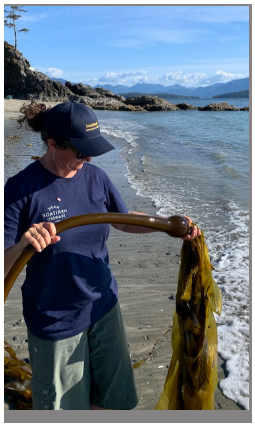
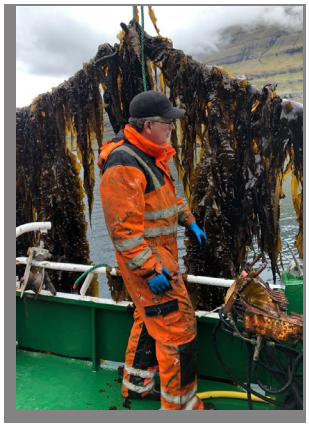
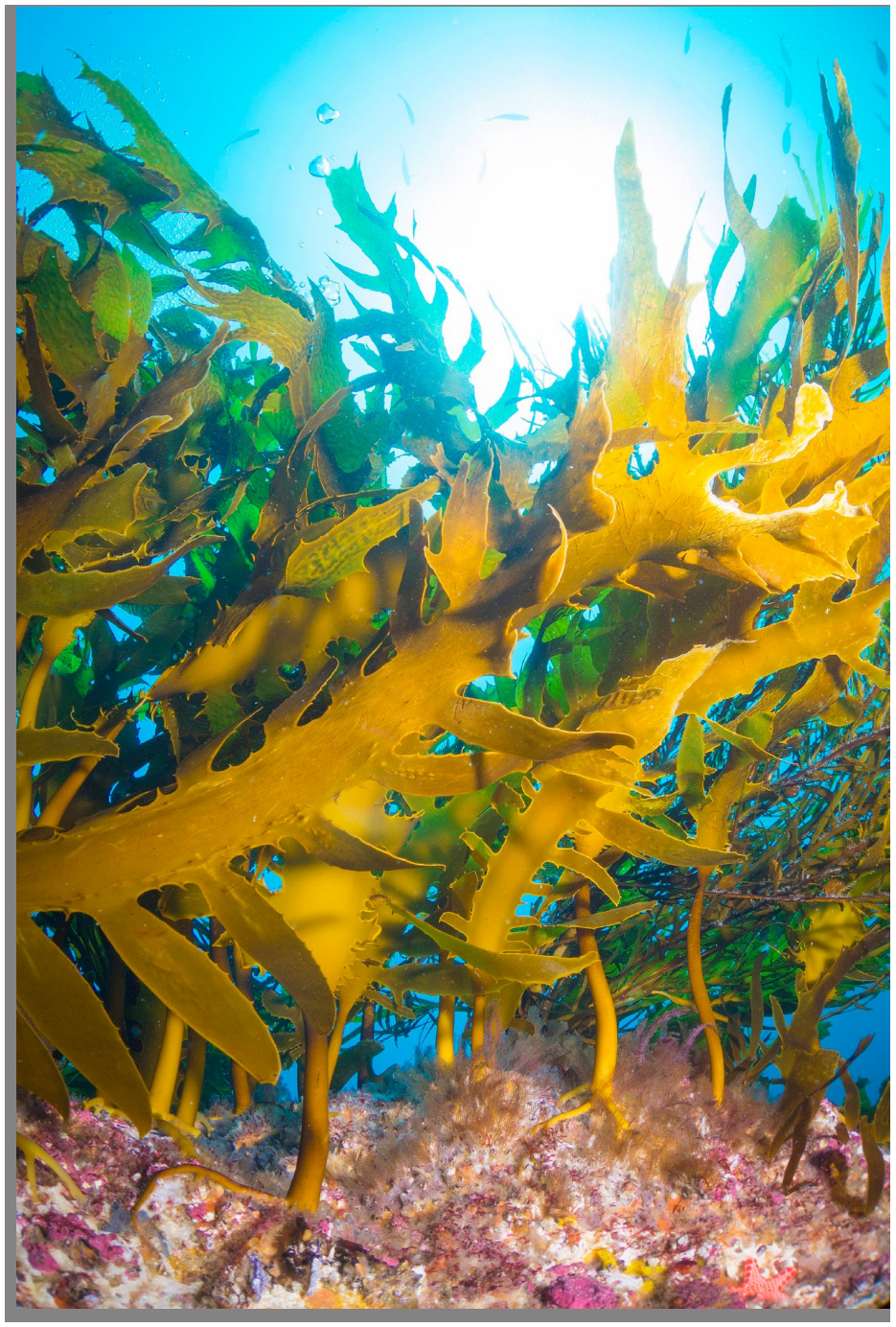
Report by Joanne Lane

Churchill Fellow 2018

The Yulgilbar Churchill Fellowship to investigate appropriate methods for introducing kelp farming aquaculture to Australia.







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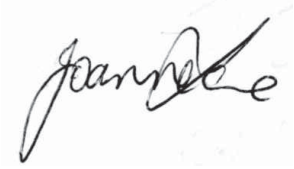
Signed: 

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My final thank you to all those we visited who were so generous with their information and their time. Please come to Australia so that I can return the hospitality!

INTRODUCTION

The marine environment fascinates me. From an early age, I have been captivated by the beauty of the ocean, its' inhabitants and the array of services it provides. I studied Marine Science at Macquarie University, but soon felt compelled to learn more about protecting this resource, so I completed a Post Graduate Diploma in Environmental Studies.

I was fortunate to have some interesting jobs along the way, and when I was working at NSW Fisheries, I processed a permit to collect marine vegetation for a local business. My interest in seaweeds was sparked and ignited into an obsession! Little did I realise that nine years later, I would buy that very business!

Seaweeds have many uses and benefits. They not only provide food and protein for our growing population but also sequester carbon dioxide, reduce ocean acidification, provide habitat and help restore ecosystems. The environmental benefits are many, and I found that this was a significant motivator for the majority of people that I met with from the industry on my Fellowship journey.

Farming of seaweeds is an industry with global potential. This project focuses on the possibility of introducing ocean-based kelp farming to Australia, and I am particularly interested in how to best meet the challenges and opportunities.

During my Fellowship, I was able to meet with expert scientists, kelp farmers/fishermen, business owners and government regulators who generously gave their information, time and support.

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REPORT OVERVIEW/EXECUTIVE SUMMARY

Oceans cover 70% of our planet and support kelp forests, which, provide food, jobs and services. Kelp forests provide habitat for marine biodiversity, reduce ocean acidification and absorb about 30% of global CO2 emissions. Sadly, the health of our oceans is reaching a tipping point. Fish stocks are declining, climate change is affecting marine ecosystems, and erosion and marine pollution from land-based sources is having significant impacts. The United Nations Sustainable Development Goal (SDG 14) calls to conserve and sustainably use the oceans, seas and marine resources for sustainable development. (worldbank.org)

Kelp farming, sometimes referred to as restorative farming is a "zero input" crop that requires no freshwater, no land and no fertiliser or pesticides to grow. It grows 5 x faster than land plants, absorbs CO2 and produces a versatile resource with many applications. Kelp is often referred to as a 'superfood' that is rich in iodine and calcium, containing natural antioxidants, vitamins, minerals and amino acids. Alginates, extracted from kelp, are found in many everyday items, including toothpaste, soaps, ice creams and cosmetics. Other uses for kelp include agricultural feed, fertiliser, biofuels, fibres, bioplastics and bioactive compounds for the nutraceutical and pharmaceutical industries.

As the global population increases, we need to rethink our food production systems and look towards sustainable ocean farming. Over the past 70 years, seaweed aquaculture technologies have developed dramatically, mostly in Asia but more recently in Europe and America. In 1949, Dr Kathleen Drew- Baker, an English phycologist (seaweed researcher) published her findings into the lifecycle of *Porphyra*, the species of red algae used in sushi. This breakthrough propelled the industry forward in Japan and Asia. Dr Drew-Baker never visited Japan; however, she is seen as a hero there, and each year they celebrate the Drew Festival in her honour!

China, Japan and Korea are the world leaders in kelp farming and contribute 95% of production. Over 8.0 million tons of kelp were cultivated and harvested in 2014 with a value of about US $1.4 billion. The global seaweed industry, including all species, is valued at $US6.7 billion.

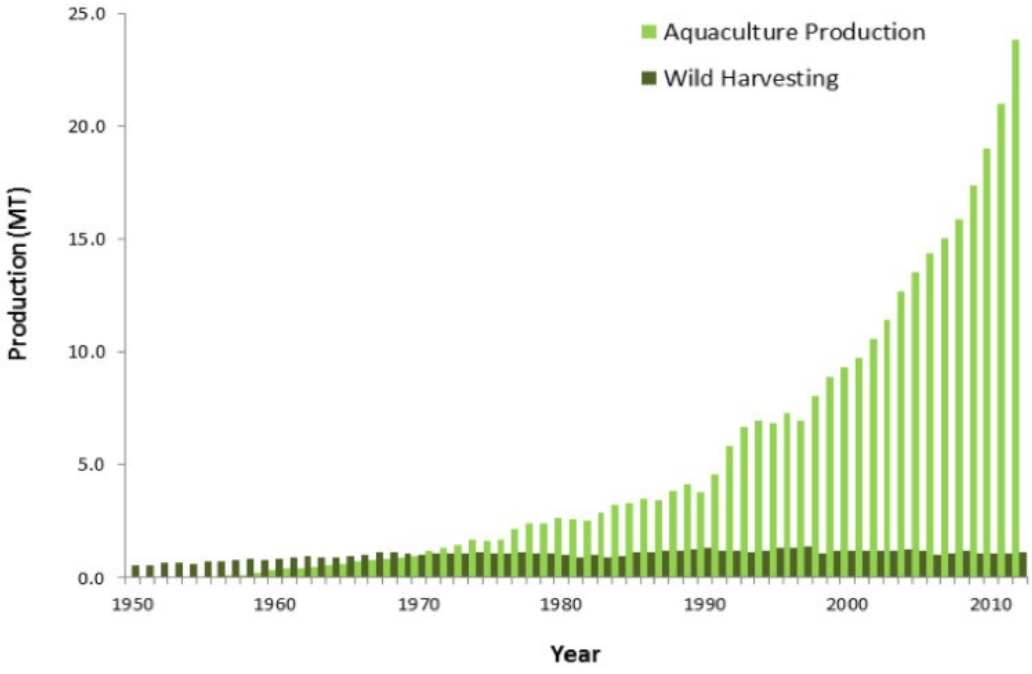


***Figure 1.* Global seaweed aquaculture production (1950-2014). FAO (2015)**

Macro-algae or seaweeds are broadly divided into three main groups - red, green and brown. Although not technically plants or animals, algae have evolved around 10,000 species with different forms and functions. Red seaweeds are cultivated for food as well as extracts such as carrageenan. Carrageenan is found in many everyday products, such as yoghurts and chocolate milk. The green seaweeds include species such as *Ulva* or sea lettuce, which is farmed and most popularly used in powdered form in many health products. The brown seaweeds (*Phaeophyceae*) have about 2000 species and include kelps, which will be the focus of this report.

