SUSTAINABLE SEAS | Ko ngā moana whakauka | National Science Challenges

Project Proposal Template

A. TITLE OF PROJECT

Spatially explicit decision support tools

B. IDENTIFICATION

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C. ABSTRACT

This project forms a key component of the Managed Seas programme, developing spatially-explicit decision-support (SEDS) tools to inform decision making. We will build SEDS models that are able to explore trade-offs between different resource uses, objectives and stakeholder values, and their impacts on biodiversity and ecosystem health. We will develop techniques that evaluate whether different representations of biophysical data and socio-cultural values, and their associated uncertainty modify model outcomes, a key challenge in EEZ scale management. To examine cumulative impacts of multiple stressors in the focal region, we will develop spatially explicit models that incorporate multiple scales and intensities of disturbance. These tools will be developed in partnership with the key policy and management practitioners in Government, Māori, community and stakeholder organisations and institutions. By integrating the stakeholders and practitioners into development of the models through participatory interactions supported by the Challenge's Cross Programme activities, we will ensure the tools and frameworks are 'fit for purpose' and are fully integrated and tested within the existing management systems.

D. INTRODUCTION

Ocean management is complex, and is challenged by increasing pressure from population growth, climate change, and a diversification of both new and historical resource uses [1,2]. Ecosystems are highly variable, complex networks between interacting species and the physical environment, where changes in one part of the ecosystem may have cascading system-wide effects [3,4]. Interactions between humans and natural systems also influence the system dynamics, and management must also consider trade-offs between economic, social, cultural and environmental objectives, and their effect on ecosystem resilience [5,6]. The consideration of such large and highly connected socio-ecological systems is a key challenge for management [5,7], and an understanding of the scientific uncertainties are essential for accurate evaluation of potential outcomes and trade-offs.

Spatially explicit decision support tools (SEDS) are one set of approaches to inform EBM, using a range of methods that visualise and/or incorporate spatially-explicit overlaps in resource use, stakeholder, community and Māori values, and environmental impacts to inform decision-making. These tools encompass a range in iterative complexity from those that enable visualisation of spatially explicit datasets (e.g., NABIS, eAtlas, DOC GeoPortal), through those that provide for simple scenario analysis combined with mapping to inform decision-making (e.g., MarineMap[8], SeaSketch[9]), to tools that analyse implications of different management scenarios (e.g., NIWA's benthic disturbance/recovery models[10,11]), and optimise management across potentially conflicting uses (e.g., Marxan[12]; Zonation[13]), or across different ecosystem services[14].

Recent New Zealand marine applications where SEDS have informed decision-making include the Chatham Rock Phosphate EPA application[15]; the Ross Sea, Antarctica MPA application[16]; the SPRFMO Vulnerable Marine Ecosystem analysis[17,18]; the Department of Conservation's Ecosystems of Significance project[19], and the Hauraki Gulf Marine Spatial Plan[20]. These decision-making processes have highlighted some of the current key challenges in using SEDS, including uncertainty in the spatial distributions of modelled species commonly used to inform spatial optimisations[15,21,22], and uncertainty in how different resource uses (e.g., deep sea mining) and cumulative impacts are likely to impact on biological communities and ecosystem health[23,24]. Further challenges include a lack of guidance on how to weight different data layers, values and resource uses as to their relevance and relative importance in management scenarios[25], and how to accommodate quantitative biophysical data alongside socio-economic data which is often qualitative in nature. This project will address these key challenges bydeveloping novel techniques and adapting SEDS tools to create new applications that suit the evolving world of ecosystem-based management.

