

Innovation Fund Research Proposal Template 2.2.2

A. PROJECT TITLE

Huataukāina Tō Iwi E: Developing marine bioactives economic opportunities from Tairāwhiti kīna to combat diabetes, heart disease and inflammation.

B. PROJECT TEAM

<p>Project Leaders:</p> <p><i>Dr Matthew Miller, Cawthron Institute 98 Halifax Street East, Nelson 7010 matt.miller@cawthron.org.nz 03 5482319</i></p> <p><i>Pia Pohatu Hikurangi Takiwa Trust Ruatoria pia@uritukuiho.org.nz</i></p>	<p>Scientific Investigators:</p> <ul style="list-style-type: none"> ▪ <i>Donato Romanazzi, Industry Research Liaison, Cawthron Institute</i> ▪ <i>Prof Marlena Kruger, Massey University</i> ▪ <i>Dr Fran Wolber, Massey University</i> ▪ <i>Prof Richard Beasley, Medical Research Institute of New Zealand</i> <p>Kīna working group (to assist community uptake and input):</p> <ul style="list-style-type: none"> ▪ <i>Panapa Ehau, Hikurangi Enterprises Ltd</i> ▪ <i>Ruihana Paenga, Te Riu o Waiapu Charitable Trust</i> ▪ <i>Tina Ngata, Te Wānanga o Aotearoa</i> ▪ <i>Paora Brooking, Customary Fisherman</i> ▪ <i>Marijke Warmenhoven, Nga Papatipu o Uepohatu Charitable Trust</i> ▪ <i>Murray Palmer, Aquatic Research Coordinator, Nga Mahi Taiao Ltd</i> ▪ <i>Dr Joanne Clapcott, Habitat Cultural Assessment, Cawthron Institute</i> <p>Commercialisation:</p> <ul style="list-style-type: none"> ▪ <i>Manu Caddie, Hikurangi Bioactives Limited Partnership</i> <p>Scientific Advisory group:</p> <ul style="list-style-type: none"> ▪ <i>Agnes Walker, Te Aitanga-a-Mate Hapū Customary Fisheries Committee, Hikurangi Takiwa Trust</i> ▪ <i>Prof Peter Shepherd, Maurice Wilkins Institute, Auckland University</i> ▪ <i>Dr. Tom Wheeler, Cawthron Institute</i>
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C. ABSTRACT

The phrase ‘huataukīna tō iwi e’ comes from the waiata ‘Hikurangi’ composed by Kuini Moeau Reedy, based on an old Ngāti Porou phrase that means – when the kaimoana is abundant and the hapū have strings of kīna, whānau are prosperous and healthy. This project aims to utilise kīna (*Evechinus chloroticus*) from the coastal marine areas of East Coast hapū to create commercial opportunities through the development of new high-value nutraceutical and functional food ingredient products.

This project will produce the essential groundwork knowledge that is required to build a viable kīna oil industry on the East Coast of New Zealand (Te Tairāwhiti). Specifically, the research will establish benchmarks for yield and natural variation of bioactive content in wild kīna and data supporting its efficacy as a health-promoting food supplement. This research aims to stimulate economic development in the Tairāwhiti region.

The vision of this project is to grow the marine economy in the East Coast by developing a nutraceutical industry based around kīna bioactives. This has the potential to grow to other marine bio-resources as the industry matures. Presently kīna is underutilised and undervalued. As a competitor in the Sea urchin marketplace, it is unable to penetrate the high-value food markets in Asia and other regions due to unfavourable visual aesthetics. This project will bypass this limitation and build on New Zealand’s reputation for producing quality, sustainable and safe products from natural sources to deliver a novel health-promoting supplement and function food ingredient to the large and growing Asian market.

The initial focus of the enterprise will be the health supplements and functional foods markets, but there are also potential spill-over benefits into pharmaceutical applications, which would be evaluated for possible development later. Direct benefits for East Coast hapū will result from increased value for their presently underutilised kīna catch. There is also the future potential for aquaculture of kīna. There will be efforts to evaluate and utilise the whole resource (shell/offal/spines/roe) to reduce waste and enhance revenue through utilisation of by-product streams from kīna.

There is significant potential for economic development for coastal communities in New Zealand, through the commercialisation of novel high-value niche nutraceuticals and functional food ingredients from the marine environment. A successful example of this is Greenshell™ mussel oil, which is produced in New Zealand for a niche overseas markets, and provides over \$40M per annum in export sales [1]. The primary objective of this research is to investigate the feasibility for commercial extraction of kīna oil and provide data to support an evidence-based marketing strategy.

