SUSTAINABLE SEAS | Ko ngā moana whakauka | National SCIENCE Challenges

Innovation Fund Research Proposal

A. PROJECT TITLE

Sediment tolerance and mortality thresholds of benthic habitats on the Taranaki Shelf

B. PROJECT TEAM

Project Leader:	Investigators:
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C. ABSTRACT

The research in this project will determine the effects on deep-shelf benthic communities of elevated suspended sediment concentrations caused by human activities, such as seabed mining and fishing. Whereas sedimentation impacts on biological communities have been studied in very near-shore coastal environments, little information exists on tolerances of fauna from deeper shelf waters. This research will measure acute and sub-lethal physiological effects for selected marine taxa, and help establish threshold levels of suspended and settled sediment where impacts on deep-sea species become "ecologically significant". This will subsequently provide information to mitigate or manage impacts on such benthic communities. In addition, comparisons will be made of responses of the same species from shallow and deep water to explore relative sensitivities across a range of shelf depths. The work programme involves innovative laboratory experiments to assess impacts on diverse benthic fauna (sponges, bivalves, bryozoans) which are common and ecologically important biogenic habitat formers in the South Taranaki Bight. The work will inform ecosystem-based management initiatives within the Sustainable Seas programme, and extend the programme focus to deeper shelf waters, as well as having wide relevance to deep-sea communities in general across the New Zealand region.

D. RELEVANCE TO CHALLENGE OBJECTIVE

The research is aligned to the Objective of the Challenge by measuring biological responses to extraction methods within the focus region, as well as broader New Zealand waters. The research will:

- Support the Government's strategic priority to derive benefits from seabed resources while maintaining the sustainability and integrity of the natural environment;
- Address future investment signals in the National Statement of Science Investment (better understanding of the environment, reduced or mitigated environmental impact and risk); and
- Help fill a gap in offshore issues of the Sustainable Seas Challenge mission to enhance the utilisation of marine resources within environmental and biological constraints.

E. INTRODUCTION

Elevated suspended sediments can occur in coastal marine systems due to input from land, and disturbance of seafloor sediments from human activities, such as mining or fishing. The impacts of such events on deep-sea fauna are not well known. Recent applications by Trans-Tasman Resources (TTR) and Chatham Rock Phosphate (CRP) for mining permits were declined in 2014 by the Environmental Protection Authority (EPA), with a key reason being "*uncertainties in the scope and significance of the potential adverse environmental effects*". Understanding the diversity of impacts, particularly the effects of elevated suspended sediment concentrations (SSC), is challenging, yet improving knowledge of these is an important part of scientific research to progress efforts towards exploitation balanced with environmental sustainability.

Sponges, bivalves and bryozoans are widespread around New Zealand, where they are important contributors to ecosystem functioning (e.g., via benthic-pelagic coupling, providing biogenic habitat, enhancing biodiversity; Hewitt et al. 2005, Dewas & O'Shea 2011, Bell et al. 2015). They are potentially sensitive to sedimentation effects, but little is known. The majority of studies of sediment impacts on sponges have focused on shallow water species with only Tjensvoll et al. (2013) studying a deeper species (*Geodia berretti* (NE Atlantic)), where they recorded a major reduction in respiration rates when exposed to sediment loads. In New Zealand there has been just one study of sponge response to SSC in the shallow water *Tethya* sp. (Murray 2009). Similarly, there has been only a single study on New Zealand bryozoan responses to SSC, which found lowered feeding activity of an intertidal species, and evidence of cuts and abrasions by silt and clogging of feeding apparatus (Best & Thorpe 1996). There are, however, documented negative effects of elevated SSC on several shallow water New Zealand bivalves (e.g., pipi, cockle, horse mussels; Ellis et al. 2002, Hewitt & Pilditch 2004, Hewitt & Norkko 2007, Safi et al. 2007, Norkko et al. 2006). Anecdotal evidence from around New Zealand suggests sedimentation and run-off effects include decreased sponge cover (Parsons et al. 2004, Morrison et al. 2014), reduced distribution of dog cockle, *Tucetona laticostata* (McKnight & Grange 1991, Dewas 2008), and decreased colonisation rates of bryozoans (Batson & Probert 2000, Grange et al. 2003). Nevertheless, many species are able to tolerate sediment and have specific adaptations to cope (e.g., cessation of pumping, mucous production, development/modification of skeletal structures to prevent sediment intake, reversal of water currents and expulsion of large particles), but the thresholds at which these become ineffective in maintaining normal functions are unknown.