Kelps grow in cool, nutrient-rich waters and can form dense forests. They provide habitat and build ecosystems and are as important as their land comparison – rainforests for the services they provide. The marine environment is seen in the same way the rainforest was 20 years ago – a frontier to be explored for potentially bioactive compounds. There could be so many potential medicinal products found by studying marine plants and algae. Seaweed is accessible and easily cultivated. We already know some of its uses, but with further study, we could learn just how valuable it potentially is.

With increased awareness and acceptance of seaweed, its many uses and environmental benefits, seaweed aquaculture continues to grow. Kelps are more suited to open ocean farming than land-based aquaculture, and there are several stages to consider when looking at setting up an industry.

Kelp farm,
South Korea

1. Breeding or hatchery set up,
2. Farming (permits, gear, site selection, farm size and set up)
3. Harvesting/processing
4. Markets and delivery of product.

With ongoing research into technological advances at all stages of the process, kelp farming will become a viable industry globally and in Australia.

Despite our vast coastline and clean oceans, the seaweed industry in Australia is currently quite small. There are a few land-based aquaculture facilities, and a handful of permits for beach cast collection in NSW, VIC, SA and TAS as well as wild harvest of *Undaria* in Tasmania. More recently (2018), trials have begun into ocean-based kelp farming in Tasmania with three kelp species (*Macrocystis, Lessonia and Ecklonia*). These trials are part of an IMTA project (Integrated Multi Trophic Aquaculture) utilising nutrients from salmon farms. IMTA is recognised as a way forward in sustainable aquaculture. The role of kelp in the IMTA system is to provide a food source for fish, crustaceans and mollusc species and to utilise the organic waste generated by the farmed species. There is evidence that shellfish grow stronger and larger shells when farmed alongside kelp.

The environmental benefits of kelp farming are many and include:

- increased marine habitat and local biodiversity
- CO2 sequestration to help mitigate climate change
- reduced ocean acidification
- nutrient absorption and bioremediation capability
- IMTA – Integrated Multi Trophic Aquaculture improved resource utilisation

There are also economic benefits, and as the industry grows, it will lead to new employment opportunities, particularly in regional areas. The increased biomass as a result of farming kelp will allow new markets to develop e.g. food, pharmaceuticals, nutraceuticals, cosmetics, agricultural feeds and fertiliser.

Further research into identifying various functional properties of different seaweeds (e.g. fucoidan from kelp) and best extraction techniques will provide opportunities for high-value end uses and new markets, particularly in the nutraceutical and pharmaceutical field.

These benefits all sound extremely positive, but there will be challenges to overcome when introducing kelp farming aquaculture to Australia. Similar to America, Australia does not have a long history or culture of eating seaweed, and there will be obstacles to introducing it as an everyday food item. There is scope and opportunity to develop new and interesting food products utilising kelp (e.g. Kelp Jerky, kelp pesto, surf snacks, pasta etc. are some examples from overseas). Australia has the opportunity to be creative and develop unique products using kelp, maybe kelp pies?

Another challenge is to develop and optimise strains that are tolerant to temperature changes, disease resistant and are fast-growing. Much of the research overseas has focused on Sugar Kelp (*Saccharina latissima*), which doesn't occur in Australia. Australia has many unique species that may be suitable for aquaculture; however, research into breeding will require funding.

Pyropia farm, Wando, South Korea

Much of Australia's coastline is quite exposed, so it is essential to design and develop farm systems that are robust, cost-efficient and able to withstand storm events.

Ocean-based algae aquaculture in Australia is a new and innovative field, and I believe the potential for developing this industry is quite significant. We have a vast coastline, fantastic, dedicated algae researchers and research institutions, and we have some very unique species found only in Australia. My study allowed me to visit kelp farms globally and see the potential challenges and benefits for introducing this technology to Australia.

The highlights of the trip include

- Scale of Korea and insight into processing facilities
- Meeting with people of the industry who I have looked up to for many years
- Learning techniques which can be adapted to breed and develop kelp farming in Australia

Key Learnings

- Collaboration: Many successful projects involve partnerships between industry and researchers
- Markets: it is necessary to develop a market and industry simultaneously
- Be patient and work with nature

Itinerary

Date	Country	Organisation / Person / Purpose / Other
April 26th – May 5th	**Korea**	
		Jeju Island, Korea International Seaweed Symposium, including field trip to Wando
May 6th – May 14th	**Ireland**	
		Kate Burns Islander Kelp Stefan Kraan, The Seaweed Company Maeve Edwards, Anna The Irish Seaweed Consultancy Evan Talty Wild Irish Seaweed Company Jenny O'Halloran Blath na Mara
May 14th - May 17th	**Scotland**	
		Dr Phil Kerrison SAMS – Scottish Association of Marine Science
May 17th- May 21st	**Faroe Islands**	
		Olavur Gregersen Ocean Rainforest Agnes Mols Mortensen Tari Seaweed
21st May – 8th June	**Norway**	
		Andreas Quale Lavik Seaweed Energy Solutions David Cohen Eukaryo
9th June – 23rd June	**USA East Coast**	
		Dr Brian von Herzen Climate Foundation Scott Lindell WHOI Professor Charles Yarish University of Connecticut, Suzie Flores Stonington Kelp Kendall Barbery Greenwave Jaclyn Robidoux Sea Grant, Maine Alison Feibel Acadian Sea Plants, Maine Morgan-Lea Fogg Nautical Farms Shep Erhart Maine Coast Sea Vegetables PeterFischer, Seth Barker Maine Sea Farms Lisa Scali, Mitchell Lench Oceans Balance
24th June - 10th July	**Canada**	Professor Louis Druehl Canadian Kelp Resources
10th July – 23rd july	**USA West Coast**	
		Catherine O'Hare Saltpoint Seaweed Dr Mike Graham Monterey Bay Seaweeds Dan Marquez PharmerSea

MAIN BODY

The journey began in Korea at the 23rd International Seaweed Symposium, Jeju, South Korea.

A pre-symposium field trip to Wando was a highlight, and I was amazed at the scale! The species grown were *Saccharina japonica, Undaria pinnatifida, Sargassum horneri*, and *Pyropia tenera*. Much of it is for human food production while some is produced to feed the large abalone industry.

We were taken out on boats and able to see each species and the different gear used.

The following day we visited several different processing facilities and saw the many stages of processing - it is extremely labour intensive. I was surprised at the equipment needed and the time and steps required to make sushi sheets, for example. The processes have been refined and developed over the last 50 years or more.

Professor Jang Kim from Incheon University was our guide and so knowledgeable about everything to do with seaweeds in Korea. He has worked with the industry, studied in the USA and has experience with red, brown and green varieties of seaweed.

Wando Kelp farm tour – kelp was initially grown to feed abalone

Nori sheets in production.

Processing facilities in Korea

Wando Kelp farm tour

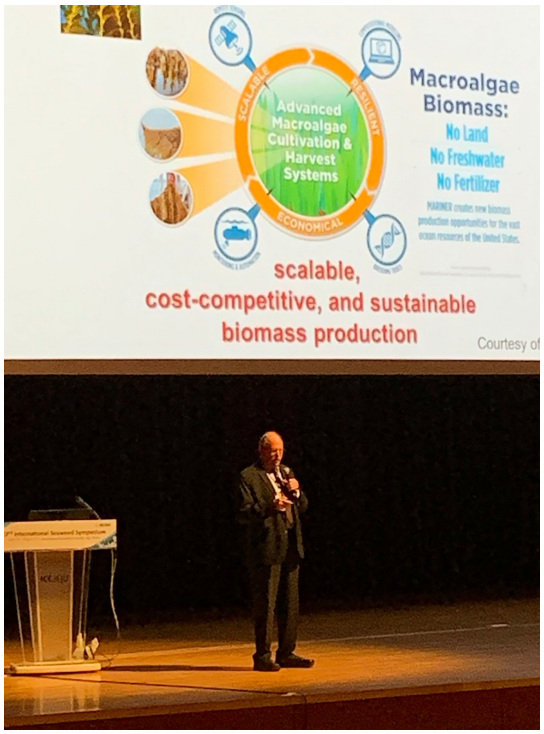
China, Japan and Korea are the leading nations in kelp production, and in 2016 Korea produced 1.4 million ton of seaweed.

After the field trip, I spent a week at the symposium attending lectures and meeting with delegates from around the world. The conference was invaluable to learn more about different applications and current areas of research in seaweed.

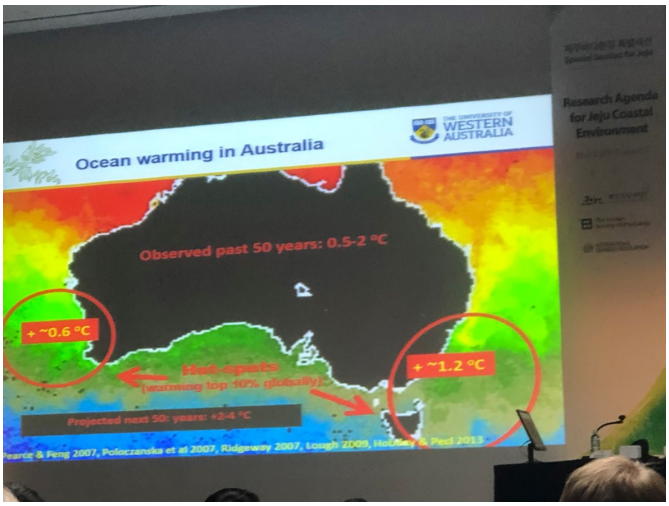
Seaweeds are a significant part of their long history and culture in Korea. A highlight was learning about the Haenyo divers who would dive for abalone and kelp. This culture dates back to the 17th Century, and Haenyeo are celebrated as one of Jeju's most valued treasures. Numbers are declining now, and the Korean government shows its appreciation for the unique contributions of the haenyeo to Jeju's culture by subsi- dizing their gear and granting them exclusive rights to sell fresh seafood. In March 2014, the government requested UNESCO add haenyo to its Intangible Cultural Heritage List.

Key Messages from Korea

- huge scale
- considerable labour force
- quite a lot of processing for nori
- decades if not centuries of perfecting methodologies



Professor Charles Yarish at ISS, Jeju



Slides from Thomas Wernberg and his research into Ecklonia kelp forests.

