Innovation Fund Research Proposal Template

A. PROJECT TITLE

Submarine canyons: how important are they for connecting coastal and deep-sea ecosystems?

B. PROJECT TEAM

Project Leader:	**Investigators:**
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C. ABSTRACT

Summarise what your proposal will achieve, including key innovations. Max 200 words.

The physical characteristics of canyons vary widely and largely determine the degree to which they connect coastal and deep-sea ecosystems.

In this project we will compare the contribution of land and coastal-derived plant material to the sediment and food web of the high productivity Kaikōura Canyon and the low productivity Hokitika Canyon using compound-specific stable isotope analyses (CSIA) and multivariate mixing models.

This method, which will be adapted for the study of connectivity between nearshore and deep ocean ecosystems for the first time, will provide insights into the mechanisms responsible for the exceptionally high productivity of Kaikōura Canyon seabed communities, which may be driven by food inputs from outside the canyon. On a global scale, the application of this and other tracer methods will help clarify the fate of the vast quantities of fine, land-derived organic matter entering the oceans but which does not get preserved in marine sediments.

In combination with a newly developed, biologically-focused canyon classification scheme, the results of the analyses for the contrasting canyons will be used to assess the wider regional influence that canyons have in the delivery of land-derived organic matter to support the productivity of New Zealand deep sea benthic communities.

D. RELEVANCE TO CHALLENGE OBJECTIVE

Demonstrate alignment with the Objective of the Challenge "Enhance utilisation of our marine resources within environmental and biological constraints". Use bullet points. Max 100 words.

The proposed research will directly align with Project 4.1.1 "Ecosystem connectivity: Tracking biochemical fluxes to inform ecosystem based management" by:

- Evaluating energetic subsidies between coastal and deep-sea habitats
- Tracing organic matter through marine food webs
- Predicting the input of terrestrial and coastal organic matter to the deep sea that is facilitated by canyons on a New Zealand scale, thus
- Providing knowledge that will help inform management measures designed to maintain ecosystem structure and function in deep-sea ecosystems

E. INTRODUCTION

Insert background, rationale and key details of your proposed research, including gaps in the Challenge that your research will address. Include why your work is important to the Challenge Objective. Max 500 words.

Deep-sea canyons that incise the continental shelf can facilitate the transfer of terrestrially and coastally-derived organic matter to the deep ocean, thus potentially providing important food resources to deep-sea benthic communities. Accordingly, some canyons are recognised as hot-spots of benthic biomass and activity; none more so than the Kaikōura Canyon, which hosts the highest biomass yet recorded at the deep seabed globally[1,2]. However, other canyons do not seem to be significant conduits of organic matter from the land and shelf nor influence the structure of deep-sea benthic communities[3]. Canyon morphology and distance from the land is thought to influence this variability in the degree of ecosystem connectivity[4,5]. Because the physical characteristics of canyons can vary considerably along continental margins[6], it is not straightforward to appreciate how important canyons are for connecting coastal and deep-sea ecosystems at regional scales.

The project will characterise two very different canyon systems: a very steep gradient, coast-proximal system off Kaikōura on the east coast of the South Island (Kaikōura Canyon), and a narrow, lower gradient, channel-like system off Hokitika on the west coast (Hokitika Canyon). The project will test the following hypotheses: (1) that the steep topography and proximity to the coast of Kaikōura Canyon results in higher organic matter enrichment from coastal and/or terrestrial sources relative to Hokitika Canyon, and (2) that this greater input of organic matter from shallow sources in Kaikōura Canyon fuels greater secondary productivity (benthic biomass) relative to Hokitika Canyon.

The project will utilise existing unanalysed sediment and benthic biological samples collected from previous MBIE-funded voyages to Kaikōura and Hokitika canyons and held in NIWA collections. Bulk and novel compound-specific stable isotope analyses will be used to identify the sources of organic matter in the sediments and for key benthic taxa in the canyons, and will involve comparisons with likely riverine and coastal sediment deposits along each of the respective coasts.

The results of the analyses for the contrasting canyons will be used to assess the wider regional influence of canyons to deliver land and coastal-derived organic matter to support the productivity of benthic communities of the deep sea around New Zealand. To this end, the project will complete and use an as yet unpublished geomorphological classification of New Zealand's canyons, which characterises various canyon attributes including distance from land and morphology.