E. AIM OF THE RESEARCH AND RELEVANCE TO OBJECTIVE

This project will develop a suite of spatially explicit decision-support tools to support ecosystem-based management, within the New Zealand context. These SEDS tools will provide the basis for economic development and environmental protection through facilitating risk and trade off (economic, cultural, social, environmental) assessments. In phase one (2016-2019), this project will develop spatially explicit decision support frameworks and tools and apply these to case study areas within the focal region. Case studies for tool developments are anticipated to focus on key spatial management design challenges that have been previously identified, using datasets and questions of relevance in the focal region. These are likely to include applications that address: 1) incorporation of multiple extractive uses with different scales and intensities of impact, or different types of biodiversity protection with unequal benefits across species or habitats; 2) incorporation of both quantitative and qualitative ecosystem services; 3) challenges in understanding the implications of uncertainty in either species distribution models and habitat suitability predictions, or in socio-cultural value layers on model results; and 4) incorporation of multiple scales and types of disturbances in evaluating ecosystem resilience. Case studies will be prioritised based on concurrent work throughout the Challenge programmes, identified through stakeholder engagement in *Our Seas* Project 1.1.1 and 1.1.2 (Participatory Processes) and within the Challenge Cross-Programme Projects, and also be aligned with the case study areas and scenarios identified in the *Managed Seas* Project 5.1.1 (Whole of ecosystem models) and Project 5.1.4 (Participatory tools). Models will be parameterised by information collected in *Valuable Seas* and *Tangaroa* (socio-economic and cultural layers) and in *Dynamic Seas* (biophysical disturbance impact layers, relative impacts of different management scenarios). In phase two we will extend the development of spatially explicit tools to other locations/systems, and further integrate these tools across the Programme projects.

F. PROPOSED RESEARCH

This project will consider what spatially explicit decision-support tools will work best to support ecosystem-based management, within the New Zealand context. There are two aspects of SEDS development within the first phase of the Challenge:

(1) Prioritisation and trade-off models

Quantitative methods and computational tools for spatial conservation prioritisation (e.g., Zonation, Marxan) have been developed in recent decades to allow decision-making to balance biodiversity datasets against perceived costs to resource users in selecting optimal areas for biodiversity management[12,13]. Use of these spatial optimisation tools is now commonplace, with a range of recent NZ applications[16,17,20,26]. However, the datasets available for decision-making are often poorly suited for cost-benefit or cost-effectiveness analyses, and development of SEDS tools and their applications is ongoing to develop new techniques that provide robust solutions to management requirements within existing data limitations. For example, how should we, in a New Zealand context, reconcile different management options or resource uses and their impacts on biodiversity within a cost-benefit analysis? To better incorporate uncertainty and use of species distribution models in spatial prioritisation analyses, we also need to better understand the effect of different representations of species distribution and habitat suitability predictions, and uncertainty within these predictions due to differences in different modelling algorithms (e.g., Boosted Regression Trees, MaxEnt) on optimisation model outputs.

Here, we will create new applications (modules) and techniques for software tools that suit the evolving world of ecosystem-based management. Most of these developments will build on existing software and applications (e.g., multiple management zones in Marxan[27]). We envision exploring four main concepts in the first phase of the Challenge within the focal region, with a focus on case studies in Tasman and Golden Bay, and on the Chatham Rise. We anticipate that ongoing management needs for spatial conservation prioritisation will result in identification of further research and modelling adaptations for development in the second phase of the Challenge. The phase one applications will be informed by case study engagement with Maori and stakeholders, and are anticipated to include:

1. Exploration and refining of techniques that incorporate uncertainty in modelled species distribution layers and habitat suitability models, and in socio-cultural value layers, and how this affects optimisation predictions in spatial prioritisation exercises.
2. Development of techniques that allow incorporation of multiple scales and intensities of resource uses that are common in complex multi-user marine environments.
3. Development of techniques to allow cost-benefit or cost-effectiveness analysis using multiple types of management zones, where each management zone is associated with different positive or negative impacts on key species and habitats.
4. Development of weighting techniques that allow incorporation of both quantitative and qualitative layers in the evaluation of cost-effectiveness of difference scenarios that include different types of ecosystem service layers.

