MARCH 2024

REGENERATIVE AQUACULTURE FARMING ON THE NSW SOUTH COAST

INVESTIGATION OF BUSINESS CLUSTER

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The Blue Economy CRC, with a 10-year life, the Blue Economy CRC brings together 45 industry partners, government and research partners from ten countries with expertise in aquaculture, marine renewable energy, maritime engineering, environmental assessments and policy and regulation.

Through targeted industry-focussed research and training, the Blue Economy CRC paves the way for innovative, commercially viable and sustainable offshore developments and new capabilities. Our vision is that our blue economy industries in offshore aquaculture and renewable energy are globally competitive, at the forefront of innovation and are underpinned by a robust environmental planning and management framework which consumers trust and value.

The Blue Economy Cooperative Research Centre (CRC) is established and supported under the Australian Government's CRC Program, grant number CRC-20180101. The CRC Program supports industry-led collaborations between industry, researchers and the community. Further information about the CRC Program is available at www.business.gov.au.

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According to the Food and Agriculture Organization (FAO) of the United Nations, the world needs 50-70% more food by 2050.

Regenerative aquaculture farming as a solution for food security and economic growth gains more traction. These regenerative practices involve cultivating of seaweed and shellfish in coastal areas to meet seafood demand sustainably.

Research suggests it can benefit ocean health and at a large scale create significant economic opportunities for coastal communities around the world, expanding on the USD $264 billion in revenue and employment opportunities for 20 million people that the aquaculture sector is already providing to. However, clear implementation pathways are critical.

This report examines the business cases for kelp and shellfish farming on the NSW South coast from an innovative industry cluster perspective. While kelp farming lacks a clear business case due to unknown biomass models, there is significant potential for growth from a market demand site.

Currently, a few businesses processing beach collected kelp into value-added products for local/ national consumption.

Furthermore, innovation in kelp is striving through a novel kelp hatchery. However, further progress in regenerative aquaculture farming is prevented by complex and costly application processes (see reports 1-3). Shellfish farming is well established in the NSW South Coast and offers significant opportunities for scaling and diversification.

This report centres around two established business case studies from the NSW south coast (kelp and shellfish) to illustrate the opportunities, challenges, and bottlenecks for each business case. The report will further map-out existing and emerging innovative aquaculture businesses within the region before concluding with key recommendations for government and industry.

Figure 1: Wild caught kelp and fresh farmed oysters (source: author).

Key Take Aways:

- Regenerative aquaculture farming has a great potential to drive economic growth into the NSW South Coast through investment and job creation in a highly sustainable industry.
- There is no kelp business case in the NSW hsouth coast due to a lack data for biomass modelling which can assist in the set-up of a strong business case. Additionally, the long and costly process for permits makes it difficult for proponents due to high uncertainty in the biomass models.
- Shellfish farming is well established in the NSW south coast. The opportunity lies in up-scaling and new value creation for the diversification of the high-value products.
- There is limited infrastructure e.g. processing facility in the NSW south coast to process product effectively and efficiently, add value and ship to customers.
- Government actors need to support the industry by reducing uncertainty around farm location and anticipated biomass models through initial community consultation and trial lines. The process needs to be streamlined especially when operating with local species of kelp, seaweed and shellfish.
- There is a desire by Traditional Owners to lead and be part of regenerative aquaculture industry on the NSW South Coast. A clear roadmap for the industry is required that provides meaningful space for Traditional Owners.

1. Introduction

The University of Wollongong (UOW) and the Blue Economy Cooperative Research Centre (BE CRC) have collaborated with the NSW Government and the regenerative aquaculture industries to identify social, cultural, and economic impacts and opportunities that may be associated with future development of this new and emerging industry on the south coast of NSW.

This report contains the outcomes of the investigation into current business practices to inform this industry's current and future development. The report provides insights into existing and emerging blue economy businesses that are currently operating on the NSW south coast including existing collaborations for the wider emerging regenerative aquaculture industry network. To understand current regenerative aquaculture farming processes, business challenges and opportunities more clearly, this section is guided by the following question:

What is the status-quo of the regenerative aquaculture industry on the NSW south coast and what are the opportunities and constraints to further develop this emerging cluster?

In order to gain insights into the questions eight interviews with innovative existing business owners were undertaken that form part of the wider regenerative aquaculture industry. Further, two extensive case studies were undertaken consisting of multiple interviews and analysis of archival data.

The case studies represent two established businesses in the regenerative aquaculture industry on the NSW south cost termed South Coast Mariculture and Sea Health Products. Finally, Land Council CEOs from the south coast were interviewed to share their view on Indigenous participation in the industry. All interviews followed a semi-structure interview guide.

Figure 2: Wild kelp collected onshore (source: author).

This report is the fourth of a series focusing on business related outcomes and is structured as follows.

Section 2 provides a brief global overview of the regenerative aquaculture industry.

Section 3 presents a detailed case study overview of two established businesses. This section further highlights the challenges and opportunities which these businesses are currently facing.

Section 4 provides an overview of innovative companies that form part of the wider regenerative aquaculture eco-systems including established collaborations among members and further opportunities. Lastly, Section 5 provides conclusive remarks, a summary of key findings and recommendations for industry, government and community.

Additional information and resources for industry and government can be found in the appendices section of this report such as international practices and benchmarks.

2. Blue Economy and Aquafarming: An International Overview

The Blue Economy (BE) aims to integrate economic growth and the health and well-being of the ocean.

Globally, the aquaculture sector is navigating through a pivotal transformation, driven by the urgent need to balance increase in seafood demand with the imperative of ecological sustainability. Amidst this backdrop, regenerative aquaculture emerges as an opportunity to rejuvenate marine ecosystems, enhance biodiversity, and ensure sustainable food sources innovatively and sustainably.

To the interest of this report, kelp and shellfish farming reflects the principles of regenerative aquaculture, highlighting its ability to deliver environmental, economic, and social benefits across diverse global contexts. For example, in a recent global seaweed report by the World Bank (2023), it was identified that 10 globally established seaweed markets exists with the potential for these markets to grow to USD 11.8 billion by 2030. However, much of the seaweed value remains untapped; especially in the Australian context.

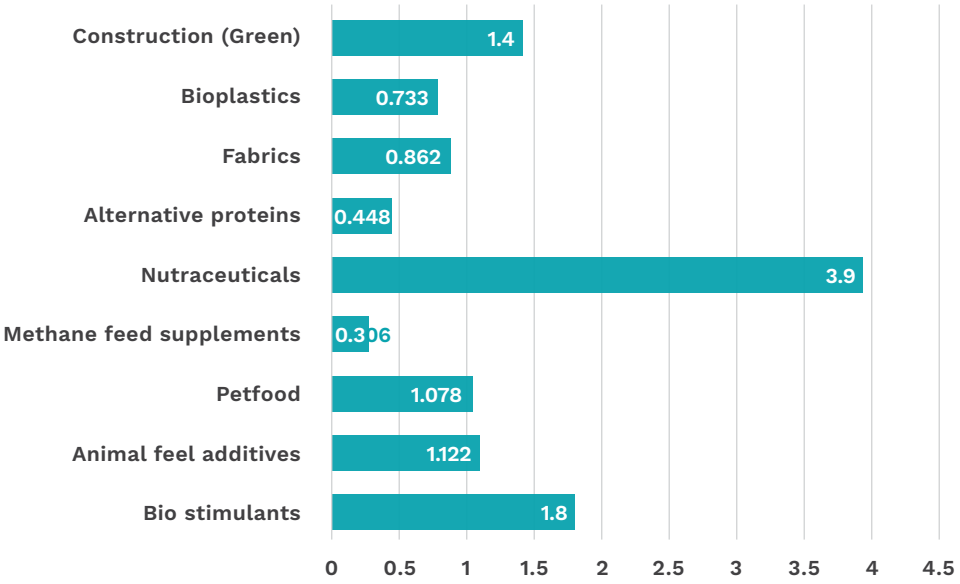
This report ventures into kelp and shellfish cultivation, as a part of the regenerative aquaculture discourse, to unfold its potential as a sustainable practice with global implications.

Through examples from around the world, including the nutrient-rich waters of the North Atlantic, the innovative farms in the cold Pacific Northwest, and the community-driven projects in the temperate regions of Asia, this analysis highlights how regenerative aquaculture farming not only contributes to carbon sequestration, nitrogen cycling and water purification but also offers a sustainable livelihood for coastal communities and a resilient supply of seafood.

Today, most farmed seaweed is used for direct human consumption, as fresh feed in aquaculture, or as hydrocolloids. However, seaweed-farmed products may be able to displace fossil fuels in sectors such as fabrics and plastics and can generate socioeconomic benefits in fragile coastal communities. Further, the market is currently dominated by a few Asian countries, which produce 97.38 percent of farmed seaweed by volume globally (see Appendix 7.1).

A recent survey by the World Bank (2023) demonstrated that the opportunities for growth in new markets and applications are high, particularly for seaweed. Figure 3 below illustrates the global projected market for seaweed (and global marine derived products) in various industries and markets is expected to increase exponentially in the course of the next 6 years.

Figure 3. Projected Market Growth for Seaweed 2022-2030 (World Bank, 2023).



*Pharmaceutical sector market data is not available at present.

The Australian coastline extends approximately 34,000 kilometres (excluding all small offshore islands) but includes more than 1000 estuaries (Australian Government, 2023). Additionally, approximately 50 percent of the Australian population resides within seven kilometres of the coasts, ports and other infrastructure are also pivotal in supporting the primary industries and tourism of the country (Australian Government, 2023). Sustainably producing food for the growing population and alternative packaging products has seen innovative materials such as seaweed bioplastics, nutraceuticals, methane-reducing feed, alternative proteins and fabric enter the Australian market. However, majority of the raw materials that are marine derived are imported due to a lack of stable supply to meet these growing demands.

According to the Food and Agriculture Organization (FAO) of the United Nations, the world needs 50-70% more food by 2050.

Regenerative aquaculture has been proposed as a solution to satisfy these increasing food demands while supporting biodiversity and climate action and sustainability goals.

