SUSTAINABLE SEAS
Ko ngā moana whakauka
National SCIENCE Challenges

A. TITLE OF PROJECT

4.2.1 Tipping points in ecosystem structure, function and services

B. IDENTIFICATION

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C. ABSTRACT

Evidence is accumulating worldwide that subtle but cumulative impacts can profoundly change the nature of marine ecosystems. These changes are often called 'tipping points' and when they occur the way ecosystems deliver valued ecosystem services are put at risk affecting the benefits we enjoy from the sea. Our mission is to show how we can better manage marine resources to allow for many uses without loss of ecosystem functions and benefits. This project assesses the potential for rapid and surprising changes in marine ecosystems, identifies what activities are likely to cause them and what parts of the ecosystem are likely to be most affected. From this new knowledge we will offer evidence and advice on how we can better identify the risks of major change, how they relate change to the types and magnitudes of stressors, and how we can be better prepared to cope with change.

D. INTRODUCTION

The *Sustainable Seas* mission is to enhance the use of marine resources within biological constraints. The problem is that it is often hard to define these constraints within systems that are naturally changing and have multiple different users. Making wise choices about the balance between different uses and different values for our marine environment requires evidence of how ecosystems respond to different (and multiple) activities. Decision makers should worry about multiple stressor and cumulative effects (hereafter 'cumulative effects') because small changes in stressors could have big consequences on how ecosystems function and support values [1 2 3]. Subtle effects with surprisingly large consequences is the science of tipping points and is essential ecosystem science required to underpin effective EBM [4 5]. Tipping points are often also called thresholds, state changes or regime shifts; they all represent a non-linear change in ecosystem state, often from a valued to a less valued one [2]. Usually, but not always, they are accompanied by a change in how ecosystem components link together, and frequently they are unanticipated (surprises).

'Ecological resilience' is the capacity of ecosystems to maintain their state in the face of stressors and is directly linked to tipping points. Evidence of abrupt changes in ecosystems, at time scales relevant to society, is growing [6] [7] and examples include New Zealand [8] [9,10]. Tipping points are an emergent property of complex systems and while theory is advanced, empirical evidence has been hard to gather except with hindsight [2]. Where ecosystem change is likely to be profound and abrupt we need to drastically rethink our ways of managing the environment [11]. Managing up to the limit, currently defined by a single stressor considered in isolation, leaves no room for a new stressor or climate change [12]. This does not mean we cannot benefit from marine resource uses, but it does mean we need to engage in challenging science to better assess the risks of tipping points, what ecosystem functionality we may lose and how we can better inform society about ways to insure against and manage for surprise.

In this project we address complexity, assess the potential for cumulative impacts and tipping points and investigate opportunities for managing to enhance the resilience of marine ecosystems. We do not expect all ecosystems to exhibit tipping points nor do all changes occur on the same time scales. However, we must learn how to categorise functional relationships between major cumulative stressors and key ecosystem functions. We will contribute techniques to identify tipping points and identify potential indicators that underpin cumulative risk of tipping points in selected ecosystem functions; we will provide ecological insights to support better engagement in enhancing resilience and coping with surprise. To ensure maximum value from the knowledge we anticipate strong links to other projects in the Challenge (see section H).

E. AIM OF THE RESEARCH AND RELEVANCE TO OBJECTIVE

Our research will investigate the ways in which multiple uses of marine ecosystems affect the risk of abrupt change in ecosystem function. It will provide clear evidence of the biological constraints on ecosystems and real examples of links between stressors and ecosystem responses so that we can gauge the implications of human activities in different circumstances. This will foster wiser and more secure investment in marine ecosystems. We will contribute new techniques to identify tipping points and potential indicators, provide knowledge to underpin cumulative risk assessments for selected ecosystem functions and provision of services, and analyse the implications of our findings for management techniques and setting of environmental thresholds and targets. Ultimately, improved capacity to address these risks among investors, stakeholders, iwi, managers and policy makers will foster the implementation of EBM and identify new opportunities to insure against surprising changes and facilitate management for resilience.