(2) Disturbance and recovery models

This second theme within the SEDS project will adapt an existing modelling tool to examine seafloor disturbance within the case study area (Tasman and Golden Bays), which occurs from three fishing sectors (oysters, scallops, finfish), in addition to land-based impacts resulting in sedimentation plumes, and natural disturbances from storms, waves, and tides. Within this project, we will develop better understanding of the multiplicity of influences on community dynamics, including both natural and human-induced disturbances that cause ecological responses at different spatial and temporal scales[28]. When these disturbances occur at large scales over areas of high environmental variability, it is difficult to assess impacts using either species richness or individual species distributions due to species-specific responses to environmental drivers (e.g., exposure, sediment, temperature) and species interactions[29]. Heuristic tools such as models can be used to predict changes in community dynamics at scales relevant to science and management perspectives that are difficult or expensive to examine empirically[10,30]. While models cannot predict real distributions of species with respect to disturbance, we can facilitate our understanding of how organisms are distributed under different management scenarios. Unfortunately the majority of tools available for addressing impacts on biodiversity incorporate simplifications such as logistic/production functions that are likely to over-estimate recovery rates as they ignore species interactions and habitat dependencies.

Here, we will develop spatially explicit disturbance/recovery models that incorporate multiple scales and intensities of disturbance (e.g., natural disturbance, mining, benthic fishing) for the case study area. As impacts on benthic communities are key concerns for multiple economic uses of the seafloor, our case study in phase one of the Challenge will entail a model of benthic impacts. We will adapt an existing individual-based model of benthic functional groups to contribute to a Management Scenario Evaluation approach to quantify the relative benefits to functional diversity (and thus ecosystem function) for different management scenarios such as spatially restricted fishing areas, rotating harvest closures, reduction of fishing effort (disturbance rates), and methods for monitoring fishery impacts and recovery processes. Specific model development will be determined through interactions with stakeholder communities (particularly fisheries and mining/petroleum industries), and in response to national and international policy needs. A key novelty of this project is that it will be directly testing scenarios alongside other decision-support tools within other Managed Seas projects, allowing for comparison of model results across different tools with different data requirements and model complexity. Key project steps proposed include the following:

- Workshop with industry, stakeholders and resource management agencies to determine suitable management scenarios to evaluate for the case study area of the Tasman Golden Bay region.
- Develop spatially explicit models that incorporate multiple scales and intensities of disturbance in the case study area.
- Populate the model to investigate multiple concurrent benthic disturbances, e.g. coastal sedimentation, climate-related changes in storm frequency, fishing impacts, mining impacts.
- Use data collected in Dynamic Seas to refine models and incorporate higher resolution data on temporal and spatial scales of benthic impacts.
- Phase II: Apply SEDS to areas outside the focal region for assessing impacts and trade-offs for use by Maori, stakeholders and resource managers in the implementation of EBM.

G. ROLES, RESOURCES

The project will be led by Dr Carolyn Lundquist, who has extensive experience in marine spatial modelling using multiple types of approaches, models and software, and in engaging with a wide range of stakeholders during the process of developing scenarios and models. She will be supported by an experienced research team, in particular John Leathwick, who has led innovative research in species distribution models, statistical analysis, and biodiversity prioritisation in freshwater, terrestrial and marine ecosystems in New Zealand. Lundquist and Leathwick are the New Zealand experts that are called upon to perform spatial prioritisation exercises to support marine spatial management in New Zealand, including recent spatial planning processes (e.g., Hauraki Gulf Marine Spatial Plan), resource consent applications (e.g., Chatham Rock Phosphate), and other spatial assessments (e.g., Ross Sea MPA proposal by New Zealand and USA, South Pacific Regional Fisheries Management Organisation analysis presented by New Zealand in October 2015). Lundquist has also developed a number of other modelling applications, for example, a model of fishing disturbance that will be built upon in this project, and spatially explicit models of density dependence for invertebrate fisheries, and recently lead authored a chapter for the IPBES assessment on scenarios and models of biodiversity and ecosystem services.

