Insights for the emerging seaweed industry in Australia

Jo Kelly, 2022 Nuffield Scholar

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Scholar contact details

Name: Jo Kelly

Organisation: Australian Seaweed Institute

Email: jo.kelly@australianseaweedinstitute.com.au

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NUFFIELD AUSTRALIA Contact Details

Nuffield Australia
Telephone: 0402 453 299

Email: enquiries@nuffield.com.au

Address: PO Box 495, Kyogle, NSW 2474

Executive Summary

Australia has a small, emerging seaweed industry with the potential to develop into a commercially significant new aquaculture sector within the coming decades. Seaweed cultivation and products are already a large global industry with enormous growth potential as the demand for natural, sustainable seaweed products expands.

The major focus of the Australian seaweed industry is on a native seaweed species called *Asparagopsis*, which, when incorporated as a ruminant livestock feed supplement reduces methanogenesis by over 80%. This natural seaweed supplement could be a game-changer for reducing emissions from agriculture.

As enteric livestock methane emissions contribute over 10% of Australia's total emissions footprint and almost 7% globally, it's high time that methane emissions from livestock are recognized and addressed as the major route to agriculture and food system decarbonization.

With the global methane-reducing additive market estimated to grow at 57% CAGR to 2030 according to the World Bank (2023), there is now an opportunity to accelerate the establishment of the supply chain in Australia. *Asparagopsis* seaweed cultivation and its development as a low emissions feed supplement is currently being supported by the Federal government through a grant to the industry group Australian Sustainable Seaweed Alliance (ASSA) until June 2025.

However, policy change and ongoing investment are needed from government if Australia is to establish itself as a global leader in this space and continue the current momentum towards establishing supply, reducing costs of production and accelerating uptake of methane reducing livestock feed supplements. This is also important for Australia's meat and dairy sectors as domestic and global expectations and demand for sustainable products increase.

Through my Nuffield scholarship project and travels, I have learned about different seaweed industries and R&D programs in other countries, policy approaches for decarbonization of agriculture and collaborative models for industry development.

This report outlines the key insights and recommendations for the emerging Australian seaweed industry.

Keywords: seaweed, sustainable agriculture, decarbonization, livestock methane emissions

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Foreword

My theory of change is that to transition from a fossil fuel dependent economy then Australia must actively develop new industries that will provide new jobs and economic development opportunities in a low carbon society. My involvement in the seaweed industry started in 2018 when I combined my skills in business strategy, sustainable investment and environmental engineering together with my mission to contribute to establishing new, sustainable industries for Australia.

In 2020 I authored the Australian Seaweed Industry Blueprint (Kelly, 2020) which outlines the opportunity for Australia to establish a new $1.5 billion seaweed sector over the coming decades. In 2021 I went on to establish, and chair, the Australian Sustainable Seaweed Alliance (ASSA) as the peak seaweed industry representative group with 10 major growers from around Australia as members. In 2023 ASSA were successful in obtaining an $8.1 million grant from the federal government for development of the seaweed industry with a particular focus on *Asparagopsis* cultivation to support decarbonization of the meat and dairy sectors. ASSA now has 8 full-time staff along with two research partnerships to support and fast track industry development over the coming decade.

However, the current funding ends in June 2025 and ongoing government support for policy change and R&D is needed to continue building this emerging industry and incentivize decarbonization of meat and dairy sectors if medium term seaweed industry growth projections of 1,200 jobs and $100 million in gross value of production are to be achieved (Kelly, The Australian Seaweed Industry Blueprint, 2020).

My overall goal for this project was therefore to gain insights that could be applied to developing the Australian seaweed industry. This involved learning about seaweed industries in other countries and about how agricultural decarbonization policy and livestock methane solutions for meat and dairy sectors are emerging.

The personal travel component of this project allowed me to focus specifically on key seaweed industries of interest including New Zealand, Japan, United Kingdom, France, Spain and The Netherlands. My personal travels also enabled me to present at and attend key seaweed industry conferences (Monaco Ocean Week March 2022, 2035 Oceania Agriculture Summit in New Zealand 2022, International Seaweed Symposium February 2023, European Commission's Algae summit October 2023,) where there was the opportunity to speak with a wide range of seaweed industry participants including from South Korea, China, USA, Canada, Mexico, Malaysia and Indonesia. Previous seaweed industry visits in South Korea, Israel and Indonesia in 2019 have also informed the discussions and conclusions in this report.