D. RELEVANCE TO CHALLENGE OBJECTIVE

This project aligns to the Sustainable Seas objectives by:

- *Diversifying the marine economy through new commercialisation projects.* At present, there is minimal economic activity and value derived from the marine environment for hapū along the East Coast. This project has the potential to create a new high-value industry based on bioactive extracts from an under-utilised inshore species.
- *Adding value to existing marine industries, reducing waste flow and environmental burden.* Utilising internationally recognised researchers in marine bioactive chemical characterisation, proof of efficacy and molecular mechanisms to underlay their mode of action, the project aims to utilise the whole resource to produce a range of extracts and minimise waste or environmental burden associated with the industry.
- *Identifying new marine-based commercial ventures support for and from Māori economic programmes.* The project has been initiated by hapū members approaching Cawthron and will be led by hapū

representatives to support their aspirations for sustainable economic, cultural, environmental and social development.

E. INTRODUCTION

Sea urchins are regarded as a delicacy in many countries, particularly in Asia, where their gonads are commonly consumed. Their high economic value as a food product has led to them not being utilised as a bio-resource for nutraceutical products. Therefore, bioactives research on sea urchins has primarily focused on by-products such as shell, spine, and offal [2-11]. New Zealand kīna roe has been unsuccessful as an export to these high-value Asian food markets due to the occurrence of an intermittent bitter taste and variable gonad quality, in particular issues around colour [12]. However, an alternative route to market is to process the kīna bio-resource into nutraceutical products, in particular extracts derived from the lipid-rich roe. Compounds contained in sea urchins are potential bioactivities [9, 13-16], but no studies have yet been undertaken on equivalent extracts from New Zealand kīna.

Kīna roe, as well as other species of sea urchins, are lipid-rich and contain unique marine bioactives. Some of these have shown promise in promoting human health, although their effects have not yet been fully investigated [9, 13, 14]. Sea urchins contain a number of health-promoting bioactives, including echinochrome A (Ech A), echinenone, furan fatty acids (F-acids), vitamin B12, branched chained fatty acids (BC-FA), long-chain omega-3 polyunsaturated fatty acids (LC n-3 PUFA) and non-methylene interrupted fatty acids (NMI-FA). Echinochrome A has antioxidant, antimicrobial, anti-inflammatory and chelating properties [15, 16]. Echinenone is the major carotenoid in most sea urchins including kīna [17] and structurally related compounds have shown potential in aiding inflammation, diabetes, obesity and metabolic syndrome [18-23]. Also, Sea urchin have been shown to contain several bioactive including carotenoids and omega 3 FA, NMI-FA, F-acids and BC-FA. Therefore, it seems likely that a bioactive-enriched extract could be produced from the lipid rich roe of kīna, as well as spines and shells, that contains significant health-promoting properties of value to the Asian and local markets.

The kīna fishery is presently under-utilised with around 700-900 t of kīna harvested nationally per year for the last decade, compared with a Total Allowable Commercial Catch (TACC) of 1,147 t [1, 24, 25]. In Te Tairāwhiti region (fishery region SUP 2A) only 18.8 t of kīna was reported as commercial catch from the 80 t TACC available in 2016 [25]. Thus, there is potential to develop a new high-value, sustainable industry for an otherwise low income region with limited economic development opportunities beyond the traditional primary industries. We have estimated (from current knowledge on yield and nutraceutical market) from just the present unutilised catch available from Te Tairāwhiti (60 t), there is \$400,000 p.a. in potential commodity nutraceutical oil available to develop a viable commercial processing plant. The development of a successful kīna nutraceutical industry will increase the value of the resource and create new jobs and increased income for communities with access to the abundant marine resource.

F. AIMS

The overarching aim of the project is:

To grow the marine economy of the East Coast by assessing the unique characteristics of kīna extracts and develop a nutraceutical industry based on bioactive extracts from this unique kaimoana.

This will be realised by achieving the following goals (which are all milestones in section N):

- a) Establishing mutually beneficial relationships between whānau, hapū, marae and community-owned companies based on the East Coast and researchers based at Cawthron Institute, Massey University, Hokkaido University and Medical Research Institute of New Zealand.

- b) Utilising analytical tools and processes to characterise the bioactives that are present in kīna extracts.
- c) Assessing the seasonal abundance and variation of bioactives in wild kīna populations over a series of locations and habitats on the East Coast.
- d) Developing scalable extraction and quality assurance methods.
- e) Verifying the bioactivity of extracts in developed models of efficacy.
- f) Identifying a number of market channels for kīna extracts and developing commercialisation strategies for each of them.

