Australian Seaweed Industry Blueprint

A Blueprint for Growth

by Jo Kelly
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COVER: Seaweed Farm in South Korea where it is a large industry. ***Photo credit:*** *Australian Seaweed Institute.*

INSIDE COVER: Juvenile giant kelp (*Macrocystis pyrifera*) growing on a longline in Storm Bay, Tasmania. These kelp are approximately 30 cm long and 4 months old, and are growing at a deep water and exposed aquaculture site. ***Photo credit:*** *Cayne Layton, Institute for Marine and Antarctic Studies, University of Tasmania.*

Foreword

Australia's pristine and isolated coastal environment provides a massive opportunity for the development of seaweeds within Australia. Historically, seaweed has been imported in Australia for use in a range of products. However, the real potential in developing new ingredients and alternative uses for seaweed, such as animal feed, fertiliser, pharmaceuticals, and nutraceuticals is just being realised, in addition to the numerous environmental benefits.

Australia has the skill set to develop both seaweed cultivating and harvesting industries. But a key challenge is the development of commercially focussed research, development and extension and a clearly articulated strategy to ensure that the industry can progress towards its growth ambitions.

AgriFutures Australia commissioned this project with the Australian Seaweed Institute to look at the long-term growth of the Australian seaweed industry, and to identify and prioritise critical research, development and extension gaps and opportunities for this highly valuable marine resource.

This blueprint is the result of extensive consultation with seaweed value chain stakeholders across production and value-added products, regulators and environmental professionals, and offers a pathway to create a high-tech and high-value seaweed industry.

This report has been produced as part of AgriFutures Australia's Emerging Industries Program. It is an addition to AgriFutures Australia's diverse range of over 2,000 research publications and it forms part of Arena 4 which focuses on new industries with high growth potential. Emerging animal, plant and aquatic/marine industries play an important part in the Australian agricultural landscape, they contribute to the national economy and will be key to meeting changing global food, health and energy demands.

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About the Author

Jo Kelly is CEO of the Australian Seaweed Institute and an impact entrepreneur with over 20 years' experience in business. Jo brings a unique perspective and multidiscipline approach to drive industries for the future. She combines experience in strategy, sustainability, innovation, ethical finance and environmental engineering to bring new high impact ideas to life. Jo is passionate about growing a new regenerative, seaweed industry in Australia to support thriving oceans and communities. Jo has an MBA, a Bachelor of Environmental Engineering and a Graduate Certificate in Innovation & Sustainability and was awarded a prestigious Myer Innovation Fellowship in 2019 for her innovative work to establish a regenerative seaweed industry in Australia.

Acknowledgments

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Stakeholder engagement across the seaweed industry in Australia was conducted and the Author would like to acknowledge the contribution of the industry participants who provided input.

Abbreviations

ABS – Australian Bureau of Statistics

AIMS – Australian Institute of Marine Science

AUD – Australian Dollars

CRC-P – Cooperative Research Centre – Project

CSIRO – Commonwealth Scientific and Industrial Research Organisation

FIAL – Food Innovation Australia

FRDC – Fisheries Research and Development Corporation

FTE – Full Time Equivalent

GVP – Gross Value of Production

IMTA – Integrated Multi-Trophic Aquaculture

MLA – Meat and Livestock Australia

RD&E – Research, development and extension

RIRDC – Rural Industry Research and Development Corporation (now AgriFutures)

USD – US Dollars

UTAS – University of Tasmania

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Golden Kelp used for food products at SeaHealth Products in NSW.
Photo credit: *Honey Atkinson.*

Executive Summary

What the report is about

This report outlines the extensive economic, social, and environmental benefits that could be realised from the development of an Australian seaweed industry. By synthesising the knowledge from key industry players, academics, and regulators, this study identifies the primary opportunities, barriers and research needed to grow the industry.

Seaweed biomass can be used for an array of possible uses including food, animal feed, high-value pharmaceutical/industrial compounds, biofuels, and fertilisers. It can be cultivated either on land in tanks, or at sea where it has few environmental costs – and may, depending on the context, have environmental benefits (Gentry et al., 2019). Despite being historically used extensively as wild catch by Indigenous Australians (Thurstan et al., 2018), today Australian commercial seaweed production lags behind the well-established industries in Asia, and the fast-growing industries in Europe and the Americas (Buschmann et al., 2017).

Australian coastal waters are home to thousands of native seaweed species, many of which show promise in a variety of the aforementioned markets. Of particular note is the native genus of red seaweeds, *Asparagopsis spp.*, which, when incorporated as an animal feed reduces methanogenesis and could revolutionise the world's approach to mitigating livestock emissions. The scale of opportunity in building the entire supply chain from producing, to processing, to consuming seaweed products has the potential to create jobs in regional areas and across value chains, improve the diets and health of Australians, and protect Australian ecosystems.

Who is the report targeted at?

This report is aimed at Federal and State Government aquaculture and environmental policy and regulatory departments, prospective and current seaweed producers, impact investors and researchers, including academics, who are interested in growing an Australian industry and seizing its potential benefits.

Where could seaweed farming industries be located in Australia?

The key locations with immediate potential for development of sizeable industries to 2025 are the coastal areas of: South Australia, Tasmania, southern Western Australia, southern NSW and regional Queensland.

Background

The Australian industry today reflects its state in 2010 when it was described as small, fragmented and research focussed with no industry management or development strategy (Lee, 2010). However, momentum is building rapidly in 2020 with new commercial players entering the space in the last 12 months and significant need for an industry plan to drive growth.

Aims/objectives

The key aim was to develop an Australian National Seaweed Industry Blueprint consisting of a research, development and extension (RD&E) plan that will, at a minimum, deliver a $10 million gross value of production (GVP) per annum industry by 2025. This includes an engaged industry stakeholder group with a clear position on the industry opportunity, pathway to development and RD&E priorities to get there.

The key objectives are to:

- Verify the economic, social and environmental opportunities for the industry;
- Identify gaps and barriers to industry development;
- Identify and prioritise seaweed RD&E needs;
- Empower the development of a cluster group to influence and collaborate for industry development; and
- Define a clear action plan for industry development to meet the AgriFutures Emerging Industries target of creating a $10 million GVP per annum industry by 2022.

The Australian Seaweed Industry Blueprint quantifies the opportunity for a significant seaweed industry in Australia and the RD&E plan to get there.

Methods used

The project was implemented as follows:

1. Forty-seven industry stakeholders were identified from across industry, academia, and government.
2. Thirty-seven semi-structured interviews conducted with stakeholders to assess opportunities, gaps/barriers and RD&E needs.
3. Review of relevant literature for input to the assessment.
4. Modelling of the economic, social and environmental opportunities.
5. A virtual workshop with 35 stakeholders to validate the opportunity assessment, key findings and RD&E needs.
6. Initial discussions about industry group formation and outcomes from the workshop with AgriFutures Australia.
7. Stakeholders contributed prioritised research needs and follow up discussions conducted as required.
8. Synthesis of assessment and RD&E needs into a five-year plan for industry development.

Key findings

- The Australian Seaweed Industry target for 2025 is $100 million (GVP), 1,200 direct jobs and a domestic greenhouse gas emissions reduction of 3%.
- If all recommendations are applied there is potential for a $1.5 billion industry by 2040, creating 9,000 jobs and a 10% emissions reduction target.
- The growth of the industry will rely on significant expansion into ocean cultivation of seaweeds and development of high value functional food and bioproducts for humans, animals and plants.
- Development of *Asparagopsis* cultivation at scale is the single biggest opportunity for rapid industry growth and optimising social and environmental outcomes.
- However, there are a number of gaps and barriers namely regulatory approval for large ocean leases and funding for necessary RD&E to close technical knowledge gaps for species cultivation.
- Strong industry leadership and RD&E funding are critical for the potential to be realised.
- The RD&E plan aims to build the industry through development of three critical success factors:
  1. Industry leadership and collaboration;
  2. Production capability and scale; and
  3. Innovation for the future.
- Investment of $8.1 million over two years is now needed to fund critical path activities to capitalise on this opportunity.

Implications for relevant stakeholders

There is a significant opportunity to develop a seaweed industry in Australia that could generate over $100 million (GVP) by 2025 and create up to 1,200 direct jobs in regional, coastal communities. In addition, the industry could reduce Australia's greenhouse gas emissions by 3% per year from 2025. This report demonstrates that a seaweed industry can make a sizeable contribution to achievement of the National Aquaculture Strategy and can support Australia's economic recovery post-COVID 19. Federal and State Government support for the industry development plan is needed to capitalise on the enormous potential of an Australian Seaweed Industry.

Recommendations

Investment of $8.1 million over two years is sought to fund critical path RD&E activities. The key elements of the RD&E plan that require new funding are:

1. Establish an industry leadership group to drive implementation of the National Seaweed Industry Blueprint and work with government, research and supply chain collaborators to achieve industry potential.
2. Prioritise accelerating *Asparagopsis* cultivation and developing products and markets immediately.
3. Develop a National Hatchery Network that can provide seedstock to rapidly scale cultivation efforts, starting with *Asparagopsis* and Kelp, and expanding to other species over time.
4. Develop cluster plans for key regions in South Australia and Tasmania, southern NSW and southern Western Australia to drive supply chain development in these areas.
5. Support extension of Kelp Integrated Multitrophic Aquaculture (IMTA) throughout temperate regions to follow on from Cooperative Research Centre – Project (CRC-P) completion in 2022.

The next steps will be to launch the National Seaweed Industry Blueprint and fund the RD&E Plan. The key recommendations to achieving this are:

- Launch the National Seaweed Industry Blueprint to build support and obtain funding from key Federal and State Government departments and impact investors for its implementation.
- Put forward a proposal to the National COVID Coordination Commission to include the establishment of the seaweed industry in Australia's post-COVID economic recovery and resilience strategy.
- Support the Marine Bioproducts CRC proposal as it is a critical vehicle for attracting and leveraging private R&D funding for growth of the seaweed industry over the next 10 years.

Seaweed raceways (*Ulva ohnoi*) for prawn wastewater remediation in Northern Queensland.
Photo credit: *Nicolas Neveux, Pacific Biotechnologies.*

Introduction

Introduction

A seaweed industry offers Australia a sustainable, high-tech and high-value new economic opportunity. By investing and fostering seaweed production, we have the opportunity to improve the health of our bays, oceans and reefs, provide jobs in regional coastal areas, produce high-value products for domestic and export markets, and even make significant progress on mitigating Australia's carbon emissions. Development of a seaweed industry will also assist achievement of the National Aquaculture Strategy's target to increase the current value of Australia's aquaculture industry to $2 billion by 2027.