F. PROPOSED RESEARCH

To be targeted and effective, this project has five **highly interactive components** that maximise the benefits and synergies of this essential complex research. **This work is transformative because** of the challenging and integrative nature of the science and its relevance to advancing our decision-making and knowledge of choices and consequences about our activities in marine ecosystems. By generating empirical evidence of tipping points, techniques to assess the risk of their occurrence, knowledge of how ecosystem functions change in relation to stressors and putting this knowledge to work across the Challenge, we will show how evidence-based science can inform actions and policy on cumulative impacts – especially those that can generate surprises in ecosystem responses. The five components are:

1. **Annual workshops** that will focus on developing the scientific programme, respond to changes brought about by our learnings and translate our findings in ways which ensure knowledge uptake in the context of participatory processes (in conjunction with Prg 1 *Our Seas*), ecosystem services and blue economies (Prg 2 *Valuable Seas*) and cumulative risk assessments (Prg 5 *Managed Seas*). We will foster engagement with Tangaroa as specific projects develop in that space and work with the Challenge management team to enrich these workshops with Vision Mataranga. Key people from other Challenge projects, other Challenges (e.g., Biological Heritage *Tipping* Points), iwi and broader interest groups/stakeholders will participate as appropriate. The workshops will also ensure integrative research across *Dynamic Seas*, for example by linking to connectivity studies in 4.1.1 and

4.2.2 and providing feedback to these projects on cumulative impacts and ecosystem function change. During the two-day workshops significant time will be dedicated to dealing with the highly technical issues needed to progress this project. The focus of our first workshop will be on developing criteria to screen data sets for clues of tipping points [13] and development of conceptual Complex System Models (see below).

2. **Indicators of tipping points.** We have empirically demonstrated evidence of tipping points in New Zealand estuaries using ecological time series [8]and relationships between sediment primary production and muddiness [14]. Here we will extend this approach by searching for signs of tipping points across the widest range of NZ marine data sets possible (sourced from regional councils, government agencies, NIWA and academic institutions). Once suitable data have been identified, we will employ state-of-the-art numerical and statistical methods (e.g., genetic programming [15], break points [14]), CART models [16] and indicators of shifts in variance [17] or spatial structure [18] to derive indicators of tipping points. Both ecological and stressor time series data are required for such analysis and unfortunately our experience tells us that data suitable for such analyses will be limited. Acknowledging this possibility we also plan to take a more ecological approach by scrutinising particular marine ecosystems and conceptualising how key interactions (e.g., trophic cascades, collapse and loss of key species and effects on biogeochemical and physical interactions in seafloor sediments) respond to major stressors implicated in tipping points (sediments, nutrients, organic loading, habitat disturbance). This approach differs from purely statistically derived indicators of tipping points (e.g., detecting raising variance prior to a threshold) because we inform our interpretation on the potential for change with our knowledge of specific system interactions. Our team is capable of moving beyond simply letting the data tell the story because of our in-depth knowledge of these ecosystems and the key stressors (see CVs). For example, some NZ spatial datasets (that are available for the Tasman-Golden Bays case study area) could be analysed in this way to determine the occurrence of such ecosystem interactions and could then be used to develop complex system models (see component 3).

This stocktake and analysis of existing data will serve many purposes: defining gaps in what is measurable and informative, how current data can be used in a multiple stressor and multi-use framework, what is needed to provide indicators of tipping points, how this can inform policy and management of cumulative effects and, importantly, identifying actions that foster resilience and insurance against surprise in marine ecosystems. We anticipate early scientific, policy and societal outputs from this component to include evidence of tipping points, examples of where subtle and cumulative changes can increase the risk of surprise, feedback on current national monitoring and EIA strategies to improve assessment of the risk of change.

3. **Complex system models** (CSMs) will be used to improve co-learning among stakeholders (in conjunction with *Our Seas* and *Valuable Seas*), as a heuristic tool, and to refine hypotheses for empirical testing in components 4 and 5. CSMs seek to capture the essence of the dynamics of specific systems, with a focus on feedbacks between subsystem components using simple rules. CSMs are not overly complicated, and are frequently used in physical systems to advance understanding [15], but they encompass (complex) non-linear behaviour and lag-effects that are frequently unforeseen. We have successfully used these models to better understand biophysical interactions and disturbance-recovery dynamics [19,20]. These models fit our purpose because they put our understanding of interactions within ecosystems to the forefront. By focusing on interrelationships that highlight self-organisation and emergent properties, they help us reveal the ecosystems dynamics that can lead to tipping points.

