Research proposal

A. PROJECT TITLE	Thinking outside the can: engineering a sustainable future for toheroa aquaculture
"SHORT" TITLE	Thinking outside the can: engineering toheroa aquaculture
B. THEME / PROGRAMME	Blue Economy Innovation Fund

C. PROJECT KEY RESEARCHERS

Role	Name	Institution / company	Email
Project Leader	Phil Ross	University of Waikato	phil.ross@waikato.ac.nz
Project Co-Leader	Taoho Patuawa	Te Roroa	tpatuawa@teroroa.iwi.nz
Project Co-Leader	Jonny Hill	Bluetide Aquaculture	
Project advisor and co-supervisor of MSc students	Leo Zamora	Cawthron Institute	

D. PROJECT PARTNERS

Name	Organisation / company / agency / Iwi / Māori	Role in project
Taoho Tane (General Manager Te Roroa,) Thomas Hohaia (Manawhenua Board Chairman)	Te Roroa	• Represent hapu and whanau of Te Roroa; • Support the co-design, implementation and governance of the project; • Support the development and inclusion of mātauranga Māori into the project; • Provide tikanga, kaitiakitanga and holistic approaches to knowledge and action; • Provide data relevant to the project design and implementation; • Provide leadership/support for korero with iwi/hapu/whanu in Te Taitokerau; • Provide an in-kind contribution of staff time via attendance at meetings, collaboration and other work.
Jonny Hill Tom Vosper Cody Taylor Scott Harvey	Bluetide Aquaculture	• Provide and develop novel rack and mould aquaculture system; • Support the design, implementation and governance of the project; • Design and implementation of recirculating aquaculture systems.

E. ABSTRACT/SUMMARY

The iconic toheroa is a species with the potential to kick start the blue economy of Taitokerau. Toheroa are delicious, nutritious and internationally renowned, and have a cultural identity which makes them valuable and marketable. Unfortunately, due to the failure of adult toheroa populations, a commercial fishery is no longer viable. However, post-settlement juveniles (spat) still recruit to west coast beaches in large numbers and we believe they can be sustainably harvested to supply a community-based toheroa aquaculture industry that will generate economic benefits and support the well-being of the people of the Taitokerau. While the approach of on-growing wild-harvested spat has been successfully implemented in mussel aquaculture, we do not know if it will work for toheroa. To begin addressing the uncertainties of this kaupapa, we will conduct research to (1) determine the reliability of spat supply and the sustainability of wild spat harvest, and (2) quantify the performance that can be achieved through optimisation of spat selection, diet and culture conditions. This information will tell us if toheroa aquaculture is viable and inform future research and commercialisation initiatives. We have assembled an expert research with a shared vision for toheroa aquaculture that is Māori owned and operated, promotes education and employment, and reconnects people to their taonga and Te Taiao. Te Roroa will provide governance to ensure the research outcomes address the needs of the people of Taitokerau and that our kaupapa is built on the principles of mauri, whakapapa, kaitiakitanga and manaakitanga.

F. PROBLEM DEFINITION/OPPORTUNITY

Taitokerau (Northland) is one of the poorest and most deprived regions in New Zealand[1]. Unemployment is high, incomes and rates of school-level qualification are low, and few opportunities exist for well-paid employment. While Taitokerau does possess valuable natural resources, this has not translated into wealth or employment opportunities for the masses. For example, 70-80% of mussel spat sustaining the $400 million mussel aquaculture industry is harvested from Te Oneroa a Tōhē (90 Mile Beach)[2]. While this natural resource provides employment for a small number of local people, mussel spat is shipped out of Taitokerau to other regions where most of the industry's economic benefits are realised. Aquaculture is touted as an industry that benefits regional economies[3] and Taitokerau aspires to be more than 'just an exporter of spat'. However, significant aquaculture opportunities do not currently exist in the region.