In this proposed study, we will test the extent to which deep-sea sponges, bivalves and bryozoans are sensitive to SSC, and additionally whether for the same taxa found in both deep and shallow waters, those from the deeper environment will be more susceptible to such disturbance. This will be the first attempt to measure threshold rates of SSC on deep-shelf taxa in New Zealand, and hence will provide a new and innovative line of research to the Challenge, as well as being directly relevant to the main Challenge objectives.

F. AIMS

The research will:

- Define ecologically significant thresholds of SSC, and acute or sub-lethal impacts for selected ecologically important marine taxa in soft sediment deep-shelf areas of New Zealand.
- Compare the effects of SSC on the same species collected from shallow and deep water allowing an assessment of variation in species sensitivities with habitat characteristics.
- Contribute to sedimentation components of Ecosystem Based (EB) models, by providing information on (i) levels of SSC likely to impact the benthos, (ii) real data on SSC to improve definition of the model's biological parameters, and (iii) the suitability of the model's existing biological parameters to document these impacts.
- Extend the Challenge scope into deeper shelf waters, enhancing the relevance of the outcomes.

Results will provide information that commercial industry and environmental managers can use to mitigate or manage impacts from human-induced sedimentation on benthic communities and enable threshold levels of sediment load to be set. These are fundamental outputs to help support the Challenge objective of enhancing utilisation of resources within environmental constraints, and its mission that includes increasing use while maintaining ecosystem health of marine assets. Results will be published on NIWA/Sustainable Seas webpages, in publicly-available reports and in scientific papers.

G. PROPOSED RESEARCH

Study area and species:

Our focus regions include Patea Shoals, South Taranaki Bight (60-80 m), and the Wellington south coast (<20 m). These areas are part of the Sustainable Seas study region but will extend the scope into deeper water. This project will study important and dominant species of this region—an encrusting sponge (*Crella incrustans*); the dog cockle (*Tucetona laticostata*); and a bryozoan species (Family Catenicellidae) (see Beaumont et al. 2013).

Crella incrustans is a common subtidal demosponge, which is distributed extensively throughout New Zealand (Kelly 2015). It is an important ecological component of subtidal reef systems due to its abundance (e.g. Berman & Bell, 2010), competitive and facilitative interactions with algae in shallow water (Cárdenas et al, 2012), and strong pelagic interactions through feeding activities (Perea-Blázquez et al. 2012). We focus on *C. incrustans* because it is widespread, a potential representative species for impact studies (e.g., ocean change, microplastic pollution: Bates 2015); our previous successes maintaining this species in laboratory studies (Bermann & Bell 2010, Bates 2015); and its defined oscula that facilitates feeding and nutrient studies.

Tucetona laticostata is a large infaunal bivalve common in sand, shell and gravel substrates in coastal areas (<80 m; Powell 1979). There are relatively dense beds in the Challenge area, including South Taranaki Bight (Gillespie & Nelson 1996), Tasman and Golden Bays (Grange et al. 2003) and Marlborough Sounds (Davidson et al. 2010). *T. laticostata* appears to prefer clean-swept areas of high water flow, particularly in channel environments and off headlands (Fleming 1950, Powell 1979), but is also found in less dynamic (e.g., sheltered, deeper) soft sediment environments, where it forms biogenic, structurally complex habitat. While the robust shell makes it resistant to damage, it is potentially susceptible to sedimentation (McKnight & Grange 1991, Dewas 2008).

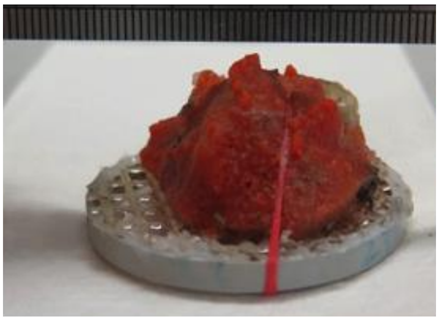
Catenicellid bryozoans in the Taranaki region include bushy colonies up to ~15 cm high: *Costaticella bicuspis; C. solida; Orthoscuticella fissurata; O. innominate; O. margaritacea*. These species are widespread throughout New Zealand waters. Although bryozoans can be hard to cultivate, a New Zealand species was successfully collected from ~80 m off Otago and maintained in the laboratory (Batson et al. 2016).