This approach aligns with global strategies for environmental sustainability and food security (The Nature Conservancy 2022; FAO 2023). By illustrating these market opportunities and international best practice examples, the report aims to illustrate the universal relevance of seaweed and shellfish aquaculture as a scalable solution for environmental restoration and economic development, marking a path forward for the Australian aquaculture industry (which is still in its infancy) in the pursuit of sustainability and regeneration.

The National Marine Science Plan estimates that Australia's Blue Economy activities such as seaweed and shellfish will bring AU$100 billion to the economy and provide AU$25 billion worth of contribution to the wider ecosystem (National Marine Science Plan, 2015). Table 1 below provides an overview of various BE activities and groups them according to ocean service, industry, and drivers of growth.

Table 1. Blue Economy Activities (World Bank, 2016).

Type of Activity	Ocean Service	Industry	Drivers of Growth
Harvest of living resources	Seafood	Fisheries	Food Security
		Aquaculture	Demand for Protein
	Marine Biotechnology	Pharmaceuticals, chemicals	R&D for healthcare and industry
Extraction of non-living resources, generation of new resources	Minerals	Seabed mining	Demand for minerals
	Energy	Oil and gas	Demand for alternative energy sources
		Renewables	
	Fresh Water	Desalination	Demand for fresh water
Commerce and trade in and around the oceans	Transport and Trade	Shipping	Growth in seaborne trade; International regulations
		Port Infrastructure and services	
	Tourism and recreation	Tourism	Growth of global tourism
		Coastal Development	Coastal urbanisation
			Domestic regulations
Response to ocean health challenges	Ocean monitoring and surveillance	Technology and R&D	R&D in ocean technology
	Carbon Sequestration	Blue Carbon	Growth in coastal and ocean protection and conservation activities
	Coastal Protection	Habitat protection and restoration	
	Waste Disposal	Assimilation of nutrients and wastes	

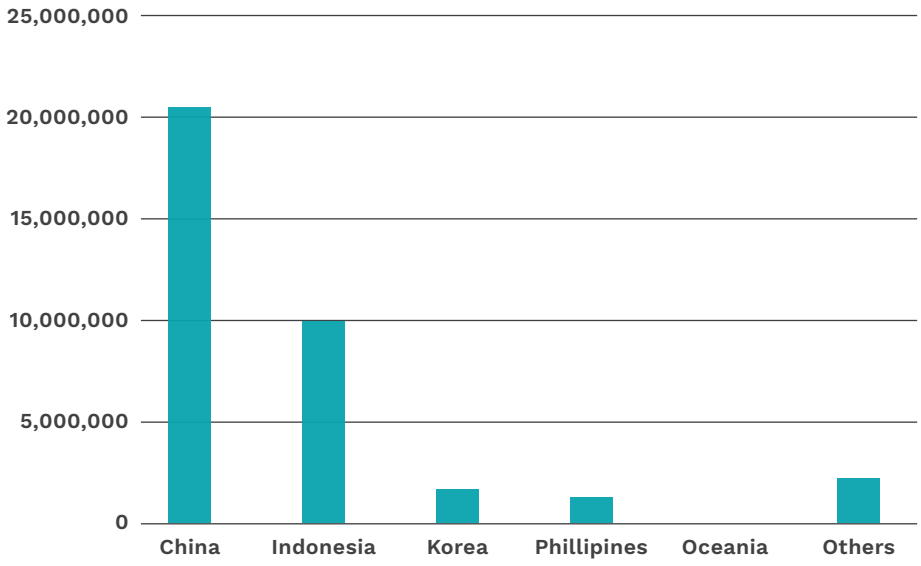
The regenerative aquaculture industry has been identified as a critical industry for regional growth, attracting employment and economic multiplier advantages, as highlighted by the National Marine Science Plan 2015-2025 (National Marine Science Plan, 2015; The Nature Conservancy 2022).

Noteworthy is the economic potential of seaweed globally. In 2017, the value of the seaweed marked worldwide was 4.1 billion USD. This number is predicted to almost triple by 2030 to 11.8 billion USD (World Bank 2023).

Australian seaweed farming as part of the Oceania accounts for less than 1% of the global seaweed production and most of the seaweed production stems from wild collection as demonstrated in Figure 4 below (FAO, 2021).

Figure 4. Global distribution of Seaweed farming.

Global distribution of Seaweed farming.



However, although there is evidence of an overwhelming growth and high contribution of Blue Economy activities such as regenerative aquaculture across the globe, in recent years, an evaluation assessment by Hatch Innovation Services (2023).

The report advises that although there is an increasing support for regenerative aquaculture activities in the West, the industry is facing a myriad of challenges.

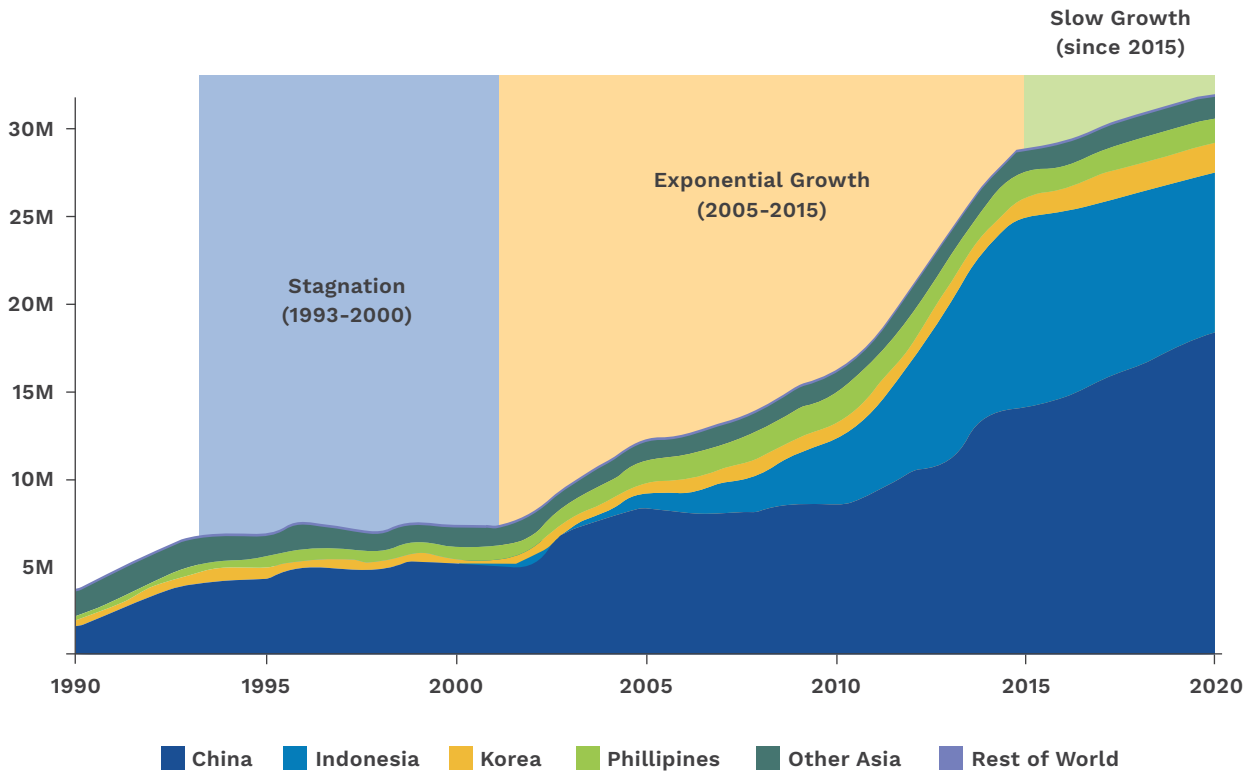
According to the graph image in Figure 5 on the following page, there is a stagnating or decreasing volume of aquaculture production particularly seaweed across the globe specifically in some of the top seaweed producing industries.

Their report summarised these challenges to be because of climate change, a lack of innovation and issues with accurate data reporting especially from the Asian producing countries (Hatch Innovation Services 2023).

The World Bank (2023) further suggests that due to these challenges faced especially in countries who dominate the seaweed aquaculture market, there are very few novel cultivation practices that are not necessarily a recipe for success that can be applied into the Western frameworks.

It is therefore important to consider place-based business models and frameworks with support from practically informed research.

Figure 5. Global seaweed production volumes 1990-2020 in key countries, in tons wet weight (FAO 2022a).



Australia has a significant mussel farming industry, particularly in regions with favourable water conditions such as Tasmania, South Australia, and Victoria.

According to the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Australia produced approximately 9,000 metric tons of mussels in 2019–2020. Global mussel production was estimated to be around 2.6 million metric tons in 2018 and steadily climbing since according to the Food and Agriculture Organization (FAO, 2019; 2020).

Major mussel-producing countries globally include China, Spain, Italy, Netherlands, and Chile. While Australia is a notable producer of mussels, its production volume is relatively small compared to global leaders like China and European countries. Similar to seaweed, China alone accounts for a significant portion of global mussel production, often surpassing other countries by a wide margin. Despite its smaller scale compared to global leaders, Australia's mussel farming industry plays a vital role in supplying domestic markets and contributing to the country's aquaculture sector.