The toheroa, an iconic and culturally important surf clam that was once a world renowned New Zealand seafood export, is a marine resource that is not currently utilised in a commercial sense anywhere in New Zealand[4]. Although not viable as a wild fishery, toheroa aquaculture has the potential to kick-start a sustainable blue economy in Taitokerau, providing new business and employment opportunities while promoting the well-being of local communities. Toheroa were once plentiful on the west coast of Taitokerau, but populations collapsed in the 1960s after decades of unsustainable harvest. Toheroa have not recovered despite 40 years of protection. Habitat degradation is a likely explanation and the topic of ongoing research and restoration efforts[5,6]. While Taitokerau beaches may not sustain adult toheroa in the way they once did, post-settlement juveniles (toheroa spat) still arrive to these beaches *en masse* and were recently recorded at densities of more than 6,000 m^{-2}[7]. While most of this toheroa spat is destined to perish in the wild, it is possible that these juvenile toheroa could be harvested and used to support an aquaculture industry that brings wealth and employment to the north. This approach of harvesting wild spat and on-growing them on farms is what makes mussel aquaculture both simple and successful[2]. A similar approach could be used to farm toheroa.

On paper, toheroa are the perfect aquaculture species. Known to some iwi as "the food of the gods", they are delicious, nutritious, fast growing and thrive at high densities. Toheroa were one of New Zealand's first exports, were esteemed both locally and internationally and have a history and cultural identity that makes them valuable and marketable[4]. While appearing perfect in theory, we do not currently know how to farm toheroa. Unknowns include the reliability of wild spat supply, feasibility of hatchery-based spat production, growth and mortality rates, possible culture substrates, feed requirements, conversion rates, stocking densities, time to market, production costs, and the size and value of markets for different products. While the list of unknowns is large, through this project we will begin the process of acquiring the fundamental knowledge required to determine the viability of toheroa aquaculture.

High abundances of toheroa spat observed at Te Oneroa a Tōhē in November 2019

G. OUTPUT/SOLUTION

While the scientific aim of this project is to generate knowledge that will facilitate the development of toheroa aquaculture, the greater objective is creating opportunities that will contribute positively to the social, cultural, economic and ecological well-being of Taitokerau. We will do this by creating new knowledge, increasing human capacity, and refining novel technologies, which together will support the development of sustainable community-led aquaculture.

Outputs:

- **MSc theses**: (1) spatio-temporal dynamics of toheroa recruitment; (2) influence of spat selection and diet on the performance of toheroa in aquaculture;
- **Research papers published in scientific journals** reporting the above MSc research as well as the influence of temperature on the performance of toheroa in aquaculture;

Outcomes:

- **Creation of new knowledge** regarding toheroa physiology and ecology to support aquaculture and restoration initiatives;
- Refinement of **novel aquaculture technology** (relevant to toheroa and other bivalve species);
- **Increased local capacity** to participate in, and lead, aquaculture ventures and ecological monitoring/research;
- **Employment of tangata kaitiaki** on this research project;
- **Enhancement of mana** for the communities involved through their work with a taonga species and the creation of new employment and education opportunities;
- Development and implementation of **new educational opportunities** for tamariki and rangatahi.

As partners in this project, Te Roroa will provide oversight and governance to ensure the outputs and outcomes meet the needs of the Māori communities of Taitokarau. We anticipate that this venture will serve as a model for the development of community-based aquaculture elsewhere in New Zealand.

H. PROPOSED RESEARCH/APPROACH

To begin the process of determining the viability of toheroa aquaculture, we will conduct a two-year research programme, building on our existing technology, expertise and regional partnerships, to develop new ecological and technical knowledge that will be needed to sustainably farm toheroa in either land-based or in-water aquaculture. The initial research will focus on (1) determining the reliability and ethics of utilising wild spat supply through an investigation of recruitment dynamics, and (2) developing the technical knowledge required to on-grow wild harvested toheroa spat in land-based systems. At the same time, we will deliver an education and capacity-building programme (predominantly through co-funding) to help prepare the communities and young people of Taitokerau to take advantage of employment and business opportunities associated with future aquaculture initiatives.