G. PROPOSED RESEARCH

A measured and structured approach is planned to establish a kīna nutraceutical industry on the East Coast. This will be overseen by a working group led by Pia Pohatu, and will establish a strong working relationship between Cawthron and representatives of hapū collectives, companies and East Coast-based researchers that incorporates iwi values and builds a strong partnership.

PROJECT SCOPING & PLANNING:

This stage involves establishing the operating principles under which the research project and commercialisation will operate. The Working Group will build on the initial hui already undertaken, in order to share existing science on marine lipids and bioactive extracts, explore the project purpose, key values and tikanga. Key principles are reciprocity, joint responsibility, shared benefit and the protection of intellectual property.

Project planning has to date involved more than 20 local leaders from hapū and research organisations in the participating communities. Schools and tertiary education providers have also expressed a high level of interest in staff and students contributing to the project.

LITERATURE & ORAL TRADITIONS REVIEW

Working Group members will continue to compile a database of literature and other research (particularly mātauranga contained in oral histories and traditional practices) relevant to the project scope with a focus on the kīna lifecycle, beneficial properties, traditional uses and local knowledge about kīna growth, distribution and harvesting.

REGULATORY & TIKANGA COMPLIANCE

Protocols for accessing kīna samples from hapū marine areas will be developed by the Working Group in conjunction with hapū fishery committees. No other regulatory compliance is anticipated and the volumes required on a quarterly basis will be well below recreational daily limits.

CHARACTERISING KĪNA BIOACTIVES, EXTRACTION & ANALYSIS METHODS

Methods will be developed for quantification of Ech A, echinenone and a series of bioactive fatty acids using solvent extraction and liquid chromatography mass spectroscopy (LC-MS) or gas chromatography (GC)-MS. The concentration of bioactives in samples from wild kīna populations will be determined over a series of locations on the East Coast to determine how habitat, location, age and seasonality influences concentration of the bioactives. Also, the relative concentration of each of the bioactives in the different kīna parts (shell, gonad/roe, and offal) will be determined. This will result in a detailed understanding of the bio-resource to target kīna for optimal extraction of bioactives. Specific bioactive compounds in kīna are:

Echinochrome A (Ech A): Ech A is an active component of HistoChrome[®], a health-promoting natural product promoted for its hemoresorption, retinoprotective, and antioxidant properties [26]. It has also

been investigated for its application to lung disease [5], exercise capacity [3], mitochondrial function [8, 9], Alzheimer's disease [4], as well as its anti-oxidation properties [27, 28]. Sourced from the shell and spines a method will be developed for quantifying this compound using LC-MS.

Echinenone: is a carotenoid that is structurally related to fucoxanthin and astaxanthin which are known to have anti-inflammatory properties [29]. These compounds have shown efficacy for alleviating metabolic syndromes such as diabetes and obesity [18-23] as well as inflammation [30, 31]. We have developed a method to assay a series of different carotenoids (using LC techniques) and shown enhanced echinenone abundance and a possible protective function in two micro-algal species that were experimentally stressed by nitrogen and phosphorous depletion (manuscript in preparation).

Bioactive fatty acids: The gonad of the sea urchin, and by implication also that of kīna, synthesises and stores a range of complex and modified FAs [32-34]. Kīna is known to contain moderate amounts of omega-3 FAs (5-12%). Omega-3/bioactive fatty acids have well characterised cardiovascular protective [35] and enhanced mobility effects, including inflammation [36, 37], joint [38, 39] and bone health [40-42]. Sea urchin contain FAs that are not found in commonly produced marine oils. Therefore, kīna oil has potential unique properties compared with its marketplace competitors. In one example, Cawthron researchers have recently identified F-acids in oil from kīna roe (manuscript in preparation). F-acids have been shown to have enhanced anti-inflammatory activity compared with standard fish oil [43-45]. Methods for analysis of these FAs are established or in development at Cawthron.

The project will leverage the specialised chemical analysis capabilities of the Cawthron Institute. This team has proven expertise in the analysis and extraction of novel bioactive compounds from marine sources [46, 47]. Extraction methodologies will be adapted from experience gained through recent programs highlighted below.