CSM are valued for their ability to advance understanding through the use of reduced complexity[21]. Specifically, to assess the potential for tipping points we will pay close attention to capturing the potential positive (or negative) feedbacks and cross-scale interactions such as biogenic enhanced nutrient supply and productivity [22], tropic cascades [23] and relationships between landscape structure and recovery potential[9] which are recognised for their potential to result in tipping points[24]. This focus on feedback interactions is an organising principle that will connect our understanding of different marine ecosystem components (coastal soft-sediments, shelf, rocky reefs).

We initially expect to focus on major stressors known to be current in the case study area, the focal area and the wider marine environment, produced by a variety of human activities: nutrient and sediment loading; changes in turbidity and light climate, and habitat destruction. CSMs will be developed that predict how specific ecosystem interaction networks deliver particular ecosystem functions and how these change with different (mixes of) stressors. The particular functions are expected to be those that underpin a range of ecosystem services including habitat formation, productivity, processing nutrients and organic matter but will be chosen in conjunction with participatory processes organised in *Our Seas* and *Valuable Seas*. We do not anticipate that all of the 'systems' we will investigate will exhibit the potential for tipping points, but this approach allows us to develop empirically testable hypotheses (see components 4 and 5) and, importantly, reveal relationships and mechanisms linking changes in ecosystem function(s) to multiple stressors. Once specific conceptual models are built, we will parameterise them to investigate dynamics, the potential for tipping points and the functional form of relationships between ecosystem function(s) and combinations of different stressors. We anticipate being able to parameterise some models with currently available data (see component 1), while others will require new data to be collected. All models will need to be tested and validated (see components 4 and 5).

In component 3 we will also initiate and partner in a co-development process for tools through connections to *Valuable Seas* (ecosystem services and blue economy potentials) and *Our Seas* (participatory processes) and Tangaroa (Kaitiakitanga in Practice). These tools will help define cause and effect relationships in complex systems and the potential for surprise; this capacity building will be the main initial products from this part of the project.

4. **Experiments** demonstrate mechanisms and the consequences of environmental change, providing real-world evidence of change that has the potential to persuade stakeholders, managers and policy makers before specific ecosystems have become degraded. Within the *Challenge*, experiments provide a powerful mechanism for integrative research across *Dynamic Seas* projects and evidence to foster engagement with specific projects in *Our Seas, Valuable Seas* and *Tangaroa*. We will use experiments to test the validity of our conceptual CSMs in specific situations and investigate the nature of how relations and consequent functions are changed by stressors. This method of grounding tipping points research in real-world ecosystems to improve our assessment of how different stressors can lead to the risk of surprising change was pioneered by team members[10]. This approach used an ecosystem interaction network (EIN) described in the international literature to design and conduct a field experiment producing data that were analysed by structural equation modelling[25,26]. This work demonstrated that key stressors could remove positive feedbacks within the EIN and change the functional attributes of the ecosystem. Building on this approach, and research in components 1-3, we will use conceptual CSMs for different systems, different functions and stressors both to develop testable EINs and define key experimental treatments (associated with multiple stressors and environmental change). We will choose experimental locations carefully to maximise wise use of our research budget, experimental rigor and relevance to the Challenge mission. Due to logistic and economic constraints, initial manipulative experiments are expected to be conducted in shallow coastal systems. An overarching hypothesis (that subtle changes in environmental factors will weaken or remove positive feedbacks within EINs, affecting the resilience of local ecosystem functions) will drive our experimental design. Other hypotheses and design elements will be system-specific and developed at workshops, but we have extensive experience in both traditional hierarchical experimental designs and gradient-based designs and will use these as appropriate.

One proposed experiment is focused on coastal soft sediments; these are both the receiving and processing environments for multiple stressors (elevated turbidity, sediments and nutrients). These stressors interact, and legacy effects or current sediment impacts may pre-dispose the system to a tipping point in nutrient processing and thus increase the risk of coastal eutrophication. This experiment requires us to work in multiple sites that vary from highly turbid to clear, as a direct stressor on underwater light climate and an indicator of sediment deposition. Final locations will be decided during our first workshop, but harbours in Northland, Auckland, Coromandel, Canterbury, Otago and/or Southland are likely. Each harbour will have sites differing in turbidity and other environmental factors that will be either factored into the experimental design or teased apart in our subsequent analyses. Extensive research has identified four critical interacting components: large macrofauna; microphytobenthos; biogeochemical processes associated with nitrogen cycling; and sediment grain size [27-29] which we will measure or manipulate. Large experimental (>10m^2) plots, in which nutrient loading is manipulated, will allow for repeated sampling and we will run this experiment over multiple years measuring changes in biogeochemistry, organic matter processing, nutrient pore water concentrations and fluxes, microphyte production, the density of large macrofauna and biogenic sediment microtopography.