This kaupapa will make use of a novel 3D-printed rack and mould system developed by Bluetide Aquaculture. This novel system addresses one of the primary obstacles to toheroa aquaculture, which has been the need to use sand as a culture substrate. Utilising this system, toheroa (and other species) can be held at high densities in a 3D matrix under more hygienic and controllable conditions than would otherwise be possible. Development of the rack and mould system will continue in parallel to this project.

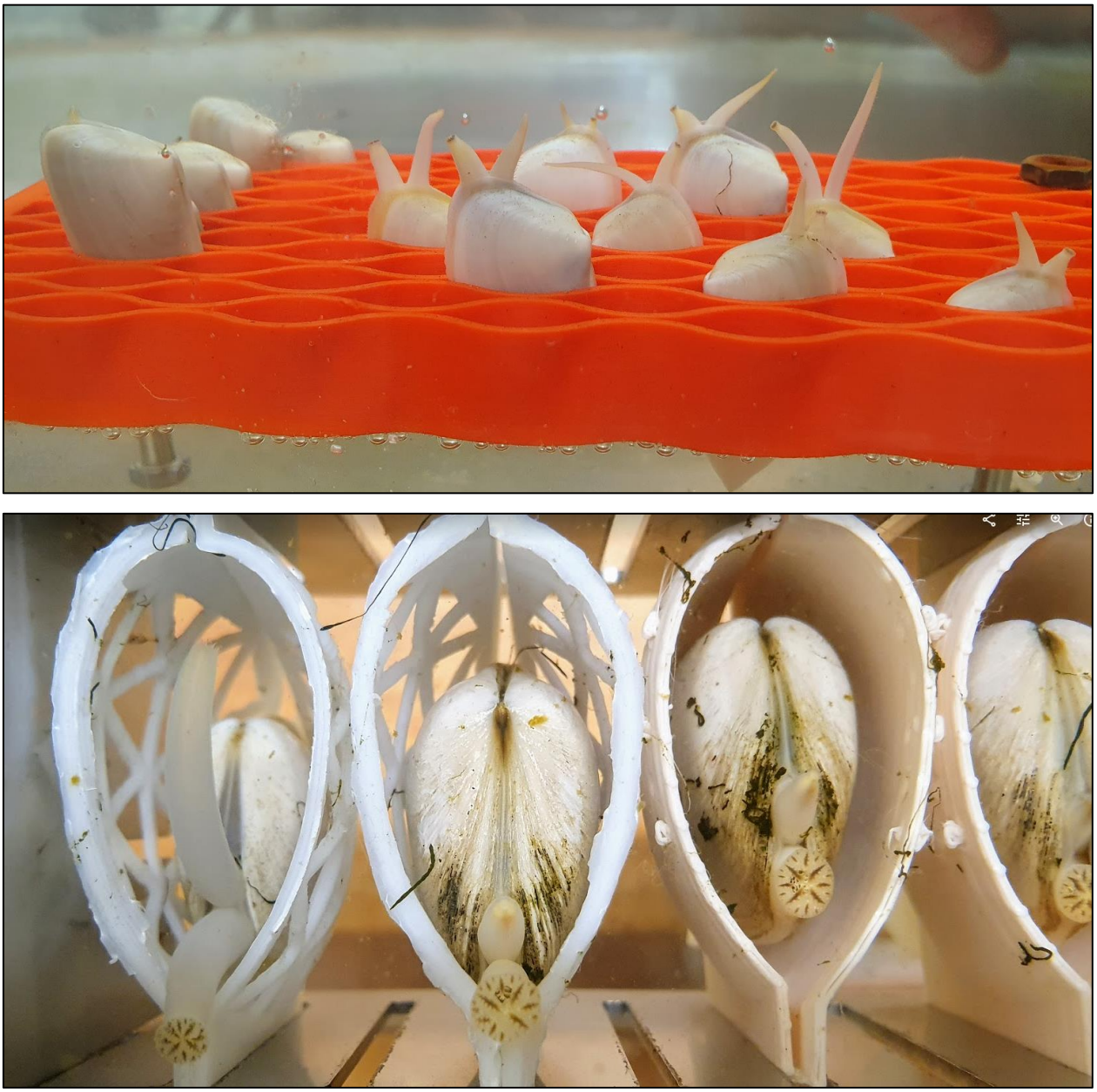
The components of the research programme are as follows:

