

## Research Proposal

A. PROJECT TITLE	Pātangaroa hua rau: The economic potential of collagen and bioactives from eleven-armed sea-star to manage overpopulations
“SHORT” TITLE	Pātangaroa hua rau: the bioactive potential of sea stars
B. THEME / PROGRAMME	Blue Economy Innovation Fund

C. PROJECT KEY RESEARCHERS			
Role	Name	Institution / company	Email
Project Leader	Matt Miller	Cawthron Institute	matt.miller@cawthron.org.nz
Project Co-Leader	Kura Paul-Burke	University of Waikato	kura@waikato.ac.nz
Project Co-Leader	Mathew Cumming	Plant and Food Research	mathew.cumming@plantandfood.co.nz
Project support	Shaun Ogilvie	Cawthron Institute	

D. PROJECT PARTNERS		
Name	Organisation / company / agency / Iwi / Māori	Role in project
Charlie Bluett	Te Rūnanga o Ngāti Awa, Manager Customary Fisheries	Research Partner – Has been working with Dr Paul-Burke to ascertain the effect of pātangaroa in Ōhiwa harbour and codeveloping management options
Tuwahakairiora O'Brien	Te Rūnanga o Ngāti Awa, Deputy Chair	Research Partner – Has been working with Dr Paul-Burke to ascertain the effect of pātangaroa in Ōhiwa harbour and codeveloping management options
Trevor Ransfield	Te Upokorehe Resource Management Team	Research Partner – Has been working with Dr Paul-Burke to ascertain the effect of pātangaroa in Ōhiwa harbour and codeveloping management options
Wallace Aramoana	Te Upokorehe, Kaumātua	Research Partner – Has been working with Dr Paul-Burke to ascertain the effect of pātangaroa in Ōhiwa harbour and codeveloping management options

E. ABSTRACT/SUMMARY
<p>An over-abundance of pātangaroa (<i>Coscinasterias muricata</i> and <i>Sticaster australis</i>; eleven-armed sea-stars) is depleting shellfish stocks and causing management issues in coastal areas of Aotearoa NZ, in particular the Ōhiwa harbour<sup>1</sup>. Pātangaroa are voracious predators of shellfish, causing dramatic decline in populations of mussels, pipi and cockles<sup>2</sup>. As a result, local iwi with the support of the Bay of Plenty Regional Council and co-management Ōhiwa Harbour Implementation Forum (OHIF), are seeking innovative ways to manage pātangaroa.</p> <p>Presently there is no economic value for harvesting pātangaroa and population management comes at a high cost. Low-value products such as fertiliser and protein for animal feeds have previously been suggested as possible uses for this bioresource<sup>3, 4</sup>. Pātangaroa are a potential bioactive resource, particularly as a source of marine collagen which is in high demand for cosmetics<sup>5</sup>. There is a growing body of evidence that, due to their ability to regrow lost limbs, they have properties/bioactivities that would aid wound healing and skin health<sup>6-8</sup>. The aim of this project is to identify the bioactive potential of pātangaroa, including unique collagens and marine bioactives, and estimate their economic potential.</p> <p>This project will work with local iwi to determine the bioactives found in pātangaroa to aid in its management and create a novel blue economy model. The ultimate goal is to work with iwi to create a sustainable economic opportunity that could fund the management of the pātangaroa and aid an ecosystem-based model for the harbour and surrounding coastline that aligns with local Māori values.</p>

## F. PROBLEM DEFINITION/OPPORTUNITY

Seastars (pātangaroa) play a role in subtidal benthic communities, however, they are voracious predators of ecologically- and culturally-important shellfish (e.g., mussels, cockles and pipis) in harbours and coastal areas<sup>2</sup>. Shellfish (especially mussels) are a significant intergenerational source of kaimoana as well as important socio-cultural-ecological species which are considered an important marine taonga for Māori. Over the years, Te Rūnanga ō Ngāti Awa and Te Upokorehe have led research to understand the causes for significant degradation in the mussel/shellfish populations in Ōhiwa harbour and approaches to assist in their recovery has become a priority<sup>9, 10</sup>. This has resulted in strong support from surrounding communities and government agencies promoting shellfish as the number one management action in the refreshed Ōhiwa Harbour Strategy (2014)<sup>9</sup>. Local iwi and regional councils have identified that pātangaroa are causing depletion of shellfish stocks and causing management issues in Ōhiwa harbour<sup>1</sup>. Biomass assessments determined there was an excessive population, 672 tonnes or 1.2 million, of pātangaroa in 2009 (Figures 1)<sup>11</sup>. Removing unwanted marine species is very expensive. We are proposing a novel blue economy approach to incentivise the recovery of Ōhiwa harbour by identifying promising economic opportunities to remove pātangaroa biomass.



