# Algal Aquaculture for the Eastern Bay of Plenty

## Scoping economic opportunities for macro algae aquaculture in the Eastern and Broader Bay of Plenty, New Zealand

Prepared by Dr. Ralf Schlothauer, Whio Innovations, on behalf of Priority One

Opotiki Harbour Transformation Project, Workstream 15: Supporting Innovation
Task 4.2.1 Algal Aquaculture
Task 4.2.2 Algal Bio-actives

30 June 2017

## Executive Summary

There are two clear opportunities of high relevance to Opotiki. First of these is onshore aquaculture of seaweed via a High Rate Algal Pond (HRAP); second is farming of target seaweed species in the existing consented water space. Both of these methods of production have multiple potential product outcomes, ranging from soil additives to pharmaceuticals. However the key issue for most of these is being able to produce enough product, at enough scale and quality, to support commercial operations.

The production of macro algae in HRAP is an exciting emerging field in biotechnology and food production. Macro algae farming may be a sustainable complement for any traditional aqua farming opportunity in the Bay of Plenty (BOP). It can also feature to offset nitrogen emissions from stock and municipal effluents.

Production rates of HRAP are unmatched by any terrestrial agricultural method. The uses of algae biomass span from biological charcoal (biochar), bio-stimulants and fertilisers, stock and pet food, animal husbandry products, high quality human food to high end bioactive chemicals.

The Bay of Plenty infrastructure and location support a unique opportunity. Sunshine hours, average temperatures, low value low lying pastoral land at the coast, and disperse and concentrated nitrogen effluents provide close to ideal HRAP locations.

In this report we looked at a few key locations that will be ideal to set up HRAP systems for nitrogen sequestration and algal biomass production. In the Eastern Bay of Plenty, the Opotiki harbour (Otara and Waioeka rivers) and the Waiotahi Estuary provide particular opportunities, while in the broader Bay of Plenty, the Kaituna river mouth and Rotorua lakes provide other potential sites. We further established biomass uses for summer seaweed incursions washed up in the Tauranga harbour and Bay of Plenty ocean beaches.

The University of Waikato Marine Field Station, under leadership of Prof Chris Battershill, has a long standing relationship with James Cook University (JCU) in Townsville. Prof Rocky de Nys of JCU has been spear heading the macro algae biomass production in HRAP for over a decade working very closely with MBD Energy Pty (MBD) in Queensland. We have a unique opportunity to work in close conjunction with MBD in the form of a local New Zealand joint venture.

The new infrastructure will be able to also support off shore algae farming. However we identified the immediate opportunity for the BOP lies in HRAP, followed by sea based algae farming in Opotiki after the construction of the local harbour.

Contents

## 1 Introduction

This report provides an initial assessment of commercial opportunities around algae for the Eastern Bay of Plenty. In particular, it reviews the potential for algal aquaculture to deliver new industry that in turn drives use of the proposed new harbour development at Opotiki.

The nature of the opportunities are such that this includes some discussion of opportunities for the broader Bay of Plenty, which for example might generate use of processing facilities based in and around Opotiki, alternatively might provide important additional resources necessary to make any initiative viable.

This report focuses on the commercial opportunities for macro algae aquaculture. It will not give justice to the full wide bandwidth of local algae species and their long term potential commercial use for New Zealand.

We are intending to prioritise and zoom in on those species and technologies that have been tried and tested elsewhere and that create unique opportunities locally for the BOP ecosystems. They should be opportunities that can be commercialised within the next three years rather than within the next decade.

We focus on options that can be swiftly commercialised, creating jobs and local know how, and use the local geography and infrastructure. Special attention will be given to the Opotiki District and the impending harbour development there.

## 2 Background

Macro algae aquaculture is a fast growing sustainable production of foods, feeds and bioactive around the world. This technology sits right at the sweet spot, binding CO2 from the atmosphere, binding water based nutrients and using mostly freely available solar energy to do so.

The productivity can reach a staggering doubling of algal material per week for fast growing simpler species which is completely unrivalled by any terrestrial agricultural production system.

Globally the focus on macro algae based biotechnology and food productions qualifies for a very exciting trend. Companies like the Olmix Group in Brittany, France, are developing and marketing a variety of algae based products for agricultural use and animal husbandry.

The use of macro algae for feeds, foods and medicine is not novel in Asian culture. However, the traditional hot spots of algae aquaculture in Asia do experience the challenges of increasing pollution. Access to clean coastal waters does severely restrict the ability to supply for local demand in countries like China, Korea and Japan.

Even if the effects of pollution could be mitigated to achieve edible quality, the local consumer will still be very aware of various food safety scandals and may much prefer produce grown in cleaner waters.

Algae aquaculture is attractive for fast high value biomass production, but there is another commercial aspect explored by James Cook University in Townsville, Queensland in conjunction with the company MBD.