Australia has the natural resources, skills, and environment needed to advance a seaweed industry that could be globally competitive within 20 years. New aquaculture and biotechnology ventures offer potential commercial financial returns and long-term value creation opportunities that can improve social, environmental and economic outcomes for Australia. It is with this strategic intent to create a sustainable new economy post-COVID that seaweed makes even more sense than ever before for a long-term sustainable food, aquaculture and biotechnology opportunity for Australia.

The project scope covers marine macroalgae (seaweed) and does not cover other marine plants, freshwater species or microalgae. The following aquaculture types were considered:

- Land-based seaweed aquaculture
- Ocean-based coastal seaweed aquaculture
- Ocean-based off-shore seaweed aquaculture
- Collection via beach cast and wild harvest

Sea Forest cultivating *Asparagopsis armata* gametophyte.
Photo credit: *Supplied by Sea Forest.*

Despite Australia's considerable marine resources, history of use, and its deep cultural and economic connections to the sea, it has lagged behind the rest of the world in seizing the opportunities that seaweed production presents. While a small industry currently consists of wild harvest and land-based cultivation these modes of production present significant technical, logistical, economic, and environmental limits to growth. Instead, the future of the industry will rely on significant expansion into ocean cultivation of seaweeds and development of high value functional food and bioproducts for humans, animals and plants (Roos et al., 2018; Winberg et al., 2008)

Recognising these opportunities, the interest in Australian seaweed production is accelerating across diverse segments of society, from researchers to regulators. However this report has identified several barriers to rapid adoption exist and without industry leadership and planning to navigate these challenges, growth will be slow to realise the full potential of the industry. This project has brought together the regulators, researchers and industry stakeholders for the first time, to outline a vision and RD&E plan to grow seaweed to a significant new industry in Australia.

Aims and Objectives

The key aim is to develop an Australian National Seaweed Industry Blueprint consisting of a research, development and extension (RD&E) plan that will, at a minimum, deliver a $10 million gross value of production (GVP) per annum industry by 2025. This includes an engaged industry stakeholder group with a clear position on the industry opportunity, pathway to development and RD&E priorities to get there.

The project objectives are:

- Verify the economic, social and environmental opportunities for the industry.
- Build upon previous assessments of the Australian seaweed sector to identify gaps and barriers to industry development. Where possible, estimate potential contribution to improving GVP if gaps and barriers are addressed.
- Identify and prioritise seaweed RD&E needs and provide key recommendations for investors on traditional and novel applications for the Australian seaweed industry (e.g. new food and food ingredients, oil, protein and carbohydrate, energy and fuels, fertilisers, personal care products, feedstock, pharmaceutical, building products and wastewater treatment opportunities).
- Empower the development of a cluster group that can influence and collaborate for industry development to identify both current and future growth opportunities for the seaweed market (domestic and internationally) and new and more efficient seaweed production techniques.
- Define a clear action plan for industry development that considers present constraints and future potential and that can specifically meet the target of creating a $10 million industry by 2025.

Methodology

The approach taken was to:

1. Identify key stakeholders who could provide input to the National Seaweed Industry Blueprint. Forty-seven stakeholders were identified and contacted to provide input to the review. The stakeholder list was approved by AgriFutures Australia and FRDC. Stakeholders invited to participate consisted of key representatives from:
    a. Government aquaculture research and management from all States and Territories.
    b. Entrepreneurs / business owners in seaweed production or manufacturing.
    c. University researchers working on seaweed projects.
    d. AgriFutures Australia and FRDC.
2. Conduct a review of previous AgriFutures Australia reports and relevant research for input to the assessment. A summary of the current state of the industry and previously identified industry issues was validated with stakeholders through interviews and workshop.
3. Engage stakeholders through semi-structured interviews to determine opportunities for growth, gaps and barriers and the priority RD&E needs. Thirty-seven interviews were conducted with questions tailored to each stakeholder segment.
4. Model economic, social and environmental outcomes based on stakeholder input and literature.
5. Deliver a workshop to validate growth opportunities, gaps and barriers and the priority RD&E needs. Forty-seven invitations were sent for the workshop and 35 attended. Eighteen stakeholders responded to a follow-up for their top three RD&E priorities and key gaps and barriers.
6. Synthesise inputs into a report for review and approval by AgriFutures Australia.

Current State of the Seaweed Industry

Global Industry Overview

Seaweed is a global industry with a production value of USD $11 billion (AUD $16.8 billion) in 2016 (FAO, 2018). At a global production of 30 million tonnes (wet), this puts the global average wholesale price of seaweed at approximately USD $3.60/kg dry weight (AUD $5.4 / kg). Food products make up the vast majority of market value, 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 biomass is also used for animal feed, fertilisers, cosmetics, pharmaceutical products and biofuels. The inclusion of value-add retail products derived from seaweeds, such as cosmetics, nutritional supplements and novel food products, would push the industry valuation significantly higher.

The seaweed industry has been growing rapidly at around 10% per year since 2010 and is the fastest growing component of global food production (Duarte et al., 2017). Between 2011-2016 this growth was largely driven by Indonesia tripling its production of carrageenan for industrial markets (FAO, 2018). Today, most seaweeds are cultured in the ocean and less than 3% of production comes from wild harvest. The major seaweed producing nations are China (47.9%) and Indonesia (38.7%) followed by the Philippines (4.7%) and the Republic of Korea (4.5%) (FAO, 2018). Seaweed is grown predominantly on commonly used aquaculture infrastructure of long lines, floating nets or rafts in China, Japan and South Korea or in more basic, 'off the bottom' farming systems in Indonesia, Philippines and Tanzania.

Booming demand for seaweed as a sustainable product over the last decade has given rise to large scale on-land production facilities in Canada and ocean farms in the USA and Europe. Despite being well behind Asia, these emerging seaweed industries in the USA, Europe, Scandinavia and Chile are five to ten years ahead of Australia and could provide many relevant insights. For example, GENIALG, a three-year, $16 million project aimed to boost the European Blue Economy, by designing high-yielding seaweed cultivation systems for two species, will conclude later this year.

The emerging markets in the USA and Europe are currently focusing on producing high-value bioactive compounds and alternative proteins for human, animal and plant nutrition, the demand for which will likely drive growth over the next ten years. Seaweed biomass is also being increasingly used as an alternative fibre in sustainable apparel and medical wound dressing applications due to its fire retardant and antimicrobial properties and demand for edible and biodegradable bioplastics from seaweeds is also growing globally.

Even if the global growth trajectory continues at 7% annually, then it is estimated that the global market will have a GVP approaching AUD $30 billion by 2025. But it could be much greater if bioproduct innovation and consumer sustainability concerns drive demand even higher.

TABLE 1.
Growth Forecasts for the Global Seaweed Market

$ billion	2016	2020	2025	2040
Seaweed Global GVP USD	11.0	14.4	20.2	55.8
Seaweed Global GVP AUD	16.5	21.6	30.3	83.7

** exchange rate @ 4 June 2020 * 7% annual growth*

The Australian Industry (2020)

The Australian seaweed industry is small: currently valued at an estimated GVP of AUD $3 million. Of this, the majority is from one company, Kelp Industries Pty Ltd on King Island in Tasmania, who collect storm-cast Bull Kelp (*Durvillea pototorum*) predominantly for export to a large alginate manufacturer and for use in biofertiliser products. Australia Bureau of Statistics (ABS) data shows seaweed exports from Australia are valued at $1.5 million for non-human consumption and it is assumed that this is almost entirely from Kelp Industries exports.

However, Australia is a net importer of seaweed. Annual imports to Australia in 2017/18 approached AUD $40 million, of which 85% was for human consumption. Imports have been increasing, on average, at 15% per year, up from AUD $17 million reported in 2008/09 (Lee, 2010). **Table 2** shows that Australia pays a high unit price for imported seaweed food products from China and South Korea.

There are currently no commercial ocean seaweed farms in Australia and only two small land-based operations for *Ulva spp.* cultivation in Shoalhaven, NSW (Venus Shell Systems) and Ayr, QLD (Pacific Biotechnology). Both of these operations each have less than five hectares of seaweed under production.

Besides Kelp Industries, other seaweed collectors in Tasmania include Kelpomix and TasKelp. There is a license for small scale collection of Golden Kelp (*Ecklonia radiata*) in NSW at Narooma where it is dried and turned into food products at Sea Health Products. Additionally Great Gather Ocean Group, is a Chinese

TABLE 2.
Summary of Import Statistics

Imports	2017/2018	tonnes (dry)	Average $/kg	Country of origin
Fresh	$30.5 million	1,581	$19.31	Mostly China ($35.5/kg) and South Korea ($24/kg)
Frozen	$3.5 million	533	$6.50	Mostly China ($5/kg) and Japan ($8.40/kg)
Non-human consumption	$5.75 million	9,209	$0.62	Mostly Ireland, France, Chile

Source: DFAT STARS Database, based on ABS Cat No 5368.0, September 2018 data.

owned company, which has a South Australia based beach-cast seaweed business at Millicent in the south-east of the state. There are also licenses for wild harvest of the invasive species of *Undaria* in Tasmania (KaiHo Ocean Treasure) and some in Victoria. Based on information provided in stakeholder interviews and publicly available, it is estimated that there are approximately 20 full time equivalents (FTE) directly employed in commercial seaweed cultivation in Australia.

Collection of seaweeds is currently the main source of Australian seaweed today, however, there are a number of limiting factors for collection of seaweeds including availability of beach-cast seaweed, quality, seasonality, community concerns and permitting. Wild harvest of seaweed from in-sea is of concern due to the lack of information on its potential to regrow and other potential environmental impacts. Therefore, the report does not further consider the growth of this sector given the very limited opportunity from an economic, social and environmental perspective.

Two Australian seaweed product manufacturers of note are Seasol, who make a biofertiliser from Australian Bull Kelp, and Marinova who manufacture fucoidan extract from largely imported seaweeds for the health and nutrition market. There are also a small number of boutique food product producers using some Australian and imported seaweeds, such as Alg Seaweed.

Past Australian research on seaweeds is considerable although fragmented and it was generally recognised by key stakeholders interviewed that there is a lack of biological knowledge on most species which is critical in underpinning the success of an emergent cultivation industry. Previous AgriFutures Australia reports have focussed predominantly on applications of seaweeds for food, the nutritional properties of a limited number of species, and quality control in production (Lee, 2008; Winberg et al., 2008).

Currently the industry largely consists of seaweed scientists and researchers with an estimated 30 – 40 FTE roles spread across several research institutions nationwide. Australia currently has no centralised research hub for marine plants or bioproducts. Most seaweed expertise resides at marine research or biotechnology departments at several universities, Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Australia Institute of Marine Science (AIMS).