**Figure 1-** Over-abundance of pātangaroa (left; *Coscinasterias muricata*, eleven-armed seastars) in a pipi bed in Ohiwa harbour (August 2019) and excessive reef star (right; *Sticaster australis*) in the coastal marine areas of Ngāti Awa (site adjacent to Ōhiwa harbour; March 2010).

The problem that this project addresses is how to create an economic opportunity to cover the costs for the management of pātangaroa in Ōhiwa Harbour which are causing a significant environmental / biodiversity problem. This will be achieved by understanding the composition and bioactive concentrations of pātangaroa over the seasons and developing novel cosmetic economic opportunities. During this project we will undertake the essential proof-of-concept steps for producing marine collagen and/or novel bioactives from pātangaroa. This project's 5 years' aim is to incentivise management of the Ohiwa ecosystem to be better balanced, ensuring both cultural and economic sustainability.

Our project is linked with the current Sustainable Seas project, *Awhi Mai Awhi Atu* which aims to understand ecosystem dynamics and pātangaroa density/distribution inside and outside the harbour, nested within a kaitiakitanga-based approach to ecosystem-based management (EBM). Our project is viewed as a complimentary and synergistic extension to the *Awhi Mai Awhi Atu* program by our iwi partners and a regime of shared/leveraged sampling, effort, equipment, resources, time and support will be applied. Our pātangaroa project has further synergies with 1.1 *Understanding ecological responses to cumulative effects* and 3.2 *Communicating risk and uncertainty to aid decision-making*. It grows on the capability developed in *Te Huataukīna tō iwi e: Developing marine bioactives from kina*, a Sustainable Seas project which was led by Dr Miller. The structure of that successful program will be further developed with lessons learnt around developing marine bioactives with iwi partners, which will be expanded on and further refined during this program.

## G. OUTPUT/SOLUTION

This co-developed project with local iwi (Te Rōpū Kairangahau consisting of iwi representatives from Te Rūnanga ō Ngati Awa and Te Upokorehe) will provide the foundational knowledge that is required to build innovative industries that will also support the management of pātangaroa in Ōhiwa harbour.

A likely economic sector for pātangaroa extracts is skincare. Marine collagen products based on pātangaroa could be produced locally, initially on a small scale but with the possibility of production expansion. This will provide a positive marketing story that would appeal to both domestic and international markets. Starfish-containing skincare cosmetic products are popular in Asian countries (particularly South Korea) and command premium prices (~NZD\$500-\$6,000/kg). Our research team has unique connections and capabilities with 20+ years' experience in delivering bioactive products from marine sources, including marine derived collagen. A pātangaroa-based cosmetic product will be developed using a scalable small-scale extraction process and presented to iwi as a product concept. All waste streams from that process will be assessed for possible uses to fully leverage the resource and optimise the economic potential. Our aims, results and products from the project will be presented to iwi in a series of hui, which has already commenced. We have and will continue to engage our extensive ties throughout the Bay of Plenty.

The outputs from this research will enable local iwi and regional councils to develop effective ecosystem-based management plans that utilise blue economy opportunities and product development to fuel marine restoration initiatives.

## H. PROPOSED RESEARCH/APPROACH

This project aims to develop a new marine cosmetic product that embeds the blue economy with the Māori economy. We are proposing a project that will co-benefit local iwi and the local community, as shellfish populations are replenished in Ōhiwa harbour. We are looking to tailor our approach to closely link to EBM systems by increasing the economic value of an overabundant resource, that is having a negative impact on the ecosystem, and to aid regenerative/restorative projects in marine environments in response to the social, cultural and environmental aspirations of our iwi partners.