One of the many people employed by the seaweed industry in Korea

Ireland

Kate Burns - Islander Kelp

Seaweeds in Ireland have a long history, however, seaweed farming is relatively new. From Dublin, I travelled to Rathlin Island in the North East to meet with Kate Burns from Islander Kelp. It turned out to be a phone meeting with Kate, and Ellie, an employee, showed us the facilities. Kate worked in Maine, USA from 2009-2013 when kelp farming technologies were developing. She returned home, to Rathlin Island (quite stunning, by the way) to start the first commercial seaweed farm in Northern Island, in 2014.

Kates' company, Islander Kelp, has a hatchery, small farm and boat and processes *Saccharina* kelp into different products. She exports some of her kelp to Europe, and the rest is sold locally, throughout Ireland. Kate is continually developing new products, and her range includes tapenades, salsas and kelp noodles. For some products, she blanches and freezes the kelp, which makes it easier to store. She is also working with chefs to raise the profile of kelp in Ireland.

Kate had plenty of advice and encouragement but warned "don't go too big too quick. Make sure that you have a market before just growing kelp for the sake of growing kelp."

Site selection is also a critical consideration. Kelp grows best in cold waters and needs nutrients from upwelling. Kate's farm, located at the northeast of Ireland, is exposed to strong tides, where the Atlantic and Irish Seas mix with the Gulf Stream. Tide and wind/wave exposure play a significant factor in deciding the location.

Stefan Kraan – The Seaweed Company

I met with Stefan Kraan in Galway after meeting him for the first time in Korea. Stefan is the President of the International Seaweed Association and was very involved in the delivery of the recent ISS conference in Jeju, South Korea.

He has an extensive background and interest in the development of the global seaweed industry and connecting science research with industry applications. His main area of expertise is industrial applications of seaweeds and extracts in animal feed, aquaculture, biotechnology and biomedicine. I met with Stefan for 3 hours in Galway, and he generously encouraged us to think big! He also commented on the importance of collaboration.

Stefans' PhD was on the phylogenetics and aquaculture of edible seaweeds. He set up the Irish Seaweed Centre in 2001, focusing on Research and Development. He established the Irish Seaweed Industry Association in 2009 and began working on commercial ideas using seaweeds in different projects, including functional food ingredients for fish and livestock farming and algae cultivation systems for biofuel production.

Stefan Kraan The Seaweed Company

Stefan is the Founder of The Seaweed Company Blue Turtle and is currently focusing his efforts on developing large scale seaweed cultivation for food and human health, sports nutrition, cosmetics and other bioactive ingredients. He works collaboratively with agencies across Europe (AtSEA project) to investigate and test new techniques and systems.

Stefans' kelp farm is in the south-west of Ireland and is growing *Alaria esculenta*. He is also growing *Ulva, Palmaria*, and *Gracilaria* in tanks. He is trialling a new method of farming, looking outside the box of traditional long lines, and is using nets or a curtain style. The kelp can grow on both sides of the net, which can double your biomass and uses the 3-dimensional capabilities of the ocean. He is also researching how to deploy seed on to the ropes/structures at sea, to reduce hatchery time and costs.

Stefan believes that *Alaria* is easy to incorporate into foods and has named it Atlantic Wakame. If *Alaria* can replace imported Wakame, then the carbon footprint of importing seaweeds can be reduced: "We can take steps as individuals to help with climate change."

Stefan is also interested in changing food habits. He has observed that markets are changing; people want to know where their food is coming from and that it is sustainable. *Alaria* is an ingredient in the vegan Dutch weed burgers, soups and pasta. People are interested in alternative food consumption. "We can grow something that takes up nitrogen and phosphorous, cleans inshore waters, protects biodiversity, creates an oasis in the sea to increase biodiversity and creates jobs. In rural areas in the west coast of Ireland, people can find an alternative income using existing infrastructure, then things all start to line up."

Vast shores of seaweed, Ireland

Island Rose, Rathlin Island

Currently, the industry in Ireland is big, but it's small! There are many "cottage style businesses", that wild harvest.

Licencing has held things up in the area of aquaculture. The legislation has been on hold for almost ten years. This year (2019) 130 hectares was granted under licence, and the industry is gaining momentum. Stefan believes there is no limit to the number of farms as they are non-extractive and doing environmental good. There is enough market for many people to be involved.

Stefan suggests one issue to consider will be social acceptance and visual impact, because farms need flotation. His advice is to create biomass through farming, and then create some value-added products. Seaweeds can be added to bread, pasta, used in cosmetics, pet food; there are just so many applications!

He also stressed to be leaders in the industry and have all the Food Safety tests and analysis, and HACCP plans in place.

Kelps are high in iodine and can be above tolerable levels at times. Younger, new areas of growth have higher levels than the older areas of growth at the tips. Washing kelp in freshwater, and blanching can help reduce iodine levels.

Stefan is also interested in helping the industry grow in Ireland and globally. He wants to help people to develop their farms and train them in all steps of the process.

Maeve Edwards and Anna Soler Vila – Irish Seaweed Consultancy

Maeve and Anna founded the Irish Seaweed Consultancy based at the Ryan Institute National University Ireland, Galway. Both Maeve and Anna have done extensive research into macroalgae technologies, techniques and applications.

Maeve Edwards and Anna Soler Vila
The Irish Seaweed Consultancy

They work with a kelp farmer in the south-east of Ireland and conduct various research projects on a variety of species (*Laminaria digitata* and *Alaria esculenta*). Maeve highlighted this valuable partnership as a great way to develop the industry: “Work collaboratively where you can” as it is a win/win situation for the farmer and the research agency. “Keep doing trials as much as possible to keep learning; results take time!” One area to conduct trails in is harvesting techniques. If you harvest above the meristematic growth region, it may regrow and allow another harvest in the same season. As this is a new field in the southern hemisphere, it will be interesting to see the development and results of these techniques. Seaweed aquaculture has lots of benefits, and you can extract value from all parts of the plant.

Evan Talty- Wild Irish Seaweeds

Wild Irish Seaweeds is a family run business based on wild harvesting. At present, 40,000 tonnes of seaweed is harvested annually from Irish shores, and less that 5% of that is from aquaculture.

Wild Irish Seaweeds want to continue to wild harvest. They aren't interested in aquaculture as they have a sustainability plan and practice seasonal crop rotation to guarantee ongoing supply. They regularly test the water where they harvest and also run analysis on the finished products. They believe it is crucial to have this traceability for their customers, and their products are organically certified. They supply retail and wholesale outlets and employ 15 local staff.

Harvesting licences in Ireland are a little confusing to navigate. There has been recent interest from larger companies who want to gain harvesting licences. Harvesting rights are historically attached to property, and traditional harvesters who have existing seaweed rights do not require consent or a licence, whereas new companies do need to apply for a harvesting licence under the Foreshore Act. The government is working towards a national strategy to develop the seaweed sector, valued at 18 million in Ireland.

Blath na Mara – Aran Islands

We were fortunate to hear about a SLOW food festival in Clare, and the focus was on Seaweed! There I met Jenny and David from Blath na Mara. They hand-harvest seaweeds from the Aran Islands. They are interested in developing 'every day' products from seaweed and have been focusing on kelp pesto.

Key Messages from Ireland

- Introducing a Western market to edible seaweeds is a big undertaking.
- Seaweed can have an image problem - need to be creative with seaweed products
- collaborate where possible with research institutions
- site selection is important

Evan Talty, Wild Irish Seaweed

Jenny and David, Blath na Mara

Scotland

Dr Phil Kerrison - *SAMS*

From Edinburgh, I travelled north to Oban to meet with Dr Phil Kerrison from SAMS (Scottish Association of Marine Science). SAMS is a world-class facility and has two experimental seaweed farms, Kerrera Farm and Port A'Bhuiltin Farm. The mission of SAMS is "conducting research that would support an industry to develop, identifying the most advantageous species to farm, developing cultivation and harvesting techniques, exploring how to identify and control seaweed pathogens and the policies needed to manage such an industry."

Kerrera Farm began in 2013 and was the first of its kind in the UK. The farm has 60 m longlines and is set up similarly to a mussel farm, comprising a total of 180 m of double long lines. The depth of the farm is 5 - 25 m, the winds are predominantly south-westerly winds from the Atlantic, and the site is slightly sheltered by the island. This site is close to shore and has relatively easy access in most weather conditions. Much of the research here concerns temperature, light, nutrients and wave exposure on the optimal seaweed growth conditions.

Port A'Bhuiltin Farm is 30 hectares currently with a single 100 x 100 m grid system. The site can hold up to 24 x 100m lines used for upscaling studies as it approaches a size that could be commercially viable. The site is exposed to south-westerly winds from the Atlantic. Temperature and salinity are monitored at the site, and water samples are taken to measure nutrients.

The seaweed hatchery at SAMS breeds *Saccharina latissima, Alaria esculenta, Laminaria hyperborea* and *Laminaria digitata* for research and commercial supply. Importantly, SAMS also has a dedicated Culture Collection of Algae and Protozoa – CCAP, comprising one of the largest collections with around 3000 strains of marine and freshwater algae, protists and seaweeds.

Dr Phil Kerrison, SAMS


Twine used for seeding ropes

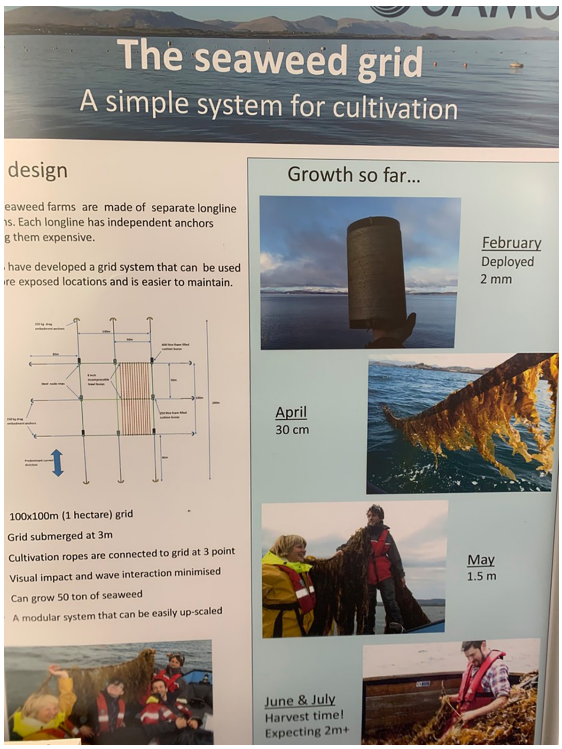
I was impressed with the hatchery facilities at SAMS and very interested to learn about their research projects with AtSea. SAMS has worked collaboratively and been part of the AtSea project recently looking at different textiles, rates of attachment, width of spools, characteristics of line/twine, lighting and temperature parameters. They have also been involved with SeaGas looking at production of bio-methane from seaweed by anaerobic digestion.