- The project leader, Dr Miller, has expertise in bioactive lipids and is an experienced marine extracts researcher, recognised internationally for analysis of marine-derived lipids (>30 peer-reviewed lipid papers, four book chapters, one book). He is the programme leader in a National Science Challenge programme looking at the nutritional value of Greenshell™ mussels (UOAX1421) and has played key roles in two MBIE-funded programmes (Export Marine Products, C11X1307 and Engineered Marine Molecules, FRST CO2X0806). He has demonstrated experience in leading multi-disciplinary research projects involving multiple research and commercial partners.
- Mr Romanazzi, has 15 years expertise in a wide range of small molecule analytics and extraction and is engaged widely with the bioactives industry. He has been key in establishing the state-of-the-art lipid analysis capabilities at Cawthron and has developed methods for a number of natural products for various NZ companies. He leads a MBIE funded NZ-Japan Strategic International Collaborative Research Programme (SICORP) on the extraction, analytical characterisation and functional evaluation of marine lipids and carotenoids sourced from molluscs and marine algae (CAWX1416).

SHARING KNOWLEDGE

The sharing of knowledge generated by the project will be key to its ultimate impact in developing a viable kīna extraction industry. This will include;

- Traditional knowledge, blended with current scientific understanding, will form the foundation of shellfish husbandry, extraction and analysis strategies as well as commercialisation strategies. Information and knowledge exchange will occur through a series of hui held throughout the lifetime of the programme.
- Opportunities will be provided for several East Coast stakeholders to intern at Cawthron to gain understanding of the extraction and analysis of kīna bioactives.

- A series of wānanga at Cawthron and in East Coast communities will share knowledge gained and further enhance relationships going forward into commercialisation phases.
- Intellectual property relating to the kīna extracts developed during the project will be held by Hikurangi Bioactives Limited Partnership and any participating hapū entities. A detailed IP Agreement will be developed through Milestone 6.1.
- Knowledge of the health-promoting properties of kīna extracts will be communicated to the scientific community through publication of research papers, and to the general public through popular articles and engagement with news media.

UNDERSTANDING THE POTENTIAL OF KĪNA EXTRACTS

The Cawthron team will develop efficient and scalable bioactive extraction techniques on a gram-scale. They have access to and experience in a range of extraction and concentration techniques including physical rendering, chromatography (flash and preparative), supercritical CO₂ and solvents, techniques that have proven successful in bioactives from other marine species. A series of distinct bioactive formulations will be produced and their health-promoting bioactivities assessed using *in vitro* models that have been established by the research team's existing research partners. These extracts will include:

- a fraction rich in echinochrome A
- a concentrated fraction of echinenone
- a total lipid extract

Researchers and efficacy models to be used include:

- Prof Kruger & Dr Wolber, Massey University. This research will build on an existing relationship looking at marine extracts and joint inflammation. Kīna extracts will be assessed in *in-vitro* models of inflammation, joint and bone health. Extracts with known concentrations of key active ingredients will be assessed for their effect on the production of inflammatory cytokines by immune cells, and on cellular functions of murine bone and cartilage cell lines. Splenic mononuclear leukocytes will be assessed for basal and leptin-induced production of IL-2, IL-4, TNF α and IFN γ . Bone osteoblasts (pre-osteoblast Mc3t3-E1 sub-clone 4) will be assessed for cytotoxicity/proliferation (MTT assay) and osteogenic production of alkaline phosphatase. Bone osteoclasts (RANKL-Induced RAW 264.7) will be assessed for cytotoxicity/proliferation and tartrate-resistant acid phosphatase production (TRAP assay). Cartilage chondrocytes (ATDC5) will be assessed for cytotoxicity/proliferation mineralisation, and production of collagen and proteoglycans.
- Prof Hosokawa, Laboratory of Bioresources Chemistry at the Faculty of Fisheries Science of Hokkaido University, Japan. Prof. Hosokawa is one of the pre-eminent biochemists working on marine natural compounds and their bio-functionality [18, 20, 21, 23] and with whom we have an established collaboration through a SICORP programme (CAWX1416). Our intent is to leverage this existing interaction to evaluate kīna extracts in cell culture and whole animal models of diabetes and obesity. Funding for this will be procured outside this program.
- Prof Beasley (Medical Research Institute of NZ - MRINZ) will lead a pilot clinical trial to test the safety and efficacy of kīna extracts. Results from the models of efficacy (above) and in consultation with the scientific advisory board will define a mechanism and plausible outcomes prior to the acute clinical trial. The MRINZ team has a track record of managing double-blind randomised controlled clinical trials of natural health products for New Zealand and overseas clients. This trial will guide the direction of future research outside this proposal to ascertain efficacy of kīna extracts.