We envision reciprocal but appropriately designed experiments on rocky reefs addressing how sediment effects on light climate can affect productivity and use of this primary production within the coastal systems. It is known, for example, that coastal sediments are effecting major changes on coastal reefs worldwide and work in New Zealand has shown this can occur through smothering by sediments, prevention of settlement by early life stages of organisms, and occlusion of the water column which reduces both the amount of light and its spectral quality [30,31]. Appropriately designed experiments in at least Northland-Auckland and Canterbury will test the flow-on effects of such key functions as primary productivity, resilience to further disturbances (e.g., human impacts) and formation of low productivity, functionally reduced zones that no longer provide key services[32,33] .

We anticipate strong links between these initial experiments and the ecosystem connectivity component of *Dynamic Seas* and in using this knowledge to inform our understanding of how environmental change can influence the delivery of ecosystem services for *Valuables Seas*. Scientific products will describe the findings from our experiments and this knowledge will be used to reinforce the potential for subtle and cumulative change to society, investors, managers and policy makers and highlight opportunities to enhance the resilience of coastal ecosystems.

5. We will **verify CSMs at broader spatial scales** and extend data gathering, supplementing data assessed in component 2. A significant proportion of this data gathering will occur within the Challenge's focal area employing highly focused sampling programmes to look for specific break points in ecosystem structure and function along stress gradients. For example, these sampling programmes will exploit gradients of sedimentation, turbidity, organic loading (associated with aquaculture) and seafloor disturbance (associated with commercial fishing) in the Marlborough Sounds to analyse changes in ecosystem function in soft-sediment and rocky reef communities. We anticipate strong synergies to the stressor footprints project within *Dynamic Seas* in designing these studies.

To provide **critical societal context for these surveys we will compare any management limits applied in the focal area** to our risk of tipping points as informed by components 1-4 above. This is an important step as we currently set management limits in isolation (e.g., quota, contaminant loads) despite the potential for cumulative effects and multiple stressors. The limits-based approach to management is proliferating due to the National Policy Statement for Freshwater Management 2014 (NPS-FM) and has important but unresolved implications for the coastal zone. Here we use the concept of a limit as any standard against which some upper or lower level of acceptable use has been defined (e.g. water quality standards, ANZAC guidelines). Working with our colleagues in national and regional government, we will draw up a list of proposed (e.g., current MfE NPA-FM process) and actual limits and test for changes to ecosystem structure and function associated with potential tipping points. The business-as-usual approach of setting management limits does not necessarily provide the adaptive capacity we need to maintain resilient ecosystems nor does it provide policy and governance options that are likely to support responsiveness and the ability to maximise opportunities. This component will therefore be important in advancing the Challenge in terms of EBM implementation.

Phase 2: In **the second 5-year phase of the Challenge**, the research will be focussed on the need to provide better evidence-based recognition of the risk of tipping points and in developing strategies to deal with surprise under accelerating environmental change. We anticipate: continued interactions between CSMs, experiments and risk assessment (project 5.1.3); a need to address the implications of climate change; and input from economic projects in the Challenge on new stressors that need to be included. We will add a new component to our workshops with an international workshop on the empirical science around tipping points and implications to policy and EBM in 2020. As knowledge and capacity accumulates in the project we will also increase our interactions across the Challenge to improve the science and the formulation of solutions to ensure we are better equipped to invest in, manage and conserve marine ecosystems in the face of surprise and to ensure we maximise our ability to make the most of new opportunities (in economy, conservation, management and knowledge generation) when surprises occur. Explicitly, the combined knowledge generated across this project partnering with Tangaroa (Prg 3) projects should also create new opportunities for kaitiakitanga - through challenging existing assumptions and developing innovative pathways for the future.