The proposed research will expand on funded Project 4.1.1 "Ecosystem connectivity: tracking biochemical fluxes to inform ecosystem based management", which mainly focuses on biological vectors of land-sea connectivity in nearshore and continental shelf habitats (<200 m depths), by including deep-sea environments down to ca. 2000 m depth. By combining biological and geological data, the proposed project will also identify what geomorphological features of canyons lead to greater connectivity between shallow and deep water environments, thus expanding the scope of Project 4.1.1 to include physical drivers of connectivity.

F. AIMS

Explain in a set of bullet points what your project will achieve. Max 200 words.

The aims of the proposed research are to:

- Compare levels of sediment organic matter content and biomass of benthic organisms in Kaikōura and Hokitika canyons
- Quantify the relative contributions of land- and coastal-derived *vs* marine-derived organic matter to the sediment organic matter budgets of Kaikōura and Hokitika canyons
- Quantify the relative contributions of land- and coastal-derived *vs* marine-derived organic matter to the diet of selected seabed organisms of Kaikōura and Hokitika canyons
- Complete a New Zealand wide quantification of canyon morphometrics, and produce a canyon classification.
- Identify which canyons on the continental margins of New Zealand are likely to represent conduits of plant organic matter to the deep sea based on the new classification of canyons, and estimate their contribution to benthic biomass at a regional scale.

G. PROPOSED RESEARCH

Details of work plan and methodology, including choice of study location. Max 1800 words.

Study areas and sample collections

Kaikōura is described in the Sustainable Seas Science & Business Plan as a "resource-rich area within the focal region" and an area for "consideration for further case studies in Phase 2 of the Challenge". This proposal would provide an ideal springboard from which to develop research questions in future focus areas within the Challenge and in deep-water environments that are to be targeted in Phase 2.

About 1.5 million cubic metres of nearshore sediment is estimated to enter the Kaikōura Canyon annually[7]. Video footage of the seabed, and observations of sediment samples from the canyon axis, show that terrestrial plant detritus is abundant and suggest that subsidies from outside the canyon are substantial. DeLeo et al. (2010) emphasised the significance of Kaikōura Canyon as a hotspot of deep-sea benthic biomass in terms of the large epifauna[1]. They hypothesised that contributions from upwelling-induced primary production and nearshore and terrestrial organic matter provided the likely energy sources to fuel this high biomass accumulation. However the relative importance of marine *vs* terrestrial material in fuelling the canyon food web remains unclear.

In 2010, sediment bacteria, meiofauna and macro-infauna were sampled in Kaikōura Canyon as part of NIWA programmes C01X0203 "Consequences of Earth-Ocean Change" and "Vulnerable Deep-Sea Communities" to determine if the high biomass observed in the larger fauna was also translated into the smaller components of the benthic community. Preliminary analyses showed elevated meiofaunal biomass in the canyon relative to nearby slope environments[2].

On the west coast of the South Island, Hokitika Canyon has been the focus of several recent geology voyages that have revealed the previously unappreciated geomorphological complexity of the system[8]. In 2013, benthic sampling using sediment corers was undertaken as part of NIWA Core-funded programmes "Marine Physical Resources" and "Vulnerable Deep-Sea Communities" to collect complementary data from within the Hokitika Canyon as had been obtained previously from Kaikōura Canyon, including samples of bacteria, meiofauna and macro-infauna. Samples were obtained at similar depths as sampled in Kaikōura Canyon in 2010 in the Hokitika Canyon (ca. 200-2000 m) to allow direct comparisons. Preliminary analysis of samples from the axes of the two canyons show that the Hokitika Canyon has lower organic carbon content than Kaikōura Canyon.

General approach

The proposed research will rely on existing data as well as sediment and benthic fauna samples from previous voyages to Kaikōura and Hokitika canyons (see above) and held in NIWA collections. Data on sediment physico-chemical properties (e.g., grain-size, total organic matter, organic carbon and phyto-pigment content) are available from samples obtained from the axis of each canyon.

In Kaikōura Canyon, abundance and biomass data are available for bacteria and meiofauna from eleven sites (n = 2-4 at each site) sampled in 2010 along the canyon axis that are consistent with the sites sampled in 2006 by De Leo et al. (2010) for seabed epifauna[1]. Replicated macro-infauna samples are also available from the same sites; these samples have not been processed and will be analysed for abundance and biomass as part of this proposal. In Hokitika Canyon, abundance and biomass data are available for bacteria from six sites sampled in 2013 along the canyon axis. Replicate samples of meiofauna and macro-infauna (n = 2-4 at each site) from the same sites will be processed and analysed as part of this proposal.

