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# **Alternative markets for farmed Scottish shellfish and associated requirements**

**Crown Estate Scotland  
August 2021  
FINAL REPORT**

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## Introduction and Background

This report on alternative markets for farmed Scottish Shellfish and associated requirements has been prepared for Crown Estate Scotland (CES) by SAOS Ltd with support from Scottish Shellfish Marketing Group (SSMG), New Nutrition Business Ltd (NNB) and ThinkAqua.

The report considers prospects for existing and alternative products and services for farmed Scottish shellfish in three areas:

- (a) existing UK retail and foodservice sectors
- (b) markets for nutra / pharma / marine biotech products
- (c) markets for carbon off-setting or other green investment opportunities that might be serviced by bivalve shellfish farming in Scotland

CES has published and is currently undertaking insight and activity on the potential for growth in mussel and seaweed farming around Scotland including the east coast and Clyde coastal areas. As CES issues the leases for aquaculture sites, this investigation will identify added value income streams and growth potential for bivalve farming. The research will contribute and add value to the strategy for developing the sector around the coastline of Scotland and the potential of the pilot projects to benefit from alternative markets considered in this report.

The focus of activity derives from the ambition to grow the Scottish farmed bivalve shellfish sector as outlined in the 2017 Aquaculture Growth to 2030 Strategy and more recently in the Blue Economy Action Plan of the Scottish Government Programme for Government (Sept 2020). Both drivers promote the sustainable growth of aquaculture in Scotland and consideration for economic, environmental, circular economy and social / cultural impact across the rural geographies that rely on the sector's activity.

Growth of the bivalve farming and processing sector will also contribute to the Scotland Food & Drink Partnership's Ambition 2030, whilst opportunities to develop new businesses and address circular economy and environmental investment opportunities will contribute to the resilience of the sector. Opportunities associated with bioactives derived from shellfish and the ecosystem services associated with the farming sites could potentially present new potential markets for the sector.

Whilst opportunities in UK food markets will be subject to several market drivers including the influence of Brexit and the legacy of COVID-19, consumer awareness in the value of credentials that support sustainable food production and the impact that supply chains can have on climate change is rising significantly. Shellfish is a healthy and nutritious food that is farmed in an environmentally sensitive, low carbon manner. Activities that promote provenance, healthy eating options and ecosystem benefits of farmed bivalves in Scotland are platforms of strength and will contribute to the growth of the sector.

Shellfish farming is recognised as a low-impact, sustainable industry producing a range of different products. The majority of production is centred on mussels on vertical single ropes suspended in the water from heavy horizontal ropes and flotation buoys arranged in long lines normally parallel to the shoreline. Scallops can be grown in a similar fashion, hanging from lines or grown in small, suspended net enclosures known as lanterns. Oysters are normally grown in bags made from heavy plastic mesh, either lying directly on the shore or laid on platforms known as trestles.

The shellfish species cultivated in Scotland are all filter feeders from the group known as bivalves. They feed by opening a gap between the shells, drawing in water containing plankton and exhaling the water, having filtered out the plankton and other food particles. The shellfish do not need to be fed by the shellfish farmer, being entirely dependent on naturally occurring food and nutrients from the sea. In a similar fashion, mussel farms are populated by young larval mussels, known as spat, arriving naturally in the tide and settling on the ropes. The natural stocking and feeding means that shellfish farming is considered to be highly environmentally sustainable. It is therefore appropriate to consider other potential income streams based around the environment opportunity as a means to contribute to the growth of the sector and its potential to attract investment.

The shellfish farming sector has been established for over three decades in Scotland, and the latest available figures in 2019<sup>1</sup> included production of around 6,700 tonnes of mussels and 4.7 million oysters – bringing in circa £30m (at retail sales) per annum. The sector has built a reputation for high quality and environmentally friendly food production, which is well received by the consumer. The sector's products are stocked in all UK major multi-national retailers, as well as most seafood wholesalers and many foodservice outlets.

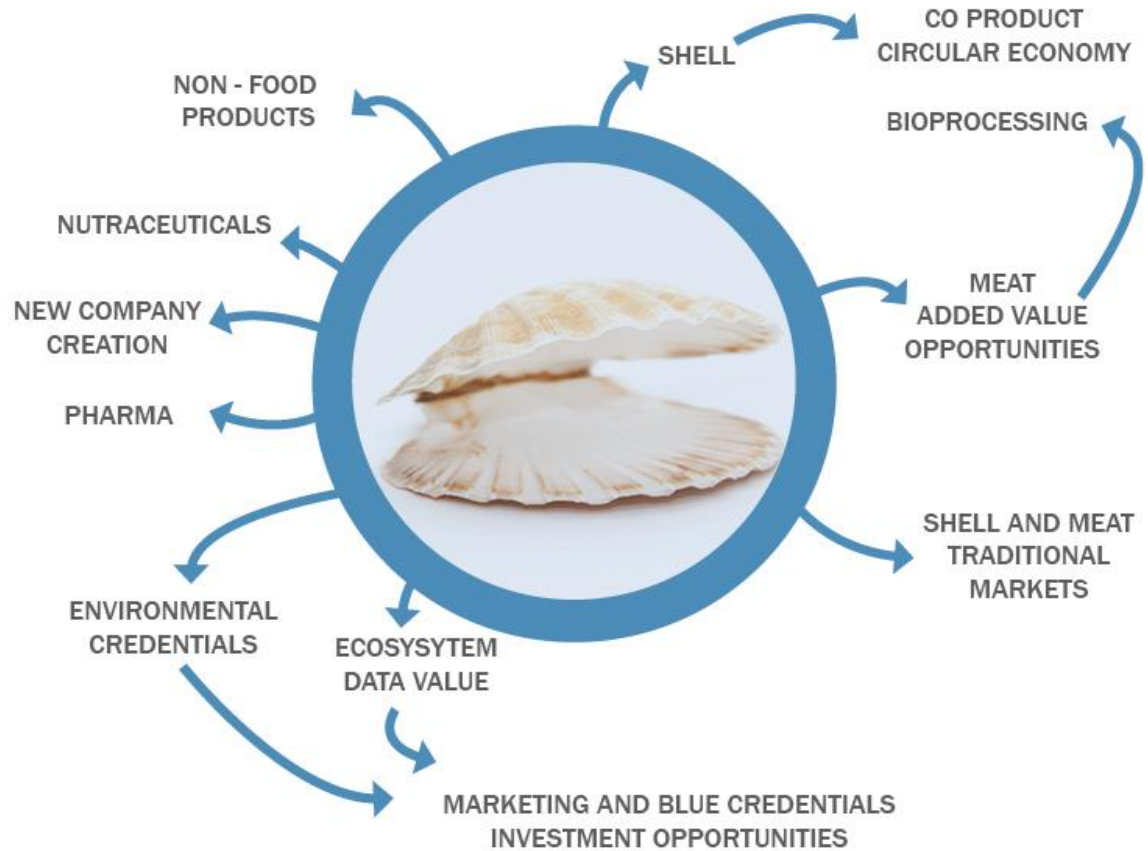
Shetland dominates Scottish mussel production at around 80% of farm output and SSMG represents in excess of 80% of the Scottish mussel sector. Domestic output has been relatively stable over the last ten years, but there is a national vision, and sufficient sea site capacity, to almost triple output by the 2030s to 21,000 tonnes of mussels (as a key component of the shellfish sector's overall target growth). This will achieve an associated increase in the value of all shellfish (following processing) farmed in Scotland to circa £90m (at current prices).