These species, and their habitats, are all widespread, and therefore our results will have relevance beyond the proposed study areas.

In situ images of the three study taxa (l to r): *Crella incrustans*, *Tucetona laticostata*, catenicellid bryozoan colony

<u>Sample collection and setup</u>:

Samples of the faunal groups (and associated sediment) will be collected at sea during a voyage of RV *Kaharoa* using grab/box-corer equipment (or SCUBA in shallower areas). They will be held in on-board aquaria and transferred to NIWA's Marine Environmental Manipulation Facility (MEMF) in Wellington, where running seawater and related environmental conditions can be precisely controlled. They will be maintained in tanks at low-light, and at flow rates and temperatures similar to those of their natural environment. All organisms will be pre-screened following collection to ensure only visibly healthy and feeding specimens are used. Sponges will be attached to a plastic disc with mesh across it (right) and kept in continuous seawater for one week prior to experiments to enable them to attach to the disc. Feeding regimes (frequency, food type) will be set dependent on the requirements of the specific taxa.



In the first phase (Year 1), the focus will be to measure key parameters at the collection sites, and to hold the organisms in the laboratory for a period to ensure conditions are optimal for maintaining healthy specimens. In the second phase (Year 2), we will assess responses of *at least two of these species* to elevated SSC.

<u>Experimental design:</u>

Our experiments will investigate the impacts of (i) SSC and (ii) SS exposure time on survival and multiple physiological response variables. For each species, four treatments (three elevated SSC and a non-disturbed control), with at least four replicates per treatment will be investigated. The choice and number of species will depend on the findings of Phase 1 and collection of sufficient numbers of individuals to satisfy the experimental design.

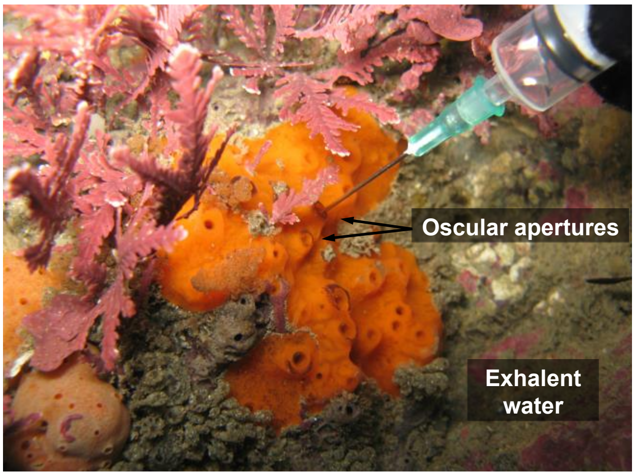
SSC and composition and will be based on new measurements during sample collection and existing data on seafloor sediment particle size (e.g., South Taranaki Bight; Beaumont et al. 2013). To enable environmentally relevant threshold levels to be measured, we will manipulate the particle size component of these sediments likely to be suspended following disturbance (e.g., from storm/waves, mining or dredging). Depending on the particle size and volumes required, we will use sediment collected from the field site (defaunated by drying), or commercially purchased sediments (e.g., koaline and marble dust). Target SSCs will be maintained for a duration of one month.

Sedimentation can affect organisms in a number of ways, and so we will measure multiple response parameters that, together, will provide information on their functioning under elevated SSC. While acute effects (survival) is a key measure, our focus will be on chronic sub-lethal effects of exposure, including: effects on metabolism (respiration, pumping rates)(e.g., Kutti et al. 2015) feeding activity (clearance rates, visual polyp assessment) (e.g., Buhl-Mortensen et al 2015, Bakus 1967, Best & Thorpe 1996), mucous production (important in sediment removal) (Bell et al. 2015), changes in or damage to skeletal/shell form and size (e.g., Ilan & Abelson 1995, Best & Thorpe 1996), and physiological condition—as appropriate for each study species. These responses will be evaluated on multiple occasions over the experiment, and maintenance of several individuals within each replicate tank will allow us to sacrificially sample organisms at predetermined intervals (e.g., after 1, 2, and 4 weeks exposure, and 2 weeks post SS). A summary of variables to be measured is given below:

	sponges	bivalves	bryozoans
Survival	x	x	x
O_2 consumption	x	x	x
Growth	x		
Tissue necrosis	x		
Feeding rates/ Particle sorting efficiency	x	x	x
Structural damage			x
Mucous production	x		
Condition	x	x	x