They utilise the ability of algae to bind effluent nitrogen fast and effectively. The fragile barrier reef ecosystem simply cannot tolerate any further nitrogen influx, thus local prawn farming was rendered unsustainable. MBD offers a nitrogen sequestration service based on macro algae ponds that brings the efflux effectively to zero, cleaner than seawater pumped to the farm from the ocean.

Thus the commercial incentives to invest into algae aquaculture are significant. New Zealand's waters are more temperate than tropical Queensland. But we do feature a similar average of sunshine hours per year and we know from recent macro algae blooms in the Bay of Plenty that some species proliferate rapidly in our conditions.

## 3 Methods and Sources

The information for this report stems mainly from four sources.

- Two expert workshops held at the Waikato University Coastal Marine Field Station on the 4th and 18th of May 2017.
- Visit of the James Cook research facilities on algae as well as MBD's R&D and production systems algae for macro and micro algae bioremediation and biotechnology on June 26/27th 2017.
- A number of field trips to Opotiki, Waiotahi estuary and the Kaituna river mouth. The field trips raised an opportunity to interview Opotiki District Council on the best sites.
- SMIL. Our pilot project dubbed: **S**ummer **M**arine **I**nnovation **L**ab hosted at the Waikato University Coastal Marine Field Station at Sulphur Point, Tauranga.

## 4 Findings

### 4.1 Macro Algae expert workshops:

We conducted two workshops hosted in Tauranga in May 2017, invited New Zealand and Australian marine experts who shared their knowhow on macro algae aquaculture. The workshops were meant to function as a stock take of past experiences with macro algae aquaculture. They functioned also an open idea forum for the experts to come up with innovative ways to derive value from macro algae aquaculture.

We focused on two work streams during the workshops. Firstly the local specimen collection of algae in the BOP coordinated by Prof Chris Battershill. Chris referred to the local biodiversity of New Zealand's macro algae that can be tapped into for new industrial application.

The second work stream focused on industrial applications of seaweed and sea based aquaculture as well as using beach cast as feedstock.

We also invited representatives from the local companies, whose main issues are growth limitations. They are restrained by available beach cast supply.

AgriSea, from Paeroa is using mostly kelp (*Ecklonia radiate*), whereas NZ Manuka from Opotiki is using red algae (*Gelidium*, *Gracilaria* or *Pterocladia*).

Both cannot expand their production with local beach cast any further. If any of their preferred species was available, they could turn any additional stock immediately to grow their production.

**First workshop held on the 4th May 2017:**

- Prof. Rocky de Nys, Project Leader Centre for Macro Algae Resources, James Cook University, Townsville, Queensland, Australia
- Prof. Chris Battershill, Manager, Theme leader: Coastal and Marine Ecosystems, Waikato University, Coastal Marine Field Station, Tauranga, New Zealand
- Prof. Ian Hawes, Faculty of Science and Engineering, Waikato University, Tauranga, New Zealand
- Brendon Barnes, Investment Manager, Quayside Holdings, Tauranga, New Zealand
- Ashley Browne, Technical Officer, NZ Manuka Group, Ōpōtiki, New Zealand
- Karl Gradon, Chief Executive Officer, NZ Manuka Group, Awakeri, New Zealand
- Caine Taiapa, General Manager, Manaaki Te Awanui, Tauranga, New Zealand
- Dr Anthony Cole, Manaaki Te Awanui, Tauranga, New Zealand
- Jill Bradley, Director and Co-Founder, AgriSea, Paeroa, New Zealand
- Dr Ralf Schlothauer, Director, Whio Innovations, Tauranga, New Zealand
- Dr John Tyrell, Research & Innovation Manager, Waikato University, Hamilton, New Zealand
- Shane Stuart, Innovation Manager, Priority One, Tauranga, New Zealand.

**Second workshop held at 18th May 2017:**

- Prof. Mike Packer, Senior Research Scientist, Cawthron Institute, Nelson, New Zealand
- Prof David Shiel, Leader Marine Ecology Research Group, University of Canterbury, Christchurch, New Zealand
- Dr Donato Romanazzi, Industry Research Liaison, Cawthron Institute, Nelson, New Zealand
- Dr Ruth Falshaw, Science Mahana Editing Services, Rotorua, New Zealand
- Prof Simon Hinkley, Science Team Leader, Ferrier Research Institute, Wellington, New Zealand
- Dr Ian Simms, Principal Scientist, Ferrier Research Institute, Wellington New Zealand
- Jill Bradley, Director and Co-Founder AgriSea, Paeroa, New Zealand
- Caine Taiapa, General Manager, Manaaki Te Awanui, Tauranga, New Zealand
- Dr Rebecca Lawton, Environmental Scientist, Bay of Plenty Regional Council, Mount Maunganui, New Zealand
- Ashley Browne, Technical Officer, NZ Manuka Group, Ōpōtiki, New Zealand
- John Tyrell, Research and Innovation Manager, Waikato University, Hamilton, New Zealand
- Prof. Chris Battershill, Manager, Theme leader: Coastal and Marine Ecosystems, Waikato University, Coastal Marine Field Station, Tauranga, New Zealand

Both workshops turned out to be very successful, but also very different in their focus. Prof Rocky de Nys from James Cook University has been working to commercialise his research with MBD in Townsville for over 10 years. It would be fair to summarise his wealth of practical expertise on actual industrial success and his enthusiasm for growing this field dominated the first workshop.