Through the group travel component, referred to as the Global Focus Program (GFP), I was able to see some different models of how other primary industries are structured and organized. Although this experience was not directly related to seaweed, it has led to some new ideas for collaboration, policy and advocacy activities for the Australian seaweed industry. Countries visited on the 5-week GFP in July 2024 included: Indonesia, France, Denmark, USA and Chile.

Please note that this report is not globally comprehensive in reach. The focus of this report is on industry development activities for seaweed cultivation, policy approaches for decarbonization of agriculture and collaborative models that could benefit the emerging Australian seaweed industry.

Table 1. Travel itinerary

Travel date	Location	Visits/contacts
3 – 14 March 2022	United Kingdom: Bath South Petherton Winscombe-Sandford Bristol Norwich London	Farm tours – Bristol Port, Cheese production, Agritourism, dairy, Thatchers cider CSC Conference UK Parliament
24 – 27 March 2022	Monaco	Monaco Oceans Week - speaker
28 – 29 March 2022	Scotland: Oban	Scottish Institute of Marine Science – Seaweed hatchery
27 – 30 June 2022	Portugal: Lisbon	UN Oceans Conference – speaker and host official side event
9 – 14 October 2022	New Zealand: Auckland Paeroa Tauranga	2035 Oceania Summit 10-11 October 2022 AgriSea University of Waikato, Coastal Marine Field Station
18 – 19 October 2022	Gladstone, Qld	CQU – Coastal Marine Ecosystem Research Centre
19 – 25 Feb 2023	Hobart, Tasmania	International Seaweed Symposium UTAS-IMAS seaweed lab
7 – 9 March 2023	Canberra, ACT	ABARES conference, presenter FRDC & DAFF Meetings
14-20 April 2023	Townsville, QLD	James Cook University GBRMPA AIMS
5 – 6 September 2023	West Beach, South Australia	South Australian Research Development

Travel date	Location	Visits/contacts
		Institute – seaweed hatchery
25 – 26 September	Netherlands: Amsterdam	Hortimare – seaweed hatchery and species research
5 - 6 October 2023	France: Paris	European Union: Algae Summit – speaker
3 – 6 June 2024	Indonesia: Sumatra	Fish farm, prawn farm, beef feedlot, crab processing, pineapple cultivation and cannery, spices and pepper production, palm oil production, rubber plantation and production, chicken egg farm.
8 - 15 June 2024	France and Demark: Normandy	Cooperative Models, Flax production and processing; feed pellet production; biogas; wind power; UniLasalle agriculture research and training; pig farm and meat production; bakery; seed nursery; potato farm;
16 – 23 June 2024	Denmark: Copenhagen Horsens Slagelse	Danish Agriculture and Food Council; mushrooms; cherry wine; free range pigs; Danish crown pig slaughterhouse; fish farm; Manssons organic farm; dairy; research institute with integrated solar and crops.
25 – 30 June 2024	California, USA: Fresno Sacramento	Onions, walnuts, almonds, peach processing; supermarkets; wineries.
2 – 7 July 2024	Chile: Santiago Conception	Sociedad Nacional de Agricultura

Travel date	Location	Visits/contacts
		Nuveen Investment (oranges, avocados, walnuts) Seedling production, winery and research centre, feedlot, dairy, walnuts, cherries
10 – 17 November 2024	South Korea: Wando Jindo	Seaweed farms, boat tours, processing facilities for food and products, product research institute, research hatchery.

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Lastly, thank you to Nuffield Australia for creating this unique opportunity to travel and learn and think differently. And to all the Nuffield scholars past and present that I met on my travels – what an inspiring group and I'm proud to be part of the Nuffield tribe!

Abbreviations

ACCU	Australian Carbon Credit Units
AIMS	Australian Institution of Marine Science
ASSA	Australian Sustainable Seaweed Alliance
CAGR	Compound Annual Growth Rate
DAFF	Australian Department of Agriculture Fisheries and Forestry
ERAC	Emission Reductions Assurance Committee
EC	European Commission
EU	European Union
FRDC	Fisheries Research and Development Corporation
GBRMPA	Great Barrier Reef Marine Park Authority
GFP	Global Focus Program
GVP	Gross Value of Production
IFEED Act	Innovative Feed Enhancement and Economic Development Act of 2023
R&D	Research and development
SALTAS	Salmon Enterprises of Tasmania Pty Ltd
SAMS	Scottish Association of Marine Science
SDGs	United National Sustainable Development Goals
UN	United Nations

Objectives

- Objective 1 – Provide a brief overview of the current state of the seaweed industry.
- Objective 2 – Identify collaborative seaweed research and development (R&D) programs and facilities in other jurisdictions that the Australian industry could learn from.
- Objective 3 – Identify any policy approaches taken in other geographies that could be relevant to development of the seaweed industry in Australia.
- Objective 4 – Uncover some interesting models of collaboration in other geographies and industries that may support broader, collective industry goals and advancement.