Survival and general health will be assessed regularly over the experiment. Sponge health (e.g., evidence of necrosis/disease, growth, tissue regression) will be evaluated using photographs taken at each sampling interval, and evaluated using a qualitative response scale. Bivalve health will be quantified via physiological and physical condition calculated using ratios of dry flesh weight (dried at 60^{o}C for 48 h) to dry shell weight (air dried for 48 h), and shell weight to shell length, respectively (e.g., Roper et al. 1991). This will be done prior to the experiment start, at the experiment mid-point, and end (multiple individuals will be included in each experimental replicate to enable destructive sampling at set points). Bryozoan polypide health (occurrence of regressed or dead "brown-body" polypides) will be assessed using light microscopy at the end of the experiment only. High resolution macro-photography (SEM) will quantify physical damage to sponge polyp and bryozoan hard parts at the end of the experiments.

Metabolic activity will be assessed using oxygen consumption measurements. For *C. incrustans*, O_2 consumption will be measured prior to the experiment start, 1, 3 and 5 days after the start, every following 5 days until 2 weeks after the experiment (the latter to assess recovery). Individual sponges will be placed in 75 mL Perspex respiration chambers, fitted with an oxygen electrode and temperature probe, and a magnetic stirrer set to 180 rpm (after Bates 2015). Similar methods will be used to determine O_2 consumption of *T. laticostata*, using larger chambers and dissolved oxygen sensors (Zebra Tech NZ), at the end of the experiment. For bryozoans, O_2 consumption of the colonies via the polypides will follow the method of Gammon (2016) developed for deep-sea scleractinian corals. For all taxa, seawater blanks (without organisms) will also be measured to account for any background respiration by microorganisms, and results will be adjusted for the volume of water in the chamber and size of the individual. In conjunction with sponge O_2 consumption measurements, exhalent water flow will be measured (for a minimum of 15 minutes, using a thermistor flow meter) to determine effects on water pumping ability and choanocyte function.



Feeding efficiency: With sponges and bryozoans, we will sample the food particle concentration in the ambient water, and in the water leaving the sponge osculum. Given the food will be a similar size to the fine sediment treatment, we will use flow cytometry to determine concentrations in the ambient and exhalent water (see Perea-Blázquez et al. 2012). Comparisons with control treatments (no sediment) will indicate potential negative impacts on feeding efficiency. This will be repeated at the same intervals as the respiration and flow measurements (but staggered). Evaluation of feeding efficiency in bivalves will follow methods summarised in Hawkins et al. (1998) for determination of clearance rates.

Fate of sediment particles and mucous/cellular debris: We will conduct additional short-term exposure experiments where sponges, bryozoans and mussels will be kept in aquaria with fluorescent-stained sediment particles. A combination of histology and fluorescent microscopy will be used to track the fine particles in the organism's tissues. In addition, for sponges, we will measure the concentrations of dissolved organic matter over time (hours) in exhalent sponge water within the same experiment to explore the production of mucous and potential turnover of sponge choanocytes as a response to sediment clogging (see de Goeij et al. 2013).

Statistical analysis:

We will use a number of standard approaches for data analysis, including ANOVA and *post hoc* testing, to identify significant effects of the treatments on the various response variables. Where appropriate, repeated measures ANOVA will be used to derive trends over time (e.g., in feeding behaviour, respiration rates). Similar analytical approaches have proven successful in previous studies (e.g., Ellis et al. 2012). The output of the analyses will be discussed with other Sustainable Seas team members, to ensure compatibility with parameters required for modelling efforts under the Managed Seas programme (see below).

Translating experimental results to actual impacts

An experimental approach under controlled conditions is an effective means of assessing the likely impacts of various levels of sedimentation. We have chosen the three taxonomic groups specifically to represent abundant and functionally important organism types, as well as key biogenic (structural) components of benthic communities in the region. Understanding impacts of SSC on these taxa will thus inform impacts on the wider benthic communities. Importantly, we will provide real information on likely changes in these groups and communities to the biological parameters included in the Managed Seas EB models. We may also identify important parameters missing from these models. The intention to incorporate results into EB modelling will be an important means of advancing from experimental results into a wider framework of assessing impacts on benthic systems (see Section I below).