Prof de Nys, one of the world’s leading experts in macro algae, has maintained a very refreshing commercial common sense. His collaboration with MBD over the years has resulted in the “rescue” of aquaculture in North Queensland.

Prawn or fin fish aqua farming in North Queensland was rendered non-economical by the tightening environmental rules on effluent discharge into the Great Barrier Reef waters.

Thanks to the algae aquaculture used for bioremediation of aqua farm effluents, the region now enjoys a sustainable AUD 60M volume prawn farming business owned by Pacific Reef Fisheries.

The second workshop had a much more local New Zealand flavour, sharing the experiences on macro algae research and farming in New Zealand waters.

It would be fair to state that New Zealand enjoyed local academic success in small pilot scale projects on line grown macro algae aquaculture.

The workshop revealed a high level of experience of individual researchers and research organisations such as Waikato University, IRL, the Ferrier Research Institute, Cawthron Institute, University of Canterbury, and Niwa et al.

We had to conclude that these localised successes never resulted in a commercial research/ commercial ecosystem comparable to the Townsville model.

New Zealand does feature a handful of small commercial entities that derive value from macro algae, but so far they have hardly been able to benefit from the research projects.

There are a number of reasons for this, from unhelpful legislation on fishing algae from the open water column to a mismatch in the selection of algae species for research, as opposed to the commercial need of local industry.

In New Zealand we should adopt the JCU-MBD ecosystem: a clear mission to select the simplest target species after managing to bind nutrients and get biomass diversification on commercial opportunities follow on.

In the Australian model, premium value extraction is based on successfully employing large scale biomass production of seaweed in a raceway system. The system is based on a fresh and saltwater species that both grow very readily in a race way system.

R&D is initially paid for by sequestration of nutrients which is now followed by a raft of newly added value opportunities.

We would use the local expertise much better if we would follow a similar system in New Zealand. Thus the following report has a strong focus on land based raceway systems growing simple fresh or saltwater species whilst sequestering locally available nitrogen sources.

# 5 Opportunity Assessment

**Definition of macro algae biomass value tiers:**

During our work on the project it became obvious that macro algae biomass can be used in a big range of products which vary widely in commercial value. Highest quality is right up there with other “delicatessen” as high quality premium foods, whereas biochar or biofuel are mass market commodities.

The different value tiers are quite distinct in their respective size, risks, post-harvest technology and returns. However our workshop discussions revealed that these opportunities are amazingly complementary, depending on how the macro algae is produced on farm or harvested from beaches. For the purpose of this report it is useful to separate five value tiers:

1. Bio fuels and biochar (charcoal) produced from macro algae.
2. Bio-stimulants for soil and plant health improvements.
3. Pet and stock food extracted from sea weed, kelp or other macro algae.
4. High quality human food.
5. Bioactive extracts and bio-polymers.

## 5.1 Biochar

Biochar is simply charcoal produced from organic material. Biochar from macro algae is somewhat distinct from biochar originating from forestry or orchards. Algae biochar displays lower carbon, but higher mineral content.

Biochar can be ploughed back into poor quality low carbon soils, which has been done by native inhabitants of the Amazon rainforest. It helps to improve nutrient and water retention as well as acting as substrate for soil bacteria. Depending on how biochar is produced, it can also act as a fertiliser but this feature is exhausted after a few seasons.

Biochar acts as a permanent carbon sink. In contrast to organic compost added to soil, it does not decompose but stays in the soil for thousands of years.

The biggest problem for widespread production and application of biochar are production costs. Various sources seem to conclude that the costs are at least $400 USD/ton and the application rate needs to be about 10t/ha or more to yield measurable improvements.

Pasture is simply not returning enough per hectare to warrant the application of biochar. There may well be discernible returns on biochar application for orchards, but we simply do not have any quality data from field applications; however this will be a field for future innovations.

According to Pyreg in Germany, a company manufacturing transportable biochar production units, there is an emerging range of applications for high quality biochar:

- **Soil conditioner resp. structure and base material for nutrients in humus production**
- **Feed additive and stable bedding in stock farming**
- **Catalyst to increase efficiency in biogas production**
- **Filter medium for air, water and waste water treatment (activated carbon)**

One of those transportable units in a 20ft container size is designed to produce about 300t of biochar per annum from 1,400t of organic raw material. The units are fuelled from the internal process gas with no external fuel needed. By-product of the carbonisation process is a sustainable 150 KW heat output, which could be used for drying feed material.