Mātauranga Māori and Engagement to iwi and stakeholders (Milestones 1 & 5)

This project has been co-developed with our iwi partners from Te Rūnanga o Ngāti Awa and Te Upokorehe. It is supported by the Bay of Plenty Regional Council and the seven partners of the co-management Ōhiwa Harbour Implementation Forum (OHIF). This project has been in development for nearly 2 years and is the result of many two-way reciprocal hui/discussions between iwi and the researchers. Our iwi partners are serious about their harbour, their mahinga kai and seeking innovative management solutions for seastars and in so doing, benefit the harbour and the wider communities as a whole. This project has arisen from the issues, challenges, actions and aspirations of Māori and is grounded in Whanaungatanga - the principle of working in meaningful, genuine collaboration to influence how mātauranga Māori and western science principles and practices are translated operationally in ways that recognise cultural values, knowledge systems and opportunities. The principles of whanaungatanga include; Kotahitanga – the concept of mahi tahi or working together to achieve a common goal. Manaakitanga – highlights the responsibility to act, at-alltimes, in a respectful manner that uplifts and enhances the mana or prestige of others. Kaitiakitanga – refers specifically to the obligation to care for the environment and taonga (culturally important) species and spaces. Rangatiratanga – promotes strategic coordination and affirmation when agencies contribute to collective decision-making<sup>12</sup>. Co-development with hapū/iwi and stakeholders is foremost throughout the life of the project and beyond, as is consistent with tikanga Māori<sup>13, 14</sup> a whanaungatanga approach to research<sup>10</sup> and the principles of kaitiakitanga<sup>15</sup>.

Formal hui will consist of meetings with hapū/iwi partner representatives of te rōpū kairangahau have been and will continue to be held formally a minimum twice per annum over the program with ad hoc hui/meetings that may also occur dependent on needs (Milestone 1&5). After these hui/meetings the representatives return to their respective rūnanga, hui-ā- marae/iwi and/or kaitiaki resource management team to discuss. The co-management OHIF forum meetings are usually held every 6 months in March and October. The researchers will submit a short report as an agenda item and present at >2 OHIF meetings, seeking endorsement of current activities/findings and approval to proceed to the next stage. The principles of successful co-development through face-toface availability/engagement are underpinned by a lived experience of tikanga Māori previously described. All field work logistics will be achieved in coordination with the *Awhi Mai Awhi Atu* program including the provision of reciprocal two-way capability development between researchers and iwi partners. This project is consistent with WAI 262 documents and recognising the rights of kaitiaki of taonga and mātauranga Māori

We are cognisant of finding the 'right fit' between obligations and priorities of kaitiaki on one hand and IP systems on the other. In recognising the rights of kaitiaki of taonga and mātauranga Māori ongoing conversations will be a priority with te rōpū kairangahau including: IP rights and priorities of kaitiaki and mātauranga Maori; ownership and copyright-related rights; ensuring the rights of kaitiaki under Article 2 of the Treaty of Waitangi.

Alignment with Ecosystems based management

This project builds on 13 years of largely volunteer work by our iwi partners tracking the over-abundance of pātangaroa in correlation with the significant decline in traditional shellfish beds, in particular, green-lipped mussels, in Ōhiwa harbour. This program is closely aligned with the Sustainable Seas funded project *Awhi Mai Awhi Atu: Enacting a kaitiakitanga-based approach to EBM*, which aims to combine mātauranga Māori, western science and local kaitiakitanga to better understand degradation, assist recovery, and generate common management approaches for Ōhiwa harbour. These programs combined will take a kaitiakitanga based approach to EBM marine management plan for Ōhiwa Harbour that will enable our program to co-develop and collaborate with work with te rōpū kairangahau (iwi partners) and Bay of Plenty Regional Council for successful pātangaroa management.

Research team

We have established a leading NZ based team of researchers and connectors to achieve the goals of the program. Dr Matt Miller (Cawthron Institute) will lead the program and conduct the bioactives abundance and compositional analysis. He is an experienced chemist who has worked previously with iwi and commercial entities to develop marine bioactives (e.g. Sustainable Seas funded Kina bioactive program). Assoc. Prof. Kura Paul-Burke (Ngāti Awa, Ngāti Whakahemo, Ngāti Māhino; University of Waikato) has been working with the iwi and regional councils for 13 years to understand the marine ecosystem at Ōhiwa harbour. She has extensive connections throughout the region through her roles as an iwi kaitiaki and applied marine research leader with/for hapū/iwi entities

and government agencies. Dr Mathew Cumming (Ngāti Raukawa ki te tonga and Ngāti Toa, Plant & Food Research, PFR) is a leading marine collagen researcher who has 10 years' experience in analysing collagen and developing products for the cosmetic, nutraceuticals and medical industries. Dr Shaun Ogilvie (Te Arawa, Ngati Awa, & Cawthron Institute) is a iwi researcher on the *Awahi Mai Awahi Atu* project and will connect our program to the Cawthron Maori business development team.