H. RESEARCH ROLES

Researcher	Organisation	Contribution
<i>Dr Matt Miller</i>	<i>Cawthron Institute</i>	<i>Project leader, analysis of bioactives and development of scalable extraction technologies.</i>
<i>Donato Romanazzi</i>	<i>Cawthron Institute</i>	<i>Analysis of bioactives and will lead the work around the efficacy of the kīna extracts through Prof Hosokawa in Hokkaido University</i>
<i>Dr Joanne Clapcott</i>	<i>Cawthron Institute</i>	<i>Cultural Habitat Assessment</i>
<i>Pia Pohatu</i>	<i>Hikurangi Takiwa Trust</i>	<i>Mātauranga Māori, hapū liaison, Working group facilitator</i>
<i>Agnes Walker</i>	<i>Hikurangi Takiwa Trust</i>	<i>Mātauranga Māori, hapū liaison</i>
<i>Manu Caddie</i>	<i>Hikurangi Bioactives Limited Partnership</i>	<i>Commercialisation strategy – market research, production planning, business planning, pipelines to market, regulatory impact assessment, etc.</i>
<i>Prof Marlena Kruger/Dr Fran Wolber</i>	<i>Massey University</i>	<i>Lab models for efficacy assessments</i>
<i>Prof Richard Beasley</i>	<i>Medical Research Institute of NZ</i>	<i>Clinical pilot study on a kina extract</i>

I. LINKAGES AND DEPENDENCIES

This research compliments the NSC Sustainable Sea Challenge across three programmes:

1. Valuable Seas Programme

The Valuable Seas Programme is most closely aligned to this project, particularly the themes 2.2.1 “Creating value from a blue economy” and the 2.2.2 “Methods to increase diversification in marine economies”. This current project is led by a local Māori community to build a novel blue economy in the East Cape. Its effect will be to better utilise the marine resource in a sustainable way and will facilitate innovation and build new economic activities. This overarching aim of the programme therefore aligns directly with the goals of the NSC, which is stated as “growing the marine economy through increasing the use and realising the value of New Zealand’s coastal assets, while maintaining the health of the marine environment”. Our understanding is that there is no other research being undertaken within the challenge on kina bioactives. This programme opens up a new area.

2. Tangaroa Programme

The project will develop innovations that enable Māori to participate as partners in marine management and decision making while supporting economic growth. It aligns with the proposed Aim 3 of the Tangaroa programme ‘Kaitiakitanga in Practice – He Pou Tokomanawa’. This project will use kaitiaki of local hapū to utilise kīna in a manner consistent with local tikanga and mātauranga Māori, to sustain the resources and in so doing continue to nourish the hapū now and into the future. This current proposed program therefore directly aligns with this the Tangaroa Programme and moreover, will inform it. Further, it will provide improved mechanisms to support the increasingly significant role hapū play in our marine estate. Finally, the programme addresses Aim 3 of the Tangaroa programme by upholding the commitment towards Te Tiriti o Waitangi, mātauranga Māori and effective knowledge exchange.

3. Vision Mātauranga

This project has direct alignment with the Vision Mātauranga programme of the Sustainable Seas NSC. The strong leadership of hapū and East Coast communities in this programme will allow it to contribute directly to Taiao (achieving environmental sustainability through iwi and hapū relationships with land and sea) and Mātauranga (exploring indigenous knowledge) themes of the Vision Mātauranga programme. With leadership from Hikurangi Takiwā Trust, Te Papa Tipu o Uepohatu Trust, Hikurangi Bioactives Limited Partnership, Hikurangi Enterprises Ltd and other participating hapū entities and customary fishery committees, Cawthron Institute researchers aim to support sustainable economic and environmental outcomes for East Coast communities. These communities have invaluable knowledge and expertise that are incorporated throughout this project, as well as significant and specific interests in project outcomes. This research is designed to incorporate Māori values, principles and knowledge to develop economic opportunities for Māori communities in the Tairāwhiti region. This aligns closely to the core ideals of Vision Mātauranga by involving Māori, industry, resource managers and communities at the heart of the decision making and the knowledge created by the challenge.

J. RISK AND MITIGATION

Risks of proposal:

1. *The current catch allowable may be too small to make an economic industry from kīna*: A recent MPI report stated that there is relatively little data that can be used to assess the status of kīna stocks [25], however the East Coast area (SUP 2A) have only been harvesting 20 tonne of the total allowable commercial catch (TACC) of 80 tonne since 2003 (see figure 1).