## 5.2 Soil Bio-stimulants

Bio-stimulants based on algae are already proven to work and enjoy a growing market in New Zealand.

AgriSea in Paeroa was one of the pioneers in New Zealand to sell bio-stimulants from fermented kelp. They have been followed recently by the NZ Manuka Group in Opotiki, who are selling a mulch based on algae by-product from their agar production.

As the name implies, bio-stimulants are not working as fertilisers as such but rather improve biodiversity and soil health. Crop health does improve based on those soil improvements.

The main off take of the macro algae produced in Queensland in race way system by MBD stems from local farms. Demand outstrips supply of algae based mulch by at least a factor of 10, supporting the investment in more race way systems at MBD.

The bio-stimulant market for New Zealand is now severely restricted by available raw material. The only legal supply of algae comes from beach cast, no diving and cutting of natural grown algae is permitted anymore.

In contrast to New Zealand, the Australian bio-stimulants stem from a scalable process that can meet demand by simply adding production capacity. This works in tandem with unlocking nitrogen discharge options for local aqua farming. As long as algae growth can balance the nutrients, both systems enjoy a natural sustainable synergy.

It has to be noted that the New Zealand bio-stimulants are based on species that are more complicated and that may not be readily growing in a raceway system, but we would strongly recommend to try bio-stimulants produced in raceway systems like in Queensland.

## 5.3 Pet and Stock food

The James Cook University undertook some seminal work on various macro algae species to be used as stock feed supplements. They recorded an amazing reduction in methane emissions by cattle fed macro algae supplements. This project is still at the research stage, but is certainly informative of the future use of macro algae as feed supplements.

The French Olmix group based in Brittany has already developed a wide range of supplementation feeds and animal husbandry products for farm animals that target digestive health, immunity, feed conversion or hygiene.

They get supplied from the 75,000 ton of raw material from local beach cast in Northern France. The Olmix group featured an annual turnover in 2013 of 56M Euros. A promotional video shows a purpose build beach harvester raking in suspended algae at high tide.

There are many beaches in New Zealand where this practice can be adopted as well. In the BOP alone there would be about 30 km coastline and the nutrient rich harbour water that suffer from seaweed blooms in summer pending prevailing winds and currents.

The washed up algae consists almost exclusively of *Ulva* species, the common seaweed which is more than likely the main supply in Brittany as well being a global ubiquitous species in coastal waters.

However the New Zealand supply would not need to be based on beach cast. *Ulva* is easily to grown in raceway systems fertilised by locally available nitrogen.

During our workshop, Prof de Nys educated us about a few simple fractionation steps required to turn *Ulva* biomass into added value. Such as wash of the sea salt, maceration and a multi temperature cooking process to separate the soluble sulphated carbohydrates from the protein.

Whilst unprocessed *Ulva* is not suitable as animal feed, the separated components can be utilised successfully for various applications.

### 5.4 High quality human food

It does as no surprise that there is a noticeable trend to look at macro algae as a global future food source. Climate change and the increasing global appetite for meat in the fast growing Asian economies have driven an increasing shortage of arable fertile land by demand on land for stock feed crops. This turns out to be an environmental disaster for regions like the Amazon where the forest is decimated to create space for feed crops.

There is nothing new in seafood cuisine based on macro algae. It is common food practice for Asia, as well as for our Maori communities.

Coupling the palatability and nutritional value of locally grown macro algae with modern aquaculture engineering, we will be on route to a new winning export crop, sustainably produced on land based in race way system or in coastal waters on anchored support structures.

The water and land spaces needed to enable this are of no conventional farming value anyway.

Low lying pasture is prone to succumb to flooding and high salinity, and land based algae farming does not impact recreational and shipping use of waterways. Filter feeders like algae and mussels create cleaner waters as a desirable by-product of coastal aquaculture

Simple physics show that a water based biological production system must be the most efficient conversion of sunlight and CO2 into plant material. Algae do not need invest any energy into fighting gravity, wind or root growth to get nutrients like a land based plant.

This is confirmed by the extraordinary growth rates of simple macro algae like *Ulva*. Over summer our students have logged rates of doubling the biomaterial in a growth cage in Tauranga harbour.

These rates were confirmed by research undertaken at JCU in Townsville. Prof de Nys pointed out that the productivity can reach as much as 70 ton per hectare and year in their race way system. In BOP the productivity might be slightly lower because of lower average temperatures, but by conservative estimate we would be reaching about 50t/ha per annum.

These productivity rates are unmatched by a land based agrarian system to grow human food.

