%).

K. PROPOSED RESEARCH

All aspects of this project are strongly interconnected, below we track the proposed research in the context of the Phase II Strategic Plan. The different research activities (RAs) are not all of equal size. RA1 uses information available to the project's researchers and that generated in RA 2 & 3 but is a desktop synthesis study building on, and adapting available frameworks. RAs 2 & 3 are the larger components of the project, both involve field research to address knowledge gaps. To achieve efficiencies in our field work we will combine research efforts in specific study locations as appropriate. Research will be co-developed and to be co-implemented with iwi, communities and managers. Hapū and iwi aspirations and priorities for their taonga species and inter-generational rohe moana underpin this project. The partners are committed to sharing knowledge and two-way capability building in relationships that actively strive towards sustainable seas, for present and future generations.

RA 1: Mahere tapuwae: Develop methods (in conjunction with project 1.2) to determine the spatial-temporal ecological response footprints of overlapping diffuse broad and local-scale stressors (20% of project)

This is a coherent, interconnected dynamic and co-developed project with information and synergies occurring across all research activities and aims. This RA will contribute to the delivery of Outputs (Section G) 1, 2, 4, 8, 9, 11, 14.

We will adapt and apply ecological footprint methodology (a resource accounting tool that tracks human demand on the Earth's biological resource flows, and compares it with the Earth's capacity to generate these same flows (see https://www.footprintnetwork.org/our-work/ecological-footprint/)) to address identified major stressors in marine ecosystems (habitat disturbance, sediments, nutrients and biodiversity loss). **Building on the knowledge generated in the project we can expand on ecologically relevant and practical indicators (Hewitt et al. 2001a, Hewitt et al. 2001b, Hewitt et al. 2005, Hewitt and Thrush 2007, Hewitt et al. 2007, Hewitt et al. 2009, Hewitt and Thrush 2009, Hewitt and Thrush 2010, Hewitt et al. 2016b, Hewitt et al. 2016c, Thrush et al. 2016, de Juan et al. 2018, Hewitt and Thrush 2019). This needs to be linked to understandings and experiences of local kaitiaki and community practitioners with tohu o te taiao or signs, signals or indicators of the natural world.** Working with other aspects of the project we will incorporate information on multiple ecosystem services and stressor interactions (RAs 2 & 3). This new application of ecological footprints led by Professor Thrush will be trailed and developed with co-development team as a new way to engage society in a broader understanding of the consequences of our activities (or inactivity) on the sustainability of marine ecosystems (Kissinger and Rees 2010, Swartz et al. 2010, Mora et al. 2011, Goldfinger et al. 2014, Pelletier et al. 2014, Oita et al. 2016, Wang and Chao 2017). To develop the tool for application in the context of EBM co-implementation processes (potentially linking to Challenge case studies), in conjunction with projects 3.2 *Communicating risk and uncertainty to aid decision making* and 1.2 *Tools for incorporating ecological responses to cumulative effects into management action*. To further the development of ecological footprints as a positive and transformative socio-ecological tool for EBM, we see potential to take this work to a further level of engagement with a Challenge funded post-doc linking it to the blue economy and marine governance research in the Challenge.

A second part of this research activity uses new satellite platforms that provides broad-scale data at high resolution. While satellite data has been used extensively to inform surface ocean characteristics free from land influences, efforts to inform the conditions in the coast have been stymied by old technology and an old school scientific approach. A fresh look is needed and this project works with a coastal physical scientist with decades of experience in remote sensing and new capacity generated by Xerra (https://www.xerra.nz/) New Zealand's recently established centre for Earth Observations and Remote Sensing. Building on applications recently employed for comparing NZ lake water quality through time (Lehmann et al. 2018) we will investigate the application of data derived from Sentinel 2 to define whole system turbidity footprints in the coastal zone at the 10 m scale. t will provide a whole of system footprint on turbidity by linking it with photosynthetically available radiation (PAR), sediment and ecological data collected in the Phase I Tipping Points Project. This is consistent with the mātauranga Māori concept, ngāhīhī o te rā which highlights the importance of light across environmental stress gradients and the sun's rays revealing the impact of our activities on an interconnected world. The first phase of this work will be a trial on 12 regions of Tauranga Harbour working with iwi researchers in project T3 *Ngā Tohu o te Ao*. In the second phase the PAR, sediment and ecological datasets from estuaries and reefs across NZ will be compared against the chromatography values from satellite, to allow us to develop an interpretation of the ecological significance of the satellite colour signatures. Key to this work is the ecological interpretation of the physical data and a focus on patterns rather than determining absolute values.