Frozen archived sediment samples from both canyons will be analysed using compound-specific stable isotope methods to determine the origins of organic material in the canyon[9]. Post flood sediment deposit samples will be obtained from rivers contributing high sediment loads near the canyons to characterise the signature of terrestrial organic matter sources[10]. Marine organic matter sources will be characterised by analysing frozen archived sediment samples from offshore sediments well away from riverine inputs off the east (Chatham Rise) and west coasts of the South Island (lower continental slope and Challenger Plateau). See 'Detailed methodology' section below for more comprehensive description of CSIA methods.

Detailed methodology

Sediment, pollen, and faunal analyses.

The sediment samples stored in NIWA collections were obtained using a multicorer, which provides undisturbed and quantitative surface sediment cores. Replicate core samples were obtained at each site and either kept frozen (physico-chemical characteristics, compound-specific stable isotope analyses) or fixed in buffered formalin (pollen counts and faunal analyses). For pollen and meiofaunal analyses, subcores (26mm internal diameter, 5 m depth) were obtained, whereas entire cores were sieved for macro-infaunal analyses (95mm internal diameter, 20cm depth). If time allows, frozen sediment subsamples from sites of both canyons will be analysed for lignin content using standard methods[11].

Formalin-fixed subcores will be used for both pollen counts and quantification of meiofauna abundance and biomass. Samples for pollen/meiofauna and macro-infauna analyses will be processed using standard methods[12,13,14,15]. Representative subsamples will be taken for bulk stable isotope analyses of macro-infaunal taxa (see below).

Compound-specific stable isotope analyses (CSIA)

CSIA will be conducted at NIWA's isotope ratio mass spectrometry facilities in Wellington. The application of CSIA as sediment source tracers is based on the concept that plant communities label soils with a range of organic compounds that are primarily exuded by their roots. Fatty acids have attributes that make them particularly suitable as sediment tracers, being bound to fine-sediment particles and persisting over long time scales (i.e., decades–centuries)[9,10,16].

To identify the sources of sediment in a deposit, the isotopic signatures of terrestrial and marine-derived organic matter will be determined. For each canyon, terrestrial sources will be characterised by sampling post-flood deposits of major nearby rivers known to contribute most to suspended local sediment loads (i.e., the Hurunui, Waiau, and Conway rivers for Kaikōura Canyon, and the Hokitika and Whataroa rivers for Hokitika Canyon)[7,17]. Marine sources will be characterised by analysing archived (frozen) sediment samples held in NIWA collections. Samples are available from Chatham Rise sites (350-3000 m depths), offshore from Kaikōura canyon and well outside any influence of river discharges. Similarly, sediment samples from the lower continental slope and nearby Challenger Plateau (300-2000 m depths), offshore from Hokitika Canyon, will be analysed.

The feasible sources in each sediment mixture will be evaluated using the Isosource[18,19] and MixSIAR ver 3.0 isotopic mixing models[20]. The former is commonly used in isotopic studies and expresses organic matter sources as a single value for each fatty acid, while the latter is a Bayesian mixing model that can incorporate and account for uncertainty in the source signatures of isotopes and resulting estimates of source contributions to a mixture[21,22].

Bulk stable isotope analyses

The contribution of terrestrial organic matter to the diet of macro-infaunal organisms will be determined using analyses of carbon, nitrogen, and sulphur stable isotope ratios. Carbon and sulphur isotope signatures provide good discrimination between marine and terrestrial sources, whilst nitrogen isotope signatures provide trophic level information[23]. Although formalin fixation can lead to shifts in isotopic signature of animal tissue, these shifts are small relative to changes expected from natural fractionation processes and have therefore no or limited influence on the interpretation of food webs[24,25,26].

The contribution of terrestrial *vs* marine food sources will be estimated using mixing models as described above. The bulk stable isotope signatures of offshore (marine) and river (terrestrial) sediments will be determined using standard techniques[27] and used as end-members in the mixing models.

Canyon classification

New Zealand has a diverse range of canyons along its continental margin. A project initiated in 2013 began with the aim to classify canyons around New Zealand based on a regional 100m bathymetry grid that included all available high resolution bathymetric data. To date, 273 canyons and channels have been identified by objectively defining canyon rims and axes using repeatable morphometric rules and characterised using their primary attributes, such as length, depth, and profile shape. These morphometric attributes have been entered into a New Zealand canyon database and used to produce a canyon classification using multivariate analysis techniques that identify non-random, self-similar groups of canyons.