By a first cursory evaluation local, species of *Ulva* by Prof Chris Battershill seem to feature a desirable flavour profile.

If this species can be grown in a raceway system, one ha would be big enough to provide 50 ton of algae raw material which can obtain a market pricing of 10 NZ$/kg, supporting an annual income of 500,000$/ha.

### 5.5 Bioactive and biopolymer extracts

Extraction of agar is likely to be one of the macro algae uses with the longest standing history in New Zealand.

*Pterocladia lucida* has been extracted for agar production since 1943 and led to the establishment of Coastal Biologicals in Opotiki in 1978. Red algae with high agar polymer content are of high value and beach collectors can expect to get up to 6$ NZ for a kg of dry raw material. Currently NZMG can only obtain 10% from local stock even at this attractive price and must import the balance from Spain or Morocco, mostly of inferior quality.

Between 2003 and 2007, Dr Ruth Falshaw from IRL led a project to aquaculture the brown seaweed species *Gigartina atropurpurea* in the Marlborough Sounds.

The trials were successful and grew algae to harvestable size in 3-6 month. Polysaccharides extracted from this species are useful in the application in cosmetics, foods and supplements. In 2007, public sector funding ceased and no private sector partnership could be secured.

Ruth and other team members from IRL have been attending our workshop in May. They are keen to share their expertise on aquaculture for biopolymer extraction during future projects

Following the experience of Prof Rocky de Nys, the extraction of value compounds from macro algae can be optimised to get maximum returns. Fucoidans, sulphated carbohydrates from *Ulva* species, do exhibit immune stimulatory and anti-inflammatory activities. They can be non-destructively extracted still leaving a protein fraction of value.

In a similar fashion one would expect that green and brown algae species can also be extracted not only for the biopolymers, but also for various bioactive that may feature new antibiotics or compounds for medical applications.

## 6 Developing an Innovation Ecosystem for Commercialising Macro Algae

One of the most striking features of the commercial opportunities around macro algae would be best dubbed as “networked commercial ecosystems”.

Rather than mutually exclusive, the opportunities must be seen as mutually enabling, resembling Russian dolls stacked into each other.

Success in one critical technical aspect appears to be the enabler for some secondary and tertiary opportunities i.e. cheap fast production of seaweed is paid for by the service of nitrogen removal which in turns makes affordable biochar and bio-stimulants.

The higher value aspects - the inner “Russian Dolls” - can be developed whilst the outer layers are paying the bills.

It is also clear that all value layers can happily coexist. The best way to picture this will be to look at the quality tiers of available nitrogen.

Simple fast growing algae like *Ulva* need seawater, sunlight, CO2 and a certain temperature range as basic requirements, then availability of nutrients in particular nitrogen becomes rate controlling.

Fortunately nitrogen is affluent in effluent. We are beleaguered with various forms of organic wastes from municipal and primary production sources. All of it contains nitrogen that fuels hypertrophy in various water bodies before it eventually lands in the sea.

The work of JCU and MBD in Townsville has shown how easily that nitrogen can be turned into valuable biomass.

If seawater is available, marine species can be grown, further inland the same technology can be applied on fresh water algae.

The origin of the nutrients or in most cases nitrogen may determine the value tier of biomaterial.

For obvious reasons no one would suggest to use municipal nitrogen sources for food. Even if no pathogen were detectable, it would be culturally unacceptable.

Municipal waste water can easily be used for the production of fertilisers and soil improvement. If appropriate specifications on pathogens are in place, it can be used for stock and pet food as well.

In the case of any heavy metal contamination from volcanic soil or from industrial effluents, biochar becomes the logical option. Trials at JCU and Massey University have shown that any toxic organic molecules are destroyed and heavy metals can be effectively sequestered, they do not leach back into the soil.

Germany was leading the way here by not allowing the disposal of biosolids in landfill - so the carbonisation in a small biochar plant became the only viable option for smaller communities.

This will lead to many secondary innovations around the use of biochar. At the very minimum, biochar production is sequestering carbon from the atmosphere for a useful purpose.

Probably the most ubiquitous nitrogen source in New Zealand stems from pastoral use of land. Close to sensitive waterways, i.e. the lakes district near Rotorua, the main communal value of fresh water aquaculture will be the preservation of recreational and drinking water quality.

The fresh water macro algae can certainly be used in applications of soil improvement and animal feeds, low quality will be carbonised to biochar.

It is a bit counterintuitive to sequester the nitrogen as late in the process as close by the coast but there are a few positive aspects.

The pathogen loading in a river estuary will be lower simply by dilution and pathogen die off. Furthermore the river will act as a natural buffer system that evens out wild swings in daily loads. Once the nitrogen rich fresh water will be mixed with tidal saltwater the resulting brackish water is ideal for some marine algae production.