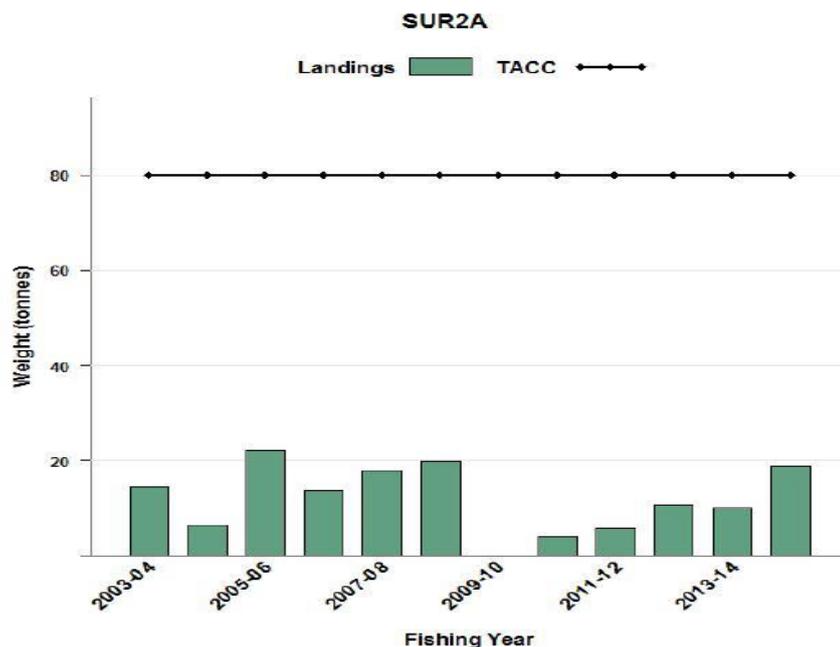


Table 1 Reported commercial landings and total allowable commercial catch (TACC) for the East Coast region (SUP 2A) taken from [25].

This data suggests that presently this area is commercially underutilised. If successful the kīna extraction enterprise can be expanded to other regions, as sea urchin distribution is nationwide. However, if the enterprise is very successful and we cannot obtain enough kīna to meet the needs of the new industry, kīna aquaculture could be used to sustain the industry. In 2004-2010 there were attempts to aquaculture kīna for the Asian food markets [48, 49]. Issues arose around the product not meeting sensory or colour parameters and therefore the product could not obtain premium prices [12]. This previously developed science could be energised with a new

nutraceutical market. Economics also depends on the type of extraction process possible for each bioactive, which is a focus of the programme. An initial estimation of \$400,000 p.a. worth of bioactives from the 60 t of kīna available in Te Tairāwhiti. Costs will be offset with local investment in extraction of terrestrial bioactives (see section K).

2. *The efficacy data is weak:* This potential issue is partially mitigated through the project plan by examining a series of different extracts in a series of different assays looking at several models of disease, chosen to assess the most likely bioactivities present in the extracts. However, if no activity is detected, additional models will be selected and tested. Experience worldwide is that it is very challenging to prove health benefits for a natural extract in a clinical setting. However, the preferred route to market as a nutraceutical does not require such a high standard of proof. The methods and relationships developed here have wider applicability in that they could be used to assess other marine sources of bioactives including seaweed, other mollusc/bivalves/echinoderms (e.g., sea cucumbers) and fish endemic to the East Coast marine area.
3. *Extraction technologies are too expensive for the price of possible bioactives:* We are mitigating this by following other successful models of marine bioactives extracted and commercialised here in New Zealand. The GSM oil industry is the benchmark in terms of extracting value from a marine resource here in New Zealand, possibly the world. However, there are other extracts developed here in NZ that are sourced from the marine environment (paua oil, oyster powders, sea cucumber powders, collagen products, shark powders, shark oils, etc.). Through this project we are attempting to extract value from the whole resource including products from waste streams. We aim for these co-products to support the economics of production.

K. ALIGNED FUNDING AND CO-FUNDING

The economic marine opportunities will be driven by Hikurangi Bioactives Limited Partnership (HBLP) and its partner companies Hikurangi Enterprises Ltd (a charitable company owned by a local charitable trust) and New Zealand Nutraceuticals Ltd. Both entities support community-led economic development in the East Coast, the region with lowest household income and highest unemployment in the country. HBLP is presently characterising and commercialising terrestrial bioactives including extracts from mānuka, kānuka, other native plants and indigenous fungi. HBLP will facilitate market entry for the kīna extracts by leveraging the distribution chain developed as part of an existing joint venture with HoneyLab. This year three natural health products based on bioactive extracts from terrestrial sources are going to independent clinical trials led by MRINZ. HBLP has established relationships with several multinational pharmaceutical and consumer goods companies, including Procter & Gamble and a Chinese company with 500,000 distributors, to develop a pipeline for terrestrial and marine bioactives. This projects also envisions to utilise the extraction technologies developed in terrestrial bioactives extraction.