Phil is an applied phycologist with extensive experience in hatchery techniques for cultivating seaweeds. I spent the morning learning so much. Below is a summary of what we discussed.

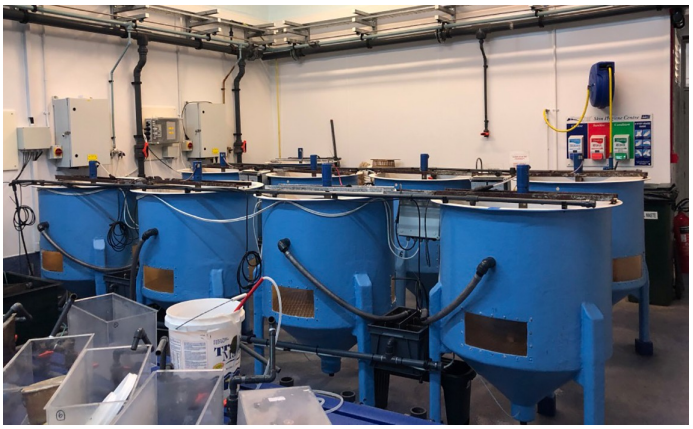
Challenges and recommendations

- Pests and disease; Always use species that are found naturally in the area. There can be problems associated with monocultures in any system. SAMS have researched invasive snails. Close monitoring is needed and "if you start to see degradation, you may have to remove the crop."
- Regulations are different in every area, start early with your permitting and legislation requirements.
- Social acceptability; Engage with community and stakeholders where possible. Kelp farming can be seen as competition for space by other ocean users.
- Research: Try to work with academics quite early into the project. There are many parameters that you can measure. Some of these are easier and cheaper than others. Studies on fish populations, before and during farm set up would be beneficial to determine positive ecosystem services.

Seaweed farming in the UK is only in the early stages of developing as an industry. In 2017 the Scottish Government released a "Seaweed Cultivation Policy Statement" which sets out a framework for the environmental impacts of seaweed farms.



Kelp farm design showing grid layout



Hatchery facilities, SAMS

Faroe Islands

Olavur Gregersen - Ocean Rainforest

I met Olavur from Ocean Rainforest in Korea, and it was wonderful to be able to visit their facilities in the Faroe Islands. Olavur is the Managing Director of Ocean Rainforest, which has two sites for cultivating seaweeds. The 'exposed site', located in open water at the outer part of the fjord has occasional significant wave heights of 6-m and a water depth of 50-70 metres. I visited the 'sheltered site' which was quite calm, though occasionally receives wave heights up to 3-m and has a water depth of 20-30 metres. The main species harvested are *Saccharina lattisima, Alaria esculenta, Laminaria digitata* and *Palmaria pulmata.*

Olavur is interested in developing the industry to large scale cultivation and is part of a group of European companies and research institutions in a project " Macro Cascade". This project aims to develop co-extraction using a biorefinery concept. Using the same seaweed biomass for multiple extracts can create a range of products within food, feed, cosmetics and pharmaceuticals and the waste streams can be used as fertiliser and biofuel. He is aiming to increase production to 100,000 tonnes per annum.

Ocean Rainforest has trialled some new textiles as part of the AtSea Project. They use the traditional vector method, but also attach a strip of seeded textile every metre, to hang vertically (about 6 metres). This wasn't as successful as first anticipated, perhaps because of light penetration.

The Faroe Islands have ideal ocean conditions for cultivating seaweed: clean, cold, nutritious, waters, and stable water temperature around 8 degrees throughout the year. During summer they also get up to 23 hours of daylight. These cold temperatures and long periods of light allow the kelp to grow and enable several harvests throughout the season. Biofouling outbreaks are quite rare as the temperatures are so cool. There have been some challenges with storms at the exposed site, and heavy anchors (about 1.5 tonnes) are needed to hold down gear. If you don't have the right weight, lines can drift and get tangled.

Recently, Ocean Rainforest purchased a processing plant in Kaldbak, that was previously used as a salmon processing facility. The building has capacity for cleaning, packaging, freezing and drying. There is also a hatchery and a laboratory established. Ocean Rainforest has been able to repurpose equipment such as anchors, chains and other assets from the fishing and salmon industry when they upgrade their salmon farms and acquire new equipment. Olavur said, "This may look like a scrap yard, but it is a valuable part of our assets."

At Kaldbak processing factory, the seaweed is fed onto a conveyor and sprinkled from above with freshwater. It is placed on racks to dry and then stored before being milled into various sizes, depending on the order and specific use. Ocean Rainforest exports a lot of product to European markets.

Olavur is very optimistic for the future of seaweed globally and the development of the 'blue economy'. He explains, three parallel developments need to happen; developing cultivation methods, developing processing methods as well as developing marketing and sales methods.

"We don't have a century or two like the fishing industry or agriculture industry to develop all this innovation - the time is now!"

Olavurs' Recommendations

- Work with nature as much as possible.
- Location, location, location. Site selection is important.
- Be prepared for hard work!
- Keep at it!

Agnes Mols Mortensen – Tari Faroe Seaweed

Agnes has a PhD in macroalgal cultivation and has dedicated her career to seaweed. She also works as a researcher and is focusing on IMTA –Integrated Multi Trophic Aquaculture, working with the salmon industry, the largest industry in the Faroe Islands.

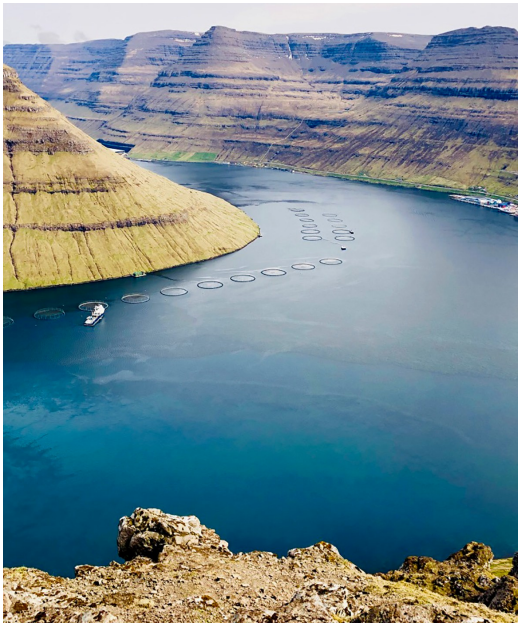
Agnes and her brother have a seaweed business – Tari Faroe Seaweed and harvest a variety of seaweed species. They supply local stores, cafes and are very keen to see this industry develop in the Faroe Islands. The cool nutrient-rich waters and long daylight hours make it very well suited for seaweed aquaculture.

Tourism is growing in the Faroes, and Agnes' Tari Seaweed is selling well in the Tourist Information Centres and local cafes, with people keen to try some of the local products.

Tari Seaweed has a hatchery, farm and drying and processing facilities. She is steadily growing her business and working with research agencies in Europe on various projects.

Agnes advises to work with research organisations where possible and be patient. "Don't rush into being too big, too soon." Being on the ocean is part of her family tradition - her grandfather was a fisherman. Agnes is very comfortable on and around the water and is optimistic but also cautious about the development of the global seaweed industry.

Agnes Mols Mortensen, Tari Faroe Seaweed



Salmon farming aquaculture, Faroe Islands

Norway

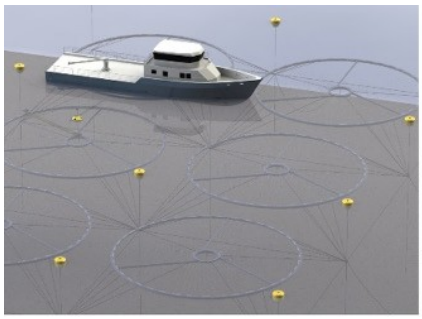
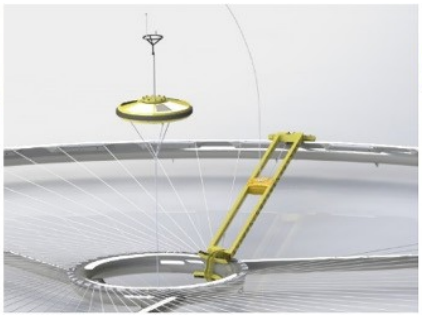
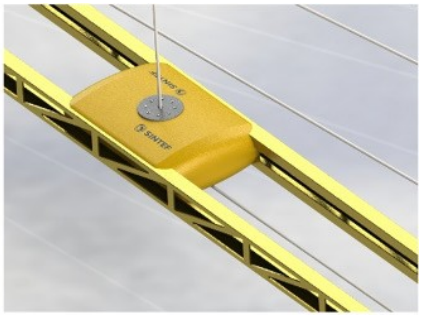
Andreas Quale Lavik

Seaweed Energy Solutions

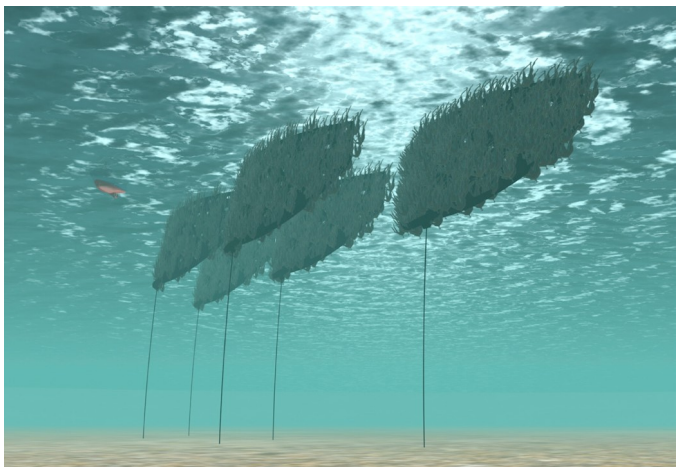
I met with Andreas from Seaweed Energy Solutions (SES) who I had also met in Korea. Andreas is the Hatchery Manager and has much experience with breeding different species of seaweeds.

SES began in 2009, focusing on developing large scale kelp farms for bioenergy. They are now growing seaweed as a raw material for a range of uses and markets throughout Europe. SES has a large pilot farm in Froya and a hatchery in Trondheim, which has recently expanded. They are continuously partnering with different agencies to develop new technologies and improve harvest quality and quantities.

There is a great deal of innovative research happening in Norway. Here is an example of a research project with SINTEFF to look at innovative technologies for kelp farming.

This model of farming, similar to a bicycle spoke dramatically increases surface area for growing kelp. It has been called SPoKe (Standardized Production of Kelp) Research in Norway – (MacroSEA Project).




Here is another innovative idea for growing kelp that has been trialled by SES. The concept is to be flexible like kelp, moving freely from a single mooring.