While there are numerous research projects taking place or being planned (Figure 1), the only lines in the water that are growing seaweed at the time of this report are two projects in Tasmania. The first project is a CRC-P project involving collaboration with Tassal, Spring Bay Seafoods and University of Tasmania (UTAS) and is expected to reap their first harvest later this year. This project aims to demonstrate the benefits of Kelps as part of an integrated multitrophic aquaculture (IMTA) approach. The second is a research collaboration between UTAS and Huon Aquaculture in Storm Bay that will also yield its first harvest in late 2020.

In stakeholder interviews, most State Government aquaculture regulators, with the exception of Northern Territory and Victoria, reported a significant increase in parties interested in obtaining aquaculture licenses for seaweed ocean farms. The Climate Foundation's seaweed permaculture concept and upwelling technology gained a lot of public interest following the documentary *2040* and close to $600,000 was crowdfunded for a small technology pilot focussed on Kelp production in Tasmania.

But much of the recent commercial interest has been sparked by the discovery that a group of native Australian seaweeds, *Asparagopsis spp.*, can reduce the methane emissions from cattle by 99% when as little as 2% is added to their feed (Kinley et al., 2016; Machado et al., 2016). This discovery is being commercialised by FutureFeed Pty Ltd, which was established by CSIRO to hold the exclusive rights to the patents from CSIRO, James Cook University and Meat and Livestock Australia.

Current State of the Seaweed Industry (CONTINUED)

As there is currently no large-scale commercial cultivation of this seaweed anywhere in the world, there is now a global race to begin large scale cultivation. FutureFeed will work with partners across the value chain to bring this product to market: establishing the production supply chain, processing, storage, distribution, QA, certification, marketing and carbon credit methodology. In Australia, there are two new entrants: 1) CH4 Global in South Australia and 2) Sea Forests in Tasmania. This is a fast-emerging, major opportunity for growth of the Australian seaweed industry and is discussed in the next section.

Each State and Territory Government provided input to this project and the table below reflects current approvals for seaweed aquaculture around Australia at the time of this report.

TABLE 3.
Current approvals for seaweed aquaculture around Australia (2020)

State / Territory	Seaweed aquaculture licenses issued	Comments
South Australia	1,220 hectares ocean leases	• Available tenure across all 22 aquaculture zones is 7,908 hectares. • Scope for pilot licenses outside of existing zones • EOI process for 6,500 ha around Port Lincoln closed in May 2020. Significant allocations for seaweed leases expected in the near term. • New zones are being added in 2020
Tasmania	1 land-based facility 301 hectares ocean leases	• 5,248 hectares has been set aside for allocation of marine farming leases for seaweed and other spp.
Western Australia	14 hectares ocean leases	• New application currently being processed for 110 hectares
NSW	1 land-based facility 50 hectares (mussel lease)	• Approximately 90 hectares of existing leases awaiting assessment to add seaweed species to leases around southern NSW
Queensland	2 land-based facilities 25 hectares ocean leases	• Great Sandy Regional Marine Aquaculture Plan 5,700 hectares available with some still available for seaweed.
Victoria	3-hectare offshore site	• Another offshore site in the pipeline • Interest around Port Philip Bay and Bonney Upwelling reported
Northern Territory	0	• No applications.
TOTAL	**4 land-based facilities** **1,613 hectares ocean leases**	

In summary, the Australian industry today reflects its state in 2010 when it was described as small, fragmented and research focussed, with no industry management or development strategy (Lee, 2010). However, momentum is building rapidly in 2020 with new commercial players entering the space in the last 12 months and significant need for an industry plan to drive growth.

Seaweed raceways (*Ulva ohnoi*) for prawn wastewater remediation in Northern Queensland.
Photo credit: *Nicolas Neveux, Pacific Biotechnologies.*

Figure 1. Current State of Australian Seaweed Industry

CURRENT STATE:

- Estimated GVP = <$3M
- Jobs = <40 FTE
- Researchers = estimate 30-40 FTE research roles focussed on seaweed at Research Institutions
- Annual Imports 17/18 = $40 M (85% food)
- Exports = $1.5M (99% non food)
- The industry is small, fragmented and disparate with no industry organisation or development strategy... but momentum is building rapidly!

Adelaide: Centre for Marine Bioproducts Development, Flinders

Innovative and green processing and extraction

South Australia: CH4 + SARDI

- FRDC funded project $175k for *Asparagopsis* production
- Heads of Agreement with Narungga Nation
- Expansion plans for vast ocean farms

Tas + Melb: Seasol

Commercial production of retail and wholesale fertiliser products from Australian Bull Kelp and some imported seaweed

Tas: UTAS, Deakin, Tassel, Spring Bay Mussels

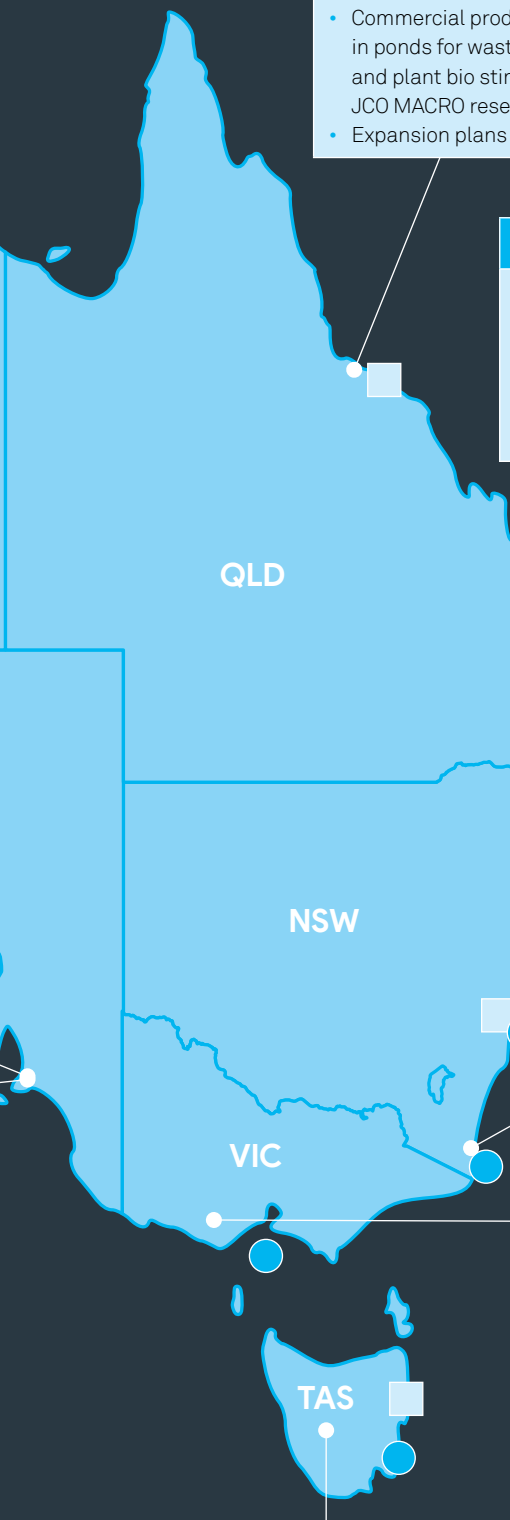
CRC-P project 2019-2021
Focus species: *Lessonia*, *Macrocystis*, *Ecklonia*. Hatchery, Cultivation and Products, IMTA integration

Tas: Climate Foundation, Intrepid, 2040, UTAS, Huon

Philanthropy funded to develop upwelling system and seaweed platform, thermally tolerant Giant Kelps with restoration focus

Tas: UTAS Blue Economy CRC

Scoping Study to start on seaweed cultivation



Ayr/Townsville: Pacific Bio and JCU MACRO

- Commercial production of *Ulva* in ponds for wastewater treatment and plant bio stimulant
  JCO MACRO research partner
- Expansion plans to Guthalungra

Moreton Bay: Oysters and USC

- FRDC project: Seaweed for nutrient removal $450k
- BIRC Aquaculture facility for Hatchery
- Ocean growing trials expected 2021-2023

Sydney: UTS Deep Green Biotech Hub

An industry accelerator that has supported a number of seaweed projects and UTS:C3 is conducting bioplastic research using a range of algae.

Shoalhaven: Venus Shell Systems / PhycoHealth and Bluebiotech

- Commercial production of *Ulva* in ponds for human nutrition and health and wound treatment research
- Expansion plans
- Bluebiotech precinct established with Shoalhaven council as innovation precinct

Narooma: SeaHealth Products

Commercial production of food grade products from beach cast Golden kelp collected under permit.

Warrnambool: Deakin Uni

Seaweed R&D Projects:

- Palatability trials Australian Native Seaweeds
- Seaweed Tech for compositional testing
- Crayweed – hatchery techniques completed moving to grow out trials
- Seaweed Feed for Dairy Production and Quality (not *asparagopsis*)
- Traditional Usage by Indigenous peoples in Temperate Australia
- Paper on *Undaria* as a potential resource (due Aug/Sept 2020)
- Seaweed Alginates and Fibers for wound dressing

Other Projects:

- Australian Aquatic Plant Names Standard – FRDC
- Harnessing seaweed genes to mitigate methane emissions from livestock, USC – ARC Discovery Project
- Operation Crayweed – UNSW restoration project Sydney
- Seaweed Farming for SDGs Workshops (UTAS/UQ/ Future Earth)
- Anticancer properties of red algae – Griffith Uni PhD
- Cosmeceutical from red algae – Griffith Uni
- International Seaweed Symposium 2022 – Feb 2022

Relevant CRCs:

- Blue Economy CRC
- Future Food Systems CRC
- Northern Australia CRC
- Marine Bioproducts CRC (2020 bid) – Flinders/UQ/ Griffith/Deakin/UTAS/CSIRO/SARDI
- Coastal Communities CRC (2020 bid)

King Island: Kelp Industries/Dupont

Beach cast collection of Bull Kelp for sale to overseas alginate extractors and local fertiliser producer (Seasol)

Cambridge: Marinova

Production of Fucoidan from mostly imported brown seaweed and a small amount of hand harvested *Undaria*

Tas: KalHo Sea Vegetables

Hand harvest 5+ tonnes of *Undaria* a year for sale as food products

Tas: Sea Forests

Pond Based Production of *Asparagopsis* under development. Expansion plans for ocean farms.

Gaps and Barriers to Industry Growth

Based on stakeholder consultation, review of previous AgriFutures Australia reports, and other relevant reports on the Australian seaweed industry and broader aquaculture sector, the following key gaps and barriers to industry development are identified.