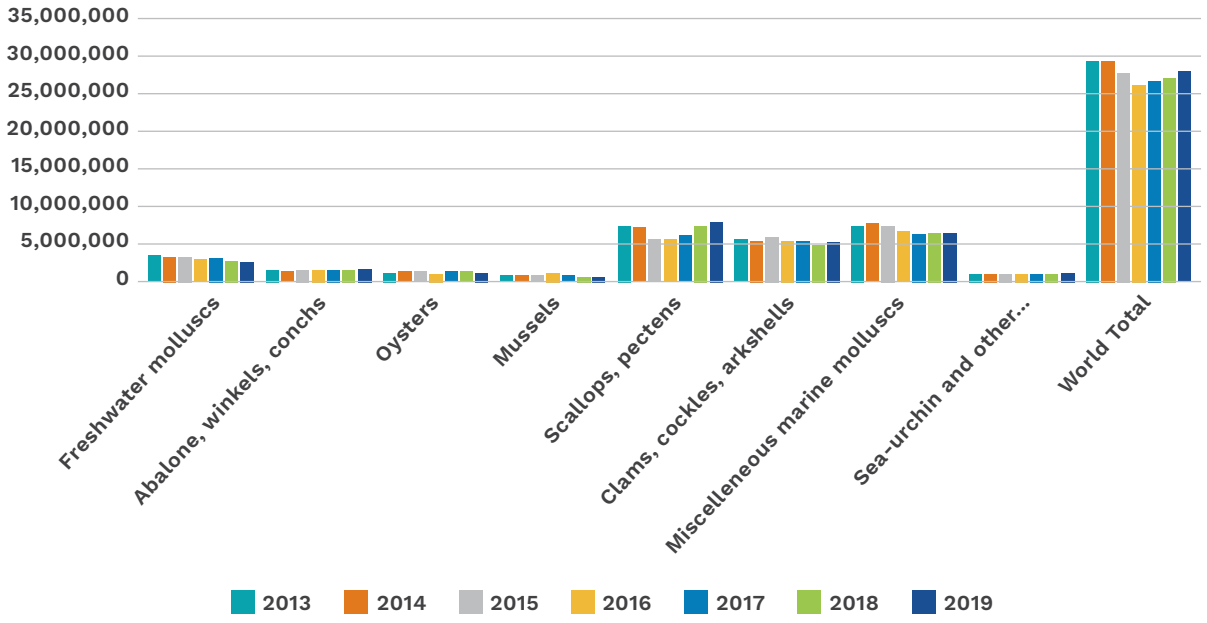
A variety of species are cultured around the world, the blue mussel (Mytilus galloprovincialis) is the dominant marine mussel species farmed in Australia. Although the mussel shares the scientific name with one from southern Europe, it is native to Australia and found in ancient Aboriginal middens sites (see Report 3).

As filter feeders, shellfish like oysters and mussels actively remove particles from surrounding waterways naturally. As part of a regenerative aquaculture, shellfish (like seaweed) transform aquatic food systems, secure livelihoods, can distribute benefits fairly and ensure conservation of biodiversity and ecosystems while producing nutritious food sources. This report targets the opportunities for expansion of already established sustainable aquaculture business value chains.

Shellfish farming as a regenerative aquaculture practice focuses on building capacity through developing and supporting the implementation of internationally agreed standards, transferring knowledge and direct training so that innovative viable policies, programmes technologies and innovations that enhance fisheries management (FAO, 2020; World Bank 2023).

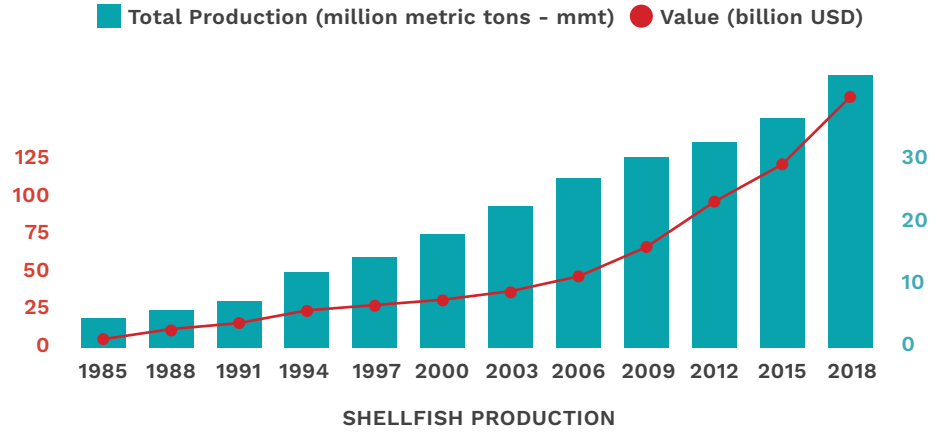
These examples can provide opportunities to expand aquaculture and upgrade value chains across the NSW South Coast region and Australia at large. Figure 6 below highlights the capture and production of shellfish globally, over a period of 6 years as developed by Barange (2019). Noteworthy for Australian context, there is an increase in capture and production (though gradually) across the world in abalone, oysters, mussels and scallops, which are currently in production on the NSW South coast.

Figure 6. Global capture production by group (Barange, 2019).



Furthermore, Figure 7 highlights the marine based shellfish where the global aquaculture production projections show that shellfish are among the most valuable groups for culture (FAO 2019). The production of shellfish has increased 10 times since 1985 with a total production capping at 27 million metric tons in 2018 and a revenue of USD 104.55 billion (FAO 2019). The Australia's mussel industry turned over USD 8.6 million alone in 2018 (Barange 2021).

Figure 7. *Global total production (in million metric tons) and its value (billion USD) of shellfish aquaculture from 1985 to 2018. (Source: FAO 2019).*



This report features two case studies of established regenerative aquaculture businesses in kelp and shellfish farming including their value-adding processes and networks. The next section highlights and explore two vertically integrated businesses within the south coast that explore the broader aquaculture industry opportunities.

3. In-depth Case Studies

3.1. Blue Harvest Group

Blue Harvest Group was formed from a merger of two stand-alone businesses: (1) Blue Harvest with an approximate revenue of $45 MIl and South Coast Mariculture (approximate revenue of $15 Mil). Both businesses were co-founded by Sam Gordon. South Coast Mariculture is the farming and processing arm of the group.

The newly formed entity Blue Harvest Group aims to exceed revenue of $80 million by 2025 with a strong focus on higher value add products. The group is governed by a highly experienced board of directors.

South Coast Mariculture is involved in restorative aquaculture on the NSW South Coast with mussel farms located in Eden and Jervis Bay. The company is also licensed to grow oysters, scallops and seaweeds (Eden marine leases only). South Coast Mariculture currently employs approximately 30 FTE (full-time equivalent) with the majority of employees working on the Jervis Bay marine lease and the nearby processing plant in Huskisson. The business supplies mussels to Coles, Woolworths, Harris Farms and wholesalers more broadly. South Coast Mariculture also processes oysters for retailers from the same facility. The focus of the case study is on the aquaculture farm operation for mussels and the processing of the same.

South Coast Mariculture has a license to operate a 50ha mussel farm in Jervis Bay. So far, the business has developed 30ha or 60%.

The farm in Jervis Bay required upfront investment of AUD 7 million. The annual operating cost is approximately AUD3.5 million. The Eden license is for the establishment of another 50ha farm. However, only approximately 15% or 7.5ha are currently developed. South Coast Mariculture is predominantly (at this stage) utilising the farm for the growth of spat while also supporting other aquaculture businesses with R&D.

Kelp businesses from the south coast are trialling to grow Kelp on the Eden lines. Mussel spat is then shipped to Jervis Bay and put out on the lines for the mussels to mature and harvested.

The logistical efforts on both farming and transportation between Eden and Jervis Bay are inefficient. However, Sam Gordon commented that:

> **'Eden is a reliable supply of spat. Nature dictates so there is little we can do about that at the moment.'**
>
> **Sam Gordon - MD**

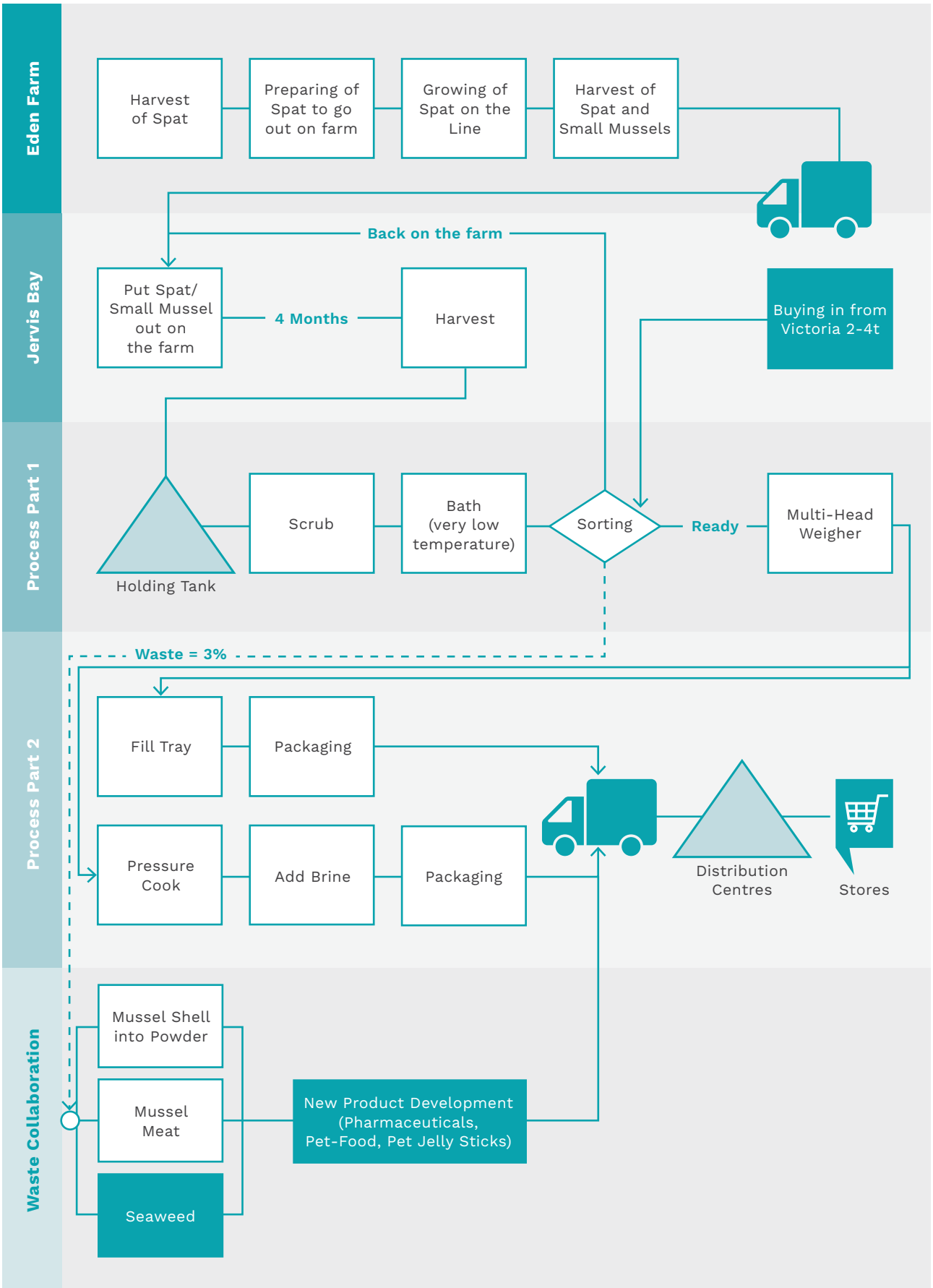
Also, the exposure to different currents and climates enhances resilience within the mussel; another important aspect as water temperatures are rising and other environmental changes impact the species.