Andreas showed me through the breeding facilities in Trondheim, consisting of several wet labs and outdoor tanks used for growth experiments and seeding lines. They use large low tubs with longer PVC pipes with seeded rope. The facilities have access to saltwater intakes eliminating the need for transporting water. They also have a red-room for gametophyte storage.

Andreas and SES have done a lot of experimenting with breeding regimes, modifying temperature and light. This has enabled quite a breakthrough to be able to grow seedlings at any time of the year. Mature plants can be 'tricked' into releasing spores when temperatures and lights are adjusted. SES is heavily involved with R&D with collaborative partners across the aquaculture sector, research institutes, universities and NGO's both in Norway and abroad in several exciting projects.

Eukaryo – David Cohen Hatchery Manager

I was greeted with a friendly G'day, which was very comforting after almost five weeks away from Australia! David Cohen, the Hatchery Manager at Eukaryo, is from Australia and has completed his Masters in Norway. He is now responsible for managing the hatchery at Eukaryo and is developing new strains to provide higher yield and better quality and stability than wild individuals. Eukaryo is in the north of Norway – Sandhornøy, just south of Bodo and they provide seeded rope ready for deployment in the sea to kelp farms throughout Norway (mostly *Alaria* and *Saccharina* species).

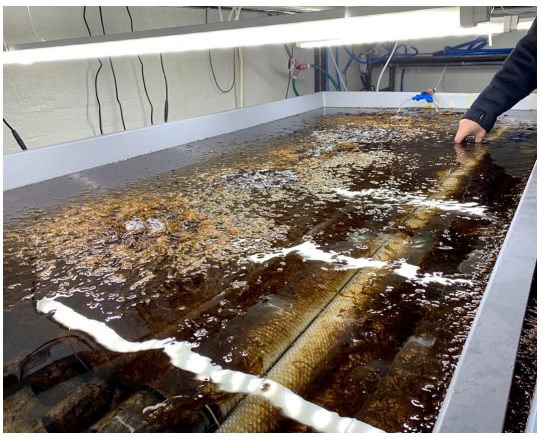
David is continuously researching and refining techniques by exposing the seaweed to different light treatments and temperature parameters. Breeding begins by selecting healthy plants from wild populations. When the seaweeds are mature, they release zoospores, which develop into male and female gametophytes. The gametophytes can be kept to grow vegetatively without reaching the reproductive phase if they are placed in a red-light environment. This process gives more control over timing and means that gametophytes can be stored until they are needed to move into the next stage - sporophytes.

The culture room was fascinating - blue light promotes reproduction and growth, so when cultures are needed, they are transferred from red to blue light. The seedlings are then attached to ropes and grown in tanks to a specific size, before being sent to the various farms around Norway. The quality control and scientific rigour was very impressive. Eukaryo is continuously monitoring for the cleanest, healthiest environment for growth.

Overview of Norway

There is a group called Norwegian Seaweed Farms [https://www.norwegianseaweedfarms.com/] They are a (mostly industry) group which meet to discuss ideas and trends and can apply jointly for funding. I had a phone interview with Christian Skår from Austevoll Seaweed Farm.

Andreas Quale Lavik, Seaweed Energy Solutions



Low tanks for growing seeded rope

Christian said there are still challenges with developing new products and markets in Norway.

Norway has a long coastline of 100,000km with many island fjords. There are approx 400 species of seaweeds found in Norway and the main ones targeted commercially are *Saccharina latissima* (96%) and *Alaria esculenta* (4%). Licences for cultivation of a range of species including *Palmaria palmata, Ulva spp., Laminaria digitata* and *Porphyra* spp. have been issued, but at present (2019), they have not been activated.

The primary aquaculture industry in Norway is salmon and trout farming. As this industry increases, measures to address the excess nutrient loads have led to the development of IMTA, using seaweed farms to absorb nitrogen and phosphorous.

Experimental cultivation of kelps at sea in Norway started around 2005 and efforts have primarily focused on developing technology to increase biomass production. The MACROSEA project was funded by the Research council of Norway through the Large-scale Program on Aquaculture Research. The project, led by SINTEFF, Norway runs from 2016-2019 and aims to "deliver knowledge on seedling quality, sea cultivation, fouling and diseases and functional genetics of selected brown and red macroalgae species".

The first commercial permits for cultivation of seaweeds were granted in Norway in 2014. The surface allocated to seaweed cultivation has more than tripled between 2014 and 2016, currently reaching a total of approx. 277 ha along the entire Norwegian coast and corresponding to a production potential of approximately 16,000 tonnes.

The "Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry" provides a guideline for current Norwegian aquaculture policies, focusing on five key problem areas, or challenges. These were designed for fish aquaculture but are also applicable to seaweed cultivation.

- genetic interaction and escape,
- pollution and emissions,
- disease,
- area utilization and
- feed and feed resources.

Seaweed Energy Solutions, Trondheim

David Cohen, Eukaryo

An emerging challenge as I continued to travel is the regulatory framework around seaweed aquaculture. Part of the problem may come with the name “aquaculture”.

If seaweed farming is categorised with other forms of aquaculture such as salmon and finfish farming, oyster farming and even mussel farming, there are some significant differences with regards to environmental impacts. Seaweed farming is a zero input and non-extractive industry, with known benefits to the environment.

The regulatory complexity around aquaculture licencing can be challenging to navigate - for example, in the United States at least 120 federal laws were identified that affect aquaculture either directly (50 laws) or indirectly (70 laws), and more than 1,200 state statutes regulate aquaculture in 32 states. Another challenge identified is social resistance/ acceptance.

In the USA, nearshore waters are heavily used and have both recreational (boating, fishing, swimming) and aesthetic (ocean and bay views from waterfront homes) values. Offshore macroalgae cultivation is a viable option, as it can address both the challenge of licencing and social acceptance (visual impacts).

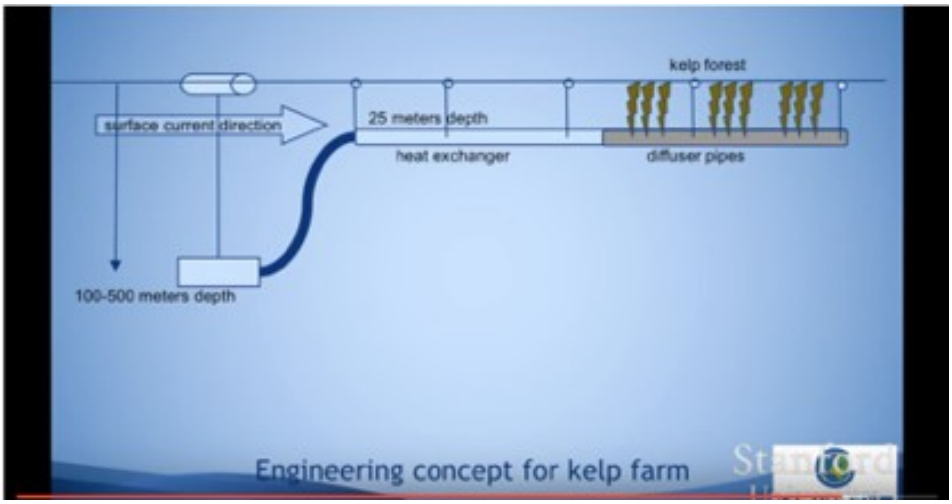
Dr Brian von Herzen - The Climate Foundation

I met with Dr Brian von Herzen and his interns at the Climate House, Woods Hole. There was much discussion about large scale Marine Permaculture, and a highlight of the visit was to watch the screening of the movie “2040”. Brian featured in this recent movie (made in Australia), which offers solutions for a better future in the context of climate change.

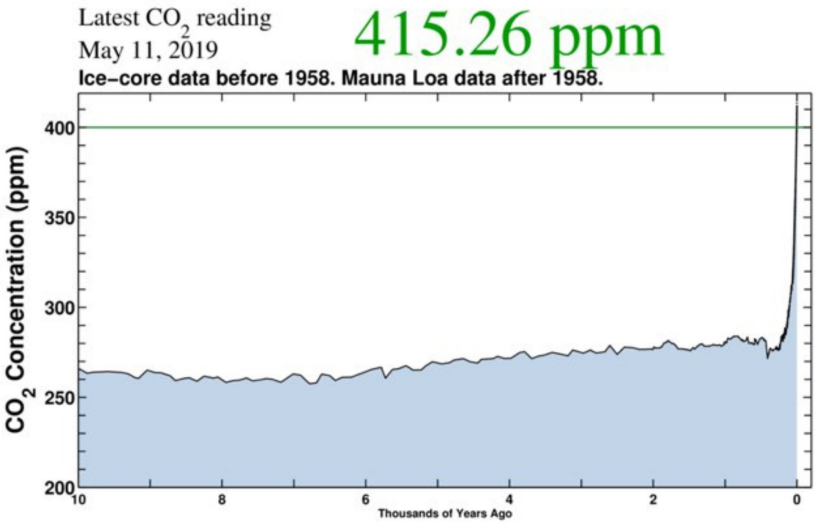
Dr Brian von Herzen is proposing to create large offshore Marine Permaculture Arrays (MPA’s). The floating structures are more like a ‘vessel’ and therefore, able to be registered through maritime agencies in a shorter timeframe than applying for an aquaculture lease site.

Dr Brian von Herzen

The Climate Foundation is developing innovative solutions to mitigate climate change – one of these is large scale marine permaculture.



MPA's are lightweight, latticed structures, a hectare in size, to which kelp can attach. This model is scalable and can grow to be hectares in size. Controlled by robots, the system can rise and fall to compensate for weather events. Cool, nutrient-rich waters from up to 500m below the surface can be pumped to the surface to 'irrigate' the kelp. Kelp is very fast growing, and with this plan to reforest our oceans, Dr. von Herzen and the Climate Foundation are hopeful that we can solve global warming in our lifetime!



Keeling Curve showing increased levels of CO2

To develop marine permaculture, engineering research and ongoing funding is needed. There is currently a lot of support for this project with many people viewing the movie 2040. Over $350K has been raised through a crowd-funding project to go towards the development of a kelp platform in Tasmania. With the right engineering, the opportunity seems enormous for marine permaculture to restore fish, restore fisheries and balance carbon.

Scott Lindell – Woods Hole Oceanographic Institute MARINER program

(Macro Algae Research Inspiring Novel Energy Resources)

Scott Lindell is a research specialist in Applied Ocean Physics & Engineering at Woods Hole Oceanographic Institute. He is part of the ARPA-E MARINER (U.S. Department of Energy's Advanced Research Projects Agency-Energy) program which is researching large scale offshore seaweed aquaculture for the production of feeds, fuels and chemicals in the USA.

The project is funded from 2018 - 2021 and is supporting projects in five areas:

1. Integrated Cultivation and Harvest System Design,
2. Critical Enabling Components,
3. Computational Modeling,
4. Monitoring Tools, and
5. Breeding and Genomic Tools.