Linking the research with future baseline and monitoring work planned by TTR may also give an opportunity to test the experimental results where there is known disturbance by fishing or exploration mining activities. Validation could also be possible in other areas where similar habitat-forming taxa occur.

H. RESEARCH ROLES

Researcher	Organisation	Contribution
Malcolm Clark	NIWA	Project coordination and overview, biological sampling, report writing
James Bell	VUW	Sponge expertise, laboratory studies, data analysis, report writing
Vonda Cummings	NIWA	Laboratory expertise, experimental work coordination and overview, data analysis, report writing
Di Tracey	NIWA	Outreach and communication, biological sampling, report writing
Dennis Gordon	NIWA	Bryozoan expertise and advisory role
Peter Batson	University of Otago	Bryozoan expertise and advisory role
Neill Barr	NIWA	Laboratory technical overview
Sarah Allen	NIWA	Laboratory technical support
TBD	VUW	Masters student, biological studies, laboratory support, data analysis

I. LINKAGES AND DEPENDENCIES

The project will complement work being undertaken within projects 4.2.1 (*Tipping points in ecosystem structure, function and services*) by defining impact thresholds, especially component 2 (indicators of tipping points, including faunal health and mortality) and component 4 (using experiments to demonstrate mechanisms and consequences of change). The project also links to 4.2.2 (*Stressor footprints and dynamics*) through understanding biologically-relevant sediment densities to model transport. It will yield underlying information for project 2.1.3 (*Measuring ecosystem services (ES) and assessing impacts*) by determining levels of risk to biodiversity from sedimentation, complementing in particular work-streams 2 and 3 (measuring Ecosystem Services) of that project and impacts on ES delivery for Kaitiakitanga and the science and Mātauranga that go with being good stewards. The research can also inform project 2.2.2 by providing information on critical levels of environmental stress from sediment loading.

Ecological components of the Ecosystem Based Models (EBM)

The results from this project will feed into refinement and quantification of spatial and ecological components of the EB Model being developed for the Managed Seas programme. This is particularly relevant for balancing the effects of mining or fishing on the seabed and habitat requirements for juvenile fish and invertebrates, the role of habitat forming species, and other marine users.

The Atlantis EB model currently uses physical environmental variables (bottom type, patterns in water temperature, nitrogen), fishing intensity, various biological parameters (changes with age, growth, natural mortality, reproduction, diet preferences, and ecological components, (habitats and marine predator and prey relationships). Sedimentation impacts are 'hard coded' into the model (e.g., where bottom trawling is believed to have modified the seabed thus changing the habitat type, then this change is applied in the model as either a sudden change or a gradual change over a set area at a selected time). This work will (i) provide information on known levels of SSC likely to impact the benthos, and (ii) provide real data on the biological parameters under these SSCs. Together, these components will assist the development of coding within Atlantis to more realistically describe this process (V. McGregor, NIWA, Pers. Comm.), thus allowing measurable data on sediment loadings and rates which influence the distribution, health and abundance of benthic organisms.

There will be strong project linkages if a sedimentation effects proposal submitted to the current MBIE Research programme round is successful. This work includes a field disturbance experiment on the Chatham Rise, as well as laboratory experiments. The latter will use coral and different sponge species to complement the work proposed here, and enable a more generic evaluation of sedimentation effects.

The project does not duplicate any research being within the Challenge, nor in other NIWA projects. It will add new laboratory and experimental capability to the Challenge methodological portfolio.

J. RISK AND MITIGATION

Key risks:

1) The sampling on RV *Kaharoa* is a low risk, as vessel and gear are proven, but it is possible that we may not be able to collect enough samples of the species. However, we have chosen organisms that have been identified as abundant in earlier studies in the Taranaki region (Beaumont et al. 2013).
2) NIWA's MEMF is recognised as a state-of-the-art facility for conducting climate change experiments to investigate resilience of marine fauna. Temperature, pH, water flow and light control will ensure the deep sea organisms can be housed in conditions reflecting their natural environments. The MEMF is fully alarmed in case of system perturbations, has strong back-up and redundancy provisions, and experienced laboratory technical support. Maintaining consistent SSC will require some new method development, but we have previous experience at smaller scales and will review options such as paddle Vortex Resuspension Tanks developed in the UK for such work (Hendrick et al. 2016). We will upgrade thermistor gear for measuring sponge pumping rates accurately, but overall, we believe there are few risks associated with the laboratory equipment/systems.
3) We will be keeping a range of organisms in artificial experimental conditions and it is possible that they may not survive or may be negatively influenced by being in the aquaria system. However, our team is very experienced in keeping a range of marine organisms alive and in *ex situ* condition. Specifically, our team has already kept *Crella incrustans*, several mollusc species, and deep-sea corals in aquaria systems from several months to years.