1. Dynamics of spat recruitment

The reliability of spat supply will determine the feasibility of a toheroa aquaculture industry based on the harvest of wild spat. Mussel aquaculture in New Zealand is only possible on account of a relatively consistent supply of mussel spat from Te Oneroa a Tōhē, yet uncertainties around the timing and supply of mussel spat are driving efforts to supplement supply through hatchery production[2]. The advantage of toheroa over mussels is that toheroa naturally settle to beaches rather than to seaweed, meaning toheroa spat will be accessible throughout their recruitment season, while most of the mussel spat that the aquaculture industry relies upon can only be accessed when seaweed rafts (naturally seeded with appropriate density and size of attached mussel spat) wash ashore at Te Oneroa a Tōhē.

For toheroa, we currently lack an understanding of the temporal and spatial availability of spat and the number of spat that recruit to a population each season. This information is needed to (a) provide an indication of the reliability of a wild spat supply, (b) an understanding of the ecological implications of harvesting wild spat for aquaculture, and (c) knowledge to inform discussions around the cultural ethics of harvesting spat for toheroa aquaculture when mauri of wild populations is diminished.

To fill these knowledge gaps, surveys of toheroa recruitment will be conducted at beaches within the rohe of Te Roroa over the two years of this project. The researchers involved in this project have considerable experience designing ecological surveys and will build upon ongoing toheroa monitoring programmes. Monthly surveys will focus on Ripiro Beach, with surveys at additional beaches (such as Waikara and Kawerua) conducted at times when spat are abundant. Surveys will consist of sampling transects at set locations with quadrats excavated and sieved, and toheroa counted and measured. Established statistical methods[8] will be used to estimate the abundance of different size classes across the length of the surveyed beaches and temporal analyses conducted to quantify spatio-temporal recruitment patterns, variability in spat-fall between seasons and natural rates of spat mortality.



Juvenile (upper) and adult (lower) toheroa and tuatua in early prototypes of the Bluetide Aquaculture aquaculture system

2. Development technical knowledge

3. Spat selection and survival

From late spring to early autumn toheroa spat recruit to the beaches of Taitokerau where they can arrive in incredibly large numbers[4,9]. In November 2019, spat were recorded at Te Oneroa a Tōhē at densities of more than 6000 m^{-2} [7]. Spat ranged in size from 3 - 23 mm in length with the majority measuring between 7 and 15 mm. It was this observation of abundant toheroa spat, made during an assessment of the impacts of mussel spat harvesting on surf clams, that triggered the initial discussions around utilising a small proportion this toheroa spat to establish community-based toheroa aquaculture in Taitokerau.

The survival and retention of the wild-harvested spat in aquaculture is highly variable and is dependent on spat size and nutritional condition[10]. Larger spat in good condition do well while smaller spat in poor condition perform poorly. The same is likely to be true for toheroa with nutritional condition of spat likely to vary over the recruitment season due to variability in water temperature and food availability. The selection of appropriate sized post-settlement juveniles, collected at the appropriate time, will therefore be an important factor in determining the survival and performance of wild caught spat in aquaculture.

In this study we will determine performance (survival, growth and nutritional content) of toheroa spat of different sizes collected early, mid and late season (November, January and March). For each time period, toheroa spat will be collected and sorted into three size classes: 4-7 mm, 11-14 mm and 18-21 mm. A subsample of each size class will be tested for calorific content (nutritional condition). The remainder will be held under standardised conditions (temperature and microalgae diet) for a period of at least two months, with performance measured at set intervals during the trial period.