#### Novel products and bioactives from pātangaroa and economic benefit

The echinoderms constitute an important phylum, whose members produce a large number of compounds with diverse biological activities<sup>16</sup>. Marine collagen products have been growing in interest and value due to favourable properties (e.g. firming and moisturising properties) and no limitations of use, unlike porcine/bovine collagen where there are religious and possible disease transmission issues<sup>5</sup>. A range of starfish species has been reported to have modest but encouraging collagen content (5-10% wet weight<sup>5, 17</sup>). Starfish extracts are also promising candidates for the treatment of hyperpigmentation disorder (darkened skin patches or spots) and useful for self-tanning cosmetic products<sup>18</sup>. Therefore, starfish-based beauty products are sold in Asia (particularly South Korea) and marketed through the animal's ability to regenerate its own limbs and its high collagen content. Such products command high prices (~NZD\$500-\$6,000/kg). Besides collagen, there is a wide variety of possible starfish bioactives that may provide high-value nutraceuticals or pharmaceutical targets such as saponins, terpenes, sterols, and carotenoids that play important roles in tissue regeneration and anticancer therapies<sup>7, 8</sup>.

#### Composition and characterisation of pātangaroa (Milestones 2 & 3):

This research will establish benchmarks for composition and concentrations of key bioactives for two species of pātangaroa (*Coscinasterias muricate* and *Sticaster australis*). There is no information regarding the composition of bioactives or collagen from these NZ starfish (one from Australian<sup>19</sup>). The project will leverage the specialised chemical and biochemical analytical capabilities of Cawthron and PFR (e.g., collagen, lipids, protein, small molecule analysis).

Pātangaroa (n=3 per species per time point) will be seasonally sampled for a 12-month period for macro proximate composition. This will determine the fat, protein, carbohydrate, moisture, and ash content of these two species and aid understanding on the composition of the resource. A further composite sample (n=1 of 3 individual starfish from each species) will be assessed seasonally for a series of bioactives that includes;

amino acids	collagen content	lipid class
fatty acid profile	sterol profile	carotenoid/pigment profile
micronutrients (e.g. calcium, phosphorous, etc)	polysaccharide/monomeric sugar profile	degree of sulfonation of carbohydrates
	terpene profile	saponin profile

As pātangaroa are not commonly consumed by humans, little is known about toxin and contaminates content. As pātangaroa consume shellfish in an area that can be affected by toxic algal blooms and a recent volcanic eruption has occurred, marine toxins (such as amnesic shellfish poisoning (ASP), paralytic shellfish poisoning (PSP) toxins) and heavy metals (Cd, Hg, As, Pb) will also be assessed. Most of these methods are already developed and validated at PFR and Cawthron. Through the project (Milestone 2) we will further develop or modify methods to adapt to this novel matrix, resulting in a suite of tailored analytics to qualify and quantify proximate composition, potential bioactives and non-nutritionals (such as toxins and heavy metals) in pātangaroa species.

Once the analytical suite has been developed, the secondary output will be a detailed compositional and bioactives factsheet on each species of pātangaroa (Milestone 3). This factsheet will be presented to iwi and council representatives at an OHIF meeting. The research will address how season and water temperature influence composition, and concentrations of bioactives and nonnutritionals. This information will enable decision makers to understand the economic potential of pātangaroa and help elucidate all possible products/opportunities.

#### Bioactive extraction and product development (Milestone 4)

In consultation with iwi and regional processors, we will develop a pilot-scale commercial process to extract collagen and other bioactives using pātangaroa suitable for cosmetic applications. It will be cost-effective and use green chemistry processing technologies available in the region. The bioactive/collagen extraction method will be designed to maximise yield and recover value from side streams.

Samples (~10kg) will be collected by the sampling team led by Dr Paul-Burke and the extraction method will be validated using ~20 starfish to prepare a dried collagen/bioactive product. This product, and the unused material will be characterised using analytical methods to determine the identity, yield, solubility, smell/colour, rheology, and molecular weight profile, including applicable analysis methods outlined for Milestones 2&3. This analysis of the unused starfish material (by-product/waste) will enable the assessment of its economic potential, so that full utilisation of the starfish can be evaluated. The final bioactive extract

will be incorporated into a concept cosmetic product (likely a face cream) to present to iwi, regional councils and other stakeholders during the final project Hui.

Our aim is to develop cosmetic products that require minimal safety and efficacy testing. Although it is possible to perform further investigations for functionality (such as bioactivity testing), this will form the focus of follow-on projects or through stakeholder investment. This future work will further add value to the concept product but is not essential for our chosen marketing strategy.