Pasture sourced nitrogen may be ideal for middle tier opportunities, bio-stimulants, feeds, biopolymers etc. It also does not carry the cultural stigma of municipal waste and it is very likely that very high spec food grade algae can be grown in river estuaries.

The most desirable situation, combining aqua farming of fin fish or prawns with macro algae raceway systems creates a point load of known origin close to the coast that does not dilute the salt water race ways too much, a culturally very acceptable form of nitrogen fertiliser.

In summary the use of algae in different value tiers may be determined by the “grade” of nitrogen. Further inland the main source of income will be the sequestration service. However, new added value uses of fresh water algae are now discovered at JCU which will be applicable to New Zealand species as well.

In coastal locations it may depend if the nitrogen stems from municipal, pastoral, meat production or aqua farming. The highest quality food will be of course offshore aquaculture, which will only depend on the background nitrogen levels found in clean seawater.

Different opportunities may find different investors, which will establish different commercial entities, but they can be networked together in an aqua farming ecosystem.

## 6.1 Visit at MBD and James Cook University in Townsville

A visit of the facilities of MBD and the research labs at JCU was part of our investigation. MBD has invested over AUD 100m over the last 10 years into macro and micro algae culture technology. Their success in bioremediation of high nitrogen aqua farming effluent for Pacific Reef Fisheries is exemplary.

At present they are in the process to franchise their technology in big scale to aqua farming operations in Thailand and Vietnam. The local operators in these countries are starting to realise that their current practise is highly unsustainable. Even without restrictive regulations in place the operators could see a business case in MBD’s nitrogen sequestration. Especially given the value chain associated with the use of macro algae biomass.

The revenue associated with algae biomass is now the major revenue earner. MBD has been developing a fresh and saltwater platform technology to convert macro algae into various products.

The developments of new commercial opportunities at the interface between JCU and MBD are extremely dynamic. The visit at MBD was very late in the process of gathering information for this report. Thus some of the assumptions and design criteria outlined in the appendix have been superseded by new information from MBD.

During the visit, the team shared some technical and commercial information in confidence and the detail could only be furnished by a prior signed confidentiality agreement.

However we can summarise two main points.

- I was surprised how much added value can be extracted from fresh water algae. It appears that for most applications bar human food, the value add model for the fresh water High Rate Algal Ponds (HRAP) will be on par with the salt water system. This opens up a lot more possibilities to look at HRAP further inland. This was not included in the considerations for salt or brackish water HRAP below. Fresh water systems close to municipal or pasture based point sources can be financially modelled on a nutrient sequestration service. This still allows the majority of the value being derived from the algae biomass as an add on to the sequestration.

- The work on fertiliser and bio-stimulants was a lot further advanced then I assumed in the report so far. Simple species grown effectively and cheaply in HRAP are by far the most economical way to produce biomass. So far any big industrial scale production of bio-fertilisers and stimulants was economically not feasible. Rocky de Nys and the team at MBD could demonstrate that this is not the case anymore. So far the opportunity in New Zealand was restricted to boutique production and niche application. Land based HRAP can lower the production costs by some levels of magnitude.

The key lesson is that much of technology to get started on HRAP initiatives already exists globally and is in large scale commercial by companies like MBD. New Zealand is a long way behind these other countries and there is significant opportunity to both rapidly accelerate and radically de-risk developments through international partnerships. Attempting to start from scratch is likely to be expensive and slow.

### 6.2 HRAP: Project and site selection

Macro algae production in HRAP does feature a confusing number of new opportunities. A first task force of NewCo would need to focus on the financial modelling and prioritise between different opportunities.

During the recent visit at MBD we discussed a few options for projects and sites:

- Opotiki Harbour: Opotiki does feature a range of striking advantages to be a first choice for a HRAP. There is enough flat low lying land on the eastern site of the harbour. This site already features a point load of effluent in form of a treatment pond for municipal waste water. This water will be high in nitrogen and can be fed either into salt or fresh water. The site allows for either option. The harbour development plan already features a salt water supply pipe. Furthermore the new green lip mussel processing facility may supply secondary effluent.

  It may be best to treat this effluent on a secondary site on the western shore. There are a couple of low lying fields that suffer from high salinity and would not be suitable for residential or industrial use. Both sites would have the ability to use fresh water from the river or seawater. As long as enough land space at the industrial zone of the harbour was available, a HRAP would allow to treat any organic industrial effluent that may be associated with processing of seafood. The MBD team was commenting very positively on various options in Opotiki while viewing the sites on Google maps.

  The industrial harbour site will be ideal for algae processing into dried, pelletised products which can then be freighted on road or on water.

- Waiotahi Estuary: This estuary close by Opotiki suffers strangely from dairy effluents. About 10+ dairy farms upstream discharging into the estuary have contaminated the Pipi (mussel) beds at the Waiotahi beach. A peninsula reaching into the estuary may feature similar advantages to Opotiki harbour. Fresh or brackish water can be drawn from the estuary at low tide; seawater would be pumped at high tide. A range of algae may thrive in a race way system. The infrastructure of the new Opotiki harbour is close by with low transportation costs.