HBLP has committed \$20,000 in funding to engage world-leading capability outside the project to evaluate the efficacy of the extracts. Prof. Hosokawa, University of Hokkaido, is a world-leading expert in the evaluation of bioactivity in seafood extracts and has established both whole animal and cell culture models of metabolic syndrome and diabetes which will be used to evaluate the bioactivity of the kīna extracts. We will leverage an established collaborative relationship between Prof Hosokawa and Mr Romanazzi developed through an existing SICORP programme.

In addition to cash co-funding, we have in-kind contribution to the project by the various East Coast hapū and other entities, comprising over 1,000 hours in volunteer and paid staff time contributing to the project.

Cawthron researchers lead a number of additional programmes that provide a large body of supporting knowledge and expertise from which this proposed programme will leverage, including;

- NZ – Japan Strategic International Collaborative Research Programme (SICORP) on "Functional Foods" - Extraction, analytical characterization and functionality evaluation of marine lipids and carotenoids sourced from molluscs and marine algae (CAWX1416). This multidisciplinary programme is a collaboration between Japanese researchers including Prof Hosokawa and Cawthron Institute that investigates the health benefits of a variety of marine organism's primarily Greenshell™ mussels and algae. No kīna extracts are included in this programme.
- High value nutrition programme – “Musseling up: high-value Greenshell™ mussel foods” (UOAX1421) – Led by Dr Miller, this programme aims to enhance the value of Greenshell™ mussels by characterising their bioactive properties relating to enhancing mobility.
- Healthy food ingredients and subsequent programmes (CAWX1318) – The project aim is to develop bioactives with substantiated health benefits, derived from micro-algae and Greenshell™ mussels as anti/hypo-allergic or anti-inflammatory food ingredients.
- Vision Mātauranga Capability Fund – This programme, led by Dr Clapcott, involves a partnership between the Hikurangi Takiwā Trust and the Cawthron Institute to identify and communicate mātauranga with the aim of building the resource capacity around environmental management. Dr Clapcott is developing an in-depth perspective of a Māori organisation, iwi and hapū values including mahinga kai (food gathering places), mahi māra (cultivation), wai tapu (sacred waters) and āu putea (economic or commercial development).

L. VISION MĀTAURANGA (VM)

This project originated and driven by East Coast Māori with Cawthron Institute support. The proposal addresses both economic development and improving health outcomes. This region has the lowest household income and highest unemployment in the country which has led to some very poor health statistics, including the highest avoidable death rate in the country [50]. The proposal's primary aim, to grow the indigenous marine economy on the East Coast, will directly benefit Māori communities. The working group of hapū and East Coast communities will ensure it contributes directly to Vision Mātauranga themes of *Taiao* (achieving environmental sustainability through iwi and hapū relationships with land and sea) and *Mātauranga* (exploring indigenous knowledge). Project partners on the East Coast already include Hikurangi Takiwā Trust, Te Papa Tipu o Uepohatu Trust, Hikurangi Bioactives Limited Partnership and Hikurangi Enterprises Ltd, who will ensure the research is designed to incorporate Tikanga and Mātauranga Māori on kīna into economic opportunities. The project also indirectly contributes to Hauora/Oranga (improving health and social wellbeing) as it focuses on disorders where Maori are over-represented (e.g. type-2 diabetes) [51]. Finally, it directly contributes to Indigenous Innovation (contributing to economic growth through distinctive R&D) by creating a unique product from Māori knowledge.

A series of hui involving kaumatua, customary fisheries committees, and recreational divers will be conducted to explore mātauranga related to kīna in the rohe of participating hapū. The focus is on sustainability and governance of the kīna resource. Traditional fermentation, storage and other uses of kīna may provide key information on husbandry, sustainable development, extraction and/or marketing of bioactive extracts and related products. The Working Group aims to actively recruit knowledge holders and leaders who can assist to the success of the project.