Outputs of **Milestone 4** will be a method to extract collagen/bioactives from pātangaroa that will be freely available to local iwi and other stakeholders and a data sheet on the final product that could be used for promotional purposes and product prototypes that will be presented to iwi and council representatives at an OHIF meeting. Further details of possible co-products from by-product streams will be highlighted to fully utilise the whole resource.

#### Program outline

We aim to start the project in Feb 2021, to avoid the summer holiday breaks and align with the initial sampling in mid-February (See figure 2). The program consists of yearlong seasonal sampling starting Feb 2021. The initial and final hui have been aligned with the OHIF, with updates possible at any time during the project. Bioactives, compositional factsheets and prototype products will be presented to the forum near completion of the project (either Oct 2022 or March 2023).

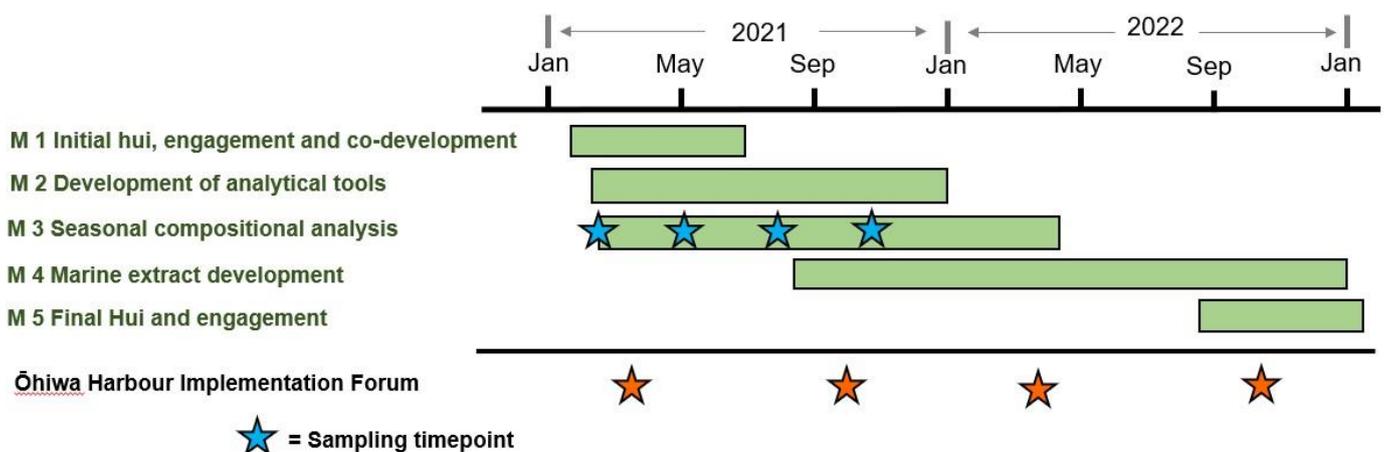


Figure 2: Gantt Chart of the proposed work program and alignment with the Ōhiwa Harbour Implementation Forum scheduled meetings.

#### Scalable model for future blue economy projects

This work aims to build a novel, relocatable, model which will allow entry by smaller players into the blue economy. To do this we will build on the previous SS-funded kina project to enable iwi/hapū and other small community groups to develop novel products from marine resources through our bespoke analytical capability and product development framework. The proposed model could be easily relocated to aid marine ecological restoration or pest management problems in other regions, with skills, networks, and capabilities transferable and accessible across NZ for novel blue economy projects. Models for intellectual property sharing, biochemical analysis and product development could aid different groups and therefore reduce replication and enhance growth of NZ's blue economy

## I. CONTRIBUTION TO BLUE ECONOMY IN AOTEAROA NEW ZEALAND

This project has arisen from the aspirations and priorities of Te Rōpū Kairangahau and the environmental issues facing Ōhiwa harbour. The development of regionally based small-scale extraction and production development processes for novel bioactives/cosmetic products from pātangaroa will financially incentivise their social, cultural and environmental-management aspirations. Overall, this will create an innovative model to facilitate marine recovery in Ōhiwa harbour and inspire similar undertakings in other regions. The enterprises arising from this project will provide community employment and further entrepreneurial opportunities, particularly for local iwi/hapū.