This ambitious program aims to “enable the United States to become a global leader in the production of marine biomass.”

“ARPA-E estimates the United States has suitable conditions to produce at least 500 million dry metric tons of macroalgae per year, which could yield about 2.7 quadrillion BTUs (quads) of energy in the form of liquid fuel, roughly 10% of the nation’s annual transportation energy demand.”

Scott and his team are working with UCONN to look at breeding of potentially suitable kelp strains, with a focus on biofuels. They have found a possible candidate - an endemic species which grows very narrow (2–5 cm), and long (~5 m), and can withstand strong currents and stress from open ocean.

Other research and development is looking into improving technologies associated with cultivation, harvesting, transport, storage, processing, of macro-algae.

Suzie Flores – Stonington Kelp Co.

Suzie Flores is a kelp farmer that has been through the Greenwave training program. She took us out on her 19ft skiff to her kelp farm - about a 40-minute boat ride. A significant factor for her in choosing the site was to make sure the farm was well away from potential social resistance. The location she selected is away from houses and has access to open ocean and nutrients, while still being slightly protected.

Her site is 10 hectares, and she is currently using 3 hectares. Together with her husband Jay, they have a company called Stonington Kelp Co. She harvests to order and supplies fresh kelp to restaurants and local markets. She has recently worked with a local brewery that adds her kelp to their beer!

Suzie and Jay have just finished their second season and are learning all the time. “In the first year, the ropes weren’t tight enough and got tangled.” The other handy tip she gave was “when seeding the ropes, you have to be careful that the string doesn’t snap and then end up with clumping of kelp!” Greenwave supplies her with seeded string, which she deploys onto lines 100m long and uses 500lb anchors.

Suzie loves being a kelp farmer and is happy to be part of an industry “restoring the planet and nurturing local communities”. She is keen to develop the industry and to help train and support new farmers.

Suzie Flores, Stonington Kelp

Professor Charles (Charlie) Yarish – University of Connecticut.

I was so looking forward to this day. I had watched Youtube videos, read the Kelp Farming Manual by Ocean Approved and read many of Professor Charles Yarish papers, so to meet with him and learn more about what he does was so exciting!

Charlie has dedicated his research career to developing kelp farming, not only in the USA but globally. Together with his team, he has developed the industry of restorative farming on the east coast USA. A detailed Kelp Farming Manual was produced in 2013, laying out step by step how to Farm Kelp. The team then travelled around giving training sessions, focusing on people with boats such as lobstermen, and people in shellfish businesses. It was at this time, they met with Bren Smith from Thimble Island Oyster Farm, and as a result, the Greenwave training model evolved. I also visited Greenwave later that day.

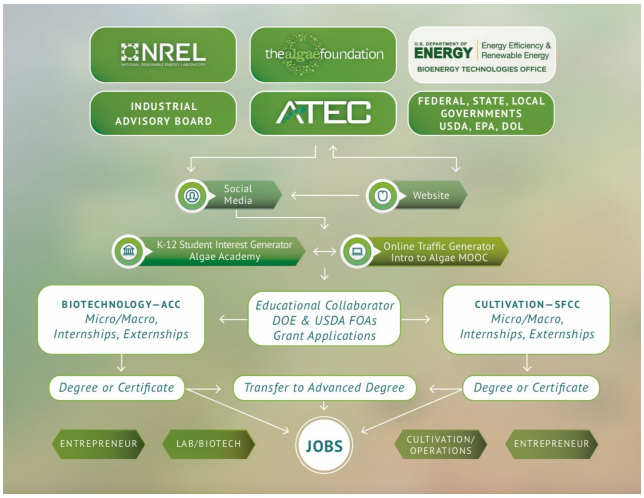
At UCONN, I toured the Seaweed Lab where they are breeding quality strains of red, green and brown seaweeds and developing a seed bank.

Then I met with Charlie and Simona Augyte and had a chat about the algae industry in the USA. I learnt so much!

Charlie approaches the development of the industry from many angles. One thing that he sees as crucial is EDUCATION. He told me about the educational resources through ATEC (Algae Technology Education Consortium). ATEC is led by the Algae Foundation and works with UCONN, industry and community to promote the Algae industry. The project has received grant funding to develop an algal-based curriculum and help people to get jobs in the industry. The model uses the community college system. Students can work closely with industry – doing internships to gain practical experience and also learn business skills. There are now 14 community colleges across the USA with the program. UCONN is also working with schools and has developed the K-12 Algae Academy.

Then, we went on to talk about legislation. The ABO - “Algae Biomass Organisation is a non-profit organisation whose mission is to promote the development of viable commercial markets for renewable and sustainable commodities derived from algae.” They recently had a significant impact on an important bill in the US - The FARM bill was amended and now includes algae in the agricultural sector. This means that Algae is considered a crop, and therefore algae farmers are entitled to insurance and other considerations of primary producers. This will have quite an impact on allowing the sector to expand further.

The press release on the ABO website states: “This legislation will help bring American agriculture into the future by welcoming the production of a new and incredibly useful crop that can sustainably provide food for millions of people, and even new chemicals, plastics, fuels and more.”



Then, we discussed some of the research projects, including large scale kelp farming research for the MARINER project, which UCONN is involved. Charlie is very interested in developing new strains for optimum conditions. Professor Yarish said: "Growing seaweed and breeding seaweed are different." He also said: "We still have a lot to uncover with genetics to capture genetic variability." It is imperative to develop and maintain a seed bank, and essential to find a suitable host; this may not always be a university.

We moved on to chat about markets and processing. Some key points from this discussion included:

- "It is vital to develop a market or demand for your products",
- Look globally at industry standards and develop appropriate HACCP and safety standards for Australia, and
- Develop your brand in a meaningful way - being respectful for the environment.
- Aquaculture is certainly the future!

Kendall Barbery, Greenwave

Kendall Barbery, Programs director – Greenwave reef replication program

Greenwave is a not for profit organisation training and supporting ocean farmers. Bren Smith is the co-founder and has a strong media presence raising the profile of this sustainable, restorative industry. I met several of the dedicated and enthusiastic staff at Greenwave office in New Haven and sat down with Kendall Barbery, Programs Director to learn more. Her role as Program Director oversees a reef replication program. In this instance, reef refers to a collection of hatcheries, farmers, farm infrastructure, transportation infrastructure, markets needed to push the industry forward. The broad goal of reef replication is to grow the industry and help facilitate partnerships and relationships.

Greenwave provides farmer training and works with farmers at their own pace. They provide support over two years - working to assist with securing leases, farm design, seed supply, farm monitoring support and access to processing facilities. They collect data from the farmers weekly so that they can make adjustments in the field as needed. By the second season, farmers have a better sense of what's going on but still have access to support. In some instances, farmers start supporting each other.

Greenwave has a farm, which operates as a floating classroom. They currently grow Sugar kelp (*Saccharina*) and shellfish (scallops, oysters and clams). They have also grown *Gracilaria* in the past, and there is increasing interest in how to cultivate other species. (e.g. *Asparagopsis*). *Asparagopsis taxiformis* is a type of red algae and has been shown to reduce methane emissions by up to 99% when added to cattle feed.

Farm set-ups can be site-specific and condition-specific. Some farmers only want to grow seaweed; some want to produce a mix of seaweed and shellfish. Greenwave can advise on the best fit that is most appropriate for each location.

Greenwave has a hatchery and supplies seeded string to their farmers. They have helped other hatcheries begin operating, as they want there to be plenty of supply for the farmers. Greenwave has a Research and Development arm and are researching different gear styles and seed strains (with UCONN)

So far, 26 trainees have gone through the program, and are at various stages of working through site development and site design.

In some areas, there are challenges with regulations; for example, in Massachusetts, you cannot sell seaweed unless you are a certified wholesale seafood distributor. These wholesale seafood distributors generally work with fish and are not sure about seaweed. Therefore, some farmers needed to become certified wholesale seafood distributors so that they were able to sell their kelp.

I enjoyed learning from Kendall and her years of experience. Some of her great advice is below:

- Start small: Learn your site and establish a market. Define a market – fulfil a need,
- Test out a few different locations if possible, similar to Maine,
- Do not underestimate other users of a site. Never assume "nobody ever uses it!" involve community and stakeholders,
- Use cameras (e.g. GO-Pro) where possible to monitor your system, rather than pulling the lines out and disturbing the crop,
- Use the right anchor type, and
- New farms often start with 1 or 2 lines. Don't expect to make a profit in the first year!!

Atlantic Sea Farms/ Ocean Approved – Maine

Atlantic Sea Farms began as Ocean Approved and started a commercial kelp farm in 2009. They have a hatchery, a network of kelp farmers and a processing facility. They can supply wholesale, restaurants and have a range of seaweed salad products and frozen kelp cubes for smoothies. I visited here on the weekend and was able to have a quick tour of the processing facility and cool rooms.

Heritage Seaweed

A shop dedicated to seaweed products – currently the only 1 in the USA. This is an excellent testimonial to the rise in interest and acceptance of the seaweed industry in America and particularly Maine. Heritage Seaweed showcases local seaweed and kelp products, including seaweed snacks and sprinkles, cosmetics, seaweed tea, as well as clothing and ocean-based products. A very charming shop, Heritage Seaweed supports the Maine Seaweed Farmers Group by having open days and generally promoting anything to do with seaweed!

Atlantic Sea Farms variety of Kelp products

Morgan Lea-Fogg – Nautical Farms, Machiasport

Travelling further north, I met Morgan at Machiasport. Morgan is very energetic and is not only a kelp farmer; she is the Director of Impact and Special projects for Akua (who have developed Kelp Jerky range). Morgan and her husband Jake (a lobster fisherman) have been farming for two seasons and are still learning all the time. They have trained through the Greenwave program and received assistance with permitting and planning of their farm. They started with an experimental lease and were farming Sugar kelp (*Saccharina*). They are planning to add skinny kelp to their lines next season.

Their business, Nautical Farms supplies the kelp for Akua's kelp Jerky, so this ensures a direct market for them. At harvesting time, they hire a refrigerated truck to get the kelp to the processing facility a few hours south. It is then batched and becomes part of the kelp jerky range.

Morgan is passionate about the environmental benefits of kelp farming and is setting up a consultancy so that she can help more farmers. Some of the challenges she faced early was ropes getting tangled as the anchors weren't heavy enough. She also commented it would be nice to have a processing facility closer.

Morgan Lea-Fogg, Nautical Farms

Maine Seaweed Symposium

While visiting Dr Brian von Herzen, I found out about the Maine Seaweed Symposium in Pembroke, Maine. I also saw it promoted in the Heritage Seaweed Shop, and thought this was another great opportunity to meet with people in the seaweed industry. It was an excellent networking opportunity and a chance to hear about the seaweed situation in Maine. There was much talk about Rockweed where there had just been a ruling about the harvesting. The legislation now stated that the intertidal zone (and the seaweed) belonged to the upland property owner. This ruling had a significant impact on Acadian Sea Plants who had been harvesting Rockweed (*Ascophyllum nodosum*) for fertiliser products.