In this project we will further develop the classification by including attributes that relate to regional processes likely to influence the flow of organic matter into and within canyons. We will use data for groundshaking[28] and wave climate[29] to determine the frequency of disturbance events (earthquakes and storms) that can cause mass downslope transport of sediment within the canyon, sediment contribution from fluvial systems[17], and surface water primary productivity[30].

This biologically-focused version of the canyon classification will be similar to the biologically-focused classification of New Zealand seamounts[31]. Because the two study canyons are distinct, they will provide endmembers that can then be placed in the context of the biologically-focused canyon classification to assess which other canyon features might facilitate organic matter inputs to the deep sea, and thereby determine the relative importance of canyons in supporting benthic ecosystem functioning in the region.

Innovative aspects and the bigger picture

It is well established that large vascular plant debris fuels a specialised deep-sea fauna[32] but the abundant fine plant detritus transported by river and down canyons is likely to be exploited more widely by a greater range of fauna. This fine terrestrial material is more difficult to trace and its contribution to continental shelf and deep-sea food webs remains unclear. Biogeochemical models indicate that only a small fraction of terrestrial organic matter transported to the oceans gets buried in sediments[33], and that most terrestrial organic matter gets remineralised, i.e., is converted into dissolved phases or enters the marine food web[34]. Compound-specific stable isotope analysis (CSIA) of sediment organic matter combined with multivariate mixing models offers a new method for tracing the origins of organic matter with more certainty/sensitivity than bulk stable isotopes or other terrestrial proxies. This approach has been applied in estuarine and shallow coastal environments[9,10,35] but will be applied here as a method to investigate deep sea connectivity for the first time. The combination of CSIA, pollen and lignin biomarkers, and bulk stable isotopes in benthic marine fauna will clarify the fate of this fine organic material, and provide the first insights into what makes Kaikōura Canyon a hotspot of biomass relative to other canyon systems in New Zealand and globally.

A global canyon classification produced in 2011 identified the need for regional classifications using high resolution bathymetric data to better understand controls on canyon processes[36]. New Zealand is in an almost unique position as an isolated continent with canyon-incised continental slopes on all sides, and the classification produced as part of this project will be one of the first country-wide canyon classifications to be completed. The methodology has been designed to be objective and repeatable, and therefore applicable to other continental margins to make global comparisons. This methodology is distinct from that used to produce the other country-wide canyon classification that currently exists for Australia, which used 'manual' digitising and a hierarchical classification method[37].

H. RESEARCH ROLES

Researcher	Organisation	Contribution
Daniel Leduc	NIWA	Benthic ecology, food webs, isotope tracer techniques
Scott Nodder	NIWA	Deep-sea organic matter fluxes, biogeochemistry, sediments
Ashley Rowden	NIWA	Benthic ecology, multivariate data analyses, canyon classification
Joshu Mountjoy	NIWA	Canyon geomorphology, canyon classification
Arne Pallentin	NIWA	GIS and spatial analysis
Andrew Swales	NIWA	Compound-specific isotope analyses, sedimentology
Max Gibbs	NIWA	Compound-specific isotope analyses, biogeochemistry

I. LINKAGES AND DEPENDENCIES

Explain how your research complements, but does not overlap with research already funded within the Challenge. Please note particular projects that your research complements, and any inter-project linkages. Max 500 words.

This project is not dependent on other projects within the *Challenge*, but will complement other *Dynamic Seas* projects. Specifically:

- 4.1.1 "Ecosystem connectivity: tracking biochemical fluxes to inform ecosystem based management". This funded project focuses on tracing organic matter, nutrients and contaminants in the shallow coastal systems of Tasman Bay and Marlborough Sounds, whereas the aim of the proposed research is to identify the sources of organic matter at deep water sites in Kaikōura Canyon and Hokitika Canyon sediments. Identifying the degree of connectivity between shallow water and deep ecosystems mediated by canyons will also help identify what deep-sea ecosystems may be most likely exposed to land/coastal-derived pollutants, which is a goal of funded project 4.1.1.

- 4.2.2 “Stressor footprints and dynamics”. Kaikōura Canyon is one of the study locations listed for experimental and modelling studies of sediment dispersal (footprint determination) in this funded project, which would provide data on the spatial and temporal scales for transport of coastally-derived organic matter to the deep part of the canyon. The likely origins of sediment and organic matter in the deeper part of the canyon could therefore be identified and compared/validated with the sediment data obtained as part of the proposed research.

J. RISK AND MITIGATION

Highlight risks to the success of your proposal and demonstrate mitigation measures. Max 300 words.