South Coast Mariculture is also collaborating with Ian Duthie from SeaPerfect in Moruya on the establishment of a land-based mussel spat supply business which was scheduled to be up and running in 2019 from Moruya. However, the black summer bushfire and Covid19 impacted on an earlier uptake. The outlook is that the first mussel spat is becoming available from the business in 2024.

Southcoast Mariculture currently harvests 600-700t live mussels a year. The business requires anywhere from 500t – 550t to break even. The mussels enter different revenue generating value streams. Currently 40% are sold as live products, 57% enter meat lines and 3% are processed into powder.

The company aims for a whole mussel approach with 0% waste. At the moment, 3% of the harvest is scrap in the form of Byssal (high in collagen) and calcium carbonate (shell). It is important to note that only 30% of New Zealand mussels are used as a human food source. The rest is used for pharmaceuticals and high protein pet food. Figure 8 provides a supply chain overview of the operation.

Figure 8. Blue Harvest Group – Value Creation Map.



Farm and Processing Operations

The Jervis Bay operation depicted in Figure 1 grows the mussels to full-size and provides further value-adding processes within the Huskisson industrial precinct.

Mussels that are ready for harvest are graded into 2 sizes. Mussels for processing require cooling which enhances quality, yield and shelf-life. Deep chill technology is a key technology that positively impacts product quality. Further, South Coast Mariculture deploys life-holding tanks with low water temperature that can hold product anywhere between 4-7 days. Again, the tanks improve product quality while simultaneously acting as an inventory buffer to balance supply and demand. South Coast Mariculture also invested a further AUD 1.5 million in post-harvest machine upgrades to provide a larger range of products including cookers that extend the shelf-life. Life mussels do have a multitude of packaging options available; however, plastic trays are predominantly demanded by the retail industry.

Mussels are living organisms and the supply chain has risks and uncertainty. Potential environmental risks can impact the health and growth rates.

For example, the south coast NSW waters are only 1/4 as fertile when compared to NZ (chlorophyll levels about 0.4 mg/m3). Whilst NZ has higher chlorophyll levels, the strong East Coast Current may negate any benefit on productivity in NZ.

More research is required to identify productivity level for different species of aquaculture products more precisely. Sam Gordon pointed out for example that Pacific Oysters appear to have a higher growth rate in places like Shoalhaven and Batemans Bay than in NZ. However, South Coast Mariculture is buying in product from Victoria (anywhere between 2-4t per week) to mitigate supply uncertainty and stabilise the supply chain.

South Coast Mariculture is employing seven[1] people on the actual farm and an additional fifteen people in the processing facility. The skill set varies from skipper license holders (3), forklift and truck licenses and food handling.

Blue Harvest operates the whole year. The business sends two trucks to Sydney every day. One truck supplies directly into a large distribution centre, the second truck delivers to a food wholesaler. Current logistic costs are AUD 0.46 per kg of product.

South Coast Mariculture is expecting to extend the logistical fleet with regular deliveries into Melbourne as well. South Coast Mariculture has made significant investments into farm and product data transparency and yield. The objective is to track mussels from spat all the way to consumption. In total, the organisation is operating twelve different systems which are only semi-integrated.

The Mussel Farm app allows the user to break down the yield per line. The data can be traced back including the spat source. Meat conditions are closely monitored through a meat index (% of meat to total mussel weight ration).

These data points are further correlated with water quality measures (e.g. temperature and chlorophyll levels). Customer data is managed using salesforce. The salesforce data is analysed so it provides new insights and correlation that were previously overlooked (e.g. seasonality, ordering patterns etc)

Mussel farming is a heavily regulated industry. Farm operations require a multitude of licenses, need to comply with a multitude of acts and operate to certain standards.

Compliance is a full-time position, expensive and includes external auditors and consultant. The list below highlights some of the regulatory requirements (non-exclusive list):

- SQF2000 (ISO is incorporated)
- Anti-Slavery Act
- Marine Park Permit
- RMS
- AMSA
- Mooring License
- NSW DPI Bio Security Permit
- Lease permits
- Aquaculture license from fisheries
- Department of Planning and Environment
- Local government (wharf fees)
- DFAT – Exporting license.

South Coast Mariculture has created jobs in the regions that they are operating and the business is predominantly deploying locally. Investment in infrastructure has a further spill-over effect within the local construction industry (sparky, builder, hydraulic etc). South Coast Mariculture recently invested AUD 1million in the processing facility alone employing local tradespeople. Mussels also feature on the local restaurant menu and the co-location of the mussel farm with an in-demand holiday destination creates opportunity for tourism growth. Further collaboration is required to fully harness the economic spillover potential with the local diving, whale watching and dining industry for the development of a joint blue economy marketing strategy.

Southcoast Mariculture has a keen interest to expand and diversify its business. The business is looking into a more diverse variety of seafood products including Sydney rock and Agasi oysters or scallops. However, any future expansion in seafood products requires scale to make it viable. South Coast Mariculture also invested heavily in drill technology during the Covid19 lockdown as services from New Zealand were unavailable. The business invested AUD250,000 into drill technology allowing for 80m deep seabed anchors to be installed. South Coast Mariculture currently is the only organisation in Australia that owns such equipment.

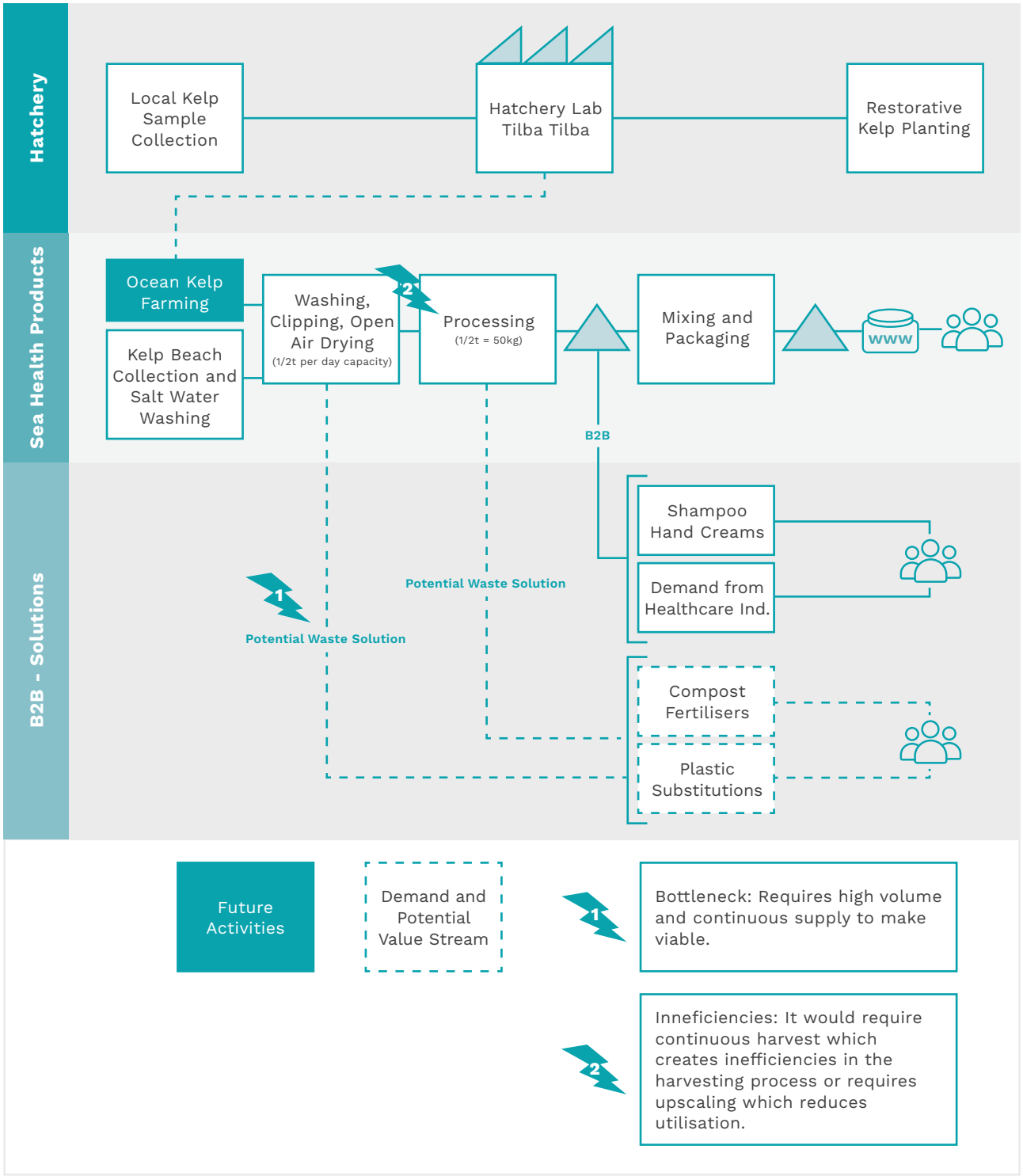
South Coast Mariculture is one of the largest aquaculture industry players on the NSW South Coast with established farms. Other large players stem from the oyster industry such as East33 and Australia's Oyster Coast. Collaborations exist with other providers such as Ian Duthie for spat and Pia Winberg (Phycohealth) for R&D in pet food products. Further collaboration is currently occurring with the Kelp industry trialling seaweed farming at the Eden site.