TABLE 4.
Gaps and barriers to growth of the seaweed industry in Australia

Barrier or gap	Implication	Proposed action
1. Seaweed is not embraced as a serious aquaculture industry in Australia.	No representation in aquaculture, fisheries or seafood industry strategies in Australia. "Due to lack of information on seaweed in Australia, seaweed struggles to be recognised by the Fisheries industry." (Lee, 1997)	Seaweed to be included in relevant Federal and State Government agriculture, aquaculture, biotechnology and advanced manufacturing development strategies. Seaweed sector to be recognised as a major contributor to the National Aquaculture Strategy and allocate funding for its development.
2. Markets for Australian products are not yet proven	But they absolutely exist both domestically and globally. There are existing markets for products both domestically (e.g. fucoidan, animal feed, replacement of food imports and input to biofertilisers) and globally for food, extracts and animal feed. New products are evolving rapidly.	Australia can focus on cultivation of known species and development of food, feed or fertiliser products into existing markets and evolve new products over time.
3. Limited availability of commercial scale ocean lease areas in most State and Commonwealth waters.	This is the major barrier to progress of the industry. Without space in which to cultivate seaweeds in the ocean, Australian production will never achieve the scale necessary to compete in foreign markets or meet growing domestic demand. Partnerships or IMTA projects with existing aquaculture lease holders seems to be the optimal model to enter the market at this early stage of industry development e.g. Tassal, Spring Bay Seafoods, Moreton Bay Rock Oysters.	Initial focus of industry development in a few key States where ocean leases are available already e.g. South Australia and Tasmania. Engage locally and regionally with existing aquaculture lease holders & Indigenous groups and other industry groups e.g. oyster industry. Work with other States and Commonwealth on areas where seaweed ocean leases could be made available in future.
4. Regulation and licensing of seaweed aquaculture is complex, onerous and different in each State.	While some States may have ocean leases available, because there are no precedents, navigating the process is prohibitive for new commercial entrants.	This will take time to resolve. As above it is recommended to focus development in a few key States where demonstration farms can go ahead and where cultivation manuals can be developed for target species. Work with regulators in those jurisdictions to evolve policy and regulation. Then expand to other States.

Barrier or gap	Implication	Proposed action
5. Shortage of people with skills, knowledge and practical experience.	Shortage of skills and knowledge will slow industry expansion.	Training and development programs will be critical to drive expansion. Engage with existing aquaculture operators, Indigenous groups and parallel industry groups on training and development program at national, regional and local levels. Post-COVID-19, Australia is well positioned to attract talent from other countries which will be suffering from continued uncertainty. Technology transfer from overseas, from areas where seaweed farming is well developed, is an important way of facilitating rapid development.
6. Lack of funding for R&D and limited collaboration between commercial and research entities.	**Related to item 5.** With a shortage of practical skills, Universities are the predominant place for knowledge on cultivation, however are not always cost effective, commercially focussed or available. State and Federal Government research agencies, while more focused on the applied research needs of commercial clients, tend not to focus on development of new industries. Also, in the Australian RDC focused primary industry R&D funding system it can be challenging to acquire the needed long-term funding to develop new industries when their primary clients are existing industry sectors.	The fledgling seaweed industry is not competing with itself – it is competing globally and Australian companies and Universities need to move beyond an intellectual property (IP) ownership debate in order to deliver the potential industry impact at scale. Key IP could be owned nationally to remove this issue. **See item 7, for an example of how this could apply.** Significant funding is needed for critical path RD&E for seaweed industry development. Government funds are needed for the first two years of RD&E until the industry could potentially become levy paying.
7. No commercial-scale hatcheries/ seedbanks.	Currently each new entrant needs to develop its own breeding knowledge, hatchery facility, seedstock and seed ropes. "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." (Lane, 2018). The alternative, government approval for wild collection of seaweed to use for start-up inoculation, can be challenging and prohibitive for new entrants.	Establish nationally-owned Temperate and Tropical Seedbank / Hatchery network that could provide seeded rope to accelerate new project developments. This would be a good investment area for AgriFutures Australia and the Fisheries Research and Development Corporation (FRDC).
8. Gaps in breeding and cultivation knowledge for many species e.g. *Asparagopsis*.	"Propagation and control of complex biological lifecycles and the physiological requirements of many Australian seaweeds are not yet well established." (Lane, 2018) New commercial entrants will have difficulty turning a profit while learning how to scale-up and optimise production and avoid pitfalls. This is a gap that is being worked on currently by Australian and international companies for *Asparagopsis*. Closing this knowledge gap is the top priority for capitalising on the expected massive demand for this animal feed additive.	Increased investment in breeding and cultivation techniques for promising species like *Asparagopsis*.

Gaps and Barriers to Industry Growth (CONTINUED)

Barrier or gap	Implication	Proposed action
9. Biosecurity – currently limited knowledge on native seaweed populations and concerns about translocation of seedstock, pests and disease.	Upscaling production of novel species could pose biosecurity concerns due to the threat of translocation of pests, disease, and genetic material.	A lot of work exists internationally on seaweed biosecurity risks and issues and this could be a starting point to highlight gaps in the Australian context. Australia can focus on endemic species and implement adaptive management plans for early operations.
10. Social license concerns	Raised extensively by stakeholders and is an issue for in-shore aquaculture generally and collection of beach-cast seaweed. This will be different in each jurisdiction depending on the local/regional stakeholders. *Community Trust in Rural Industries* is a collaborative project, run by AgriFutures Australia and initial results have highlighted that the three major drivers are: • Environmental Responsibility • Responsiveness • Products of the rural industry Seaweed can have a positive benefit and these need to be communicated and ongoing sustainable management implemented.	Nationally work can be done to raise public awareness about the benefits of seaweed aquaculture, the nutritional profile of the products and the contribution of the industry economically, socially and environmentally. This could then be tailored for each new location where seaweed aquaculture is proposed. Environmental standards for management and monitoring seaweed ocean aquaculture will be important to maintain public confidence in seaweed as a sustainable industry.

A number of these challenges are similar in other developing seaweed industries outside of Asia and a lot can be learned from the European and USA experiences. The publication *Seaweed Revolution: A Manifesto for a Sustainable Future* (Giercksky and Doumeizel, 2020) highlights the following barriers outside of Asia:

- Fragmented industry outside of Asia;
- Lack of aligned regulations or standards and insurability problems;
- Technology barriers;
- Need for social license and spatial planning; and
- Limited understanding of potential and need for advocacy.

Pyropia (Nori) Cultivation in South Korea.
Photo credit: *Australian Seaweed Institute.*

Economic, Social and Environmental Opportunity Assessment

Economic, Social and Environmental Opportunity Assessment

Environmental and Social Impacts

The extensive Australian coastline has ideal and abundant growing conditions for high value, native seaweeds. Australia has far cleaner, less polluted waters than the current leading seaweed producing nations and a reputation for high quality standards of food production. Not only can seaweed production provide a source for nutrient-dense food and natural materials for animal feeds, biofertilisers, cosmetics, medical application and bioplastics, seaweed aquaculture can mitigate impacts of climate change, and provides ecosystem services which improve the condition of coastal waters (Wijesekara et al., 2011; Chung et al., 2013; Mongin et al., 2016; Duarte et al., 2017; Kim et al., 2017; Xiao et al., 2017).

Seaweeds are some of the fastest growing photosynthetic organisms on the planet and absorb substantial amounts of carbon dioxide and nutrients like nitrogen, phosphorous and heavy metals from the water in which they are cultivated. For land-based production, this presents opportunities to grow seaweeds in aquaculture wastewater where they function as natural, profitable bio-filters as demonstrated at the Pacific Biotechnology facility in Ayr. In coastal areas, this presents a commercially viable way to remove unwanted nutrients, particularly nitrogen, from sensitive ecosystems that suffer from eutrophication (Kim et al., 2014; 2017; Xiao et al., 2017). There is also reason to believe that seaweed aquaculture can help sequester carbon (Chung et al., 2013, 2011) and potentially to buffer rising levels of ocean acidification (Xiao et al., 2017; Mongin et al., 2016).

It is believed that seaweed farming can contribute to habitat creation and support a variety of organisms in the same way that a natural seaweed bed does (Buschmann et al., 2017). A two-year tracking study in Sweden indicates that seaweed farming can significantly enhance biodiversity (Visch et al., 2020). However, while some empirical studies have borne this out in some systems for some species (Radulovich et al., 2015; Walls et al., 2016), others have shown negative impacts on surrounding biodiversity (Hehre and Meeuwig, 2015; Zhou, 2012). In this case, careful siting, monitoring and management practices will be required to limit potential negative outcomes.

> "[Seaweed Aquaculture] represents the clearest environmental value proposition given it (a) possess [sic] the lowest input requirements of any aquaculture production model, and (b) can provide ecological benefits to surrounding ecosystems in the form of water filtration, nitrogen removal, and habitat provision."
>
> *The Nature Conservancy, Towards a Blue Revolution.*

In addition to the direct environmental impacts, there are possible indirect opportunities from expanding Australian seaweed production. Unlike terrestrial agriculture, ocean-based seaweed production will not require freshwater inputs, which could help offset future freshwater demands and could provide food security during times of drought (Australia 21, 2016, p. 21; Radulovich, 2011). Food that is produced at sea also avoids the biodiversity and carbon costs of having to clear land for agriculture, which could save large swathes of terrestrial habitat from destruction (Forster and Radulovich, 2015; World Bank Group, 2016).

As mentioned above, seaweeds grown in higher nutrient areas would have plentiful nutrients and would not need additional fertiliser inputs, while those that are grown in lower nutrient areas, or in densely cultivated areas, could overcome nutrient limitations by co-culturing with fin- or shellfish in an integrated multitrophic aquaculture (IMTA) (Xiao et al., 2017). IMTA is well-documented and a proven practice in a number of countries and for many species. It can increase profits for aquaculturists by diversifying their production, increasing yields due to closed nutrient loops, and boosting social license. This leads to less water pollution and makes already existing aquacultures more sustainable. A 2009 AgriFutures Australia report highlighted the most promising development opportunities in the short term were seaweed food products cultured in integrated multi-trophic aquaculture systems (Winberg et al., 2009).

The products from seaweed can also generate significant environmental benefits. For example, cattle feeds that reduce methane emissions or seaweed bioplastics / biofabrics that replace petroleum-based products. The recent discovery in Australia of a native species of seaweed that reduces methane by up to 99% reduction at a 2% inclusion rate in feed (Machado et al., 2016) is significant given that 10.5% of Australia's greenhouse gas emissions in 2013 came from the digestion process of livestock, according to the Australian Government's 2015 inventory of the nation's sources and sinks of greenhouse gases.