Natural marine materials provide an excellent pool of bioactive molecules for therapeutic medicine and cosmetic ingredients. Collagens are widely used in food, pharmaceutical/nutraceutical, cosmetic and biomedical industries due to their gelling properties, cell bioactivity and numerous health claims (such as enhancing skin hydration and elasticity, wrinkle reduction and repairing photo-damaged skin)<sup>19-22</sup>. In 2017, the global collagen market was worth US\$3.3 billion with forecast annual growth rate of 6.8%<sup>23</sup>. The value of marine-based collagen (compared with mammalian sources) is expected to witness the greatest increase in the next 5 years due to its superior solubility and bioactivity<sup>23</sup>. Products and processes could range from small-scale cosmetics, through to higher-value ingredient markets. Side streams containing bioactives will provide additional value and even the waste stream will have some value, such as for fertilisers.

Indicative estimates to determine the potential economic benefit.

- Estimation of available resource (33% of 672 tonne<sup>1</sup>): ~200 tonne
- Estimated 5% collagen<sup>17</sup> = 10,000 kg of collagen
- Value of marine collagen<sup>23</sup> ~NZD\$500-\$6,000/kg
- Therefore, potentially \$NZD 5-60M of collagen presently available in Ōhiwa harbour
- Theoretically, 2 million, 50 g pottles (@\$30 each) with 10% pātangaroa collagen inclusion, potentially could be sold for a total of \$60M.

Through the EBM through aligned research, we will estimate an accurate potential annual allowable catch that could be factored into economic modelling. Although the predicted numbers seem impressive, a pātangaroa collagen cosmetic product could retail on the domestic market as a unique gift and will particularly appeal to tourist markets. Over the next 3-5 years, the project could create 3-5 new local jobs in collection, manufacturing, and sales/marketing of marine cosmetics products with the potential to expand. There will be additional social and cultural benefits as more shellfish will be available for cultural gathering. If demand outweighs production/collection, other locations along the coast and NZ, may be utilised as well as the possibility of aquaculture production of pātangaroa which may provide additional blue economy opportunities (Cawthron has established capability to develop aquaculture systems for novel marine species).

In the longer term, the largest financial reward would be through the development of novel bioactives for high-end cosmetics or as nutraceuticals/pharmaceuticals. Diving deeper into the composition of pātangaroa, bioactive components such as secondary metabolites, will allow us to ascertain the potential value with greater confidence. Further, we aim to utilise the entirety of the resource, which not only optimises the economic return but also reduces the environmental impact, in line with Māori understandings of maumau – of not being wasteful.

## J. BENEFITS AND CONNECTIONS TO IWI, HAPŪ AND MĀORI ORGANISATIONS

This project is initiated, co-developed and co-led by Māori, for the direct benefit of Māori, Ōhiwa harbour, the wider communities, and Aotearoa New Zealand. It relates directly to the annual customary fisheries and aspirations of Te Rūnanga o Ngāti Awa and Te Upokorehe; and to the Iwi Management Plans of both iwi partners. Our research team has strong connections with our iwi partners. In particular, Dr Kura Paul-Burke has worked with all partners of the harbour at all levels and stages for over 13 years. Her deep connections and kaupapa Māori approach to research provides a positive exemplar of authentic, reciprocal relationships and benefits for iwi partners.

For iwi, this project is intended to provide important social, cultural and environmental benefits as well as sustainable economic returns. It is understood that the health of the harbour is a direct reflection of the health of the people. This project provides a platform to promote and energise Māori voices, aspirations, ideas, practises, and knowledge, to actively assist the sustainable future of marine ecosystems for present and future generations. Further, other iwi/scientists from both the Te Ika a Maui (North Is.) and Te Waipounamu (South Is.) are making contact to report increasing seastar predation issues correlating with declining shellfish (mussel) numbers. They are seeking solutions to their seastar issues. It is intended that this project could be replicated by other coastal hapū/iwi to derive social, cultural, environmental and economic benefits for their marine species and spaces.

Social benefits include potential employment opportunities for local iwi and communities; flow-on effects for local businesses and equally as important education outreach opportunities for Kura Kaupapa Māori schools associated with the harbour. Anticipated cultural benefits are grounded in kaitiakitanga (active guardianship), whanaungatanga (relationships with humans, species and spiritual entities of the harbour), manaakitanga (an ethos care and respect), kotahitanga, (collaboration) and rangatiratanga (self determination). If the mana of the harbour is enhanced, then the mana of the people is enhanced. Consistent with the iwi management plans of our iwi partners environmental benefits include a self-recruiting mussel population thriving on the floor of the harbour with an ecologically sustainable population of seastars as a tohu of a harbour in recovery. For our iwi partners, it is anticipated that any economic returns will be used to provide a model of revenue to further assist ongoing management, research strategies and opportunities for Ōhiwa harbour.