RA2: Whakaranea: Understanding the role of stressor interactions (and feedbacks) on ecological function and ecosystem service delivery (45% of project)

This is a coherent, interconnected dynamic and co-developed project with information and synergies occurring across all research activities and aims. This RA will contribute to the delivery of Outputs (Section G) 1, 2, 3, 4, 6, 8, 9, 11, 12, 13, 14.

To capture the risks and consequences of cumulative effects we must move beyond simple additive approaches; their only function really is to draw attention to the fact that there is more than one stressor operating – which we know (Ellis et al. 2015, Gunderson et al. 2016, Hewitt et al. 2016a, Lundquist et al. 2016). As this is a truly complex problem we need to engage in an iterative process of prediction and testing. In 2019 MfE and Stats NZ identified four key stressors on marine ecosystems: sediments, nutrients, fishing and climate change (Ministry for the Environment & Stats NZ 2019). We focus on two contrasting coastal ecosystems: seafloor habitats are both the most multi-impacted but deliver most of the ecosystem services, and coastal rocky reefs because of the concern amongst community and iwi in their decline and loss of taonga species. **The key question is how do these stressors interact to drive changes in ecosystem function and services?**

Previous work in New Zealand has documented strong changes in ecosystem function associated with small changes in mud inputs in both soft-sediments and reefs (Thrush et al. 2012, Thrush et al. 2014, O'Meara et al. 2017). The Phase I national soft-sediment Tipping Point experiment demonstrated a useful approach to link cumulative effects of sediments and nutrients (specifically nitrogen) through mechanistic changes in ecological interaction networks. Simple but realistic conceptual models of feedbacks and then empirical tests were used to develop knowledge of how cumulative effects arise, where/ when change is likely and how the changes promulgates through ecosystem networks. In this project, we will extend the stressors to include habitat disturbance and the associated loss of critically important species and functions for habitat formation and ecosystem service delivery (Thrush et al. 2001, Thrush et al. 2003, Thrush et al. 2005, Thrush et al. 2006, Thrush et al. 2008b, Thrush and Dayton 2010, Thrush et al. 2013b, Townsend et al. 2014, Thrush et al. 2015). Effects of climate change can be added to the cumulative assessment framework through likely changes to wave climates and terrestrial sediment inputs and directly through including effects of temperature and sea level rise.

Building on Phase I, the approach here is to work across strong stress gradients (in light, turbidity, biodiversity and physical disturbance) to investigate when and how the system responds and use this to identify potential thresholds and develop guidelines that enhance the risk of major changes in ecological functioning and thus ecosystem service delivery. This information will be combined with information available to the project's researchers through more than 40 years research experience in addressing the ecological effects of human impacts to develop a framework for defining the potential of cumulative effects and it will be used to inform Project 1.2 and Project 3.2.

In soft sediments, we will also investigate our current model of the interactions of sediments, macrofauna, nutrients and benthic primary producers to understand the switch to bloom and scum forming macroalgae and changes to ecosystem services and traditional mahinga kai. In rocky reef systems, we will define the legacy effects of kelp cover changes (in different parts of NZ) and the potential for these changes to have accelerated cumulative degradation (or otherwise) in ecologically, culturally and economically important species. A conceptual model informed by previously collected data and linking to T2 and other Phase II projects will develop information concerning cumulative effects on kelp forest ecosystem services.

We look to make real world measurements to help parameterise and ground truth models. The modelling tools will be selected in conjunction with Projects 1.2, 3.2 and 4.2 *Options for policy and legislative change to enable EBM across scales* but are likely to include structural equation models, agent-based models and/or hierarchical Bayesian Networks. We will also extend the biological trait-to-function/ecosystem service models developed in Phase I (2.1.3 Measuring ecosystem services and assessing impacts) to inform how service delivery will be altered by multiple stressors.