A seaweed industry is an opportunity for regional development with significant employment and economic multiplier benefits (Australia21, 2016). Seaweed is recognised as having potential for making regional economic contributions in developing and developed countries including: Pacific Island Countries (Luxton and Luxton, 1999; Pickering, 2006), Tanzania (Hassan and Othman, 2019), Indonesia (Aslan et al., 2018, 2015), India (Bindu, 2011; Mantri et al., 2017), Sri Lanka (Ginigaddara et al., 2018), Philippines (Hill et al., 2012), Latin America (Rebours et al., 2014), and USA (Kim et al., 2019). Given these promising results, promoting seaweed aquaculture could provide an economic lifeline to economically struggling coastal towns in regional Australia, including those hard-hit by the recent impacts of COVID-19.

Seaweed is recognised as a highly nutritious food due to its iodine and mineral content (Bath and Rayman, 2013; Bouga and Combet, 2015), protein content (Fleurence et al., 2018, 2012) and other compounds that are demonstrated to improve heart and gut health (Brown et al., 2014; Smit, 2004) and brain function (Cornish et al., 2017). While most of this research is based on commercially available northern species, emerging research is showing that Australian species are just as nutritious and palatable (Skrzypczyk et al., 2019; Winberg, 2017). Increasing the production and availability of nutritious food and encouraging more people to eat seaweed regularly for health reasons has enormous social benefits for society (FAO, 2018b).

There is now an opportunity to create a new industry for the future that values long term social and environmental outcomes as well as commercial financial returns (O'Shea et al., 2019). It is with this lens that specific opportunity areas for development of the Australian seaweed industry have been assessed and prioritised.

Harvested Asparagopsis at Sea Forest's facility in Tasmania.
Photo credit: *Sea Forest.*

Economic, Social and Environmental Opportunity Assessment (CONTINUED)

Products and Markets

The major markets under development for Australian seaweed spans several product areas both domestically and internationally. These are:

- Food and Human Nutrition Products
- Cosmetics
- Animal Feed (emerging)
- Biofertiliser
- Bioplastics / Biofabrics (emerging)
- Bioremediation

TABLE 5.
Australian seaweed products and markets

Products	Target market	Comments
Food and Nutrition	Domestic – potential to replace imports ($30 million +); growing demand for functional food and ingredients. Marinova in Tasmania produce Fucoidan extracts from imported seaweeds and this could be replaced or increased with Australian seaweed. International – high quality, clean, green, organic seaweed from the pristine waters of Australia.	Expanding investment in functional foods and plant-based proteins has driven the high-end market for seaweeds globally with a >10% increase in food products containing seaweeds over the past two years. Approaches by large food manufacturers highlights opportunities for innovative ingredients, native ingredients, higher protein content, vegan ingredients. Research into the changing landscape of protein production in Australia estimates that there will be an additional opportunity of $19.9 billion for the sector by 2030, of which $3.1 billion is attributed to alternative protein categories (Australian Farm Institute, 2020).
Biofertiliser	Domestic – horticulture and home garden products (e.g. Seasol).	$2 billion organic fertiliser market and growing.
Cosmetics	Global – for companies where brand is focussed on Australian ingredients.	Global organic personal care and cosmetic products market is expected to reach $19.8 billion by 2022.
Animal Feed	Domestic – target dairy and beef cattle herd. Smaller opportunities exist for Abalone and Fish Feed. International – target dairy and cattle feedlots in jurisdictions with environmental standards on emissions e.g. California and European Union.	$540 million total domestic market. $180 million or 30% of Australia's domestic beef herd by 2025 is target. Demand size of market for "low carbon" meat and dairy will drive consumption based on consumer trends.
Bioplastics / Biofabrics	Global – many market segments here depending on products.	USD $7.3 billion by 2023 (Biotextiles Global Market Forecast to 2023 – Business Insider website).
Bioremediation Solution	Domestic – Great Barrier Reef protection; existing Finfish areas in Tasmania and South Australia.	Nitrogen credits will increase demand and create potentially a $50 – $500 million market in Queensland (dependent on offset demand & price) due to international significance and nitrogen pollution threat to Great Barrier Reef. Social license issues with finfish farming in southern states make Kelp IMTA appealing and offer an opportunity to develop another revenue stream.

In addition, a biorefinery processing approach has been explored in Europe and other parts of the world and can significantly increase the value of seaweed industry by producing more than one product from the seaweed biomass (Roos et al, 2018). This advanced manufacturing method could be adopted in Australia and is discussed as an opportunity further below.

Key Species

The global market is currently dominated by seven main seaweeds, many of which are either present in Australia or have closely related analogues.

TABLE 6.
Major global species and products and Australian equivalent

Species	Australian equivalent	Where	Main product
Eucheuma seaweeds, *Eucheuma spp.*	Y	Tropical	Carrageenan
Japanese Kelp, *Laminaria japonica*	Potentially – other Kelps including *Macrocystis spp., Ecklonia spp., Lessonia spp.*	Temperate	Food
Gracilaria seaweeds, *Gracilaria spp.*	Y	Tropical and Temperate	Agar
Wakame, *Undaria pinnatifida*	Y – invasive	Temperate	Food
Elkhorn sea moss, *Kappaphycus alvarezii*	N	Tropical	Carrageenan
Nori or Laver, *Porphyra spp.*	Y	Temperate	Food
Fusiform sargassum, *Sargassum fusiforme*	Potentially – Other *Sargassum spp.*	Tropical	Food

However, there are thousands of native Australian seaweed species, and while a handful of species are well known globally, most have never been investigated for potential high-value end uses. The table below outlines the main species the Australian industry is focussed on at the time of this report.

TABLE 7.
Main species under development for cultivation in Australia

	Key species	Locations	Comments	Key products	Does market exist?	Other potential products	Cultivation method
1	*Asparagopsis armata*	TAS, SA	Experimental land-based and ocean cultivation.	Cattle feed additive	New	Cosmetics	On land, Ocean
2	*Asparagopsis taxiformis*	QLD, NSW, SA	Land based experimental cultivation.	Cattle feed additive	New	Cosmetics	On land, Ocean
3	*Ecklonia Radiata* (Golden Kelp)	TAS, SA, NSW	Demonstration farm in TAS. Cultivation manual being developed as part of CRC-P project. Propagation and rope cultivation demonstrated on small-scale in New Zealand.	Food ingredient	Existing	Nutraceuticals, Abalone feed	Ocean
4	*Durvillea spp.* (Bull Kelp)	TAS, SA	Harvested as beach-cast. Grows in high energy zones so not likely to be suitable for in-shore aquaculture. Scoping study for Blue Economy CRC to consider for offshore.	Fertiliser, Alginates	Existing	Fabric	Collection TBC if suitable for offshore ocean cultivation

Economic, Social and Environmental Opportunity Assessment (CONTINUED)

	Key species	Locations	Comments	Key products	Does market exist?	Other potential products	Cultivation method
5	*Macrocystis* (Giant Kelp)	TAS, SA	Demonstration farm in TAS. Cultivation manual being developed as part of CRC-P project.	Food, Fertiliser	Existing	Fabric	Ocean
6	*Lessonia*	TAS	Endemic to Australia. Not internationally known. Demonstration farm in TAS. Cultivation manual being developed as part of CRC-P project.	Under development	No	Under development	Ocean
7	*Ulva spp.*	ALL	Commonly cultivated in tanks/ ponds/ raceways. At Venus Shell Systems in NSW and Pacific Bio in Qld. Also in Europe, USA, Israel.	Human food and nutrition, Wastewater bioremediation, Fertiliser	Existing	Pharmaceutical, Nutraceuticals, Abalone feed	On land, Ocean trials planned in Qld.
8	*Sargassum spp.*	QLD	Lab based cultivation to commence in 2020. Ocean farms in South Korea.	Nitrogen bioremediation, Biofertiliser	Existing	Food, Feed	Ocean
9	*Porphyra* (Nori / Laver)	TAS	Under consideration for future trials. Most commonly eaten seaweed and predominant species grown in Asia.	Nori / Laver Food products	Existing		Ocean
10	*Undaria* (Wakame)	Wild harvest in TAS, VIC	Very common species grown in Asia. Invasive species to Australian waters. TAS research lease approved.	Food, Fucoidan extract	Existing		Wild harvest, Ocean – to be trialled
11	*Phyllospora comosa* (Crayweed)	NSW, VIC	Restoration project in Sydney. In lab cultivation techniques developed at Deakin University.	Under development	Under development		Ocean

There are a number of other opportunities for high-value, fresh food products for boutique markets including *Caulerpa spp.* and *Cladosiphon* (Mozuku) that could be explored in future.

Opportunity Assessment

Building on the market, product and species assessments, a number of focus areas for development have emerged. These opportunities have been assessed based on their economic (GVP), job creation (Direct FTE) and environmental impacts. The opportunity for a seaweed industry is modelled using stakeholder inputs for bottom up projections and top down assumptions for production potential and job creation.

Inputs to the assumptions underpinning the economic, job creation and environmental benefits are based on stakeholder input and published literature. A conservative approach has been adopted for the purposes of this analysis.