## K. COMMUNICATION OF PROJECT RESULTS

We will communicate the project results in collaboration with Te Rōpū Kairangahau and the Ōhiwa Harbour Implementation Forum (OHIF).

We will have >2 hui where we will refine the co-developed program with stakeholders, listen to local iwi needs and aspirations and share the direction and results. These will occur in union with the OHIF that meets biannually (March and October) where we can inform, update and consult with relevant parties in the one forum. We will further give updates at the forum when necessary. Wider communication of project results will be achieved through a variety of formats including: media releases and media outlets, Māori Television and local newspapers (online/print); Hui-ā-iwi/hapū/marae; rūnanga annual reports; seminar and conference presentations; Bay of Plenty Regional Council Ōhiwa Harbour Newsletter and Website among others. We are keen to highlight the cultural, social and environmental impacts of this research as social licence is vital to the success of the program. We will extend this reach through the forum iwi/council groups involved.

If relevant and approved by the forum, peer reviewed paper(s) in indigenous/scientific journals may provide additional opportunities to share knowledge generated once stakeholder parties are comfortable that intellectual property is appropriately protected. Novel data on the composition of pātangaroa, its biochemical characterisation and collagen composition would be publishable. However, the research team are experienced in working with commercial entities and do not wish to either disclose sensitive information or create easy duplication that could disadvantage commercialisation opportunities.

#### L. CO-FUNDING (Source and amount)

In-kind contribution from Te Rōpū Kairangahau – hapū/iwi representatives from Te Rūnanga o Ngāti Awa, and Te Upokorehe Estimated at \$38K over the 2-year program. This includes;

- Administration support including office space, physical resources for reporting
- Te reo me ngā tikanga o te wahapū o Ōhiwa (peer review and support)
- Capability building, two-way reciprocal exchange of knowledge
- Assistance with marae/wānanga/hui
- Assistance (organisation, implementation) for meetings/hui between research team, hapū/iwi and the co-management Ōhiwa Harbour Implementation Forum (OHIF)
- Active contribution and participation with field work (where applicable)
- Mātauranga Māori mentoring, advice and support
- IP and Kaupapa Māori ethics (peer review and guidance)
- Assist information collation and dissemination

#### M. RISK & MITIGATION

Extraction and production technologies may be too expensive for the likely economic return: We are mitigating this by leveraging other successful NZ models of creating value from marine bioactives, notably extracting collagen from fish skin for high value products<sup>S20, 21</sup>

Risk of incentivising the removal of pātangaroa could lead to the decimation of their population: To mitigate this, we are working with regional councils and local iwi hand in hand with ecosystems-based management through the Sustainable Seas project, *Awahi Mai Awahi Atu* to create a harvest management framework or, if feasible, assist in developing novel aquaculture opportunities.

Intellectual property disputes: To reduce this we adapt the successful IP arrangement developed for the Kina project, incorporating WAI262 principles.

Disruption due to COVID: This will be minimised through video conferencing, and local teams leading collection of seastars.

Biosecurity risks: Sampling will take place under conditions stipulated in our special permit (see below).

#### N. CONSENTS & APPROVAL required to undertake research

- Collection for accessing pātangaroa samples from Ōhiwa will be carried out under Cawthron's Halifax Street Special permit (651) with MPI, collection of fish, aquatic life and wild seaweed for investigative research. Specifically, under clause 5c, where samples of aquatic life under 30kg or 200 individuals (whatever is less) can be taken for the entire project. These specimens will be collected by an authorised agent, in strict accordance with permit conditions.
- Consistent with WAI 262 we recognise and are cognisant of finding the 'right fit' between obligations and priorities of kaitiaki on one hand and the IP systems on the other. In recognising the rights of kaitiaki of taonga and mātauranga Māori ongoing conversations will be a priority with te rōpū kairangahau including: IP rights and priorities of kaitiaki and mātauranga Maori; ownership and copyright-related rights; ensuring the rights of kaitiaki under Article 2 of the Treaty of Waitangi.