We intend to use gradient studies in intertidal and subtidal (remote sampling) habitats which have been identified as important priorities by coastal kaitiaki in project T1. Our co-developers have also signalled interest in having studies situated in the Bay of Plenty, Southland, Hauraki Gulf and Marlborough Sounds.

RA3 Haumanu moana: Assessing the recovery potential of degraded systems (both rate and likelihood) and the causes of hysteresis in the recovery of key habitat forming species (35%)

This is a coherent, interconnected dynamic and co-developed project with information and synergies occurring across research activities and aims. This RA will contribute to the delivery of Outputs (Section G) 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14.

The strategic plan emphasised the need: to consider organism habitat requirements, species-species interactions, meta-community dynamics and present/future stressor regimes; to prioritise stressor management to reverse cumulative effects; and focus on kelp and shellfish beds as key habitat-forming species.

Ecological recovery potential is critical knowledge for management decisions, influencing how much disturbance a system may be able to withstand and how quickly recovery may follow from the cessation of disturbance or stress. It is also important in defining ecologically relevant scales of management and managing expectations regarding the time scales of management actions and ecosystem responses. Research demonstrates that recovery will depend on how the ecosystem has been stressed, if the stressors have left a legacy (e.g., changing a sandy sediment to mud, building up a nutrient bank) and the spatial extent of disturbance (Thrush and Whitlatch 2001, Thrush and Dayton 2002, Thrush et al. 2006, De Juan et al. 2013, De Juan et al. 2014). Mātauranga Māori inclusive of intergenerational observations and experiences will assist the consideration of the ecological characteristic of recovery considering resilience, resistance, refugia, meta-community, disturbance regimes and scales (patches and landscapes), building on previous studies of key factors such as biodiversity, connectivity and facilitation (Thrush et al. 2008a, Thrush et al. 2013a, Gladstone-Gallagher et al. 2019, Schiel et al. 2019).

Research on tipping points in Phase I of the challenge also highlights a crucial problem with management strategies that rely simply on turning off the stress – this is the problem of hysteresis (Scheffer 2009). This means that recovery of lost biodiversity and ecosystem function may occur at a much slower rate than the slide into a degraded ecosystem. The work will utilise both empirical data collection and models. Empirical data will be gathered from situations where clear gradients of disturbance exist (e.g., across MPA or management boundaries) or where management interventions or trials provide new opportunities. Our co-developer partners are determining the potential information available on disturbance gradients over which we could collect data and test hypothesis. For example, previous research in Phase I has noted major changes in bioturbation (and thus ecosystem function) across the boundary of the Long Island Marine Reserve in the Marlborough Sounds. This new data together with that already available will be used in models to both help define the times scales of recovery and management interventions that would speed recovery. We have a seafloor disturbance recovery model available, although if required we may build new recovery models specifically related to ecosystem function. Information produced by RA2 will be used to determine the relative importance of specific stressors in delaying or improving recovery potential. This work will link to NIWA Coast and Estuaries SSIF funding, collectively building extra dimensions to incorporate meta community and hydrodynamic interactions as a potential to drive lags in recovery. The model outputs will be used to develop guidelines for models of risk (Project 3.2) and marine spatial planning (Project 1.2).

The second piece of work in this RA focusses on the recognition of hysteresis traps- the feedbacks and lags that block recovery. This will be supported by mātauranga Māori understandings and experiences of localised traditional and contemporary tohu and ways of recognising, interpreting and responding to environmental signals. Hysteresis can occur because of: environmental change (e.g., removing large organisms reduces settlement sites for juveniles so no recovery even if we remove the stress); community change (e.g., stress/disturbance has changed the community increasing enhancing predator/scavengers and blocking recovery); and allee effects (density has become so low as to limit the supply of recruits of key species that will drive recovery). Thus, turning off the 'stress' taps may not be enough, and we need to understand this to inform risk assessments and help manage expectations of recovery following management intervention. This is another area that will allow us to use historical data in new ways, conduct surveys and experiments and develop models to determine likely recovery times. The work is specifically focused on kelps forests and shellfish beds and strongly anticipated links with iwi kaitiaki aspirations and researchers in projects T1 *Awhi Mai Awhi Atu* (shellfish)and T2 *Huataukina o Hapu e!*. Through these links we will co-develop a mātauranga Māori and socio-ecological aspect of recovery – recovery to what, what is possible and how to manage expectations around the time scale to recovery. While we will utilise transplant/removal experiments and disturbance gradients to generate data and test hypotheses, we are working with our co-development partners in Phase II to find specific management interventions that we could work with – areas either undergoing closure to activities or where activities are changing.