Alison Feibel, a Marine Resource Technician from **Acadian Sea Plants** was at the Symposium. She informed me about their harvesting processes and monitoring plans. The company is based across the border in Canada, and they have been harvesting Rockweed (*Ascophyllum nodosum*) in Maine for many years. Rockweed is a valuable resource, and recent figures state that an estimated 22 million pounds of rockweed was harvested with a total estimated value of over USD$21 million per year. The new ruling will mean a change for Acadian Sea Plants and other rockweed harvesters who will need to gain permission from landowners for harvesting rights.

I also met **Shep Erhart** from **Maine Coast Sea Vegetables** at the Symposium. He started harvesting seaweed in the Gulf of Maine in 1971, and now has 19 staff. The business is expanding and recently moved to a brand new purpose-built facility that is 17,600 square feet. Maine Coast Sea Vegetables predominantly wild harvests organically certified North Atlantic varieties: Alaria, dulse, kelp, laver, sea lettuce, Irish moss, rockweed and bladderwrack. They are harvested directly at low tides, dried at low temperatures by the sun, or heaters, some are milled, and then packaged.

In 2013, Shep received funding from Maine Technology Institute to develop an aquaculture farm, and Maine Coast Sea Vegetables is a research partner with the Centre for Cooperative Aquaculture Research in Maine.

Jacklyn Robidoux- Maine Sea Grant and UMaine extension program

Jacklyn is from Maine Sea Grant and is the aquaculture extension officer. The Sea Grant program is part of NOAA (National Oceanographic and Atmospheric Administration), and there is a network of 33 University based Sea Grant programs across the USA. The goal of the Sea Grant program is to "effect change by making science-based information available to inform decision making groups and institutions and to identify knowledge gaps." Jacklyn's role is to extend university knowledge by supporting a two-way flow of information exchange between industry and research. The Sea Grant Program was established in 1966, copying the land /agriculture extension program.

The Maine coast has 3,500 miles of coastline and about 200 species of seaweed. The main species used for farming is Sugar kelp (*Saccharina*), with the first trials for farming taking place in Maine in 2010. The kelp aquaculture industry is growing quite rapidly; in 2018, reported harvests were 55,000 pounds, and this number is expected to rise to 300,000 next year.

There are several reasons for the increase in kelp farms in Maine. This could be explained by the media coverage around the work of Professor Charles Yarish and Bren Smith on the east coast USA; the availability and affordability of gear, and changes to the permitting system in Maine.

Gear

The gear required for setting up a kelp farm is pretty straight forward. You will need anchors (these can be made cheaply from concrete blocks, or claw anchors can be used). Rope; 9-12mm (polypropylene lobster line), with each line being 100m, and dropper lines and floatation buoys to keep the correct tension and depth. As the kelp grows, additional floatation might be needed to keep the kelp at about 3-6 m depth. You will also need to buy seeded line and use a boat to put them out on the ropes.

Legislation

Recent changes to the permits required for aquaculture leases have made the process in Maine much easier. The Department of Marine Resources manages permits, and there are three types of seaweed aquaculture leases: LPA's, Experimental leases and Standard leases.

LPA's

The limited-purpose aquaculture (LPA) license provides the opportunity to obtain a one-year license to grow specific species in an area no more than 400 square feet. Because the license is specific to particular gear and certain species on a minimal area, licenses can be approved without the extensive review that is required for either an experimental or standard lease.

The intention of this program, developed at the suggestion of shellfish growers, is to streamline the permitting process so that growers can "try out" different locations prior to applying for a lease. This is the lowest barrier to entry and an excellent tool for testing out sites to see if it is a good area for growth. Currently (July, 2019) there are 131 LPA's in Maine, but this number is growing significantly. Within a 400 square ft area, it is possible to produce about 5-7 pounds of seaweed /square foot of line. This could land 2000 pounds (wet) or 200 pounds dry.

Whilst the numbers of LPA's is high, the total area is small and equates to approx 2 acres. LPA's need to be renewed each year and cost USD$50 for residents of Maine and USD$300 for non-residents. 75% of all LPA's are growing just seaweed.

Experimental Lease
This option is a lease, not a license, and allows farmers to scale up to 4 acres and is available for three years. Experimental leases can be for scientific or commercial purposes. Commercial leases are non-renewable after three years. There are currently 10 experimental leases for seaweed, with an approximate capacity of 33,000 pounds per acre.

Standard Lease
A standard aquaculture lease can be up to 100 acres for 20 years. Leases can be expanded, renewed and transferred. For an experimental and standard lease, a scoping session with community and harbour master is usually necessary.

Some of the challenges identified with the growing industry, are around the processing and harvesting. Lots of farmers are now growing lots of kelp - and wondering what to do with it! Post-production strategies and market development is needed. Kelp matures at the same time (at the end of winter), and there are limited processing facilities to accommodate the growing interest in farming. Technologies need to be developed to look at improving methods for blanching/freezing and exploring new uses and market opportunities. Sea Grant is working with industry to assist with these developments. If the industry grows together, there is opportunity for growth and jobs in regional areas.

Peter Fischer & Seth Barker– Maine Sea Farms
I visited Peter Fischer and Seth Barker from Maine Fresh Sea Farms on the beautiful Damariscotta River. Both Peter and Seth have a background in aquaculture and have worked in the mussel industry in the area. Mussels continue to be farmed at this location. The farm site is protected but has strong tidal flow bringing in nutrients. They grow *Saccharina, Alaria* and *Palmaria* from organic seeded string cultivated in Maine.

Maine Fresh Sea Farms was established in early 2014. The idea was to provide a test lab for sustainably grown sea vegetables that could be duplicated at other locations along the coast and that would provide a new local food source and an alternative to the wild seaweed harvest. Peter and Seth want to grow sea vegetables in a sustainable way, which can support the natural environment and also protect Maine's working waterfronts and marine-based economy.

Lisa Scali & Mitchell Lench - Oceans Balance
Mitchell and Lisa met with us in Portland and were keen to share ideas. They have some great new products, including Kelp Puree. They are expanding quickly across stores in the USA and have a good distribution network and following. They have a hatchery, a 4.5-acre farm in the Gulf of Maine, and a processing facility in Biddeford. They recently won a Greenlight Pitch and are moving ahead.

Peter Fischer and Seth Barker, Maine Sea Farms

Canada

Professor Louis Druehl

Canadian Kelp Resources

Professor Louis Druehl has dedicated his life to researching kelp, and I was lucky enough to visit him and his wife Rae in Bamfield on the west coast of Vancouver Island, BC. Together they own Canadian Kelp Resources, which was established in 1982. Louis' contribution to kelp biology has been honoured by the naming of a new kelp genus, *Druehlia fistulosa*. *Saccharina druehlii*, which is unique to Haida Gwaii in Canada, is also named after Louis.

Canadian Kelp Resources harvests several species and in 1983 started a commercial kelp farm in Barkley Sound, BC. Louis has expertise in kelp farm design and construction, kelp seed supply, product development and processing and environmental remediation.

He has written a book Pacific Seaweeds, which was first published in 2000 and recently updated in 2016, with almost 10,000 copies sold.

A leader in the kelp world, and a true gentleman, Louis is extremely generous with his knowledge and is optimistic about the future of the global kelp industry.

He has a consultancy and education service and is presently developing a "Kelp farm in a box" model (IKEA inspired!).

Rae Hopkins and Professor Louis Druehl, Canadian Kelp Resources, Bamfield, Canada.

Catherine O'Hare - Saltpoint Seaweed

Saltpoint Seaweed, founded in 2017, is owned and operated by three women – Tessa Emmer, Avery Roser and Catherine O'Hare. I met up with Catherine, who has a background in coastal ecology and sustainable agriculture. The girls met while studying and are all driven by the environmental sustainability benefits of seaweed and restorative aquaculture. They currently hand-harvest in Mendocino, northern California, and produce a range of dried seaweeds, and a new Surf Snack product. They are interested in farming native species and with funding from NOAA and Sea Grant, carried out some farming trials with Hog Island Oyster Co. For the pilot project, they grew the native red algae *Gracilariopsis andersonii* in Tomales Bay, northwest of San Francisco.

The results from the seaweed samples, sent to UC Davis for carbon and nitrogen analysis, were comparable to studies conducted on farmed seaweed on the East Coast, showing that the seaweed successfully removed carbon and nitrogen from the surrounding water. These results reinforce the many other studies, that show that seaweed has the potential to combat adverse impacts of ocean acidification and climate change.

Research has also shown that seaweed can help manage water quality by absorbing excess nutrient pollution from wastewater treatment facilities, urban stormwater runoff, and farming.

Seaweed aquaculture is growing in interest in California, and the Ocean Protection Council (OPC) recently published (2018) the State of California Ocean Acidification Action Plan which recognised the potential of seaweed as a management tool to sequester carbon and reduce organism stress from ocean acidification.

Catherine is hopeful that they can do some further studies and develop a research proposal to evaluate native seaweed aquaculture in the state. They see the benefits of working collaboratively with government agencies, industry and research organisations to bring awareness to the benefits of seaweed aquaculture in ensuring the long-term resilience of California's coastal ecosystems.

Earlier in 2019, the girls ran a kick-starter campaign to buy some production equipment, like a grinding mill, and upgrade their drying set-up to solar-powered, to increase their processing capacity. They were successful in achieving their goal. By offering recipes, surf snacks, t-shirts, tasting events and harvesting experiences, they were able to raise USD $40,000. This is an excellent validation of community support for this emerging industry.

Catherine O'Hare, Saltpoint Seaweed, California

Monterey Seaweed – Mike Graham

Louis Druehl recommended that we visit Mike Graham as we were heading down that way. At first, I was reluctant as this trip is all about Kelp farming and Mike is not farming kelp, but running a land-based aquaculture facility. Boy, am I glad we visited him and saw his facilities. Mike's company, Monterey Bay Seaweeds, is the only "farm" in the state offering fresh, live seaweed, exclusively for restaurants. Mike grows dulse, sea lettuce, sea grapes, ogo and nori, in 1000 gallon plastic vats. This method is called tumble culture and utilises sunlight, seawater and an air stone to circulate water.