TABLE 8.
Economic, social and environmental assessment of key opportunity areas

Opportunity area	2025 GVP $ M	Direct jobs (FTE) 2025	2040 GVP $ M	Direct jobs (FTE) 2040	Environmental impact
Asparagopsis for low carbon meat & dairy SA + TAS + WA	$90 – $200 M	450 – 1000	$1,000 M	5,500	GHG Reduction 3% (2025) to 10% (2040) for Australia UN Sustainable Development Goals Sustainable food Resilience
Kelp Farming IMTA – extended TAS, SA, WA	$20 – $40 M	50 – 100	$ 100 M	250	UN Sustainable Development Goals Sustainable food Food security Alternative proteins Resilience
Seaweed biofilters Great Barrier Reef	$0	25	$200 M	2,500	Nitrogen removal Reef protection UN Sustainable Development Goals Resilience
South Coast NSW Cluster – *Ecklonia*	$9 – $15 M	25 – 40	$50 M	500	UN Sustainable Development Goals Sustainable food Food security Alternative proteins Resilience
Wakame cultivation TAS	$0.5 – $5 M	5 – 15	$50 M	125	UN Sustainable Development Goals Sustainable food Food security Alternative proteins Resilience
QLD tropical seaweed Cluster	$0.5 – 3 M	5 – 10	$20 M	50	UN Sustainable Development Goals Sustainable food Food security Alternative proteins Resilience
Ulva land based – Bioremediation and functional food	$12 M	30	$42 M	75	Sustainable food Food security Alternative proteins Resilience

Economic, Social and Environmental Opportunity Assessment (CONTINUED)

Opportunity area	2025 GVP $ M	Direct jobs (FTE) 2025	2040 GVP $ M	Direct jobs (FTE) 2040	Environmental impact
Offshore integrated food, energy and CO2 drawdown systems	-	-	TBD – Large	TBD	Carbon reduction UN Sustainable Development Goals Sustainable food Resilience
Australian laver products	-	–	TBD – Small to Medium	TBD	Sustainable food Food security Alternative proteins Resilience
Biodiscovery and bioproduct innovation	Not quantified. Opens up new opportunities or increases size of opportunities above.				Zero waste Alternative fabrics and bioplastics
Breeding and cultivation technology transformations	Not quantified. Reduces costs and increases productivity and profitability – increase size of all opportunities above				All of the above
TOTAL	**$132 M – $275.5 M**	**590 – 1,220**	**$1,462 M**	**9,000**	**GHG R\reduction 3% (2025) to 10% (2040) for Australia UN Sustainable Development Goals Sustainable food Resilience**

Calculations have been based on the following assumptions:

- GVP:
  - Number of hectares (ha) planned for development gathered from stakeholder consultation
  - Average production yield of 10 tonnes dry weight / ha for ocean farming (World Bank, 2016)
    Depending on species and location production yields could be double this
  - Average production yield from land-based Ulva systems = 60 tonnes dry weight / ha
  - Unit price of *Asparagopsis* in 2025 = $25/kg and $10/kg in 2040
  - Unit price of seaweed biofertiliser (opportunity #3) = $5/kg
  - Unit price of Kelps and *Undaria* = $10/kg
  - Unit price of *Ulva* for functional food = $20/kg
  - Unit price of *Ulva* for fertiliser = $4/kg
- Number of Jobs:
  - Average of 1 FTE per hectare up to 1,000ha for new lease areas (World Bank, 2016)
  - Average of 0.5 FTE per hectare of production above 1,000ha for new lease areas
  - Average 0.25 FTE per hectare for development on existing lease areas e.g. IMTA

For each opportunity area, the challenges to realise the opportunity are different. Therefore, the other dimension to consider is the achievability from the current starting point. It should be noted that none of the barriers are showstoppers, but some will require a significant amount of work to realise. The figure below maps the assessment of the opportunity areas, from the table above, against the technical gaps and regulatory barriers.

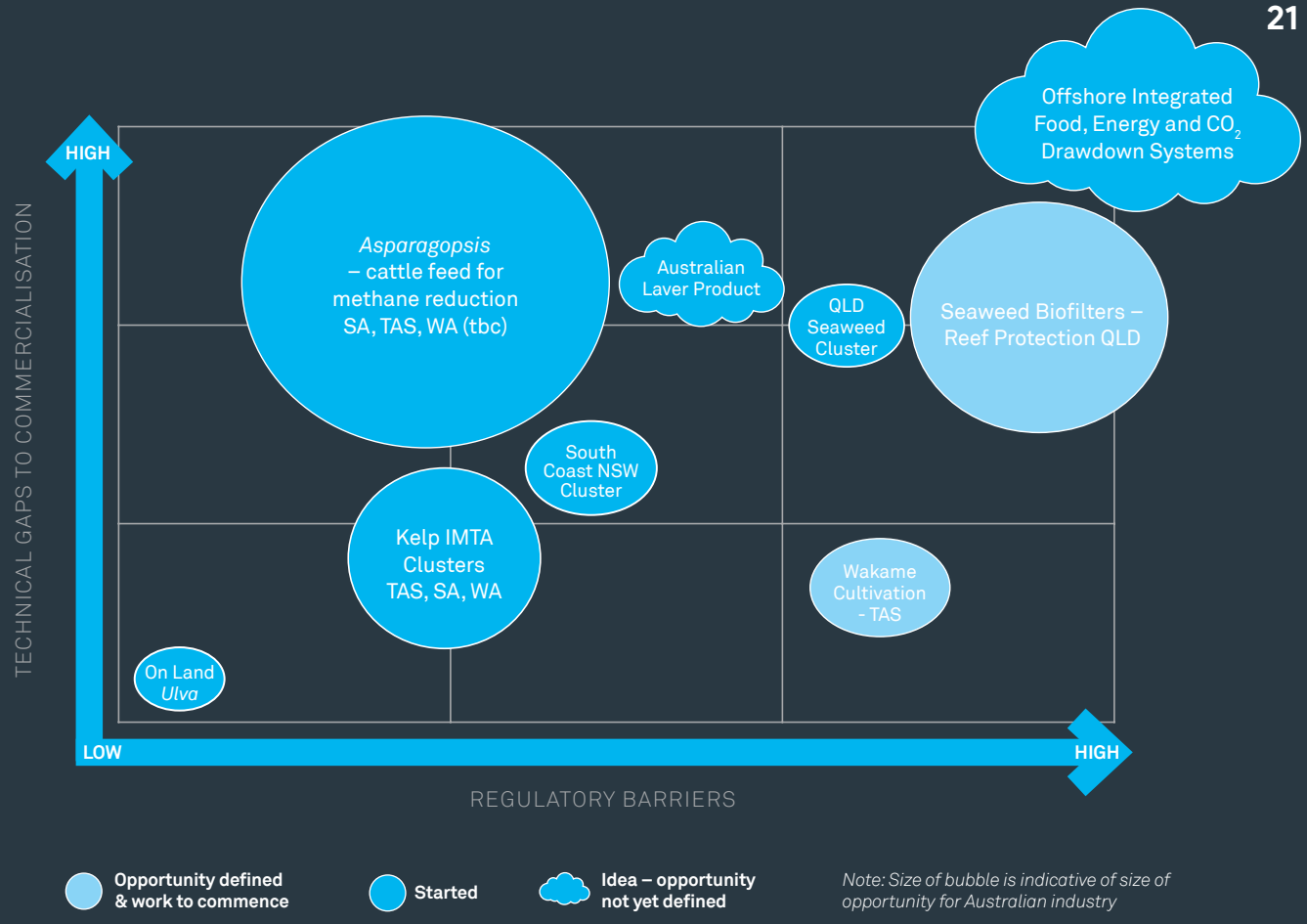


Figure 2. Opportunity assessment against technical gaps and regulatory barriers

From the opportunity assessment above, there are two key areas that are core to industry growth to 2025:

- ***Asparagopsis*** – the assessment shows that the biggest opportunity to grow the Australian seaweed industry is in producing cattle feed for methane reduction. Despite there being some technical gaps to realising the cultivation of this seaweed at scale, the demand from the meat and dairy sectors to reduce carbon emissions will mean this novel solution has a ready market and can attract significant investment. However, the breeding and cultivation techniques for this seaweed need to be developed and this requires significant RD&E to realise. This is a great example of how biodiscovery and product innovation can drive industry transformation and demonstrates why it is critical for ongoing industry development into the future.
- ***Kelp IMTA*** – The second most attractive opportunity, from a risk versus reward perspective, is the culture of Kelp within IMTA systems and the potential for extension of this model to more finfish aquaculture areas. By working with existing leaseholders and experienced aquaculture operators this opportunity could provide a solid pathway to industry growth. The CRC-P project underway in Tasmania is critical for the demonstration of this concept and following on from its completion in mid-2022 the RD&E focus will be on extension activities.

There are two major opportunities of importance for the long-term development of the industry. These are being progressed over the next five years in order to realise their potential by 2040.

- ***Seaweed Biofilters for Reef Protection*** – Seaweed biofilters between the coast and the Great Barrier Reef to intercept the nitrogen load and reduce acidification are being explored as a solution to protect the Reef. The seaweed can be used as biofertiliser to create a circular economy solution. As this opportunity will face significant regulatory scrutiny there will be significant R&D runway and investment required.
- ***Offshore Platforms*** – The Blue Economy CRC is driving a program to explore the potential for use of Australia's vast offshore space as a source of food, energy and carbon sequestration for the future. It is envisaged that these platforms will contain integrated aquaculture systems including seaweeds. The technical and regulatory challenges to be overcome will be immense, however, this is a long-term journey to design a revolutionary new model for sustainable food and energy.

The remaining opportunities represent modest industry growth potential and are in various states of progress. In order of most progressed to least progressed, these are:

- ***Land-based Ulva*** – Venus Shell Systems and Pacific Bio have expansion plans for the next five years that will drive the growth of this segment.
- ***Queensland Tropical Seaweed Cluster*** – there are two areas in very early pilot stages. The first, is Moreton Bay where a 5-ha pilot lease and a FRDC funded project will run over the next three years and determine the suitability for seaweed aquaculture in Moreton Bay. The other area is the Great Sandy Marine Park, near Harvey Bay, where a 20-ha lease area has been approved to date. More work is required to pin point the key target species and commercial viability for tropical regions.
- ***Ecklonia NSW*** – there are a number of proposals before NSW Fisheries for seaweed aquaculture around Eden, Narooma and Jervis Bay in southern NSW. There is already an existing seaweed product company in the region – Sea Health Products.
- ***Wakame Cultivation*** – the Tasmanian Government have approved a pilot lease for cultivation of the invasive species *Undaria*. This trial and impact assessment will determine the sustainability and suitability of expanding *Undaria* cultivation in Australia's southern states.
- ***Australian Laver*** – the most widely consumed seaweed in the world is Nori or Laver. A scoping study is required to determine the opportunity for cultivation and production of an Australian laver product.