For shellfish, we will work with local kaitiaki to specifically focus on localised tohu, allee effects, feedbacks between habitat change, recruitment and legacy effects, increased predation in stressed systems and feedbacks between disturbance effects on productivity and sediment-water column exchanges.

For kelp, many communities are interested in grazing kina (sea urchin) removals to aid kelp recovery and long-term management. Working in partnership with iwi and commercial kina fishermen we will determine how kelp-urchin dynamics are influenced by other stressors (sediment, temperature). The 'cumulative effects' hypothesis is that kina grazing is the limiting factor for kelp when water quality is good, where water quality is poor, kina are not the limiting factor (Spyksma et al. 2017, Blain et al. 2019, Blain and Shears 2019, Udy et al. 2019). We will also conduct a synthesis study using extensive available data from across NZ addressing our three main kelp species (*Durvillea* (south) *Macrocystis* (middle), *Ecklonia* (north)) to assess impacts and recovery rates and causes of variations in recovery potential. This will link to potential effects on culturally, economically and ecologically important species associated with these habitats.

Woven through the three RAs is the active concept of mahi tahi or working together through co-developed knowledge sharing and co-ordinated action with iwi partners. This will involve a variety of iwi prioritised activities around the country ranging from co-designed experiments and surveys, to knowledge sharing hui/meetings and wānanga/workshops (see section N). This project will work with local kaitiaki and pūkenga (traditional environmental experts); community practitioners; and co-management/co-governance forums to develop understandings of different perceptions of what ecological degradation and recovery means and looks like to them (Paul-Burke & Rameka 2015). Consistent with iwi partner aspirations we will also work with taiohi (youth) to assist capability building in the field and to identify how localised values and/or priorities change over time. This will help us to foster a tuakana/teina approach to research or reciprocal knowledge exchange between iwi partners/participants and researchers (Pere 1994; Winitana, 2012). The findings of the values and localised marine understandings will be integrated with the rules and indicators developed in RA1 to RA3 to demonstrate how they can assist understandings of ecological degradation and recovery across time and space, iwi and communities. The information collected will be used to develop a marine management tool and kete mātauranga/educational resource for iwi kaitiaki, taiohi, community and schools. This work will be conducted in conjunction with Project 3.1 and link to Project 1.2 to translate output from spatial models into ecological indicators suitable for managers/iwi.

L. LINKS TO PHASE I RESEARCH

This project has connections to many projects in Phase I, but those it most heavily draws upon are:

2.1.3 *Measuring ecosystem services and assessing impacts* - This project provides important insights into mapping services and ecosystem functions that will inform the research on cumulative effects and recovery processes.

4.1.1 *Tracking biogeochemical fluxes to inform EBM* - This project will inform us on the implications of loss of kelp forests on higher tropic levels – economically important fish and show the 'value' in recovery

4.2.1 *Tipping points in ecosystem structure, function & services* - This project provides data, conceptual frameworks and enduser connections as the foundation of the project

4.3.2 *Sediment tolerance and mortality thresholds of benthic habitats* - This provides us with information on sediment impacts on two habitat forming seafloor animals dog cockles and sponges that will help us develop us cumulative effects framework.

4.3.5 *Overnight tipping points from cataclysmic event* - Provides tools/data useful in studies of kelp recovery from disturbance

M. LINKS TO & INTERDEPENDENCIES WITH PHASE II RESEARCH PROJECTS

Our project has strong interdependences with the following projects supporting knowledge transfer, capacity building and empirical testing of concepts and models:

1.2 *Tools for incorporating ecological responses to cumulative effects into management action* - We will work with this project to develop rules for spatial models that allow a fuller integration of ecological dynamics, cumulative effects and thresholds to inform marine spatial planning and risk assessment.