Chapter 1: Introduction to seaweed

Current State of Industry

Global seaweed industry

Seaweed is a global industry with a gross value of production (GVP) of USD 17 billion[1] and with the potential to grow by an additional USD $11.8 billion by 2030 (FAO, 2024; World Bank, 2023). Food products make up most of the usage, followed by industrial extracts such as alginate and carrageenan, which are used in everyday food and personal care products. In addition to these uses, seaweed extracts and biomass are also starting to be used more widely in animal feed, biostimulants, cosmetics, pharmaceutical products and bioplastics.

The seaweed industry has been growing at around 6% per year between 2000 and 2022 with 97% of commercial seaweeds now cultivated in marine aquaculture farms and only 3% wild harvested (FAO, 2024). Over 99% of all cultivated seaweed currently comes from Asia and the major seaweed producing nations are China Indonesia, Philippines and the Republic of Korea (FAO, 2024). Seaweed is grown predominantly on commonly used marine aquaculture infrastructure including long lines, floating nets or rafts in countries like China, Japan and South Korea or in much smaller scale, shallow farming systems in Indonesia, Philippines and Tanzania. Land based seaweed farming systems in ponds and tanks are becoming more common in countries like Canada, Australia, New Zealand and Israel.

Figure 1: top left – long line seaweed aquaculture in South Korea; top right – small pond aquaculture of seaweed in New Zealand; bottom – tank seaweed cultivation in Israel. (Source: Author)

[1] Includes macroalgae and microalgae with seaweeds making up 99.7% of global production volumes and microalgae 0.3% (FAO, 2024).

The emerging markets in the USA and Europe are focusing on producing food and other high-value bioactive compounds and alternative proteins for human, animal and plant nutrition. Given the increasing demand for sustainably produced products the market for seaweed is estimated to continue its upward trajectory to reach almost $30 billion by 2030.

Australia's emerging seaweed industry

The Australian Seaweed Industry Blueprint highlighted the opportunity for Australia to develop a sustainable, high-tech and high-value seaweed industry estimated to be worth $1.5 billion by 2040 and employ almost 10,000 people (Kelly, The Australian Seaweed Industry Blueprint, 2020).

Currently Australia has a small but emerging industry that has largely been based on wild harvest of seaweeds. However recent developments in marine and land-based production methods, primarily for *Asparagopsis* seaweed for use in methane reducing livestock feed supplements, are driving expansion of the seaweed industry in Australia.

There are many benefits that a seaweed industry can offer including: sustainable biomass production, coastal water quality improvement benefits, jobs and regional development. Australia has the natural resources, skills, and environment needed to advance a seaweed industry that could be globally competitive in the coming decades. However, the industry is at a critical juncture where government policy and support for both cultivation and agricultural emissions reduction are needed to build market confidence and attract investment to Australia's fledgling seaweed industry.

Some of the key challenges for the Australian seaweed industry are high costs of production, policy gaps and a very large geographic spread which means the industry, government and researchers are spread thinly. In a review of the policy framework in 2023, it was found that most State Government aquaculture regulators (except for Northern Territory) reported a significant increase in parties interested in obtaining aquaculture licenses for seaweed ocean farms and land-based operations (Kelly & MacLeod, 2023).

Chapter 2: Agriculture's emissions reduction challenge

Agriculture's emissions footprint

In Australia, agricultural emissions contribute to 14% of national emissions and 77% of this comes from livestock methane (Zero Net Emissions Agriculture Cooperative Research Centre, 2024). Globally, enteric methane emissions from livestock contributed 2.8 Gt CO2-equivalent emissions or approximately 6.8% of global greenhouse gas emissions in 2022 (FAO, 2024).

Demand for meat and milk is predicted to increase to feed 10 billion people by 2050. While a shift to plant-based diets is an important part of the solution, addressing methane emissions from ruminant livestock is a major lever for decarbonization of the agriculture and food sectors.

In essence, decarbonization of the agriculture sector will require solutions to livestock methane emissions. This can happen by reducing herd numbers however the remaining herd will still have a methane problem to solve.