This project relies on existing sample collections held at NIWA, thereby avoiding the risks associated with undertaking new deep-sea sampling. Expertise in deep-sea benthic community analysis (Rowden, Leduc), geological processes (Nodder, Mountjoy) and GIS data analyses/management (Pallentin) are keystone skills that have been developed at NIWA over decades.

New sampling will be limited to river deltas, and this kind of sampling has been conducted repeatedly and successfully by NIWA staff in the past. The CSIA tracer technique to be used for the proposed research was developed by NIWA staff involved in the proposal (Gibbs, Swales)[9,38].

NIWA has a long history of stable isotope research in atmospheric, marine, freshwater and terrestrial programmes and the CSIA laboratory at Greta Point, Wellington is one of only two such laboratories in the country. The NIWA laboratory has been successfully delivering fatty acid-specific stable isotope data for both internal and external clients, and laboratory staff have been consulted during the preparation of this proposal.

K. ALIGNED FUNDING AND CO-FUNDING

Demonstrate your co-funding and in-kind support. Max 300 words.

There is aligned funding via the NIWA’s Core-funded programme “Ocean Flows & Productivity” (Programme 3) in the NIWA Coasts & Oceans Centre. Co-funding will be available (approx. $40k, 0.15 FTE) from the Marine Physical Processes & Resources Programme 1 of the NIWA Coasts & Oceans Centre, which is responsible for the New Zealand canyon classification project and undertook the original sample collections and analyses in the Hokitika and Kaikōura canyons. Dr Aaron Micallef (University of Malta) will also contribute to the canyon classification system (in-kind co-funding of 0.1 FTE). NIWA Core funding will be available to cover processing of Hokitika meiofauna samples (NIWA subcontract with University of Otago). An application for a European Marie-Currie post-doctoral fellow (Dr Teresa Amaro) will be submitted in September 2016, as part of an initiative to foster greater collaboration between canyon researchers in New Zealand and the United Kingdom. Dr Amaro has previous researched the benthos of canyon systems in Europe and North America.

L. VISION MĀTAURANGA (VM)

Describe whether and how your proposal is relevant to the marine management interests of Māori, and/or how it incorporates mātauranga Māori. Also outline how you plan to involve Māori in your proposal. Max 300 words.

We expect the proposed research to have a strong Vision Mātauranga component through Research Theme 2 Taiao: achieving environmental sustainability through Iwi and Hapū relationships with land and sea.

We have consulted Dr Sharyn Goldstien (University of Canterbury and science advisor to Kaikōura Marine Guardians and Te Korowai, who in part manage the Hikurangi Marine Reserve that includes Kaikōura Canyon), in order to ensure that our proposal is tailored to the needs of stakeholders, and complement any other current/planned research initiatives in the area. The proposed research has been presented at a recent Te Korowai meeting in June and obtained their full support with keen interest in the outcomes. The Te Korowai Strategy (Section 4.2.1) specifically names the Kaikōura Canyon as a place of international significance and with special significance to the people of Ngati Kuri. The location of the Marine Reserve was chosen due to its high biodiversity and significance to Te Tai o Marokura; therefore research that increases the understanding of terrestrial input to the management area is fully supported by Te Korowai.

We are also consulting with Mandy Home (NIWA's Te Wai Pounamu partnership expert) on how best to engage with Te Runanga o Ngati Waewae. We will make presentations about the project at the beginning and/or end of the project (depending on interest/requests from our iwi/guardian contacts) to explain the aim and approach of the research and foster community learning and participation.

M. CONSENTS AND APPROVAL

Does your proposal require any marine consents or ethics approvals? If so, do you have them in place? If not, outline the processes required and demonstrate they can be achieved within the time frames and budgets requested. Max 300 words.

We have contacted the West Coast Regional Council and Environment Canterbury Regional Council, who both confirmed that no consent is required for sampling sediments in river deltas. No ethics approval is needed for this proposal.

N. DATA MANAGEMENT

Describe your data management plan. Max 300 words.

Our analyses of connectivity in the Kaikōura and Hokitika canyons, as well as canyon classification system for New Zealand, will each result in a peer reviewed journal paper. We will also produce a publically available database and GIS layers of parameterised canyons for uptake by endusers and other researchers. NIWA has long standing experience with making datasets available to environmental managers, researchers, and the public via the web (for example: http://www.os2020.org.nz/#os-20-20, and http://www.bathymetry.co.nz), and is currently developing means to provide data as data services for use in standard GIS applications. Furthermore, we propose to provide data through international data portals such as the Ocean Biogeographic Information System. Data management (checking, storage) will be based on existing and well-proven NIWA processes.

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