Sea Forest's Tetrasporophyte life history phase of *asparagopsis* under lab culturing. ***Photo credit:*** *Sea Forest.*

Research, Development and Extension Plan

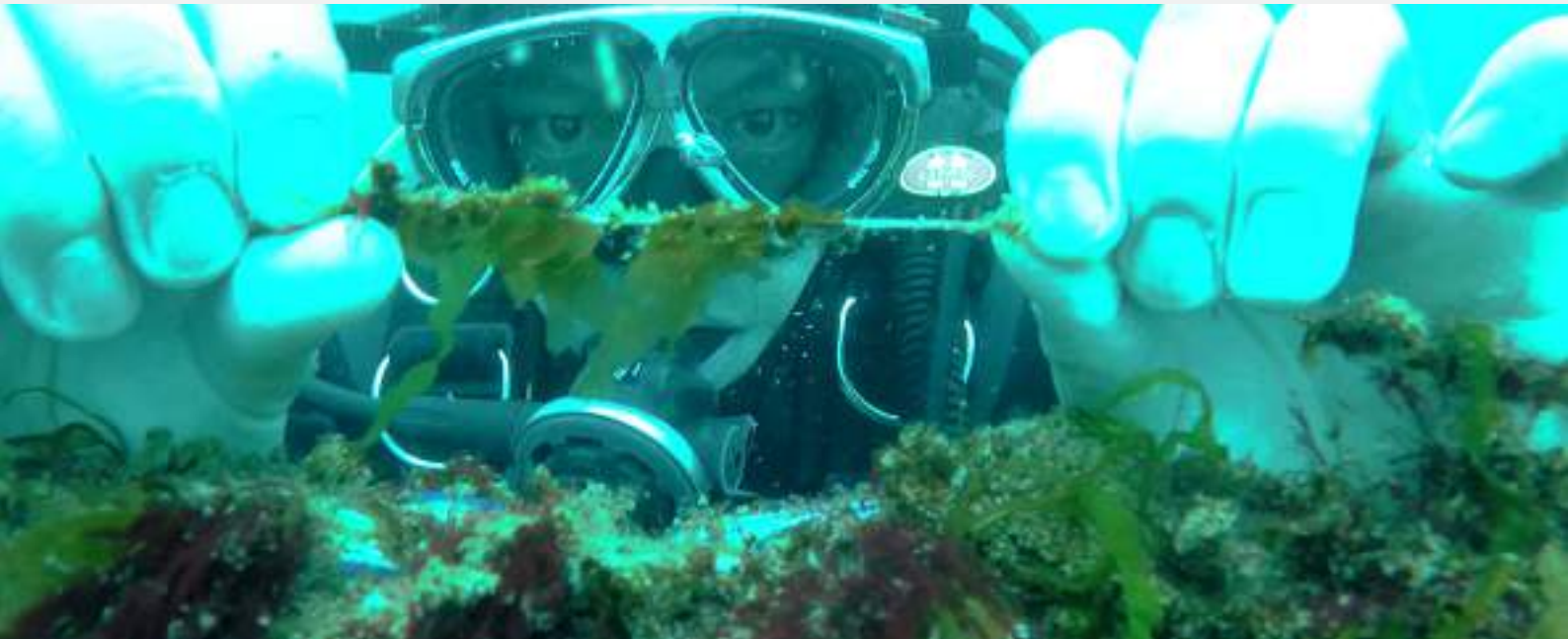
Research, Development and Extension Plan

A key challenge is to shift the industry from its current academia-dominated, interest-driven focus towards a commercially-focussed, industry development plan. At the present time, the Australian research space for seaweed is reportedly very fragmented and operates in silos. This is a major impediment to the development of an industry in Australia. However, there are more commercial players now entering this space to influence the agenda and as the industry matures, the RD&E plan will need to evolve to keep pace with new trends and technology developments.

The stakeholder interviews and workshop discussions revealed several guiding principles for industry development. These are:

- Ocean cultivation is key to major industry expansion.
- *Asparagopsis* is the biggest, immediate opportunity with a defined product and market.
- Kelp IMTA offers an important pathway to growth by working with existing aquaculture leaseholders and skilled operators.
- Given the regulatory barriers in some locations, the industry should focus initially on development in a few States where there is significant commercial interest, suitable existing aquaculture leases and large, readily available ocean lease areas i.e. South Australia and Tasmania. Bring others along on the journey over time.
- Initial products should focus on whole produce e.g. fresh/dried/freeze-dried/ milled seaweed for domestic and international markets and, as biomass supply and quality increases, evolve to a biorefinery approach that produces higher value products.
- Because each region will have different needs, a Regional Cluster approach is recommended to plan and drive forward industry development in key locations.
- Industry leadership and capacity building is critical to overcome the key barriers to national industry development.

A diver inspecting juvenile giant kelp (*Macrocystis pyrifera*) planted on longlines in Storm Bay, Tasmania. The twine on which the juvenile kelp are seeded is visible. ***Photo credit:*** *Cayne Layton, Institute for Marine and Antarctic Studies, University of Tasmania.*



RD&E Needs Assessment

The commercial opportunity analysis and stakeholder consultation identified RD&E needs that are either specific to each opportunity area or are industry wide. These RD&E needs were discussed in the virtual workshop and stakeholders were asked to follow up with their top three priorities. RD&E needs were identified across the value chain: hatchery, farming/grow out, harvesting, processing and developing markets (Lane, 2018). This has been simplified below to plan, grow and sell and the RD&E needs are identified for each opportunity area in the table below.

TABLE 9.
RD&E needs identified to 2025

Opportunity area	2025 GVP ($ M)	Hectares developed (HA)	Approx. tonnes (dry weight)	RD&E needs to achieve 2025 GVP			Priority and progress to 2025
				Plan	Grow (seed to harvest)	Sell (products to market)	
1) *Asparagopsis* for low carbon meat & dairy SA + TAS + WA (tbc)	$90 – $200 M	450 – 1,000	4,500 – 10,000	Secure lease areas – SA, TAS Cluster plans – SA, TAS Risk management	Close life cycle (in progress) Seedstock Commercial hatchery Grow out manual (in progress) Farm and harvest tech Biofouling management	Processing facilities Product testing Export market development Grazing product development	**High priority GAP** Accelerate cultivation National seedbank could accelerate Focus on SA and TAS Investigate in WA
2) Kelp Farming IMTA – extended uptake TAS, SA, WA	$20 – $40 M	200 – 500	2,000 – 4,000	Economic evaluation Extension plan Cluster plans – TAS, SA Risk management	Seedstock Hatchery techniques complete ARC LIEF for hatchery facility Grow out manual in progress Farm and harvest tech Biofouling management	Product / market assessment Handling and processing facilities Product development in progress Biorefinery trials	**High priority IN PROGRESS** CRC-P in progress National seedbank could accelerate Accelerate in SA and TAS Investigate in WA
3) Seaweed biofilters Great Barrier Reef	$-	<10 pilot scale	-	Regulatory pathway Political and social license Economic evaluation Risk management	Select species Concept design	Product / market assessment Biorefinery trials	**Low priority IN PROGRESS** Longer term opportunity given regulatory hurdles Progress to pilot stage by 2025

Research, Development and Extension Plan (CONTINUED)

Opportunity area	2025 GVP ($ M)	Hectares developed (HA)	Approx. tonnes (dry weight)	RD&E needs to achieve 2025 GVP			Priority and progress to 2025
				Plan	Grow (seed to harvest)	Sell (products to market)	
4) South Coast NSW cluster – *Ecklonia*	$9 – $15 M	90 – 150	900 – 1,500	Cluster plan – Eden/ Jervis Bay Secure lease areas Risk management	Seedstock Hatchery facility (Techniques developed in CRC-P) Grow out manual in process (CRC-P) Farm and harvest tech Biofouling management	Product / market assessment Handling and processing facilities Product development in progress (See 2 above)	**Medium priority GAP** CRC-P will provide input Dependent on lease approvals in NSW National seedbank could accelerate
5) Wakame cultivation TAS	$0.5 – $5 M	5-50	50 – 500	Extension plan (following trial) Risk management	Seedstock Hatchery and cultivation techniques known Pilot scale trial with ecosystem impact assessment	Product / market assessment	**Medium priority GAP** Progress pilot by 2025 Extension dependent on impact assessment results
6) QLD tropical seaweed cluster	$0.5 – $3 M	5 – 35	50 – 350	Cluster plan (following pilot end late 2022) Risk management	Pilot projects to select species, develop hatchery techniques and grow out manual (in progress) Biofouling management	Product / market assessment (in progress)	**Low priority IN PROGRESS** FRDC funded project in progress to Oct 2022 then assess potential opportunity for expansion.
7) *Ulva* land based	$12 M	30	1,800	Risk management	Secure extension areas and capital	Ongoing product development	Commercial operations in place.
8) Offshore integrated food, energy and CO_2 drawdown systems	$-	0	0	Political and regulatory pathway Platform concept design	Species scoping (in progress) Farm and harvest tech (in progress)	Product / market scoping	**Low priority IN PROGRESS** Blue Economy CRC Focus Proof of concept by 2030
9) Australian laver products	$-	0	0	Scoping study			**Low priority GAP** Scoping study by 2025

Opportunity area	2025 GVP ($ M)	Hectares developed (HA)	Approx. tonnes (dry weight)	RD&E needs to achieve 2025 GVP			Priority and progress to 2025
				Plan	Grow (seed to harvest)	Sell (products to market)	
R&D needs: Industry leadership and capacity				• Industry group formation, collaboration and communications channels • Market and products detailed assessment (top 10 species) • Cluster planning framework • Indigenous involvement and stakeholder engagement at national and cluster level • National legislation review and policy recommendations for seaweed aquaculture • Space planning – review of ocean lease areas nationally for suitability for seaweed aquaculture • Biosecurity risk assessment and recommendations to regulators • Environmental risk and impact assessment • Social license building at national level • Feasibility assessment of impact investment product for industry growth e.g. Blue Fund • Industry marketing strategy to increase seaweed consumption in Australia • International review of cultivation, harvesting and processing technology for seaweed • Workforce development and training plan • International partnerships and collaborations			**High priority GAP** Recommend formation of a National Seaweed Industry Group to progress these initiatives.
R&D needs: Industry innovation				Ongoing biodiscovery and product innovation e.g. Seaweed bioplastics and biofabrics. Ongoing technology improvement for cultivation, harvesting and processing.			**Medium priority GAP** Marine Bioproducts CRC proposal would deliver this component.
TOTAL	**$132 – 275.5**	**790 – 1,675**	**9,300 – 18,150**				

Research, Development and Extension Plan (CONTINUED)

RD&E Plan 2020 – 2025

Three critical success factors for industry development have emerged from the analysis and consultation:

- Industry leadership and collaboration
- Production capability and scale
- Innovation for the future

The RD&E plan has been developed from the RD&E needs assessment and prioritisation from key stakeholders. Cost estimates for each initiative are provided based on experience and stakeholder inputs where available.