The global methane-reducing additive market was estimated at USD$47 million in 2022 but projected to be growing at 57% CAGR to USD$306 million by 2030 (World Bank, 2023).

It's high time then that methane emissions from livestock are recognized and addressed as the major route to agriculture and food system decarbonization. Much attention in recent years has gone into soil carbon sequestration and reforestation/revegetation projects however it should be noted that these are carbon capture or offset solutions and do not address the source of agriculture's emissions problem which is greenhouse gas emissions (predominantly methane from livestock) to the atmosphere. Whilst we also need to accelerate and support drawdown methods for carbon dioxide reduction from the atmosphere, it is recommended that there is a shift in focus from governments and farmers worldwide to focus on the biggest portion of agricultural emissions – enteric methane from ruminant livestock.

Asparagopsis seaweed for livestock methane reduction

A native Australian seaweed, *Asparagopsis spp.*, has been scientifically shown to reduce methane emissions from cattle by over 80% or more when as little as 0.5% is added into their daily feed (Kinley, et al., 2020). The bioactive in the seaweed is bromoform and this interrupts methanogenesis in the cow's rumen.

This discovery is being commercialized by FutureFeed Pty Ltd, which holds the global intellectual property rights and have conducted 10 years of scientific research to demonstrate its application as a safe and effective feed ingredient for reducing livestock methane. Further, results published recently from trials using the *Asparagopsis* feed supplement in canola oil showed an improvement in feed use efficiency indicating a potential for productivity improvement in commercial feedlot settings (Kinley, et al., 2024).

There is now a global race to begin large scale cultivation with nine licensees in five countries to date. *Asparagopsis* seaweed cultivation and its development as a low emissions feed supplement presents a major opportunity for the Australian seaweed industry and is being supported by the Federal government through a grant to ASSA to help accelerate a solution to decarbonize the meat and dairy sectors.

In Australia, farmer adoption of the solution has been slow to date with SeaForest in Tasmania reporting that they had a backlog of supply in 2023. Government policy and targets for agricultural emissions reduction and incentives for farmer uptake are now needed to support industry development and will be discussed further in the next section.

Policy for reducing livestock methane emissions.

While in Denmark a world first agreement was reached between the government, environmental groups and farmer groups to tax greenhouse gas emissions from agriculture. Their aim is to cut overall greenhouse gas emissions by 70% and agricultural emissions by around 55% by 2030 and become climate neutral by 2045. From the discussions I had on the topic while on the GFP in Denmark, many farmers were opposed to the scheme but were also aware of climate change and that something needed to be done. In the end farmers and the Danish Agriculture and Food Council were successful in lobbying the government to delay its introduction to 2030 and reduce the initial cost burden on farmers to give them time to adopt solutions. The concept is that money raised from this tax will be used to fund the ongoing transition to a low carbon industry. In the interim EU subsidies for the green transition would be accessed by Danish farmers.

According to a presentation from a representative at the Danish Department of Climate, Energy and Utilities, agriculture contributes approximately 30% of Denmark's total emissions, with livestock methane from the large livestock and dairy sector contributing significantly. Therefore, tackling livestock methane will be essential to meeting Denmark's national emissions reduction goals. In a presentation from the Danish Agriculture and Food Council an example was given of a methane reducing feed supplement called Bovar, which is a less effective (30% emissions reduction solution according to the World Bank, 2023), synthetic competitor to Asparagopsis seaweed, however it was mentioned that the subsidy plan would be technology neutral.

At Arla, a Danish farmer cooperative that owns approximately 80% of the milk in Denmark, there was a great example shown of how dairy farmers are tracking their emissions. Farmers are benchmarked against each other and can earn up to 3-euro cents per litre of milk if they achieve higher than average emissions reduction. The dairy farmer that I visited did comment that he would be adding a feed additive to reduce methane emissions from his operations.

Figure 2: Danish dairy farmer with carbon emission tracking data as part of Arla cooperative (Source: Author)

It is anticipated that this tax on agricultural emissions will accelerate the testing and demand for methane reducing cattle feed supplements, particularly for dairy cows in Denmark in the lead up to 2030. It is also thought likely that the EU will also introduce a price on agricultural emissions in the coming years however a new European Parliament was only just elected in June 2024 so this may take some time.

New Zealand is another country that had considered how agricultural emissions would be included into the carbon trading scheme with limits set on agriculture but have since backtracked in June 2024 due to a change of government. The government has committed to investing heavily in emissions reduction technology and this could also drive greater demand for *Asparagopsis* feed supplements produced in Australia and/or the cultivation of *Asparagopsis* in New Zealand, as it occurs natively there also.