Analyses will be conducted to determine size and season (early vs. mid vs. late) specific performance over the duration of the experiment. These results will enable us to optimise spat collection protocols to maximise spat performance and ensure efficient and sustainable use of wild spat.

3.1 Diet development and growth

Toheroa grow fast in the wild. In Taitokerau, they reach *c*. 40 mm in one year and *c*. 70 mm in two years[9]. These growth rates are achieved despite toheroa only being submerged, and therefore able to feed, for a few hours each tidal cycle (because they inhabit the mid-intertidal zone). Consequently, in a recirculating aquaculture system it should be possible to obtain significantly greater growth rates through increased feeding times and an optimised diet[11,12].

In this study we will (a) characterise the composition of phytoplankton present at Ripiro Beach, and (b) examine the effect of a variety of live and commercially formulated microalgal diets on the performance of juvenile toheroa in two separate feeding experiments. In the first, we will examine the performance of toheroa when fed on a variety of single live microalgae species (e.g. *Chaetoceros, Isochrysis, Tetraselmis, Pavlova* and *Rhodomonas*). In a second experiment, the single species diets that resulted in the best performance will be combined and compared against single species diets and available commercially formulated diets. If possible, microalgae species present in the Ripiro phytoplantkton community will also be incorporated into this experiment. Each experiment will run for 60 days after which performance will be quantified to define an optimal diet that will be adopted into our standard spat culturing protocols.

3.2 Water temperature and growth

The distribution of toheroa spans the entire length of mainland New Zealand, with populations in Te Hiku (Far North) experiencing subtropical conditions, while those in Murihiku (Southland) are exposed to subantarctic water temperatures[4]. While southern toheroa do attain a larger maximum size than their northern whanau, there is disagreement in the scientific literature about the growth rates of southern toheroa and whether they exceed the growth rates that have been documented in the north[4,9,13,14]. Consequently, there is uncertainty around the water temperatures that will facilitate maximum growth in aquaculture.

To address this uncertainty, experiments will be conducted in the second year of this project to determine the effect of temperature on toheroa growth. Based on the results of the spat selection experiments (2.1), toheroa of optimal harvest size will be collected and held in aquaria at a range of temperatures where they will be fed an

optimised diet (2.2). The experiment will run for 60 days after which survival, growth and condition will be quantified to determine the temperatures promoting optimal toheroa performance.

All remaining toheroa will then be maintained using the now established optimal temperature and diet regime for the following 10 months to provide an indication of the growth rates that can be achieved over a 12 month period. Growth rate in the lab will be compared against growth in wild populations as measured in our ongoing spat surveys.

4. Education and capacity building

Alongside the research components of this project, we will deliver an education and capacity-building programme to help prepare the communities and young people of the Taitokerau to take advantage of employment and business opportunities associated with future aquaculture initiatives. This programme will include:

3.1 Kaitiaki research team

A team of kaitiaki (who are in the process of being employed to work with Te Roroa on projects based in the ngahere) will be trained in marine ecological monitoring, data management and data analysis. This team will then lead the monitoring of spat recruitment dynamics under the supervision of the Project Leaders (PR, TP, LZ), and will work with one of the project's MSc students to analyse and report on this ecological data. These tangata kaitiaki will also spend time at the University of Waikato research facility in Tauranga where they will receive aquaculture training (microalgal culture, aquaculture systems design and animal husbandry).

3.2 School holiday programme for year 11-13 students (delivered entirely through co-funding)

In collaboration with Aquaculture New Zealand and the aquaculture industry, we will develop and deliver a pilot programme where Taitokerau students travel to the Bay of Plenty for hands-on learning experiences in the fields of engineering, marine science and aquaculture. Participants will be based at the University of Waikato for lectures and laboratory sessions and will visit key aquaculture sites (farms and processing facilities) to gain an understanding of the available career, business and training opportunities.