3.1 *Perceptions of Risk and Uncertainty* - Wananga and interviews conducted by this project will be utilised to understand different perceptions of ecological degradation and recovery

T1 Awhi Mai Awhi Atu - Shared researchers will provide ecological science that complement mātauranga Māori approaches to enhance the recovery potential of coastal ecosystems and perspectives that better engage hapū and iwi

3.2 *Communicating risk and uncertainty to aid decision making* - This project will utilise our science outputs, especially those related to ecological footprints and cumulative degradation rules, while providing information back to our project on how uncertainty is affected by scale.

T3 *Ngā Tohu o te Ao* - Our work on ecological footprints and cumulative stressors will include a reciprocal sharing of ecology and mātauranga Māori via a harbour hīkoi.

4.2 *Options for policy and legislative change to enable EBM across scales* - This project's work on determining management scales and the effect of management – ecological system scale mismatches will feed into our understanding of management options for cumulative effects.

We will also promote interactions with other projects during their development phase, specifically projects *3.3, 4.3* and *T5,* projects in the Blue Economy (Theme 2), the overarching Synthesis and the regional case studies.

N. VISION MĀTAURANGA (VM)

Coastal Māori express grave concerns regarding the degradation of marine environments and depleting kaimoana (fish, shellfish, kelp), mahinga kai (harvesting areas), and want action to prevent further degradation and to allow recovery in multi-use marine ecosystems. Damage to the marine environment transgresses the basic concepts of a Māori worldview in ways that undermine cultural and individual identity. The degradation of marine ecosystems – has a significant detrimental effect on the relationship of Māori with their rohe moana (traditional marine environments) (Ministry for the Environment & Stats NZ 2019). As a result, there is an increasingly growing demand by Māori entities to investigate alternative ways of engaging with western science and monitoring of soft-bottomed harbours/estuaries and coastal reef systems (Paul-Burke et al 2018). Identifying ways in which mātauranga Māori can be captured and incorporated through co-developed trans-disciplinary research and tool development to assist kaitiakitanga of marine taonga species and spaces is a high priority (Ministry for the Environment & Stats NZ 2019).

Consistent with Vision Mātauranga policy, this project seeks to critically address the long-term aspirations for taonga species and rohe moana of Ngāti Whakahemo, Te Ātiawa-o-te-waka-a-Māui, Te Rūnanga o Ngāti Awa; Te Rūnaka o Koukourārata, Te Ao Marama and many iwi of the Hauraki Gulf who have been engaged in the Sea Change project. This project has a commitment and willingness to partner and work with the concepts behind the Vision Mātauranga policy. We have allocated specific VM funding to support engagement and a named Research Assistant. The project seeks to investigate ways to bring together mātauranga Māori and western science to provide access to a range of new tools and techniques to help improve understandings of marine ecosystems and management capabilities in response to the issues, priorities and aspirations of our iwi partners. This will be achieved by increasing two-way skill, capacity and capability development through knowledge generating wānanga, hīlkoi, workshops, fieldwork, educational resources/kete mātauranga, to assist dual understandings and explanations of dynamic and uncertain marine environments. Iwi have identified the issues, aspirations and priorities for degrading and diminishing shellfish populations and kina/kelp within their rohe moana and seek outputs which provide meaningful access to decision-making information and build capabilities of taiohi (youth) and kaitiaki. As discussed with iwi partners, the dissemination of the knowledge generated will be shared through a range of outputs appropriate for Māori audiences, including hui-ā-iwi, marae hui, Rūnanga annual reports and Māori centred publications and conferences among others. Moving from the hands-on, person to person engagements to the outputs promised, is all part of the co-development processes central to the project.

Combining mātauranga Māori and western science to assist understandings of ecosystem stability, recoverability and resilience across consecutive generations, including cultural managerial approaches (Lyver et al. 2016, Lyver and Tylianakis 2017) is an important tool for contemporary marine management in Aotearoa New Zealand.

Vision Mātauranga Deliverables

Partnerships:

VM P1 The project uses a range of new and existing relationships with hapū/iwi or Māori organisations. Existing relationships include: Ngāti Awa Customary Fishing Authority, Te Rūnanga o Ngāti Whakahemo and Te Rūnaka o Koukourārata. New working relationships include: Te Aitanga-o-te-waka-a-Māui, Te Ao Marama and many iwi of the Hauraki Gulf who have been engaged in the Sea Change project.