G. ROLES, RESOURCES

The project will be led by Prof Thrush, who has extensive experience in addressing ecosystem dynamics, ecosystem function, resilience, engaging with a wide range of stakeholders and running large interdisciplinary, multi-institutional mission-led research programmes. He will be supported by the excellent research team, in particular Prof Schiel (*Dynamic Seas* theme leader) and Assoc Prof Pilditch to support redundancy and fail-safe systems in terms of project management.

All team members have an excellent track record and willingness to collaborate, and will play multiple roles across the project. For example, component 2 is led by Prof Hewitt, Assoc Prof Coco and Dr Lundquist; component 3 by Assoc Profs Coco and Bryan. In both components the role of the ecologists and biogeochemists in data analysis and model development will be essential and all are expected to contribute. Component 4 experiments in soft sediments will be led by Assoc Prof Pilditch, Dr Lohrer and Dr Savage; on rocky reefs habitats by Prof David Schiel and Dr Nick Shears but we envision extensive cross-system collaboration. In addition to this list we have the talents of key researchers: Dr Teri O'Meara in biogeochemisty; Dr Leigh Tait diversity effects on primary production; Dr Chris Corelisen on data acquisition and species response modeling. Dr John Pirker (Ngai Tahu) will aid in liaising with iwi, in particular Te Korowai in the Kaikoura region, but will contribute to mentoring and organising activities across the project. The highly competent technical support from NIWA benthic ecology and the Universities of Auckland, Waikato, Canterbury and Otago. Laboratory facilities, field support, boats and other field equipment will be available to this project as appropriate.

We have assembled the **best national team:** in terms of the biophysical science. We have researchers who have worked at the forefront of marine science and gathering empirical evidence of tipping points, developing novel experimental approaches to assessing how multiple stressors and cumulative impacts can break critical ecosystems ecosystem interactions, analysing data to look for breakpoints, and developing complex-system models. Collectively, this team has a proven ability and willingness to collaborate, build capacity and stretch the science both internationally and in terms of real-world applications via connections across the challenge and with a wide variety of stakeholders and stockholders.

H. LINKAGES AND DEPENDENCIES

Tipping points is not dependent on any other program or Challenge projects as it delivers ecological knowledge on tipping points, ecosystem function and cumulative impacts. It has been designed to continue to work on maximising synergies that advance the science and the Challenge mission. To ensure maximum value from the knowledge we anticipate strong links to other projects in the Challenge. Specifically, working on ecological connectivity, ecosystem function and ecosystem services, cumulative risk assessment, with strong feedbacks and co-learning with Vision Mataranga/ Tangaroa and participatory research in *Our Seas* to engender a clear recognition of EBM and governance structures that offer new opportunity in managing and planning for surprise. Within *Dynamic Seas* strong links to ecological connectivity will be developed. All of these linkages will be facilitated through the project's annual workshop, the role of Prof Hewitt and Dr Lundquist as theme leaders for *Valuable Seas* and *Our Seas* respectively. We anticipate developing collaboration with the terrestrial research on tipping points and resilience in the Biological Heritage National Science Challenge (and have already made approaches).

I. COLLABORATIONS

The research team engage in a range of research but this project is not dependent on any.

J. INTERNATIONAL LINKAGES

Dr Joanne Ellis formerly of Cawthron Institute is moving to a University position in Saudi Arabia aims to continue involvement in this project and support connections to Cawthron (particularly for component 2). Around the world there is a series of colleagues working on ecosystem interactions in the coastal zone, biodiversity-ecosystem function relationships in the real-world, and complex system dynamics. We have collaborated with an extensive list of these researchers as evidenced by CVs associated with this proposal. For example: Prof Paul Snelgrove, MUN, Canada and Professor Alf Norkko, University of Helsinki are collaborating in a new SCOR (Scientific Committee for Oceanographic Research) initiative to develop global maps of seafloor ecosystem processes that incorporate the role of biodiversity and cumulative stressor effects. Profs Sally Woodin and Dave Wethey, University of South Carolina, Dr Nils Volkenborn (Stoney Brook, SUNY, USA) are collaborating in the role of seafloor organisms in modifying the rate and nature of bentho-pelagic coupling, nutrient release and the role of environmental change. Prof Paul Dayton, Scripps Institution of Oceanography, USA is collaborating in the role of episodic events in generating legacy effects in seafloor ecosystems. Dr Casper Kraan, Freiburg University, Germany, is collaborating in the development of new statistical approaches to incorporate biotic interactions into species distribution models. Prof Mariachiara Chiantore, Univeristy of Genoa, is collaborating on the effects of cumulative impacts on rocky shores and the role of anthropogenic change in affecting resilience. Professor Alf Norkko, Dr Anna Villnas, University of Helsinki & Dr Ivan Rodil, University of Stockholm are collaborating in the development of broad-scale assessments of ecosystem function and changes due to eutrophication. Prof Brad Murray, Duke University and Prof Sergio Fagherazzi University of Boston are collaborating in the development of complex system models linking coastal bio and physical processes. Dr Kari Ellingsen, NINA, Norway is collaborating in the use of biodiversity assessments to identify critical gradients of environmental change on the seafloor and impacts of different industries on the seafloor. During the extensive develop of this NSC we have also developed new and relevant international connections with Hohai University, Nanjing and Shanghai Ocean University in the development of costal models and ecosystem process studies for coastal zones in China.