In the first component of the research (prioritisation and trade-off models), both Lundquist and Leathwick will contribute, supported by Owen Anderson and GIS and database technical staff. In the second component (disturbance and recovery models), Lundquist will be assisted by Prof Simon Thrush and Dr Giovanni Coco, who both have been involved in the modelling and strategic development of the disturbance recovery model approach, and other complex systems models. The postdoctoral associate will be involved in both aspects of the project.

Throughout the project, strong links with other Challenge Programmes (*Our Seas*, *Valuable Seas*, *Tangaroa*, *Dynamic Seas*) are required. Lundquist provides direct links with *Our Seas*, as Programme Leader, that will provide necessary stakeholder engagement to support co-development of the SEDS models, and with other programmes as member of the Science Leadership Team, for which significant interactions between projects are required to provide information on socio-economic and cultural value layers to parameterise the SEDS models (in particular, *Valuable Seas*, *Tangaroa*). Thrush leads one of the *Dynamic Seas* project that will provide biophysical information to parameterise the model.

Name	**Organisation**	**Contribution**
Carolyn Lundquist	NIWA/UoAuckland	Project leader, ecological modelling, marine spatial planning, socio-ecological systems
John Leathwick	Private consultant	Biodiversity prioritisation, species distribution models, ecological statistics
Owen Anderson	NIWA	Fisheries stock assessments, deep-sea ecology, habitat suitability models
Giovanni Coco	UoAuckland	Ecological modelling, complex systems, physical oceanography
Simon Thrush	UoAuckland	Ecosystem function and measuring ecosystem services, disturbance/recovery dynamics

H. LINKAGES AND DEPENDENCIES

The programme links closely with the other programmes within the Challenge. Engagement with key agencies, Māori, and stakeholders is necessary to ensure the decision-support tools are relevant to ecosystem-based management challenges that have been identified within the case study; as such, this project will be linked closely with the *Our Seas* and *Tangaroa* Programmes, and other engagement activities that are supported by Cross Programme activities. Potential management needs to focus tool and application development will be identified and prioritised based on stakeholder engagement within *Our Seas* Project 1.1.1 and 1.1.2 (Participatory Processes) and within the Challenge Cross-Programme activities in the case study area. When feasible, modelling scenarios will be aligned within the case study areas across the different *Managed Seas* Projects particularly including 5.1.1 (Whole of ecosystem models) and Project 5.1.4 (Participatory models). Key information required to drive socio-economic and cultural value layers will be developed within the *Valuable Seas* programme. Strong programme links exist with *Dynamic Seas* through its provision of data to determine functional relationships assumed in models, as well as undertaking scientific studies to carry out model validation. In addition via the Māori and stakeholder engagement processes, we will also work in partnership with key science advisory, policy analysts, and operational managers from different Government, Māori, community and stakeholder organisations and institutions to ensure tools developed are "fit for purpose".

I. COLLABORATIONS

The success of this project is not dependent on any national or international collaborations. Key national stakeholders include the Department of Conservation, the Ministry for Primary Industries, and the Ministry for the Environment.

J. INTERNATIONAL LINKAGES

This project will strongly build on existing collaborations with colleagues at the Conservation Biology Informatics Group, University of Helsinki (Atte Moilanen), CSIRO (Simon Ferrier), University of Melbourne (Jane Elith, Brendan Wintle, Mark Burgman), and The Ecology Centre, University of Queensland (Hugh Possingham, Maria Beger, and others) in spatial conservation prioritisation tools, species distribution models and uncertainty analysis. The spatially explicit disturbance recovery model will benefit from recently initiated collaborations with the Institute of Marine Research in Norway (Lene Buhl-Mortensen; Pol Buhl-Mortensen) and the University of Oldenburg in Germany (Jan Freund, Lukas Meysick).