Other opportunities are present in the Bay of Plenty; these are relevant to Opotiki in that

- Kaituna river mouth: The Kaituna River features a dilute but very consistent supply of nitrogen. Based on the average flow rate and nitrogen concentration, about 2,500 t of daily nitrogen are discharged to the sea at the river mouth. In contrast to Opotiki, there is more low lying land to base the treatments pond area available. The opportunity will be more suitable for fresh water ponds using the Kaituna river water directly. At an average of 0.75mg/L total nitrogen the concentration for algal growth is ideal. Close by at Rangiuru, a new industrial zone is developing which can provide options for algae processing.

- Rotorua municipal waste water treatment: The lakes district close to Rotorua does suffer effluents from two sides. The city municipal waste itself, Rotorua does attract a lot of visitors in summer, it is also a growing municipality in its own right. Dairy farming around Rotorua, discharging into the lakes water ways. This causes already extreme fresh water algal blooms in the fragile recreational lakes ecosystem. The capacity of the riparian areas to sequester nutrients is exhausted. Rotorua needs to upgrade treatment systems presently. The option of HRAP will be exclusively on fresh water algae, but in Rotorua there is already a planned budget on effluent treatments systems which could be recommissioned to enable a new HRAP development.

# 7 Appendices

## 7.1 Appendix One:

**Design criteria for algal raceway system producing *Ulva* species on salt fresh water mix.**

Critical assumptions:

- Access to clean seawater. Seawater does contain a very low concentration of nitrogen and other nutrients. Algae like *Ulva* species can grow in nutrient rich currents, but it is essential that the algae can reach new nutrients via convective exchange on its surface.

  In stagnant water the nutrients will be depleted very quickly. Seawater is high in salinity at about 35 ppt and is therefore required in a HRAP raceway. Salinity for *Ulva lactuca* can be as low as 20 ppt and still grown near optimum.

- Seawater can be pumped via pipework into a raceway or flow in naturally at high tide provided that the raceway is low enough for creating enough flow at mean high tide. The flow to provide enough salinity and water exchange is estimated to be around 5,000-9,000 $m^3$ saltwater per day.

- The salt water flow can be augmented via pumped seawater. The seawater pump needs to provide about 200 $m^3$/h or 5000 $m^3$/day if tidal seawater flow is not available. The energy requirement to run the pump on this rate is about 20kW. Continuous operation would result in a consumption of 480 units/day or a daily running cost of $72 on 15 cents/unit.

  Conservatively we can assume 100 days per year when the pump has to run on 50% capacity to supplement seawater flow. This would result in $3,600 annual cost. Holding ponds of salt water can be added, that are filled at high tide can be a reservoir to gravity feed water to the raceway system.

- Pumps with this sort of capacity will be in the vicinity of 5,000 - 10,000$ NZ per pump based on a very rough internet search. 30kW at 300 $m^3$/h, NMS4 125/315.

- If no tidal flow is available and seawater has to be pumped at a constant rate of 200 $m^3$/h, the annual cost on 15 cents/unit will be $26,280NZ/annum.

- Water evaporation over the raceway facilitated by sunny, dry and windy conditions (like last season 16/17) will naturally increase salinity and reduce the need for fresh seawater. In sunny and dry conditions water evaporation can be as high as 500 - 1000 $m^3$/day ha providing a 10-20% natural salinity increase for 5000 $m^3$ required seawater/day. Holding ponds could aid the evaporating and get seawater prewired in winter.

- The nutrients needed to grow *Ulva* in the raceway system will be provided by local fresh water from rivers and estuaries.

- Small research raceways do report a maximum productivity of about 40g dry biomass/$m^2$ day (Mata et al. 2016). On a 1 ha raceway system this would equate to 400kg/ha day or 2.8t/ha week (146t/ha annum). According to Prof de Nys the actual existing raceways in Townsville show a maximum productivity of 50-70t/ha annum, which would equate to 13-15g/$m^2$ day.

- 3% is the total nitrogen content of *Ulva ohnoi* according to literature (Cole et al 2015) accordingly the annual total nitrogen requirements are about 1,5 -2ton/annum or 4.1 - 5.5kg total nitrogen daily to produce 50-70t/annum of this species in a raceway system.

- The river water inflow will be following natural gravity from a river weir. That would be the only way to warrant a managed flow based different river water levels over the season. There should be a pump back up system to aid the flow on low river levels.

- The depth of the raceway system has to allow for sufficient penetration of sunlight to be effective. At MBD in Townsville, the depth was established at about 30 cm. A one hectare raceway would therefore consist of a total volume of 3000m$^3$. On a basis of 5000m$^3$ seawater and 7,300m$^3$ river water the daily volume exchange will be about four times per day with a resulting salinity of 14 ppt diluted down from seawater at 34 ppt.