While in California I learned that the one of the barriers to adoption of feed additives in the USA is the expensive and lengthy regulatory approval process. This is restricting the adoption of methane reducing additives like seaweed even as major beef and dairy buyers set ambitious climate targets. However, the Innovative Feed Enhancement and Economic Development Act of 2023 (IFEED Act) is before Congress (since June 2023) and if approved would streamline approval for feed supplements such as *Asparagopsis* seaweed (GovTrack.us, 2024).

Meanwhile in Australia there are currently no emissions reduction targets for agriculture and no methodology approved yet for Australian Carbon Credit Units (ACCU) for livestock methane reduction. However, in July 2024 a working group made up of 130 industry representatives submitted an official expression of interest to support the introduction of an ACCU method for enteric methane reduction for ruminant livestock. This submission was assessed by the Emission Reductions Assurance Committee (ERAC) to determine prioritisation of the development of new emissions reduction methods however unfortunately it was not prioritised. Until a method is approved in Australia then it is likely that farmer uptake will be limited.

Chapter 3: Other opportunities for seaweed

Food

On my GFP and personal travels I visited supermarkets in each country and noted that seaweed food products are becoming more prolific. In South Korea and Japan, seaweed has long been a traditional part of the diet and fresh seaweed or dried seaweed features in almost every meal. In countries like Australia, NZ, UK, Denmark, France and USA there are lots of snack products on shelves that use dried seaweed as an ingredient e.g. crackers, or whole dried seaweed sheets. In Chile there was a lot of dried Kelp available that was eaten as a snack product.

Figure 3: seaweed is a common ingredient in Japanese and South Korean dishes (Source: Author)

As noted in the Australian Seaweed Industry Blueprint (Kelly, 2020), “seaweed has long been recognized as a highly nutritious food due to its iodine and mineral content, protein content and other compounds that are demonstrated to improve heart and gut health and brain function”. While most of this research is based on commercially available northern hemisphere species, emerging research is showing that Australian species are just as nutritious and palatable (Skzypcsvk, et al., 2019).

With over half of all farmed seaweed biomass currently used for human consumption and with the global alternative market growing rapidly it is projected that seaweed alternative protein market will be worth USD$448 million by 2030 (World Bank, 2023). While there are already some examples of Australian businesses with seaweed food products, this indicates there is potentially a much larger opportunity for more high value, high quality Australian seaweed food products.

Figure 4: dried seaweed products in a supermarket in South Korea (Source: Author)

Nutritional animal feed additives

Besides the application of *Asparagopsis* for methane reduction in ruminants, seaweeds are a well-known nutritional supplement in animal feeds for cattle, pigs, horses, poultry, finfish and abalone. While there is no data on the seaweed share of this market the global feed additive market was reported as $38.86 billion in 2022 (World Bank, 2023).

An example I saw on my travels was at an organic, free range pig farm in Denmark. A seaweed additive was given in the feed to enhance gut health and digestive efficiency by balancing the gut microbiome and reducing diarrhea to increase weight gain. The brand was OceanFeed's and their website mentions they source a variety of different seaweeds from Europe, North America and Southeast Asia.

Figure 5: seaweed feed supplement for pigs in Denmark (Source: Author)

AgriSea in New Zealand also had an animal nutrition supplement, made by combining their seaweed liquid with zeolite. Again, the focus of the feed supplement was on gut microbiome health, disease resistance and feed conversion.

This is a potential growth market for Australian seaweeds that meet the nutritional profile requirements.

Biostimulants

Seaweed based biostimulants account for USD$1 billion of the global market estimated to be worth between USD$2.5-$3.5 billion in 2022 (World Bank, 2023).

During my travels I visited a seaweed business in New Zealand called AgriSea who collect beach cast Golden Kelp and ferment it into a liquid fertiliser.

Figure 6: making seaweed into a biostimulant in New Zealand (Source: Author)

Although this product is not a high value product, it may be an opportunity for a secondary product stream for any excess biomass to be used after a higher value product is extracted from the seaweed. This process is known as biorefinery approach and is being developed for seaweed applications.

Bioplastics

It is estimated that the global bioplastic market will grow from USD$11.5 billion with seaweed bioplastics projected to have a market share of $733 million by 2030 (World Bank, 2023). One example is a company called Notpla, who I met with while at the EU Algae Summit during my Nuffield personal travel who were awarded the Earthshot prize in 2022 for their work on developing bioplastic food packaging made from seaweed.