M. CONSENTS AND APPROVAL

The Working Group is closely aligned with hapū fishery committees throughout the region who have indicated support for the project and part of their participation would be contributing kīna from their rohe to the project. The amount of kīna needed for this early discovery stage would be minimal (dozens per

season). This number of kīna required would easily fall under 4c of Cawthron Special Permit 507/4. This consent allows for research and education activities undertaken at Halifax St Nelson premises for aquatic life less than 30 kg or 200 individuals, but our preference is to work with hapū groups to provide the samples for extraction and analysis.

In the first six months, a series of hui will be held to share project kaupapa and invite more hapū to participate. This will build on the initial hui in Jan/Feb 2017 to establish support from key individuals and groups. Through the Working Group, the project will keep abreast of legislation based on the 2008 Nga Hapu o Ngati Porou Foreshore and Seabed Deed of Agreement. This opportunity appears to align well with the intentions of the legislation as hapū are closely involved and will have some ownership and eventual benefit from the work proposed.

The involvement of Dr Clapcott on the team is to further strengthen relationships, lead the cultural habitat assessment and oversee the Cawthron researchers to protect and enhance cultural and ecological values throughout the project.

Any future development of the industry will require local authority consents but the requirements of the development and nature of consents will be subject to the science and commercialisation work to be undertaken during this two-year project.

N. REFERENCES

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QUESTIONS RAISED BY REVIEW

Add a more comprehensive analysis, at an early stage of the project, of kīna availability and potential revenue.

Led by Manu Caddie, the team will develop a business case early in the programme to support this community-led economic development in Te Tairāwhiti. Alternate scenarios will be modelled based on various extract and/or product developments. Using available MPI catch data, in particular, looking at the

low commercial catch, we will aim to predict quantities of biomass that would support a kīna extract industry with respect to ecological sustainability and customary catch. Presently the data demonstrates a commercial take that is consistently well below the quota allocated. However, we believe the customary and recreational catch numbers are underreported. Through our meetings with hapū and communities we aim to ascertain the true kīna availability and work this data into the economic models developed.

Clarify if there could be a potential issue regarding the commercial development of kīna in an area of customary harvest.

We aim and have budgeted to work closely with local hapū around commercial development of kīna in an area of customary harvest. This is an issue that we will discuss in-depth with hapū during the first six months to work through various scenarios. We aim to get a good handle on what the customary and recreational takes are at present to explore options for managing the wild stock sustainably and/or developing land-based aquaculture options. Presently we are focusing on the underutilised commercial catch quota in the area, however we acknowledge and are aware that we do not want to reduce or effect customary harvest in any way. Significant budget has been allotted for community engagement around this issue. This project in total will take very small amounts of kīna to develop the bioactive portfolio (<100 kg of the 80 tonne commercially available). If the project is successful, Stage 2 of the project (outside this present application) will require larger amounts of kīna. This fact will inform future scenario discussion with hapū.

Clarify the low amounts of time committed to the project particularly the chemistry and ecological/sustainability aspects of the project.

Sufficient time has been allotted to facilitate the development of the required analytical and preparative methods at Cawthron (\$22K) and we will leverage off existing platforms we have developed for bio-actives in other matrices (mussel, paua etc.). This will reduce cost in the development of these new methods for kīna.

A base understanding of the cultural and ecological sustainability of the project for future commercial production will be initially obtained through our community engagement. Furthermore, Joanne Clapcott's time in the project (\$10K) leverages off an existing VM placement providing support to further strengthen relationships, lead the cultural habitat assessment component of the research and oversee the Cawthron researchers to protect and enhance cultural and ecological values. If the project is successful, we will work with ecological and sustainability scientists from the Cawthron Institute, Callaghan Innovation and possibly universities to establish a monitoring and/or assessment programme in Stage 2 of the project (outside this present application).

Clarify what has been budgeted to cover the costs of engagement with the local community.

Engagement with the community and local hapū is vital for the success of this project. We have significant amounts of people time dedicated to this. The majority of Pia Pohatu's time, with help from Manu Caddie and Agnes Walker, is dedicated to hui for engagement with hapū (including resources for meeting venues/kai/ koha etc). This equates to ~\$23K pa in personnel time and \$5K in meeting costs and overheads. Ultimately, we would like to work with more hapū around collection of kīna and sharing of knowledge of the resource. We are also developing some information resources with participating hapū including a section of the Hikurangi Bioactives Limited Partnership (HBLP) website dedicated to the project, printed material explaining the process, and further communication around the project.

Clarify if the \$20,000 for work in Prof Hosokawa's lab is new money or leveraged from the existing SICORP programme.

This is new money, separate from the SICORP programme. HBLP will provide these funds.

Q. CURRICULUM VITA