3.2. Sea Health Products (Ecklonia radiata)

Sea Health Products is one of the oldest established Seaweed businesses in Australia and was established by Betty Long in the 1970s. The business was taken over by Jo Lane in 2015. Jo has a background in marine science and sustainable coastal environments.

The business has expanded through an in-house e-commerce platform as well as a hatchery lab at its headquarters in Tilba Tilba. Sea Health Products holds commercial licenses for the beach collection of Golden Kelp (Ecklonia radiata). Figure 9 provides an overview of the value creation of Sea Health products including key markets, identified future revenue streams and potential system bottlenecks.

Figure 9. Sea Health Products – Value Creation Map (source: authors).



Sea Health Products hand-harvests kelp (under license) from local south coast beaches. The kelp is washed, and processed to produce a range of health and wellness products.

The current rack capacity for wet Kelp is about 500kg which results in 50kg of dry product. Racking capacity for open-air drying can easily be extended; the existing infrastructure has spare capacity.

Existing revenue streams for finished products are through a supply of brick-and-mortar retail stores, an in-house online store for consumer-direct shipments as well as a B2B (wholesale) solution with a local company that uses Golden Kelp for Shampoo and Hand Cremes.

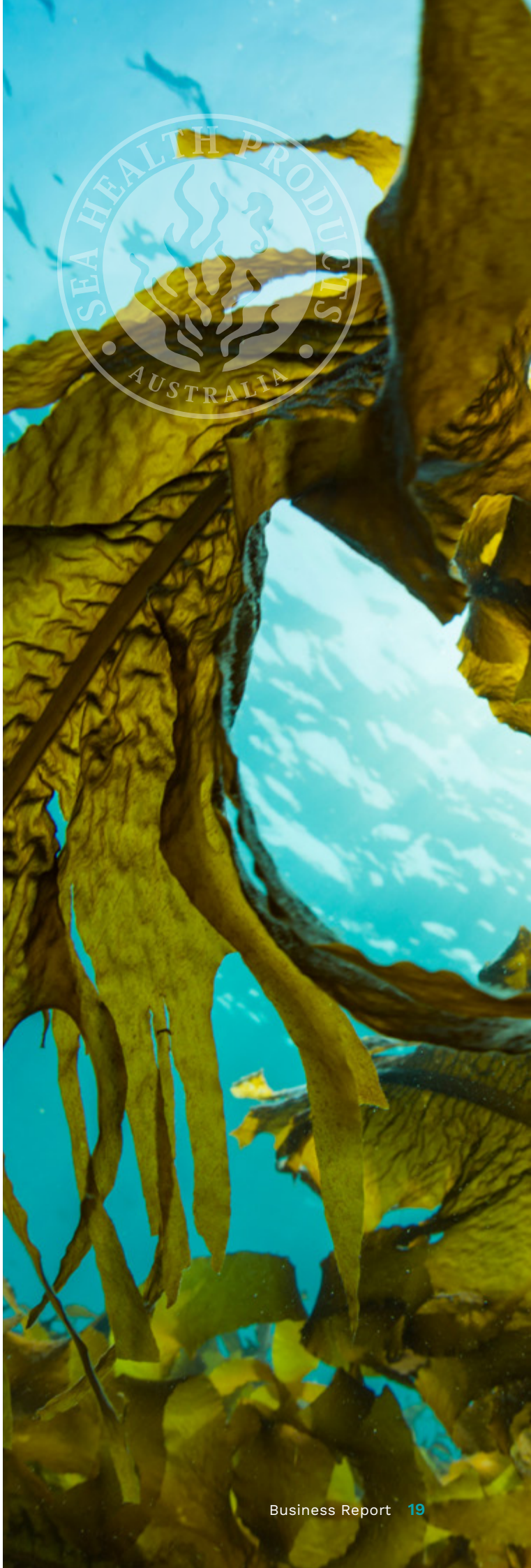
A 50gr jar of Golden Kelp is currently being sold for $17 and in some instances $25. The total turnover of Sea Health Products last financial year was close to AUD100.000.

Sea Health Products has invested heavily in R&D by establishing a Kelp Hatchery at their headquarters in Tilba Tilba. Unique know-how on how to successfully spore Ecklonia radiata as well as other species has been developed. This know-how is in high demand by industry and government, in particular in South Australia.

Sea Health Products has a keen interest in Ecklonia radiata ocean farming as they are currently unable to meet demand for finished products with the beach-foraged kelp supply.

They have won the initial tender for two lease areas on the NSW South Coast: each 30 hectares (ha). Kelp forests are under distress by warming ocean waters and urchin infestation which negatively impacts the amount of kelp naturally occurring on the local beaches.

However, at the same time, Sea Health Products have experienced a strong increase in demand that they are unable to fulfil, in particular from the healthcare industry. A proposed 30-ha farm would result in 300 lines (each 100 meters) of Kelp that is anticipated to yield 300kg of wet Kelp every 6 months. The capacity can be doubled when applying an alternative farm set-up method that is unproven in Australia at this point in time.



The company conservatively predicts a total of 4,000kg of wet Kelp/ha (which would result in 12,000kg of dry product per year for a 30-ha site. These estimates are based on an average yield of 3-5 kg /metre and were developed with scientific experts from Australia and were judged conservative.

Uncertainty remains on the actual technical feasibility of Kelp farming with a few tests underway within NSW waters. However, these conservatively predicted volumes would open up new market opportunities currently not available due to inconsistency of supply.

Table 2 breaks up the yield for different markets excluding the utilisation of clippings/waste products for the production of fertilisers or Bioplastics. Here it is anticipated a 50/50 split in terms of retail and wholesale.

Table 2. Sea Health pricing and anticipated revenue breakdown per ha farm.

Market	Dried product per ha	Price per kg	Revenue per ha
Retail (50%)	200kg	$340	$68.000
Wholesale (50%)	200kg	$180	$36.000
Total	**400kg**	**Avg 260**	**$104,000 (per ha)**

However, the large influx of supply would create other problems on the processing site such as racking capacity and inventory storage. Smaller scale investment would be required to mediate the impact. Sea Health products has an existing processing facility that can be scaled as well as an existing hatchery which will reduce costs for seed stock supply and also potentially be another income source.

It is worth noting that Sea Health Products have established strong collaboration with the knowledge centres internationally through the Churchill fellowship in 2019 as well as existing relationships with UTS Green Start-Up hub and UOW BF-Tri as well as iAccelerate to gain support and momentum for business growth.

4. Innovators in the wider Regenerative Aquaculture Eco-System

Blue Economy innovators on the NSW South Coast vary from new product development, IT support as well as aquaculture farming.

Table 3 provides an overview of various identified businesses. All businesses in Table 3 have been consulted and/or interviewed. It is important to note that this is not an exclusive list as other players in the market are championing industry good practices such as urchin processing businesses, abalone industry and fishing cooperatives. These are all additional members of a fast-growing industry cluster. These networks and ecosystems are dynamic and constantly changing and evolving.

The research team has evaluated and assessed the businesses in Table 3 through the lens of dynamic capabilities. Dynamic capability focuses on the capacity of an organisation *"to sense opportunities and threats, seize these opportunities, and reconfigure both internal and external resources, as well as operational capabilities to meet unmet needs."* (Tabaklar, 2021).

Businesses mobilise their dynamic capability to create and deliver value in three distinct phases (1) sensing a market opportunity; (2) seizing the identified solution to realise the opportunity; and (3) transformation of resources to facilitate delivery of value (Helfat and Peteraf, 2009) as visualised in Figure 11. Additionally information on Dynamic Capability Mobilisation can be found in Appendix 7.7.

Figure 11. Dynamic Capability Mobilisation – 3 Phase Model.

Name	Website	Product/Service	Link to Regenerative Ocean Farming	Barrier	Existing Collaboration
South Coast Seaweed [C]	www.southcoastsea-weed.com.au	Cultural Eco Tours, Oceanart and Seaweed Flakes **[Seizing];** Farming – **[Sensing]**	Indigenous start-up company. Application of traditional methods of harvesting and collection to create eco-friendly products. South Coast Seaweed aims to create First Nations led aquaculture farms to cultivate and harvest sea kelp naturally.	Requires high infrastructure investment and access to markets. Owners working full-time.	Unknown.
Kelpy (early stage start up) **[I]**	www.kelpy.co	Biodegradable Plastic Substitution **[Sensing]**	Manufacturing IP to convert seaweed and seaweed waste into biodegradable plastic substitution. Ambition to develop regional manufacturing hubs globally. Early packaging trials with Nestle and Colgate using seaweed.	Early product testing stage. Requires regional investment into manufacturing and continuous high-volume supply of seaweeds.	UTS Green Start-Up Hub, Bega Regional Circularity Hub.
Oceanfarmr (scaling internationally) **[I]**	www.oceanfarmr.com	Ocean farm finance, and operations management app/ software **[Transforming]**	Digitalisation of bespoke farm knowledge to streamline farm operation. The major hurdle to get the technology implemented was farm financing. A novel farm financing model was developed that also requires the lender to use the software.	Operates at international scale. Aquafarm software solutions. Software requires the investment arm to get established.	UOW SMART Sensor network (IoT sensors for regenerative aquafarming). Software deployed by some oyster farmers.
Ocean 2 Earth (Joint Venture – Pentarc Permaculture) – scaling nationally **[I]**	www.ocean2earth.com.au	Soil enhancer, fish waste recycling business **[Seizing]**	The company recycles organic marine waste (e.g. fish scraps, urchin waste, mussel, oysters etc) and turns it into compost and soil enhancers. Unique natural fertiliser that overcomes agricultural deficiencies. IP in how to naturally posturise fish waste using unique microbial molecules.	Fish waste is now contested (company pays for it and it is getting more competitive). Requires high volume of supply to maintain viable.	Early conversations with Phycco Health and BlueHarvest Group
South Coast Sea Urchins	https://www.south-coastseaurchins.com.au/	Urchin Roe **[Transforming]**	The company harvests short-spine sea urchins via dive on the Saphire coast of the NSW. Post-harvest processing includes extraction of roe and packaging in Pambula, predominantly for export.	Post-harvest staff retention.High level of casualisation.On-going geo-political tensions with key export markets.	Ocean 2 Earth for urchin waste.