There are several emerging companies in Australia who are developing seaweed bioplastic solutions with seaweed sourced from countries like Indonesia as they require high volumes of very cheap seaweed. It is unlikely that Australia could provide seaweed economically for this low value market unless it was a biproduct from another higher value product, again using the biorefinery approach mentioned in the section above.

Chapter 4: Collaborative models for industry development

The important role of industry groups

I firmly believe that industry associations play a critical role in industry development including, funding key R&D activities that benefit the whole industry, representing industry needs to government on policy, developing skills and workforce and supporting their member businesses.

It was beneficial to see so many examples of industry groups on my GFP travels and gain an understanding of the types of activities they conduct on behalf of their members and key policy initiatives that they undertake.

The table below summarizes a selection of industry bodies that I visited during my Nuffield scholarship and their key functions.

Table 2. Industry bodies visited

Industry Group	Description	Key functions
Interbev, France	Represents the French livestock and meat industry – France is the leading beef producer in Europe with 10 billion Euro turnover.	Industry events and comms including studies, market knowledge, regional representation, information sharing Insurance – regional cleanup fund Note: 50% budget comms and marketing
La Cooperation Agricole, France	A federation representing agricultural cooperatives.	Representation on policy and regulation Assist farmers to access funding and subsidies Strengthen and support cooperatives
Danish Food and Agriculture Council	A private organization representing the farming and food industries of Denmark representing a Euro 20 billion industry and 22% of Danish economy.	Promotes political influence of ag and food sector Input to policy and regulatory frameworks on behalf of sector participants R&D programs for food safety, animal health and welfare, environment and energy.

Industry Group	Description	Key functions
Fresno County Farm Bureau	Non-profit representing Fresno's farmers who produce a third of the USA's vegetables; two-thirds of the USA's fruits and most of the nation's nuts.	Policy and political advocacy Community outreach and education Water and labour are the biggest issues Note: trade associations/ marketing groups also exist for each crop type.
Society National de Agriculture (SNA), Chile	Brings together 47 associations and chambers.	Policy and advocacy Free trade agreements Workforce capacity
Aotearoa New Zealand Seaweed Association (ANZSA)	NZ seaweed industry association	Networking and knowledge sharing at annual conference
Global Seaweed Coalition	International membership group representing seaweed globally	Hosts knowledge sharing webinars and events and advocates to the UN for seaweed as a sustainable industry globally that contributes to the sustainable development goals (SDGs).

One of the most valuable functions that industry groups can provide is policy and advocacy to governments on behalf of the industry. Additionally, communications – both internal network knowledge sharing as well as external promotion / marketing is provided by some industry groups. For most industry groups, it appears that their core operations are funded by their members with additional funding for bigger projects coming from government grants or other donors.

Collaborative business models

Greenwave's not-for-profit model

I was fortunate to meet in person and hear a panel discussion with GreenWave founder and author of the book "Eat like a Fish", Bren Smith when I was in New Zealand for the 2035 Oceania Summit in 2022. Greenwave is a not-for-profit company that is developing a global network of regenerative ocean kelp farmers. Farmers pay a fee to participate in the training and development, access the knowledge hub and benefit from the distribution channels. It's a great model funded by donations, grants and seaweed farmers who pay a fee for service. A consortium of NZ companies are collaborating with Greenwave to run a kelp farm pilot that was just getting underway when I was there in 2022.

French Cooperatives

There are around 2,100 cooperative businesses in France in the agriculture and food sector according to a presentation from La Cooperation Agricole, a national union of agricultural cooperatives in France. Around a third of all French food brands and 75% of French farmers participate in cooperatives. In the French cooperative model farmers are suppliers to and shareholders of the cooperative. Cooperatives all have their own rules and policies, and many cooperatives have a specific geographic focus. The strength of the cooperative model is resilience to market shocks, knowledge collaboration, capital and risk sharing between farmers.

For example, an alfalfa and sugar beet pulp dehydration cooperative we visited had a very large drying and processing facility that they recently transitioned from coal fired heating to biogas. Instead of each individual farmer drying and producing their own pellets and then selling them to the animal feed market, the cooperative model enables efficiencies and economies of scale to be achieved in production, distribution and sales.

Another example was Agrial Cooperative, a very large cooperative in France with 11 product lines, 12,000 farmer members and 7 billion Euro in sales across meat, dairy and other crops. Typically, this cooperative will buy raw input from farmers on a five-year commitment then process and sell the end products. 80% of all their food products are sourced from within 200km of the processing facilities.