3.3 Wānanga for primary and secondary students in Taitokerau (delivered entirely through co-funding)

Wānanga will focus on STEM and mātauranga Māori. The format will be similar to the wānanga run for Tauranga rangatahi (https://tinyurl.com/y854h5wm). Students attending the school holiday programmes will help deliver these wānanga. The programme will be run in collaboration with Manaaki Te Awanui and will be funded through cash and in-kind support from Aquaculture New Zealand, University of Waikato and Taitokerau iwi.

I. CONTRIBUTION TO BLUE ECONOMY IN AOTEAROA NEW ZEALAND

Te Roroa supports the concept of the blue economy in Aotearoa New Zealand and emphasises the very strong need for decisive Maori leadership across activities looking to contribute to this concept. The role of Te Roroa as an Iwi organisation is to support our marae, hapu, and whanau within our communities to identify and become active in opportunities such as this project with toheroa.

The use of the word aquaculture in this sense can be considered as a contemporary application of technology which supports traditional knowledge and matauranga application of very established values and principles of mauri, whakapapa, kaitiakitanga and manaakitanga. Not only does this project provide scope for activities of economic value, but it also provides an opportunity to generate and uplift cultural, social and ecological well-being values as well. Culturally, this project will contribute by reconnecting our people to a significant taonga shellfish species for this rohe. The opportunity for matauranga and tikanga to guide cultural harvest of toheroa spat and other science activities within this project is a significant component of this partnership. Socially, we have opportunities to provide local employment, practical education in industry, and experience in shellfish science and research which can also contribute significantly to decision making around the aspirations for customary kaimoana harvest and monitoring. Ecologically, the project offers the ability to harvest spat which

may otherwise be vulnerable to the impacts of vehicle damage and ongrowing with a shared vision of economy and conservation through repatriation.

The context of this project in conjunction with the blue economy concept offers a very unique opportunity. Firstly, this partnership supports the aspirations of Te Roroa exercising tino rangatiratanga and mana motuhake by allowing for decision making, participation and active involvement in all aspects of the project. These aspirations from an Iwi perspective have a direct pathway to our marae, hapu and whanau to activate our people in industry, and develop skills in science and matauranga investigation .
This aspect of the partnership alone has the ability to inform the future direction of the aquaculture industry and Maori striving to achieve holistic benefits within the blue economy.

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

This kaupapa is a partnership between Te Roroa, University of Waikato and Bluetide Aquaculture with additional support from Cawthron. The vision all partners share is for toheroa aquaculture that is Māori owned and operated, promotes education and employment, and reconnects people to their taonga and the environment. Te Roroa will provide guidance and governance to ensure the research incorporates mātauranga and the outcomes address the needs of the people of Taitokerau.

The immediate benefits of the of the project will include:

- Facilitating the engagement of Te Roroa with the marae in their rohe as well as the marae of Te Uri o Hau and Ngapuhi located on the Pouto peninsula;
- Employment of tangata kaitiaki;
- Educational opportunities for tangata kaitiaki, rangatahi and tamariki;
- Enhancement of mana for the communities involved through their work with a taonga species and the creation of new employment and education opportunities;
- Strengthening and building relationships with industry, government and research organisation;
- Reconnecting people to each other, taonga species and to the environment;
- New knowledge and human capacity to contribute to environmental management.

In the medium term, if this project leads to further research and development or if production is scaled up to point where toheroa are made available to the community or region, the benefits to Māori will include:

- Further employment, education and business opportunities;
- Sustainable customary harvest (via aquaculture) and the enhancement of mana associated with provision of this treasured kai.

In the longer term, if aquaculture reaches a scale of production where toheroa are exported beyond the region or internationally, there will be economic and associated social and cultural benefits for iwi and hapu who either run or co-invest in aquaculture facilities.