- Field trials will be required to screen or adept local varieties of *Ulva* to thrive in low salinity water. It is also not clear how low salinity will affect taste parameters of edible algae.

- Return on sequestered nitrogen from Townsville Pacific Reef prawn farms is 35$ AUD per kg Nitrogen which would return in our case 150-180 $NZ/day if that was ever a chargeable service. Given that the Kaituna flows with 39 m$^3$/second or 2,340m$^3$/min and delivers a nitrogen load to the ocean of 1.76 kg Nitrogen. If that was charged at 35$ AUD per kg the liability would be $61/min or $88k/day.

- The operation can be mainly automated but I would estimate 0.5 FTE for harvest and 0.5 FTE on call for maintenance and repair.

- Storm proof. Procedures need to be established to isolate systems from power and get water damage minimised. The design calls for very low lying land which will be flooded more frequently than surrounding pasture unless it can be isolated by some sort of floodgate. This will increase the costs of the design.

- Species selection is critical for human consumption. Is the taste profile variable over the year? Is it variable on different levels of salinity? Does the species go into sporulation? Can we breed cultivars that keep an even taste profile and do not sporulate?

- Bio burden of fresh water. The bio burden will be highly variable over the year. We will need challenge tests to verify what is the level of contamination with pathogens the process can cope with. E Coli is readily monitored, but not sure about other pathogens.

- The only way the product can get stored in dry state. So different options of drying processes have to be trialled. Air drying will be cheapest - how does that affect flavour profile, bioburden? The shelf life of wet product is very short. What are the transport times of wet biomass to spray drying?

## 7.2 Appendix Two:

### Bio-stimulants and fertilisers

- Inorganic nitrogen is very poorly retained in soil; around 65% is lost in the run off. Nitrogen from seaweed compost presents the nitrogen in a much more utilisable form. It enables the soil microbiota to grow a lot faster which provides a better environment for the plants. In order for the compost to enable higher nutrient value growing crops faster, it will need a high ration of seaweed to standard compost. Standard compost will be a lot higher in carbon but trials at JCU shows that the growth of plants is retarded in comparison to a seaweed containing compost.

- Standard compost is estimated to have a value of about $250/t. The data from Cole et al 2015 shows that seaweed compost would grow crops up to three times faster. Which would represent a value of 750$/t on this performance. Compost does contain about 65% moisture thus a yield of 50 -70t dry biomass/annum per ha would supply at least 150 - 210t/seaweed compost. The annual income on that basis will be around $120,000 - 150,000/ annum ha. Basically less than a third of the human food returns. However, given that compost will be a much lower risk crop and also the demand per ha for an organic high value crop will create a high volume of demand quickly. MBD states that they can sell all of their current *Ulva* crop to local banana farms.

- The running costs of the raceway systems are going to be the determining factor whether the compost application will be economical. The required exchange of fresh and saltwater has to be managed on a low energy costs basis. Access to available land and access to nitrogen rich river water is not going to be any problem at the BOP coastal sites.

## 7.3 Appendix Three:

### Biochar

- 50t annual biomass per hectare would conservatively produce 11t of biochar (datasheet from Pyreg carbonisation plant) which would be valued at 400USD /t at 4,400 USD /annum ha or equivalent of 6,000 NZD/annum ha.

- Given this low return, biochar will never be the first choice for conversion from macro algae biomass. However given that up to 3000t of beach cast have to cleaned up from local BOP beaches during seasons of algae blooms, the investment into a small biochar unit could offer some productive use for this waste product. In algal bloom years top to 1000t of biochar could be produced, which would be a value of 400,000 USD. This could return the investment in the first season. The problem that needs to be solved for this approach is cost of cartage and drying of the beach cast as it is washed up on the beach.

- Biochar may offer a synergistic benefit to seaweed compost. It may offer better retention of nutrients resulting in slow release system for much more effective conversion by the plant and less runoff into waterways. We would need to explore the value added by a 10% biochar addition to seaweed compost. If this addition could lift the overall performance by 30%, the value of biochar production from one ha of raceway system could come up to $20,000/ annum ha. This would represent a very low return on a high quality nitrogen source. It will be the only available option if the nutrient sources may represent a biological hazard i.e. from municipal effluent. The algae biomass sources from such effluent would need to sterilised and decontaminated by the carbonisation process.

- In such effluent treatment system the value cannot be derived only from biochar but income needs to be derived from the effluent decontamination as a service.

- Many value aspects of biochar such as increased water holding capacity, soil carbon sequestration, increased microbial activity, enhanced aeration of soils, pH amelioration etc. have not been properly investigated yet. In the future the value of biochar may increase significantly if the advantages are taken into account.