K. ALIGNED FUNDING AND CO-FUNDING

Prof Schiel and Canterbury University holds a subcontact with NIWA core funds COM1602, which will have strong synergies with this project. NIWA COM1602 is focused on ecosystem function research and while not aligned to the project will also provide strong synergies. The Universities will also bring co-founding in the form of supervision of post-graduates students (estimated at academic 200 hrs per PhD student per year), support for student research and use of resources for research and student supervision. They also bring meeting facilities and outreach venues (e.g., Goat Island Discovery Centre). All these activities can be monetarised. NIWA also brings research equipment and considerable infrastructural support to the project.

L. VISION MĀTAURANGA (VM)

Vision Mātauranga seeks to unlock the innovative potential of Māori knowledge, resources and people to assist New Zealander's to create a better future. There are four themes in the Vision Mātauranga (VM) policy framework (Indigenous Innovation, Taiao, Hauora/Oranga, and Mātauranga). We intend to capitalise on the opportunity provided by this project to develop innovative and/or distinctive products, processes, systems, and services. Specifically, Taiao looks to achieve environmental sustainability through iwi and hapū relationships with land, and in this Challenge, sea. When identifying and understanding the many uses of marine resources and ecosystem benefits, and the output of new knowledge, where possible, we will endeavour to express: iwi and hapū knowledge; culture and experience; kaitiakitanga.

Māori as tāngata whenua aspire to live in sustainable communities and healthy environments. As kaitiaki, dealing with uncertainty due to the multiple types and magnitudes of stressors on these environments, is becoming an all too common reality and a major point of connections to tipping points.

The intent of VM will be to work with the project leader and team in an observer capacity, to promote and enable the interface of indigenous knowledge with the project's investigation into changes in marine ecosystems. This will include consideration of what activities are likely to have effects and what parts of the ecosystem are likely to be most affected. This has the potential to contemporise kaitiakitanga in the marine environment by developing a distinctive product, process, system or service that responds like the adaptive resource management approach, as provided for in the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012. Working closely with the project leader and team will identify whether further investigation is necessary and how the VM programme and Dynamic Seas programme will work together to address that need. Opportunities for capacity building in relation to the project's field experiments, interactions with iwi resource managers and hapū will also be provided.

M. COMMUNICATION AND OUTREACH

We will use stakeholder workshops in Our Seas and Valuable Seas and hui in Tangaroa as important vehicles for communication and co-learning. We will engage directly with stakeholders, investors, managers and policy makers to ensure of scientific findings are translated and considered in the context of choices and actions. We will use the outreach and Communications facilities of the Challenge to the fullest effective and engage with communities and school groups through Discovery Centre (UoA) and Marine Studies Centre (UoO)

N. CAPACITY BUILDING

Empirical experiments will substantively add to the capacity of this interdisciplinary research. We will train students and researchers in thinking and using complex system models and school students in developing simple tools that allow results of models to played out. We will work in partnership with *Tangaroa* (Prg 3) in 'Kaitiakitanga in Practice' to build capacity in iwi led environmental management. Across society and within marine governance institutions we will engender constructive thinking about the resilience of marine ecosystems.

O. ETHICS APPROVAL

Animal or Human ethics approvals are not needed for this research.