In the current partnership, the lead Māori organisation is Te Roroa. Earlier in the year when the initial proposal (EoI) was submitted we were also looking to partner with Te Rarawa, Te Aupouri and Ngati Kuri. However, these Te Hiku iwi have since decided that they are not able to commit to the research project at this time. This is primarily due to ongoing process of developing and implementing a Code of Practice for mussel spat harvesting at Te Oneroa a Tōhē. Te Hiku iwi will be kept informed of the progress we are making with this research and we have expressed our desire to resume our collaboration with them at a time when they are ready to join us.

K. COMMUNICATION OF PROJECT RESULTS

An agreement around the sharing and communication of intellectual property, data and the results will be determined in partnership with the iwi and hapū collaborating on the project. This agreement will incorporate mechanisms for giving effect to Wai 262.

Communications will be targeted to three main audiences: Industry/government; general public; and Taitokerau Māori communities.

Industry/government focused communications will target organisations including Ministry for Primary Industries (MPI), Te Puni Kōkiri, Aquaculture New Zealand and Northland Regional Council (NRC). Communications will be through presentations (Māori Fisheries conference, New Zealand Aquaculture Conference, MPI Shellfish Working Group, New Zealand Marine Science Conference) and research publications (MSc theses and journal publications). The project leaders have existing relationships with MPI, Aquaculture New Zealand and NRC and will be in regular communication with these organisations throughout the project.

Communications with the general public will be achieved through mainstream news media channels. There is considerable public interest in toheroa as evidenced by coverage of PR's research over the years (print and radio)[16,17] and the volume of public feedback/communications to PR following the reporting of each media story. We have also discussed filming a story with Māori Television and believe there would also be interest from mainstream TV shows such as Country Calendar who have previously covered clam harvesting.

Communications to the Māori communities of Taitokerau will be achieved through hui, wānanga and social media. The project will commence and finish with a series of hui at the marae across the Te Roroa rohe and Pouto Peninsula. Wananga will be run for tamariki and rangatahi. Te Roroa will provide leadership in the communications of the research to other iwi in Taitokerau and there may be opportunities to this present this research to the Te Oneroa a Tōhē Board.

L. CO-FUNDING (Source and amount)

- **University of Waikato**: $25k for MSc scholarship and $30k in-kind support for school holiday programme outlined above;
- **Bluetide Aquaculture**: $20k in-kind support for technology and aquaculture system development and construction;
- **Te Roroa**: $ *not quantified* In-kind contributions will include time spent in partnership meetings, reporting back to governing bodies and any other work promoting or working towards the objectives of the project;
- **Cawthron**: $9k in-kind support in form of expert advice and student supervision from Leo Zamora;
- **Callaghan Innovation**: $10k cash already contributed to technology development;
- **Curious Minds**: $30k cash - Te Roroa has received funding for a curious minds project that will now be aligned with the education initiatives outlined above.
- **Aquaculture New Zealand**: $ *not quantified* Aquaculture NZ have agreed to contribute cash and in-kind support to the wānanga to be run for tamariki and rangatahi in Taitokerau but we are yet to determine level of support
- **Aquaculture Industry**: $ *not quantified* In-kind support for wānanga and school holiday programmes including visits to aquaculture sites.

M. RISK & MITIGATION

Risk	Mitigation
COVID-19 travel restrictions prevent travel to Taitokerau	We will prioritise training of tangata kaitiaki so they are able to continue survey work independently if regional travel restrictions prevent in-person collaboration
Recruitment of suitable tangata kaitiaki	Te Roroa are currently identifying suitable candidates for their 'Jobs for Nature' projects who will also be suitable for this project
Recruitment of MSc students	Recruitment of MSc students can be challenging. To minimise this risk we have already begun discussions with suitable candidates

N. CONSENTS & APPROVAL required to undertake research	• PR already holds an MPI Special Permit to conduct research on toheroa. No other consents or approvals are required for this project.

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