Table 3. Additional innovative businesses interested in regenerative farming on the NSW South coast.

Name	Website	Product/Service	Link to Regenerative Ocean Farming	Barrier	Existing Collaboration
Phyco Health (scaling internationally) **[I]**	www.phycohealth.com	Food products and cosmetics. Petfood **[Transforming]**	Converts nutrients and carbon dioxide from the Manildra plant into micro algae for products. Exports now into the UK. R&D with Blueharvest on Waste Mussel and Seaweed into petfood. R&D with UOW into BioInks for wound healing.	Bioinks have high value adding potential. However, time to get product to market in human application healthcare is long.	Established relationships with UOW-Tricep, BlueHarvest Group, Sea Health Products, UTS Green Start-Up.
Joonga Land and Water Aboriginal Corporation Scaling locally **[I]**	https://www.nar-oo-maaboriginal-tours.com.au	Cultural tourism, SmartDrumline, Government contracts **[Sensing]**	Joonga's scientific dive team is monitoring and mapping out sea urchins in the local waters. Strong interest in getting Kelp back into the waters.	Established business, operating for 1.5years. Regulation and funding required to do more regenerative work. Community capacity constraints.	Established relationships with UOW BlueFutures.
SeaPerfect [C]	https://www.seaperfect.com.au	Spat and consultancy **[Seizing]**	New supplier of premium shellfish spat. Pacific Oysters, Flat Oysters and Mussels, are the start of our quality product range.	Moruya operation is still gaining momentum.	BlueHarvest Group.
AusKelp [I]	www.auskelp.net	Seaweed farming (planned) **[Sensing]**	Planning the development of large-scale seaweed farms.	Early testing stages of Kelp farm development; access to water for biomass models.	Sea Health Prudcts, UOW BF-TRI, BlueHarvest Group, Ocean2Earth.
Signature Oysters [I]	https://www.signatureoysters.com.au	Oyster farming **[Transforming]**	Adoption of innovative practices in Oyster farming (flip farm, visual grading systems, e-marketplace, etc)	-	Oceanfarmr, UOW.

Name	Website	Product/Service	Link to Regenerative Ocean Farming	Barrier	Existing Collaboration
UTS Green Start-Up Hub [C]	https://www.uts.edu.au/climate-change-cluster/our-research/deep-green-biotech-hub/innovation/green-light-accelerator-program	Science, R&D, Knowledge hub, commercialisation **[Transforming]**	Green light accelerator program supporting the development of algae biotech solutions.	Operating from downtown Sydney. Strong focus on land-based solutions.	Phycco Health, Sea Health Products, Kelpy.
UOW [C]	https://www.uow.edu.au/ancors/bf-tri	iAccelerate, TRICEP, SMART, ANCORS (BF-TRI) **[Seizing]**	Enabling support for aquaculture industry to develop. Strong focus on social and business aspects.	Continuous funding, distance (operating out of Wollongong).	All.
Regional Circularity Hub – Bega [I]	https://begacircularvalley.com.au	Product stewardship and circularity **[Sensing]**	Working with aquaculture industry to develop 'whole of fish' approach and circular solutions.	Early days, still gaining traction and developing momentum.	UOW, Ocean2Earth, Kelpy.

Table 3 provides a non-exclusive list of innovative companies in the wider NSW BE eco-system. The investigation into the ecosystem identified that the network is currently loosely coupled. Collaboration occurs predominantly amongst established businesses that are either complementary and/or have the potential to create new markets. The two Indigenous businesses are currently least integrated with the existing structures. However, opportunities for collaboration and knowledge sharing have been acknowledged by most interviewees.

Cluster approaches to ecosystem development are well established in the literature. It spans a variety of industries such as the semiconductors industry (Browning et al., 1995), the steel industry (Gnyawali et al., 2006), the pharmaceuticals industry (Quintana-García and Benavides-Velasco, 2004), or the food industry (Galdeano-Gómez, 2015) with very limited application in the Australian context. A concept that is inherent in cluster development is termed co-opetition. Co-opetition requires companies to collaborate and compete comfortably and simultaneously.

The key assumption of co-opetition is that there are different degrees of interdependence between companies and these interdependencies can be leveraged to create value (Gurnani et al. 2007). Companies within the eco-system are split into four categories; (1) Customers; (2) Suppliers; (3) Competitors; (4) Complementors. Complementors are defined as businesses that add value to a focal company's products or services more than when the company offers those alone. Together with the focal firm, businesses and their interdependencies make up a value network.

The drivers vary from external drivers such as industrial characteristics, technological demands and external stakeholders (Luo et al. 2006); or relational specific drivers such as partners complementary resources and capabilities, goal congruence, and technological asymmetry (Gnyawali et al. 2006; Gurnani et al. 2007); to internal drivers such as companies' specific motives, resources and capabilities. However, the process of establishing co-opetition is considered to be dynamic, complex and challenging. Network members are known to have multiple and conflicting roles with other firms, which can result in tensions in the network (Johansson 2012).

However, research has shown that co-opetition can result in strong performance outcomes such as:

- Enhanced innovation performance through co-opetitive arrangements (Huang & Yu 2011)
- Knowledge sharing, knowledge-creating and knowledge acquisition (Ho & Ganesan 2013)
- Economic, financial and customer performance (Liu et al. 2014)
- Trust and maintenance of relationships, goals and outcomes realisations (Liu et al. 2014)
- Network resilience during times of high uncertainty (Boehme et al., 2020)

The regenerative aquaculture industry is still in its infancy on the NSW south coast and has been described by many as a cottage/ boutique industry.

Mussel farming in particular has matured and scaled over the past 5 years and is dominated by a single player. However, the regenerative aquaculture industry currently operates with high levels of uncertainty stemming from the environment increasing the risk of stable supply. Also, inefficiencies were discussed within the industry. For example, a lot more work needs to be done in order to optimise farm set-up and develop from an efficiency perspective that drives lean practices into farm management including optimum farm size and layout.

Seaweed farming has gained interest by industry players however the commercial viability and technical feasibility remain questionable which has been acknowledged by most parties interviewed.

The seaweed industry in particular faces high risks in regard to viability and feasibility as presented earlier. However, high up-front investment is required to meet regulatory compliance, which makes this particular industry a higher risk for investors. Raising capital by industry players is further impeded as farming is conducted in leases on common waters which is ineligible as a security when raising capital. Interviewees further acknowledged that a willingness to collaborate and share resources (including assets), knowledge and innovative business models while accepting a level of competition is a critical component for the cluster to move forward. Table 4 provides a summary SWOT analysis conducted from industry reports and interviews with the wider regenerative aquaculture eco-system.

Table 4. SWOT analysis of regenerative aquaculture business in the NSW south coast.

Strength	Weaknesses
Δ Water purity – non-intensive aquaculture (no feed required) Δ Fast growing (seaweeds can double in biomass every day) Δ Rich marine resources Δ Government interest in establishing an industry (alignment) Δ Innovation and research capabilities within the network Δ Tight, close-knit industry (players are known) Δ Willingness by industry players to gain traction and to collaborate. Δ Strong support by Traditional Owners Δ Strong local knowledge base – TO as well as scientist involvement in the industry Δ Labour intensive – strong job creation potential	Δ Australia currently has no Blue Economy roadmap including regenerative aquafarming Δ National policy platform is missing Δ Limited infrastructure on the NSW South Coast (long distance to market) Δ Complex regulatory compliance process Δ Public perception of a cottage and lifestyle industry (not being taken seriously) Δ Capital intensive with limited access to funding Δ Unclear biomass models for seaweed (viability?) Δ High swells and currents (feasibility?)
Opportunities	**Threats**
Δ Circularity opportunity (whole of mussel and seaweed approaches) Δ Strong market demand globally for Δ sustainable and eco-friendly products Δ Strong global demand for protein-rich food products Δ Export potential Δ Driver for regional employment Δ Undiscovered attributes of seaweeds with high-value potential Δ New technologies (e.g. sensors) on the horizon for automated farm management (de-risk farm operation) Δ Co-location of aquaculture industry and windfarms (European model) Δ Enhance domestic food/feed production. Δ Strong know-how and established hatcheries for seaweed (Kelp) and mussels Δ Collaborative approach to regional marketing with complementors (e.g. diving, eco-tourism etc) Δ Natural eco-system under threat (Kelp forests shrinking) Δ Restoration	Δ Difficult to raise capital Δ Image issues – greenwashing and misconception Δ Uncertainty around the warming of the ocean and aquaculture farming (resilience) Δ Global market competition is growing Δ Regulatory and compliance processing hindering the uptake. Δ No guarantee of success – viability and feasibility (seaweed farming) Δ Government process for farm licensing is counter-productive towards industry collaboration (competition from the beginning) Δ Social license to operate

Based on Table 4, the regenerative aquaculture industry exhibits strengths in its international and national product demand. However, weaknesses arise from feasibility and viability challenges tied to biomass and technology, compounded by financial risks due to site unpredictability.

A potential longer-term opportunity lies in offshore wind colocation with seaweed and mussel farming, along with the potential to collaborate with Aboriginal communities for Sea Country healing and restoration. However, regulatory requirements pose the greatest threat to industry growth, introducing high risk and uncertainty for the business model, exacerbated by the issue of high costs and open market processes to attain a permit.

5. Conclusion

According to the Food and Agriculture Organization (FAO) of the United Nations, the world needs 50-70% more food by 2050.

Regenerative aquaculture farming as a solution for food security and economic growth gains more traction.

The NSW south coast has an unrealised regenerative aquaculture potential.

The mussel industry is well-established. The seaweed industry is still in its infancy and more R&D needs to be conducted to confirm viability.

However, the regenerative aquaculture industry has the potential to be a significant regional economic development driver with economic spill-over potential to adjacent industries such as post-harvest processing and tourism.