The cooperative models in France provided some good examples of how to pool capital and share risk while achieving economies of scale and could be a solution to establishing the processing of animal feed supplements and other potential products in the Australian seaweed supply chain.

Collaborative Aquaculture Hatchery Examples

There are several examples I visited of jointly owned and funded aquaculture hatcheries that provide broader industry benefits. Four examples I have had the opportunity to learn from are discussed below.

Scottish Association of Marine Science Seaweed Hatchery

The Scottish Association of Marine Science (SAMS) is partnering with industry to operate the industry's first seaweed hatchery in Oban, Scotland. The hatchery receives reproductive seaweed samples from seaweed farmers around Scotland and uses these to bulk up the spores and create seeded twine that is then sent back to the seaweed farmer to plant out on their ocean farm. The farmer pays a price to SAMS for the seedstock, and this service provided by SAMS reduces the overheads for each seaweed business by providing an economy of scale in the hatchery phase.

Figure 7: SAMS seaweed hatchery (Source: Author)

Tasmania Salmon Industry Hatchery

Salmon Enterprises of Tasmania Pty Ltd (SALTAS) is a producer of eggs and smolts for the Tasmania salmon industry. It was originally established as a joint venture between Tasmanian State Government and a Norwegian company in 1985 and SALTAS are now a registered research service provider with a cutting-edge selective breeding program. Industry partners are Tassal and Huon which are the biggest salmon producers in Australia, with CSIRO and University of Tasmania among the research partners. The selective breeding program and other R&D projects carried out here help salmon farmers to decrease production costs, increase growth rates and disease resistance and improve quality of the salmon.

Black Tiger Prawn Research Hub

This program is a collaboration between industry and research organisations funded by Australian Research Council (ARC). ARC's Industrial Transformation Research Hub for Advanced Prawn Breeding is a consortium involving researchers and industry from James Cook University, CSIRO, Australian Genome Research Facility, University of Sydney, Vlaams Instituut voor Biotechnologie and Seafarms Group.

The goal of the Research Hub for Advanced Prawn Breeding is to develop and transfer to the farmed black tiger prawn industry the capacity to benefit from advanced genomic-informed breeding programs.

Western Australia Government multispecies aquaculture facilities

The Western Australian Department of Primary Industries and Regional Development (DPIRD) operates three commercial and research hatcheries that supply a range of species to industry and undertakes research to support aquaculture industry development across Western Australia.

An aquaculture R&D team of over 20 experts assists the Western Australian aquaculture industry to increase its productivity and market competitiveness by

supplying juvenile fish and shellfish spat for start-up commercial operators and conducting applied research and development projects. The group operates out of six sites between Albany and Geraldton. This is a great example of government supporting industry development through hatchery R&D in aquaculture.

Key benefits of industry hatchery programs

Key takeaways from these examples are:

- The development of staff for the industry is also a core part of the value proposition of hatchery facilities.
- Biosecurity is paramount in aquaculture and ongoing R&D is a critical function to support industry development that is carried out at these facilities.
- Long term commitment and sufficient ongoing funding is needed to continue operation of these facilities and remain relevant to emerging industry needs.
- Australia has several examples of aquaculture hatcheries that support industry development with ongoing funding from government.

Government funded R&D programs for seaweed

I was fortunate to be asked to speak at the European Commission's Algae Summit in Paris in October 2023. While I was there, I heard a lot about the Seaweed Based Market Application (SeaMark) R&D program which is an EU funded, 9 million Euro (AUD$15 million) program that kicked off in June 2022. The project aims to help develop the emerging seaweed industry to meet growing demand for seaweed-based products by helping industry to scale up cultivation, support product development through biorefinery approaches, influence policy and build a marketing strategy for EU seaweeds. The focus of the program is on cultivation of sugar kelp and sea lettuce with products for human consumption, animal feed and nutraceuticals. Selective breeding and helping build the environmental credentials for a seaweed industry in Europe are also key parts of the program (SeaMark, 2023).

At the EU Algae Summit, I also learned about the South Korean Government's program for aquaculture disaster insurance. As far as I know this is the only one of its kind in the world for seaweed aquaculture and protects sea farmers from natural disasters and biological hazards like contamination or pests and disease. Farmers can receive between 70-80% compensation for their average yearly production and this is something that Australia could benefit from to reduce the risks to sea farmers. Additionally, the South Korean delegate at the conference spoke about the government's focus on reducing plastic use and cleaning up plastic pollution from seaweed farming operations. Seaweed farms use a lot of plastic buoys and South Korea were putting in place a program for renewable plastic buoys and cleanup operations to reduce plastic pollution.