K. ALIGNED FUNDING AND CO-FUNDING

The proposed work aligns with NIWA Coasts and Oceans Centre core funded 'Our changing ocean' programme and NIWA's Fisheries Centre core funded 'Ecosystem Approaches to Fisheries Management' programme. While the project is presently independent of aligned NIWA core funding, it builds on approaches developed under NIWA's Biodiversity and Biosecurity OBI (now core funding in 'Our changing ocean'), and Aquatic Restoration programmes. The spatially explicit disturbance recovery model (which builds on approaches developed under NIWA's MBIE funded Marine Futures programme, NIWA's FEEARS programme, and MPI BRAG Funding (ZBD200295)) is presently being examined for its use in predicting indicators of tipping points under a project funded within 'Our changing oceans' (project COME1602). Information on dispersal modes and effects of connectivity of regional species pools on recovery gained within aligned core funding (COME1601) will be utilised within this project.

At present no co-funding arrangement exists, however, given the number of recent freshwater and marine spatial prioritisation applications undertaken recently by project members it is likely that co-funding will develop throughout the project.

L. VISION MĀTAURANGA (VM)

Vision Mātauranga is seeking 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). It is considered that there is an opportunity in this project to develop innovative and/or distinctive products, processes, systems, and services through the development of new tools that enhance understanding and participation in ecosystem-based management.

One of the four themes in VM is Taiao. This theme looks to achieve environmental sustainability through iwi and hapū relationships with land, and in this Challenge, sea. Māori are active participants in resource management, as well as having world views with strong environment ethics, as evidenced in recent EPA hearings on potential minerals and petroleum exploration on the seafloor that used biodiversity prioritisation tools and species distribution models to inform placement of potential mitigation sites to protect biodiversity. Spatially explicit decision support tools have the potential to support the role of kaitiaki by providing management tools spatially specific to their area of interest or mana motuhake, while at the same time, providing tools to support Māori investors in investment decisions. Decision-support tools will be developed that integrate mātauranga Māori, enabling predictions to be evaluated with respect to cultural standards, and iwi and hapū wellbeing.

Another theme of VM is Mātauranga. Engagement with iwi and hapū and incorporation of mātauranga and tikanga Māori into the design of the research are integral to the long-term success of the project and for enacting EBM. As kaitiaki of the sea, mana whenua have invaluable knowledge and expertise that can enhance environmental decision making. The dual responsibility of Māori as kaitiaki and as partners in emerging co-governance and co-management arrangements requires collaborative engagement to allow knowledge sharing and the co-development of appropriate management tools. This research will build Māori capabilities in social and ecological sciences and environmental decision making that will have beneficial effects at the local level and as partners in environmental management.

M. COMMUNICATION AND OUTREACH

There are a wide range of stakeholders and end-users that participate in, or manage marine resources and the marine environment that supports generation of these resources. Those that will directly benefit from the knowledge and tools produced range from the regional to national level, and include MfE, MPI, DoC, Maritime NZ, EPA, iwi, hapū, regional authorities, and fishing and mining/petroleum exploration sectors. This broad engagement will generate many communication and outreach opportunities for the Sustainable Seas Challenge. In particular, we anticipate broad engagement opportunities associated with models developed to support participatory decision-making processes within the case study area. These engagement processes will be coordinated across the entire Challenge, minimising stakeholder fatigue, and coordinating objectives and scenarios across all Challenge projects.

N. CAPACITY BUILDING

Capacity building will be achieved via supervision of early career Post-doctoral research associate in ecological modelling, jointly supported via NIWA aligned funding. Further capacity to integrate decision support tools into decision making will be developed with Māori, industry, civil society, policy makers and managers in the use of spatial management tools to resolve trade-offs and assess environmental impacts.

O. ETHICS APPROVAL

Ethics approval is not anticipated to be required for this desk based modelling project. Should linkages with other participatory process projects require human ethics approval, ethics approval will be sought from NIWA's Human Research Ethics Committee.

Q. REFERENCES

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