## REFERENCES

1. Wilcox, M.; Jeffs, A., Impacts of sea star predation on mussel bed restoration. *Restor. Ecol.* 2019, 27 (1), 189-197.
2. Paul-Burke, K.; Burke, J. *Report on the findings of sub-tidal sampling surveys of Perna canaliculus Green Lipped Mussel populations in Ōhiwa harbour* Bay of Plenty Regional Council: Whakatane, New Zealand, 2016.
3. Lee, C. F. *Technological studies of the starfish* US Dept of Interior, Fish and Wildlife Services: Washington DC, USA, 1951; p 52.
4. Te Tai, N. *Literature Review of mussel restoration and sea star management in Ohiwa harbour.*; Bay of Plenty Regional Council.: Whakatane, NZ, 2015.
5. Coppola, D.; Oliviero, M.; Vitale, G. A.; Lauritano, C.; D'Ambra, I.; Iannace, S.; de Pascale, D., Marine Collagen from Alternative and Sustainable Sources: Extraction, Processing and Applications. *Mar Drugs* 2020, 18 (4).
6. Dai, Y.; Prithviraj, N.; Gan, J.; Zhang, X. A.; Yan, J., Tissue Extract Fractions from Starfish Undergoing Regeneration Promote Wound Healing and Lower Jaw Blastema Regeneration of Zebrafish. *Sci Rep* 2016, 6, 38693.
7. Zhou, P.; Gu, Q. Q.; Wang, C. Y., Survey of studies on starfish saponins and the other bioactive substances. *Marine Science* 2000, 24, 35-37.
8. Lazzara, V.; Arizza, V.; Luparello, C.; Mauro, M.; Vazzana, M., Bright Spots in The Darkness of Cancer: A Review of Starfishes-Derived Compounds and Their Anti-Tumor Action. *Mar. Drugs* 2019, 17 (11), 617.
9. Bay of Plenty Regional Council *Ōhiwa Harbour Strategy Refreshed* Whakatāne, 2014.
10. Paul-Burke, K.; Burke, J.; Bluett, C.; Senior, T., Using Māori knowledge to assist understandings and management of shellfish populations in Ōhiwa harbour, Aotearoa New Zealand. *New Zealand Journal of Marine and Freshwater Research* 2018, 52 (4), 542-556.
11. Paul-Burke, K.; Burke, J. *Green Lipped Mussel Populations Ōhiwa Harbour*; Client report for Bay of Plenty Regional Council, Ōhiwa Harbour Strategic Consultation Group: Whakatāne, NZ, January 2014.
12. Waitangi Tribunal *Ko Aotearoa tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity (WAI 262)*; Wellington, New Zealand: Legislation Direct, 2011.
13. Mead, H. M., *Tikanga Māori: Living by Māori values*. Huia Publishers.: Wellington, New Zealand, 2003.
14. Te Awakotuku, N., *He tikanga whakaaro: Research ethics in the Māori community*. Manatu Māori.: Wellington, New Zealand, 1991.
15. Jackson, A. M.; Mita, N.; Hakopa, H. *Hui-te-ana-nui: Understanding kaitiakitanga in our marine environment. Ko ngā moana whakauka*; Sustainable Seas National Science Challenge, Ministry of Business Innovation and Employment: 2017.
16. Kelly, M. S., Echinoderms: Their Culture and Bioactive Compounds. In *Echinodermata*, Matranga, V., Ed. Springer Berlin Heidelberg: Berlin, Heidelberg, 2005; pp 139-165.
17. Lee, K.-j., Biochemical Characterization of Collagen from the Starfish *Asterias amurensis*. *Journal of the Korean Society for Applied Biological Chemistry* 2009, 52 (3), 221-226.
18. Jeong, M. H.; Yang, K. M.; Kim, J. K.; Nam, B. H.; Kim, G. Y.; Lee, S. W.; Seo, S. Y.; Jo, W. S., Inhibitory effects of *Asterina pectinifera* extracts on melanin biosynthesis through tyrosinase activity. *Int J Mol Med* 2013, 31 (1), 205-12.
19. Cianciosi, S. C.; Hird, F. J. R., The collagen content of selected animals. *Comparative Biochemistry and Physiology B-Biochemistry & Molecular Biology* 1986, 85 (2), 295-298.
20. <https://www.revolutionfibres.com/2020/04/activlayr-successful-launch-on-south-korea-homeshopping-channels/> (accessed 25/8/2020).
21. Scoop news <https://www.scoop.co.nz/stories/BU2005/S00149/premium-nz-collagen-skincareproduct-sells-out-on-south-korea-home-shopping.htm> (accessed 25/8/2020).