TABLE 10.
RD&E plan 2020 – 2025

Critical success factor	Project / activity	Description	Year	Estimated funding
1. Industry leadership and collaboration	1.1 National industry group formation	A formal representative body with capability and responsibility for Blueprint implementation and ongoing advice on RD&E strategy. Incorporation, charter, board appointments, quarterly board meetings.	1 – 5	$200,000 / year
	1.2 Regional cluster plans	Develop a cluster planning framework and apply to key regions for seaweed development. Including infrastructure, workforce, product supply chain, ocean leases, seedstock hatchery and funding strategy at key locations.	1 – SA and TAS 2 – Sth. NSW and Sth. WA	$50,000 / plan
	1.3 Space planning, legislation and policy review for ocean aquaculture	Audit of ocean lease availability, legislation and policy review for seaweed ocean aquaculture. Engagement and recommendations for change.	1 – SA and TAS 2 – Sth NSW and Sth WA 3 – Qld	$50,000 / State
	1.4 Pest, disease, biosecurity review	International literature review on seaweed pest, disease and biosecurity issues and recommendations.	1	$100,000
	1.5 Industry stakeholder engagement and communications	Regular engagement, newsletters and website.	2	$50,000 / year
	1.6 Industry impact investment fund	Feasibility assessment to develop a Blue Fund to attract impact capital to the sector and finance industry development.	2	$50,000 feasibility
	1.7 Market and products detailed assessment (top 10 species)	Review and consolidate existing research and fill in the gaps.	2	$100,000
	1.8 Social license, environmental standards, quality standards	Put together guidance for Regulators and operators on these key topics.	2	$100,000
	1.9 Workforce development plan	Scoping study on capability needs assessment and development planning.	2	$50,000
	1.10 International alliances and collaboration	Sponsorship for International Seaweed Symposium 2022 – Tas Feb 2022.	2	$100,000

Critical success factor	Project / activity	Description	Year	Estimated funding
2. Production capability and scale	2.1 Accelerate *Asparagopsis* culture techniques	Close the lifecycle for *asparagopsis* and optimise grow out techniques.	1	$2.5 million / year
	2.2 Develop a National Hatchery Network (NHN) to provide seedstock	Scoping for national seedbank project to provide seedstock to commercial entrants.	1 – *Asparagopsis* 2 – Kelps 3 – other species	$100,000
	2.3 Biofouling management	Study on biofouling issues and management techniques.	1	$100,000
	2.4 Information and advice service for new ocean farming projects.	Advice service – national industry group website, directory, case studies, examples, links to handbooks and other published material.	2	$100,000
	2.5 Broker collaboration projects for manufacturing facilities at key locations	From cluster plans progress project development for facilities where needed.	2-5	As needs
	2.6 Support progress of advanced aquaculture technologies important for scale	Global technology review of cultivation technologies that could be brought to Australia.	2	$100,00
3. Innovation for the future	3.1 Bio-innovation program for target species	Ongoing bio innovation for new products from target species.	2 – 5	$$$
	3.2 Biodiscovery program for new species	Ongoing research on novel species.	2 – 5	$$$
	3.3 Seaweed biofilters for reef protection R&D program	Concept design through to pilot project.	1 – 5	$$$
	3.4 Offshore platforms R&D	Concept design through to pilot project.	1 – 5	$$$$

Asparagopsis armata growing naturally on a reef in Gulf Saint Vincent, South Australia. ***Photo credit:*** *Algal Production Group, South Australian Research and Development Institute (SARDI).*

Kelp Ocean Farm in South Korea. ***Photo credit:*** *Australian Seaweed Institute.*

Research, Development and Extension Plan (CONTINUED)

The RD&E delivery plan for the first two years is shown below and the total funding estimates per year are shown for each item.

TABLE 11.
RD&E delivery plan and required funding for first two years

Critical success factor	Project / activity	Year 1	Year 2	Total $
1. Industry leadership and collaboration	1.1 National industry group formation	$200,000	$200,000	$400,000
	1.2 Regional cluster plans • Year 1 – SA and TAS • Year 2 – Sth. NSW and Sth. WA	$100,000	$100,000	$200,000
	1.3 Space planning, legislation and policy review for ocean aquaculture • Year 1 – SA and TAS • Year 2 – Sth NSW and Sth WA	$100,000	$100,000	$200,000
	1.4 Pest, disease, biosecurity review	$100,000		$100,000
	1.5 Industry stakeholder engagement and communications	-	$50,000	$50,000
	1.6 Industry impact investment fund	-	$50,000	$50,000
	1.7 Market and products detailed assessment (top 10 species)	-	$100,000	$100,000
	1.8 Social license, environmental standards, quality standards – guidance for regulators	-	$100,000	$100,000
	1.9 Workforce development plan	-	$50,000	$50,000
	1.10 International alliances and collaboration – ISS2022	-	$100,000	$100,000
	Subtotal – leadership and collaboration	**$500,000**	**$850,000**	**$1,350,000**
2. Production capability and scale	2.1 Accelerate *Asparagopsis* culture techniques	$2,500,000	$2,500,000	$5,000,000
	2.2 Develop a National Hatchery Network (NHN) to provide seedstock. Scoping Study. • Year 1 – *Asparagopsis* • Year 2 – Kelps	$100,000	TBD	$100,000
	2.3 Biofouling management	$100,000		
	2.4 Information and advice service for new ocean farming projects.	-	$100,000	$100,000
	2.5 Broker collaboration projects for manufacturing facilities at key locations	TBD	TBD	TBD from cluster plans
	2.6 Support progress of advanced aquaculture technologies important for scale.		$100,000	$100,000
	Subtotal – Production capability and scale	**$2,700,000**	**$2,700,000**	**$5,400,000**
3. Innovation for the future	3.1 Bio-innovation program for target species • Year 2 – Develop product development pipeline	-	MB CRC	
	3.2 Biodiscovery program for new species	-	MB CRC	
	3.3 Seaweed biofilters for reef protection R&D: • Year 1 – Concept design • Year 2 – Proof of concept	$350,000	$850,000	$1,200,000
	3.4 Offshore platforms R&D program: • Year 1 – Scoping study	$150,000	TBC	$150,000
	Subtotal – Innovation for the future	**$500,000**	**$850,000**	**$1,350,000**
	TOTALS	**$3,700,000**	**$4,400,000**	**$8,100,000**

National Seaweed Industry
One Page Strategy

VISION:
A high tech and high value, sustainable seaweed industry supporting thriving oceans and coastal communities.

2025 GOALS:
- $100 million plus GVP
- 600 – 1,200 new direct jobs
- 30% methane emissions reduction from Australian Meat and Livestock sector
- 3% National GHG emissions reduction (from 2013 baseline)
- Actions towards United Nations Sustainable Development Goal 14 – Life Below Water

2040 GOALS:
- $1.5 billion plus GVP
- 9,000 new direct jobs
- 99% methane emissions reduction target from Australian Meat and Livestock sector
- 10% National GHG emissions reduction plus more globally (from 2013 baseline)
- Nitrogen removal from Great Barrier Reef Catchments
- Significant contribution to UN Sustainable Development Goals 2, 3, 8, 10, 12, 13 and 14 **https://sdgs.un.org/goals**

CRITICAL SUCCESS FACTORS

1. Industry leadership and collaboration

1. National industry group formation
2. Regional cluster plans
3. Space planning, legislation and policy review for seaweed ocean aquaculture
4. Pest, disease, biosecurity review
5. Industry stakeholder engagement and communications
6. Industry impact investment fund
7. Market / product / species knowledge centre
8. Social license, environmental standards, quality standards
9. Workforce development plan
10. International alliances and collaboration (ISS 2022)

2. Production capability and scale

1. Accelerate *Asparagopsis* culture techniques
2. Develop a National Hatchery Network to provide seedstock
3. Biofouling management
4. Information and advice service for new ocean farming projects.
5. Broker collaboration projects for manufacturing facilities at key locations
6. Support progress of advanced aquaculture technologies important for scale.

3. Innovation for the future

1. Bio-innovation program for target species
2. Biodiscovery program for new species
3. Seaweed biofilters for reef protection R&D program
4. Offshore platforms R&D program

RD&E PRIORITIES TO 2025

RD&E INVESTMENT
= $8.1 million over two years is needed to achieve

In year one focus on top four activities above. Kick off activities 5 – 10 in Year two.	Main focus on applied research expertise for accelerating *Asparagopsis* culture and development of a National Hatchery Network.	Funding from: • Blue Economy CRC; • GBRF /Reef Trust; • Marine Bioproducts CRC (pending approval in 2020)
TOTAL = $1.35 MILLION	**TOTAL = $5.4 MILLION**	**TOTAL = $1.35 MILLION**

Recommendations

There is a significant opportunity to develop a seaweed industry in Australia that could generate over $100 million (GVP) by 2025 and create up to 1,200 direct jobs (FTE) in regional, coastal communities. In addition, the industry could reduce Australia's greenhouse gas emissions by 3% per year from 2025. Longer term projections indicate the potential for a $1.5 billion industry, creating 9,000 jobs and 10% emissions reduction per year.

This report demonstrates that a seaweed industry can make a sizeable contribution to achievement of the National Aquaculture Strategy's target for a $2 billion aquaculture sector by 2027. Federal and State Government support for the industry development plan is needed to capitalise on the enormous potential of an Australian Seaweed Industry to support Australia's recovery post-COVID.

Investment of $8.1 million over two years is sought to fund critical path RD&E activities. The key elements of the RDE plan that require new funding are:

1. Establish an industry leadership group to drive implementation of the National Seaweed Industry Blueprint and work with government, research and supply chain collaborators to achieve industry potential.
2. Prioritise accelerating *Asparagopsis* cultivation and developing products and markets immediately.
3. Develop a National Hatchery Network that can provide seedstock to rapidly scale cultivation efforts, starting with *Asparagopsis* and Kelp, and expanding to other species over time.
4. Develop cluster plans for key regions in South Australia and Tasmania, southern NSW and southern Western Australia to drive supply chain development in these areas.
5. Support extension of Kelp Integrated Multitrophic Aquaculture (IMTA) throughout temperate regions to follow on from CRC-P completion in 2022.

The next steps will be to launch the National Seaweed Industry Blueprint and fund the RD&E Plan. The key recommendations to achieving this are:

- Launch the National Seaweed Industry Blueprint to build support and obtain funding from key State and Federal Government departments and Impact Investors for its implementation.
- Put forward a proposal to the National COVID Coordination Commission to include the establishment of the seaweed industry in Australia's post-COVID economic recovery and resilience strategy.
- Support the Marine Bioproducts CRC proposal as it is a critical vehicle for attracting and leveraging private R&D funding for growth of the seaweed industry over the next 10 years.

There is a significant opportunity to develop a seaweed industry in Australia that could generate over $100 million (GVP) by 2025 and create up to 1,200 direct jobs (FTE) in regional, coastal communities.

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One of the last remaining patches of giant kelp (*Macrocystis pyrifera*) forest in eastern Tasmania. The decline of this species in eastern Tasmania is associated with climate change and ocean warming. Photo by Cayne Layton, Institute for Marine and Antarctic Studies, University of Tasmania. ***Credit:*** *Climate Foundation.*

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