K. ALIGNED FUNDING AND CO-FUNDING

There is no specific aligned funding from MBIE or NIWA. However, the work follows on from sedimentation research started under NIWA's MBIE-funded project "Enabling the Management of Offshore Mining" (contract C01X1228) which is mapped into Sustainable Seas.

The project has been discussed with Trans-Tasman Resources (Matt Brown). He has expressed a positive attitude towards the project, in that it would provide additional and complementary information to the overall baseline research programme that TTR is looking at developing. At this stage in their re-application process to the EPA, TTR can make no formal commitment to co-funding, but have expressed a willingness to consider support if they progress their sampling programme. This could include access to vessels if further sampling was required, and linking in aspects of their baseline and monitoring plans to "ground-truth" the experimental results.

L. VISION MĀTAURANGA (VM)

The project will complement work being undertaken within the research delivery for Kaitiakitanga and the science and Mātauranga that go with being good stewards. The importance of dialogue with local iwi, councils and the wider community is acknowledged and project includes time for science staff to liaise with the team of the Tangaroa and Our Seas Programmes.

Advice on iwi engagement has been sought from Te Kūwaha, but this will be followed up by discussions with James Whetu (Sustainable Seas Vision Mātauranga leader), Liana Poutou (chair of the Kahui for the Challenge) and Linda Faulkner (the Challenge's Tangaroa Programme science leader). We are aware that an advisor for the Dynamic Seas programme is to be appointed, and we will also consult with them.

In order to ensure there is good communication with Māori, links will be made with iwi (primarily in the Taranaki region) to ensure the Challenge's desired outcomes of the Taiao and Mātauranga themes of Vision Mātauranga, are achieved. Our team will work with the Challenge and Te Kūwaha colleagues in NIWA to develop close relationships where appropriate. In the first few months of the project, a hui will be held (with the support of senior Challenge staff) in Taranaki (Hawera or New Plymouth) to outline the project objectives and methods, and gain feedback from local iwi. This will ensure we have a "kanohi kitea" or "seen face" which is an important part of a successful working relationship to benefit Māori, and ensure also that we take into account their views and suggestions that can improve the research and its uptake.

Feedback to Māori, as well as to industry, and regional and central government, will be via informal meetings, entries on the Challenge website, and perhaps also blog postings. We will work with the Challenge Communications and Outreach Strategy team to communicate plans and results to a diverse range of end-users.

M. CONSENTS AND APPROVAL

We will ensure that all MPI biosecurity requirements are met. Our MEMF is PC level 2 accredited, and all water from the facility can be treated prior to discharge if required.

Sampling at sea will be within 12 nautical miles of the coast, and hence will not require any formal notifications to the EPA under the EEZ Act. Nevertheless, we will inform the EPA of our activities.

The experiments involve only invertebrate species, and hence there are no issues with animal ethics responsibilities.

N. DATA MANAGEMENT

At the commencement of the project, discussions will be held with key Challenge data personnel, to ensure that our data management plan fits with existing processes and systems.

Data management (checking, storage) will be based on existing and well-proven NIWA processes. For the ship-based collection, each sampling event and associated meta-data will be recorded and logged in NIWA's *Cruises db*, and systems are established for other data sources such as: CTD data processed and stored in *Fisheries CTD* db, and Physical Oceanographic CTD Archive; sediment samples in the NIWA Marine Geology store and files; surplus faunal samples deposited in the NIWA Invertebrate Collection (logged in the *Specify* collection db), and any photographic data recorded in NICAMS. We will serve information and data products through NIWA's Coastal and Marine Data website to facilitate ease of public access.

At each step, data will be entered and stored on NIWAs server network, and protected by NIWAs IT security systems, and disaster recovery programs. At the end of the project, all data will be provided to the Sustainable Seas Project or Data Manager.

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