Mike is Director of Aquaculture at Moss Landing Marine Laboratories and has been studying seaweed and aquaculture for over 25 years. His Masters was in kelp forest ecology, and he has spent a lot of his career travelling the world looking at kelp ecosystems. He continues to work for the University and also operates his business with his wife, who is a chef and knew that restaurants would embrace the idea of 'sea vegetables'. Chefs are getting very creative with Mike's sustainable salads. Sea lettuce is used in cooked dishes and can be sauteed, like kale. Dulse is sometimes called bacon seaweed because when sauteed with olive oil, it gets a bacon flavour! Fresh nori is very different from the nori, which is processed into sushi sheets and is used in salads and wrapped around vegetables and meats.

Monterey Seaweeds ships fresh, live seaweed to Michelin star restaurants around the USA, including San Francisco, New York and LA. Mike says "When chefs receive it, it's like they picked it off the rocks themselves." Their philosophy is that they "should be able to plate it out of the box". The seaweed is packed with a small amount of water to maintain freshness.

Setting up a land-based aquaculture facility meant it was easier to get through all the legislations and regulations currently in California.

Being located at Moss Landing, Mike pumps seawater directly to his tanks. The seaweeds grow vegetatively, using sunshine and capturing carbon dioxide. They can be harvested every two weeks.

Although this is not kelp farming, this technology is quite exciting and has many advantages. Tumble culture could be adapted to several Australian species to supply a restaurant market. "Chefs are very critical to the development of the seaweed industry in the United States. When you deal with a raw product, the chefs are the ones that have to turn it into something else. You need their creativity and their excitement with the product to turn it into something".

Professor Mike Graham, Monterey Bay Seaweeds.

Dan Marquez - PharmerSea

Dan has one of the only licensed kelp farms in California, due to their strict environmental regulations. His farm is 25 acres, and together with his wife Ana, they supply kelp for their Thalassotherapy business Ama Sea Beauty. They also have a permit to wild harvest. Dan has a lot of experience in aquaculture design and has set up several hatcheries in the USA and also offers a consultation service.

He is also motivated and driven by the ecosystem services that kelp farming delivers and is hopeful that delays in the regulations will soon be resolved, so that the industry can move forward.

CONCLUSIONS AND RECOMMENDATIONS

When I left Australia, I was of the impression that we were lagging somewhat behind in the kelp farming world. Upon returning, I am both excited and cautious about the future of developing a kelp aquaculture industry here. There are many benefits, both economically and environmentally, to developing this industry, but certainly, there will be challenges along the way.

What I learnt from my Fellowship is, besides Asia, the field of kelp farming is still evolving and emerging globally. Technologies are being adapted and discovered, and new markets being explored continually. Australia is well placed to learn from overseas and to develop a kelp farming aquaculture industry in the near future.

There are four main categories to consider with developing a kelp farming industry:
Hatchery; Farming/Grow out; Harvesting and Processing; and Developing Markets.

1. Hatchery:
Hatchery set up costs can be expensive, and the production of sporophytes takes some level of knowledge and expertise. I visited hatcheries in Scotland, Norway and the USA and learnt new technologies to enable breeding throughout the year. Although the lifecycle of kelps are similar, much of the research to date has been on *Saccharina latissima* (Sugar Kelp). Further research and development is needed in Australia to optimise culture techniques for our unique species. Throughout the Fellowship, several people advised about the importance of establishing a seed bank of gametophyte cultures, and to continue selective breeding for different conditions. Research organisations across Australia would need to collaborate to facilitate this.

In many parts of the world, hatcheries can provide seeded string or seeded rope to farmers. This model allows farmers to concentrate on licencing, permitting and physical set-up of their farms without the expense of a laboratory for breeding.

2. Farming:
Coastal waters and aquaculture licences are managed state by state in Australia. For aquaculture to develop, permitting and licencing agencies will need to be willing to accommodate this industry. One of the major challenges farmers face overseas is the paperwork and lengthy permitting process. The LPA licence model from Maine, USA is a useful tool for farmers to test a location, species or gear.

The most common method used for farming kelp is the 'vector' method. Seeding ropes, with anchors attached at either end and floating buoys to control depth of lines. As described earlier, there is quite a lot of research into different technologies and gear to improve growth and efficient use of space. Trials will need to be conducted in various conditions to determine the most suitable locations for kelp farms. Australia has a vast coastline; however, we are exposed to some huge swells and tides. Open-sea cultivation can be unpredictable, and engineering of gear will need to allow for major storm events. Different species will have different growth rates. At certain times, usually coinciding with warmer water temperatures, bio-fouling of lines can be a major issue, and kelp should be harvested before this occurs. This will require an understanding of growth rates and the best timing for deployment.

3. Harvesting & Processing:
Equipment needed for harvesting includes a boat with a crane or winch. A Co-Operative style model could share costs of such assets to limit the barriers to entry to the industry. Before setting up a farm, farmers will need to have a processing plan to sell their crop. With all the positivity surrounding kelp and its benefits, many people want to become involved. In some areas, I spoke with farmers who had to dispose of their crop, especially in the first year, as they didn't have buyers or any way of processing the product.

Depending on the final product desired and the market, there will be different processing needs. Investment into processing infrastructure and research into various methods to optimise efficiency and quality will be needed. Also, the high water content of seaweeds demands that most farmed seaweed is dried after harvest, which can be expensive, especially if sun drying is not an option. Some examples of processing overseas involve blanching, freezing, and mechanically cutting into different sizes (e.g. noodles). At a large scale, this requires investment for specialised machinery.

4. Markets & Analysis:

With increased biomass from farming, new markets can be explored – foods with kelp added are becoming popular overseas (e.g., pasta, bread, salsa, pesto, teas, and so the list goes on)! Kelp can also be used in the cosmetics industry, added to agricultural feed, pet foods, fertiliser, biofuels and research into plastic alternatives. A focus should be on developing high-value products, such as bio-actives. Extracts from seaweeds contain many compounds, which are beneficial to human health, such as antioxidants, anti-cancer compounds such as kinase inhibitors, and compounds with anti-inflammatory and immune-stimulatory properties. Once again, collaboration with research agencies will be essential to investigate these possibilities.

It is imperative that industry standards are high and appropriate HACCP and Food Standards established at all stages of the process. Australia has a clean and green reputation, and we have the potential to grow very high-quality crops that will appeal to the Australian and global market. Nutritional, heavy metal, bacteriological and chemical analysis data will be needed to support the new industry.

Recommendations for introducing kelp-farming aquaculture to Australia:

- Collaboration: It will be essential for research organisations, industry and other stakeholders to work together and develop partnerships to progress this new industry.
- Sustainability: Moving forward, environmental sustainability must be the primary consideration at all times. Only endemic species should be farmed and monitored regularly for pests/and or disease. Interactions with other marine wildlife species should be considered and monitored.
- Regulatory frameworks: There are many agencies involved with regulations in the marine environment. To streamline the application process, agencies should work together to develop guidelines for approvals. Rather than intended farmers having to meet with 11 or more different agencies (e.g. Fisheries, Maritime, MPA's, local councils, heritage, national parks, naval etc.), it would be beneficial for strategies to be developed that incorporate all the concerns/regulations guidelines into one document and one approval agency. This is the case in NSW with the recent development of the 2018 NSW Marine Waters Sustainable Aquaculture Strategy. The Australian Government has prepared a National Aquaculture Strategy (2017) with an aspirational goal of increasing the value of aquaculture from $1 billion to $2 billion by 2026. It also recognises in this document the need to establish streamlined approval processes for new aquaculture development.
- Development and storage of gametophyte banks: The CSIRO could possibly host this. As the industry develops it will be very valuable to have a national seed bank, especially as new thermal resistant strains emerge.
- Funding for more research: As this is a new and emerging field, there is so much to learn and discover. We are already finding that the more we learn, the more questions we have. To develop this new form of regenerative agriculture and provide sustainable jobs, we will need to understand the processes and develop new efficient technologies.

Research priorities could include:

- nutritional profiles of kelps, and specific health benefits of new species
- gear design to improve farming efficiency
- food technology and development of new foods and markets
- extraction processes, new bio extracts and their properties
- environmental and ecological services
- genetics and development of thermal resistant strains

The Blue Economy (CRC) Co-Operative Research Centre has recently been established to find innovative and sustainable offshore industries to increase Australian seafood and marine renewable energy production. The government has invested $70 million over 10 years, and part of this significant project includes research into offshore seaweed farms.

Large scale offshore seaweed farming is not the same as developing a network of small kelp farms and a working waterfront. I believe, Australia could benefit from developing both of these industries.

Challenges:

Research and Technology: Although seaweed cultivation and applications hold great potential, the technology in Australia is still in its infancy and requires strategic and robust R&D support. Australia has no tradition in the cultivation of seaweed and application of the science supporting it. The propagation and control of complex biological lifecycles and the physiological requirements of many Australian seaweeds are not yet well established.

Disease: Little is known of the potential of weeds, pests and diseases for cultivated seaweed. In agriculture, monocultures can occasionally lead to a disease outbreak, and there have been reported cases of invasive snails damaging Sugar kelp crops (in Scotland). Farming a variety of crops (e.g. kelp and shellfish) has advantages, developing an ecosystem type approach. Ongoing monitoring and data collection will develop best practices for kelp farm management.

Social Acceptance: NSW DPI (Fisheries) has recently released a new aquaculture strategy. During the consultation phase, the primary concerns raised by the community included:

- Water quality and seafloor impacts
- Marine fauna entanglement
- Visual amenity
- Disease and Pests
- Navigation.

Reflections:

I was inspired to undertake this investigation for several reasons. As the Fellowship journey continued, I became more and more interested in the environmental benefits and drawdown capabilities of kelp farms.

There is growing excitement and interest globally surrounding the environmental potential of seaweed aquaculture, particularly with the recent 2019 UN Climate Action Summit recognising that Ocean-Based climate action could deliver a fifth of emissions cuts needed to limit temperature rise to 1.5°C. The new scientific report *The Ocean as a solution for Climate Change: 5 opportunities for action* includes one of these solutions as "Utilising low-carbon sources of protein from the ocean, such as seafood and seaweeds, to help feed future populations in a healthy and sustainable way, while easing emissions from land-based food production could support emission reductions of up to 1.24 GtCO2e each year by 2050."

Global action to address the state of the ocean has never been more urgent. There are solutions available to help curb climate change and contribute to the development of a sustainable ocean economy while protecting coastal communities from storms, providing jobs and improving food security.

Australia is well placed to not only learn from overseas technologies but to also partner with and collaborate with organisations to establish kelp-farming aquaculture as a new, sustainable, innovative industry.

No doubt there will be challenges along the way, however with all the economic and environmental benefits, perhaps not farming kelp may create more significant future challenges for us all.

Dissemination and Implementation

Since returning, I have been on local ABC radio, presented to the Red Cross Zone conference, Narooma Chamber of Commerce, Batemans Bay U3A (University of the Third Age), and the Tuross Garden Club. I was accepted into the IAccelerate business course and pitched the idea of kelp farming in NSW, winning Judges Choice and People Choice Awards.

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THANK YOU!