In Australia the seaweed industry has been fortunate to be supported through several Government funded programs including:

- Department of Agriculture Fisheries and Forestry (DAFF) provided an $8.1 million grant to Fisheries Research and Development Corporation for ASSA's National Hatchery Network and seaweed cultivation program.
- Livestock Methane Emissions programs are funding product trials of feed supplements including *Asparagopsis* seaweed.
- Marine Bioproducts Cooperative Research Program – co-funds projects with universities and businesses to benefit specific seaweed businesses.

- Blue Economy Cooperative Research Program – co-funds projects for specific seaweed businesses.
- AgriFutures Australia funds ad hoc projects identified through an expression of interest process.

The challenge is that there has been a lack of coordinated strategy across these programs of work and some of the matched funding programs drive competition and privatization of intellectual property rather than support industry wide development. While coordination and communication has improved in the last 12 months through the establishment of ASSA, there is still work to do to ensure R&D funding is optimized and focused on industry development needs.

Conclusions

Through my Nuffield scholarship travels and research project, I have learned about seaweed industries and R&D programs in other countries, policy approaches for decarbonization of agriculture and collaborative models for industry development.

The following key conclusions can be drawn from the discussion:

- Primary producers need environmental policies to support decarbonisation objectives in agriculture. Many farmers want to be more sustainable however the economic rationale is not there without the necessary policy change. In particular for the seaweed industry, it will be critical to incentivise and reward livestock farmers to apply methane abatement solutions and this is now critical to support seaweed industry development in Australia.
- Primary producers also need subsidies to transition to sustainable operations. Subsidies for Australian primary producers are critical for industry development to thrive given the high labour costs, land costs and barriers to entry and scale requirements to achieve profitability. Without these there is a very high hurdle rate and increasing competition for emerging primary industries in Australia such as seaweed.
- The high cost of labour, capital and approvals for seaweed aquaculture mean Australia cannot compete with low-cost countries like China, Indonesia, Philippines where large seaweed aquaculture industries are already established. Therefore, a collaborative approach for technology adoption and bioprocessing to reduce costs and increase product value are important in establishing the new seaweed industry in Australia. Collaborative models that share the high costs of capital could work in emerging seaweed growing regions where there are enough growers and supply chain partners. The cooperative models in France provided some good examples of how to pool capital and share risk while achieving economies of scale and could be a solution to establishing the processing of animal feed supplements and other high value bioproducts in the Australian seaweed supply chain.
- Drawing on examples such as the EU's 9 million Euro SeaMark program and collaborative aquaculture hatchery models in Australia and overseas, ongoing investment from the Australian Government for seaweed hatcheries, and the important role they play in industry and workforce development, are needed to support the emerging seaweed industry.

Recommendations

The overall objective of this project was to identify key industry development activities and approaches that could benefit the emerging Australian seaweed industry. In light the context of this objective the key recommendations are:

- There is a clearer focus from governments and farmers worldwide on the biggest driver of agricultural emissions – enteric methane from ruminant livestock. For example, enteric methane contributes 77% of agriculture's total emissions footprint in Australia (Zero Net Emissions Agriculture Cooperative Research Centre, 2024).
- Australia takes a leadership role to set an agricultural sector emissions reduction target with a price on carbon to drive decarbonisation of the agricultural sector with a particular focus on livestock methane reduction methods.
- Key farmer representative groups, supermarkets and environmental groups work together to prepare a policy submission to the Federal Government to recommend how subsidies could be utilised to support the transition to sustainable, low carbon agriculture and food production in Australia.
- Australian seaweed industry should collaborate to capitalise on markets where livestock methane solutions will be in demand first e.g. Denmark and New Zealand.
- Identify strategic partnership opportunities for seaweed production and share knowledge to accelerate supply e.g. Indonesia, South Korea, Japan.
- Ongoing significant government investment for industry wide initiatives to support Australia to become a leader in *Asparagopsis* seaweed cultivation and feed supplement production. This includes ongoing funding for a network of seaweed hatcheries which will provide critical R&D and workforce development to industry.
- Consider further the opportunity for a cooperative model for processing of *Asparagopsis* animal feed supplements for the Australian seaweed supply chain. For example, federal and state governments could work with ASSA and industry to focus on a few priority regions to encourage a critical mass of growers and encourage collaboration for supply chain establishment and technology development needed to achieve scale quickly.

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