VM P2. The project will increase 2-way skill, capacity and capability development through co-developed wānanga, educational resources, kete mātauranga, hikoi and fieldwork.

Distinctive Contribution:

VM D1. The project will result in distinctive and innovative outputs specifically tailored to Māori interests including wānanga, hikoi, workshops, fieldwork activities, educational resources, kete mātauranga, taiohi moana training (marine youth).

VM D2. Project outputs are aligned to the identified issues and priorities of iwi partners.

Meaningful Outcomes:

VM M1. The project identifies and reflects Māori aspirations by prioritising Māori issues and needs within the research design including investigating ways to use mātauranga Māori with western science to assist better understandings of degradation and assist recovery of hapū/iwi prioritised marine taonga species and spaces.

VM M2. The project provides for the appropriate dissemination of knowledge and outputs to Māori, including hui-ā-iwi, marae hui, rūnanga annual reports and Māori centred publications and conference presentations.

O. ENGAGEMENT REQUIRED WITH IWI AND STAKEHOLDERS

This project works in partnership with iwi from across the Bay of Plenty, Hauraki Gulf, Marlborough Sounds and Te Waipounamu to support case studies and experimental research. This project has developed positive working relationships with Tangaroa projects and will work to ensure these will flourish to best support the implementation of EBM. Our co-development team provides important links to government and coastal SIG for Regional Councils as well as key links to Moana New Zealand which are deeply focused on developing sustainable practice and balancing kaitiaki and economic responsibilities. This builds on positive and long-term relationships with local, national and international civil society groups, multiple regional councils and government agencies.

We intend to engage with the project's co-development team both in terms of specific information and in reaching out through their networks. This will be a regular agenda item at our 6-monthly meetings and will provide opportunities to both engage appropriately and in a timely fashion as the co-development process involves. Added to this are the location of key project researchers at multiple research institutions across New Zealand all of whom have extensive local and national networks to link to civil society, community groups, regional councils, industry and government. All of the researchers involved in the project can be trusted. The experience with the tipping points project also highlight the value of post-graduate students in communicating research and attracting attention to EBM and marine ecosystems. This was a major engagement and communication success story from Phase I. The potential for capacity building is further enhanced through the research led teaching and post-graduate training of the future generations of EBM researchers and practitioners. These networks will be constantly fostered throughout the duration of the project via workshops, wānanga, harbour hīkoi, meeting discussions and presentations. The project leaders in conjunction with the Theme Leader will also interact with the proposed Theme 1 Impact Advisory Group (we anticipate that some of our co-development partners may even be appointed to this group) which will further ensure research is focused on delivering the Challenge mission.

P. PROJECT COMMUNICATIONS

We will use our connections (see above) to engage media in communications about the issues the underpinning science, partnership with iwi and community groups and challenge case studies. We will use Sustainable Seas and co-development partners' channels to target end-users and consider trade media articles and other established channels/activities that reach key audiences and end users. Again, experience with the Phase I Tipping Points project in the media and public communications demonstrates that we have been successful. We will also facilitate information exchanges via hui-a iwi and wānanga. Specifically:

- We are developing input in story-telling and engagement in the project through DOC as part of our co-development processes
- We will work with schools in NZ to enhance knowledge and action for the future
- We plan to work closely with other Challenge projects to ensure a wide target audience for popularisation of the ecological science and mātauranga Māori, and its relevance to the possible future of our marine environment
- As the project matures, we will investigate options to engage authors in stories about the pathways to sustainable solutions for our marine ecosystems
- As exemplified in the Phase I Tipping Points project we will present numerous public talks and the field work around the country allows us to engage very effectively with society
- We will continue to use scientific presentation and publications as a key component of information dissemination and verification because communication has to also be a vehicle to build trust in science.

Q. RISK & MITIGATION

- Risk: intellectual and cultural property rights where hapū/iwi may wish to keep certain information closed impacting publications and public presentations. Mitigation includes conversation and shared agreement of what is open and what is closed knowledge, at beginning of the research.

R. CONSENTS & APPROVAL required to undertake research	• Human ethics approval will be sought through UoW for work in this project and T1. • We will consult with local communities and regional councils and DOC to ensure field experiments and sampling are approved and if necessary permitted (as needed). We anticipate our co-development team will assist in the regard • Animal ethics will not be required for this research

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