Overall, demand for protein rich products is strong and growing at a global scale. Focusing on the NSW south coast:

- Many innovative businesses exist within the NSW south coast Blue Economy, some of which are operating at an international scale
- Two well-established aquaculture businesses on the south coast with strong demand and established channels to market
- Industry roadmap is lacking and stifling the industry moving forward
- Strong Indigenous leadership and participation within the aquaculture space is desired by the community
- Currently loosely coupled network of businesses with some early collaborative attempts predominantly in the R&D space (untapped potential in the coopetition space)
- Post-harvest processing has the highest socio-economic impact within the region and a strong contributor to job creation
- Business maturity in mussels but kelp still in its infancy
  - Access to trial lines is required to develop biomass models that would support business development and attract investors.
  - The NSW regulatory process for the identification of potential aquaculture farm leases followed by a competitive tendering process is counterproductive in collaborative eco-system development. Businesses are forced into competition before the business is being established.

The following key recommendations are being made for further consideration:

- The current site identification and selection process requires an overhaul. Biomass models require to be investigated prior to tendering to allow the formation of a business case for new entrants into the market.
- Provision of certification of preference for proponents that have invested time and effort into site identification and selection. Certificate of preference would provide first right of refusal that can be re-assessed in the event of inactivity.
- An industry roadmap needs to be developed that incorporates the desires of the Traditional Owners and establishes Aboriginal businesses as critical nodes within the network.
  - e.g. inshore and nearshore regenerative aquaculture is Indigenous owned and led (consider also implications of Native Title claim on the NSW South Coast)
  - value-adding capacity within the industry is required to diversify products and create more opportunities for national and international markets.
  - co-branding for specific regions to attract tourism (e.g. Hunter Valley and vineyards).
- New investment and funding strategies are required to make capital more easily available for the regenerative aquaculture industry.
- Establishment of a NSW South Coast Blue Economy cluster focused on regenerative aquaculture activities that can:
  - foster stronger collaboration within the industry to allow for joint R&D projects, sharing of risks and rewards and potentially asset sharing arrangements
  - provide upskilling and skill sharing opportunities for new and emerging industries such as kelp and other regenerative aquafarming activities. A capacity and capability gap exist along the value chain. There is a need for a workforce development in emerging industries.
  - Establishment of a regional readiness program that includes a pathway for skills development and transfer to youth and Indigenous communities
  - contribute towards infrastructure development for post-harvest activities.

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Appendices

7.1. Global distribution of Kelp

Table 5. Total production of seaweed across the globe from cultivation and wild collection.

Country/area	Total production from cultivation and wild collection (tons)	Share of world total (%)	Aquaculture share in total production (%)
World	35,762,504	100.00	96.97
Asia	34,826,750	97.38	99.10
China	20,296,592	56.75	99.14
Indonesia	9,962,900	27.86	99.55
Republic of Korea	1,821,475	5.09	99.52
Philippines	1,500,326	4.2	99.98
Democratic People's Republic of Korea	603,000	1.69	100.00
Japan	412,300	1.15	83.80
Malaysia	188,110	0.53	100.00
Americas	487,241	1.36	4.69
Chile	426,605	1.19	5.08
Peru	36,348	0.10	0.00
Canada	12,655	0.04	0.00
Mexico	7,336	0.02	0.14
United States of America	3,394	0.01	7.75
Europe	287,033	0.8	3.88
Norway	163,197	0.46	0.07
France	51,476	0.14	0.34
Ireland	29,542	0.08	0.14
Russian Federation	19,544	0.05	54.10
Iceland	17,533	0.05	0.00
Africa	144,909	0.41	81.29
Republic of Tanzania	106,069	0.30	100.00
Morocco	17,591	0.05	1.55
South Africa	11,155	0.036	19.32
Madagascar	9,655	0.03	91.72
Oceania	16,572	0.05	85.32
Solomon Islands	5,600	0.02	100.0
Papua New Guinea	4,300	0.01	100.0
Kiribati	3,650	0.01	100.0
Australia	1,923	0.01	0.00

7.2. Global Market Sectors for Seaweed Products

Table 1. Identified market sectors for seaweed in a global context and the projected growth capacity.

Market Sectors	Market Size 2022 - Overall	Market Size 2022 - Seaweed	Projected Market Growth 2030 - Global	Projected Market Growth 2030 - Seaweed
Bio stimulants	2.5 – 3.5 billion	1 billion	10%	1.8 billion
Animal feed additives	38.86 billion	Currently used but no market data available	3.9%	1.122 billion
Petfood	115.5 billion	Currently used but no market data available	5.11%	1.078 billion
Methane-reducing feed supplements	47 million	Currently used but no market data available	57%	306 million
Nutraceuticals	450 billion	Currently used but no market data available	7.5%	3.9 billion
Alternative proteins	10.2 billion	Currently used but no market data available	36%	448 million
Fabrics	17.18 billion	Currently used but no market data available	10%	862 million
Bioplastics	11.5 billion	Currently used but no market data available	20%	733 million
Pharmaceuticals (global marine derived)	2.56 billion	No data and not in use	5-10%	unknown
Construction (Green)	312.5 billion	Research trials	10%	1.4 billion

7.3. Pros and cons of aquaculture farming in South Korea

Most seaweed farms in South Korea are multi-trophic (containing finfish, shellfish, and seaweed). The co-cultivation of Kelp with oysters, sea cucumber and abalone has been conducted in South Korea for decades. The table below summarises some findings from the research.

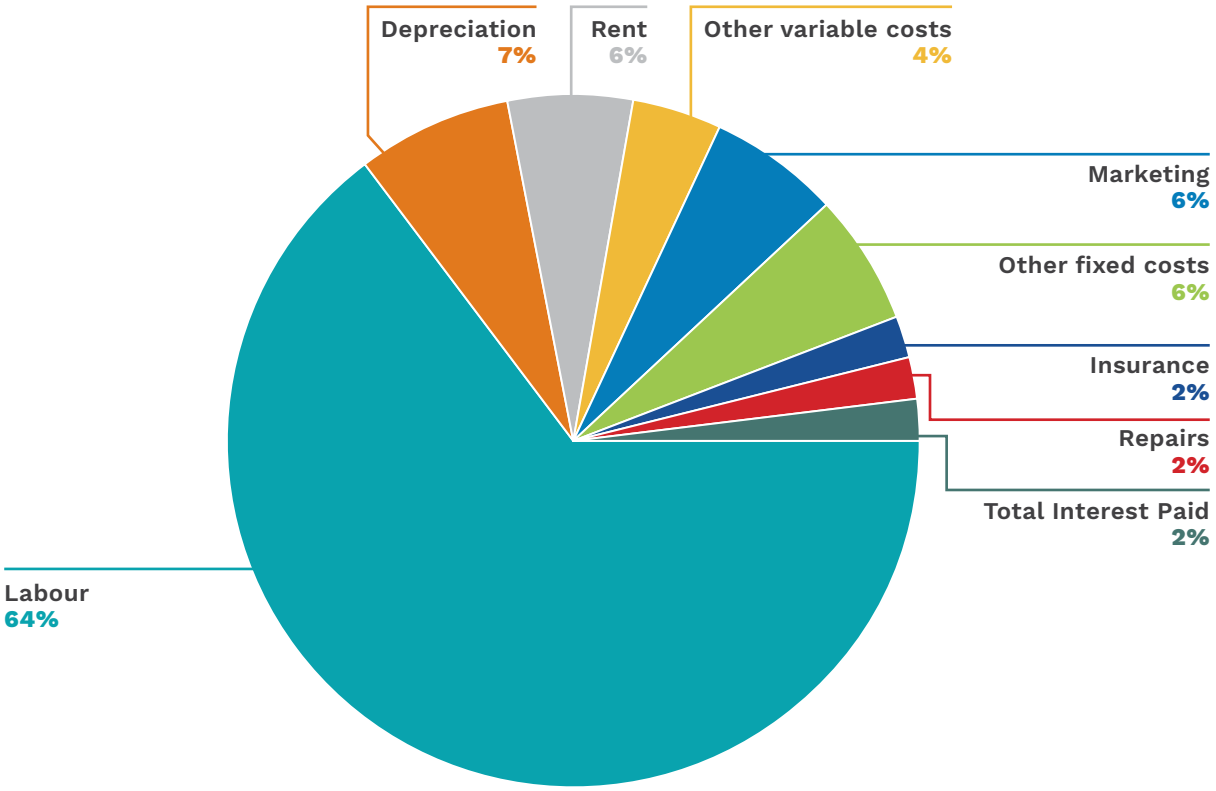
Table 6. Pros and cons of aquaculture in South Korea..

Type of aquaculture	Benefits	Challenges	Researchers	Requirements
Kelp ***(U. Pinnatifida & S. japonica) and Abalone (Haliotis discus hannai)***	Meets the needs of abalone feeds.	Nutrient balance challenges & can cause eutrophication, hypoxia and/or anoxia. Abalone retains 80% of consumed seaweed, the rest becoming waste in the local environment. Feces and uneaten seaweed from the farms may change sediment composition, increase organic material and biological oxygen demand.	Kim et al. 2011	Properly designed production system to create a balanced ecosystem in this polyculture area.
Seaweed ***(S. Japonica and S. fulvellum)and Pacific Oysters (Crassostrea gigas)***	Highly successful – both seaweed and oysters grew faster compared to those in monoculture. Its success led to large scale system being developed. *U. pinnatifda, G. chorda* (red kelp) along with the oysters were cultivated near finfish cages and sea cucumbers placed underneath the cages. All organisms grew better than those in monoculture farms. Extraction of seaweeds and oysters removed nitrogen in the water very efficiently.	Did not consume nitrogen coming directly from finfish. High water temperatures led to the death of red kelp.	Park et al. 2018, Kim et al., 2017; Reitsma et al 2017; Kang et al. 2011	Infrastructure required.

7.4. Cost allocation

According to a case study in Maine (US), the aquaculture industry has grown rapidly from sales of US $57.3 million in 2013 to USD 88 million in 2019 (DMR- Maine, 2022). The aquaculture farms raise a diversity of species, including well-established crops such as oysters and emerging seaweed crops (Cole et al., 2016). According to Carol et al., (2022), the cost structure of starting and running a seaweed farm is presented below. Most respondents were small-scale farmers based in Maine who had seed spools provided by the processor and did not incur a cost for seed acquisition.

Figuren 11. Cost Allocation.



A similar study in Indonesia identified that labour accounted for the greatest share of variable costs across most budgets representing around 50% of total costs of production. The table below indicates the estimated annual labour costs for a 30-km floating line seaweed farm in Indonesia (2009). The second Table 9.3 indicates the annual labour costs for a 27X12-m floating line farm in Zanzibar Tanzania.

Table 7. Labour cost involved in seaweed farming in Indonesia.

Item	USD/km/cycle	USD/km/year
Attachment of propagules to lines	6	48
Placement of lines	4	32
Harvesting of lines	4	32
Drying of seaweed	4	144
Total cost per km		144
Total cost per farm		**4,320**
Total cost per kg of dry seaweed		**0.13**

Table 8. Annual labour costs involved in a 27*12-m floating line seaweed farm in Zanzibar (Tanzania).

Activity	Man hours per cycle	Wage (USD/hour)	Number of cycles	Total cost (USD)
Tying propagules	32	0.03	8	7.27
Planting	2	0.03	8	0.45
Farm management	3	0.03	8	0.68
Harvesting	12	0.03	8	2.73
Transporting seaweed to drying Location	2	0.76	8	12.12
Packing	0.25	0.03	8	0.06
Transportation to market	0.5	0.23	8	0.91
Tie-tie separation	15	0.03	8	3.41
Total cost				**27.63**
Total cost per kg of dry seaweed				**0.03**

It is important to note that the useful life for infrastructure of 10 years was assumed for the initial investment on propagules reported in Indonesian, Philippine, and Indian seaweed farm systems in the study. However, local conditions vary these assumptions widely. As a result, the enterprise budgets presented in above omit financial expenses (interest on operating capital and long-term loans).

Based on the case studies in the study, floating farms are nevertheless the most profitable alternative as die-offs are minimized in this system.

7.5. Business case study example

The table on the following page is a comparative enterprise budget for seaweed farming in six developing countries in 2009 based on studies by Valderram (2015). The table summarises the production parameters, variable costs and fixed costs involved in seaweed farming using different techniques.

The production in most cases takes place throughout the year except for India and Mexico which have short production seasons due to climatology factors. High productivity achieved in Mexico is due to the favourable environmental conditions found in the Yucatan area, high growth rates can also be attributed to the use of large (100 g) high-quality propagules.

The high productivity levels were however achieved in experimental trials which are assumed to be replicated at a commercial scale. The most economical investment corresponded to the off-bottom system in TZ (USD 0.15/m).

The low productivity reported by the Indonesian farm was attributed to being influenced by challenges associated with managing a large operation (30km of culture lines). In the Philippines, low productivity was attributed to the impact of diseases such as ice. Small-scale farms were studied to make it easier to achieve higher leads in TZ and India.

Farm-gate prices varied widely across all countries. For example, as illustrated in Table USD 0.27/kg (TZ) to USD 1.09/kg (Philippines). Distance to processing centres is the key factor influencing farm prices, the lowest prices were reported in the most remote producing regions (TZ and Solomon Islands), while seaweed produced in Indonesia, the Philippines and Mexico fetched higher prices. However, despite the proximity to the processing Centre, Indian markets face low prices (USD 0.33/kg).

Table 9. Comparison table for business case study across six seaweed farms in six different countries (Valderram, 2015).

Item	Unit	Indonesia	Philippines	Tanzania		India	Solomon Islands	Mexico	
Floating	Floating	Off-bottom	Floating	Floating	Floating	Off-bottom	Floating		
Production Parameters									
Total length of lines	m	30,000	2,000	270	288	2,565	4,000	10,000	10,000
Number of cycles per year	cycles	8	5	7	8	6		4	4
Length of a cycle	days	45	63	45	45	45		60	60
Annual yield of dry seaweed	kg	33,000	2,850	662	806	5,400	21,700	53,778	53,778
Annual productivity	kg/m/year	1.1	1.43	2.45	2.8	2.11	5.43	5.38	5.38
Cycle productivity	kg/m/cycle	0.14	0.29	0.35	0.35	0.35		1.34	1.34
Farm-gate price	USD/kg	0.85	1.09	0.27	0.27	0.33	0.38	1	1
Gross Receipts	USD	28,050	3,107	179	218	1,785	8,246	53,778	53,778
Variable Costs									
Propagules	USD							13,264	13,264
Labour	USD	4,320	759	26	28	1,041	3,556	8,853	8,853
Fuel	USD	29	332				1,117		
Maintenance and repairs	USD	420							
Sales and marketing	USD	600						7,115	7,115
Total Variable Costs	USD	5,369	1,091	26	28	1,041	4,672	29,232	29,232
Fixed Costs									
Depreciation	USD	2,501	906	26	24	432	1,157	2,274	2,934
Administrative costs	USD	900							
Utilities	USD	120							
Fees for coastal land usage	USD							3,109	3,109
Total Fixed Costs	USD	3,521	906	26	24	432	1,157	5,383	6,043
Total Costs	USD	8,890	1,997	52	52	1,473	5,829	34,615	35,275
Net Returns	USD	19,160	1,109	127	166	312	2,417	19,163	18,503
Production Cost	USD/kg	0.27	0.7	0.08	0.06	0.27	0.27	0.64	0.66

7.6. Comparison of kelp farming in South Korea, Canada, United States of America and Europe

Table 10.. *Comparison table of kelp farming in South Korea, Canada, United States of America and Europe.*

Aspects	South Korea	United States	Canada	Europe
Geographic Presence	Extensive	Coastal regions in ME, CA, Pacific NW	Atlantic provinces (NS, NB)	Various coastal regions
Key species	Kombu (sweet kelp), Wakame, winged kelp (badderlocks)	Kombu, winged kelp, Sea lettuce flakes (dulse)	Kombu, sea lettuce flakes, Irish moss (carrageen moss)	Kombu, Laminaria spp. , Fucus spp.,
Cultivation techniques	Longlines, vertical systems, kelp forests	Longlines, vertical systems, kelp forests	Longlines, submersible farms	Longlines, submersible farms, floating systems
Economic Impact	Significant employment, export-driven	Job creation, export opportunities	Economic diversification, export potential	Employment, local market
Sustainable Focus	Carbon sequestration, water quality improvement, habitat provision	Carbon sequestration, biodiversity support, water quality improvement	Carbon sequestration, biodiversity support, water quality improvement	Carbon sequestration, biodiversity support
Market Demand	Strong domestic and international demand for kelp-based products	Growing domestic demand, export opportunities	Emerging domestic market, export potential	Increasing consumer interest, diverse products
Regulatory support	Government support, financial incentives, regulations	State-level support, research funding, regulations	Government and provincial support, research initiatives	Varied regulatory approaches by country
Research and innovation	Collaborations with research institutions, innovation in cultivation techniques	Collaboration with universities, research on biofuels and applications	Research on cultivation and commercial potential, extraction of bioactive compounds	Research on cultivation techniques, biodiversity studies
Food and culinary use	Popular in Korean cuisine, various seaweed dishes	Increasing use in salads, snacks, and culinary products	Emerging as a nutritious food source, traditional use in fishes	Used in traditional European cuisine, expanding into modern dishes
Environmental conservation	Supports marine conservation efforts, acts as a natural habitat	Aligns with environmental sustainability goals promote biodiversity	Aligns with environmental sustainability goals and contributes to marine conservation	Contributes to coastal ecosystem health
Export opportunities	Major exporter of kelp products internationally	Expanding export markets, particularly for kelp products	Export opportunities for seaweed products	Growing interest in exporting seaweed products
Community engagement	Engages local communities through education and employment	Involves local communities in harvesting and processing	Supports rural coastal communities, job creation	Engages with coastal communities
Challenges and opportunities	Disease outbreaks, competition, scaling challenges, poor water quality/low nutrients	Regulatory hurdles, seasonal variations, competition	Regulatory challenges, research, and diversification opportunities	Regulatory variations, scaling challenges

Given the promising outcomes observed in these regions, advocating for the expansion of seaweed aquaculture emerges as a potential economic remedy for financially distressed coastal towns in regional Australia, particularly those grappling with the aftermath of COVID-19. In addition to its economic potential, seaweed is recognized as a highly nutritious food source. Its iodine and mineral content (Bath and Rayman, 2013; Bouga and Combet, 2015), protein content (Fleurence et al., 2018, 2012), and other health-promoting compounds that benefit heart and gut health (Brown et al., 2014; Smit, 2004) and cognitive function (Cornish et al., 2017) contribute to its nutritional significance.

Although existing research predominantly focuses on commercially available northern species, emerging studies indicate that Australian species exhibit comparable nutritional value and palatability (Skrzypczyk et al., 2019; Winberg, 2017). The increased production and availability of nutritious seaweed as a dietary choice for health reasons offer substantial social benefits for society, as emphasized by the Food and Agriculture Organization (FAO, 2018b). This presents an opportune moment to establish a future-oriented industry that prioritizes long-term social and environmental outcomes alongside commercial financial returns, aligning with the perspectives of O'Shea et al. (2019). The assessment and prioritization of specific opportunity areas for the development of the Australian seaweed industry have been conducted through this lens.

7.7. Dynamic Capability - Theoretical Overview

The Dynamic Capability concept posits that an organisation's ability to grow in a fluctuating environment is based on its entrepreneurial ability to sense changes in customer and market needs, and to seize the opportunity that prevails through transforming resources (Konopik et al, 2022). Sensing capabilities enable organisations, through environment scanning, to develop, co-develop, and assess opportunities that deliver customer value (Teece, 2018a; Dong et al, 2016).

Seizing capabilities reflect the ability of an organisation to reconfigure, acquire and adapt resources and systems to create a value-capturing mechanism that realizes the sensed opportunities (Mousavi et a, 2018). Value-capturing mechanisms include adapted business models, innovative technologies, and managing partnerships (Hill and Rothaermel, 2003; Teece, 2018b). Transformation capabilities recognize the continuous nature of change and the importance of ensuring the alignment of an organization's business model with its strategy (Helfat et al, 2007).

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