Approximately 5% of cultivated stocks are currently exported from the UK and the remainder enters the domestic UK market, particularly England. During the COVID-19 pandemic, the overall volume of sales has been broadly similar to the preceding period, but with much of the share that was typically absorbed by the catering trade now distributed to new retail customers.

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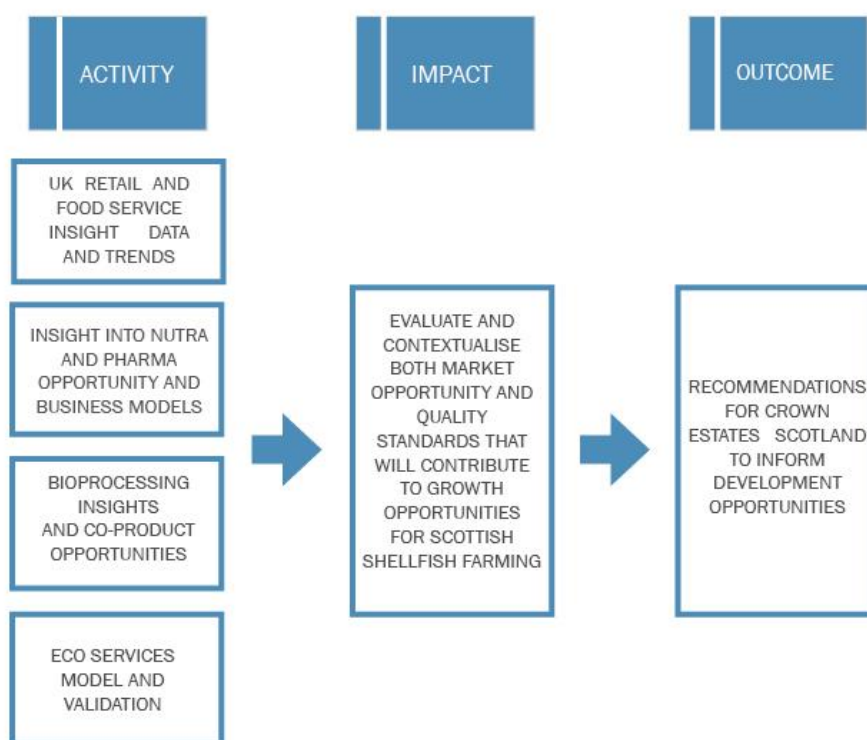
<sup>1</sup> Marine Scotland Data

The diagram below outlines the mapping of opportunities that contribute to shellfish value creation and the proposed deep dive approach of this investigation will build insight as to the potential of these opportunities.



## Approach

A logic chain approach was adopted to provide insight into each activity area from which recommendations to CES could be presented.



The report covers three areas of opportunities which can contribute to shellfish value creation in addition to growth and resilience of the sector. The methodology for each area investigated relied on combinations of both primary and secondary research and the specialist expertise of the partners.

### Prospects for existing and alternative products and services in UK retail and foodservice sectors

The approach relied on access to sector and category data and was informed by attitudes of key buyers in multiple retailers to meet modern markets for bivalves as well as the specialist knowledge within the consortium. A slide deck in Appendix 1 accompanies this section.

### Market prospects for nutra / pharmaceutical products and bioprocessing insights

The approach to this Work Package was a combination of primary and secondary research with analysis of the opportunities together with implications for required quality standards. Primary interviews with selected industry experts, both to identify key insights and to sense check findings from desk research and conclusions, were undertaken by NNB. Secondary research was desk and web based. Appendix 2 contains a slide deck to accompany this

section. Bioprocessing insights was undertaken by desk research and primary interviews with key Scottish SMEs and organisations which are either developing relevant technologies or supporting the bioprocessing sector.

### **Markets for carbon offsetting / 'green investment opportunities'**

Through a combination of desk-based literature scanning and informed interviews, the feasibility of payment for ecosystem services (including sustainable financing for low-carbon footprint food production) and payment for sensor-based data collection, was undertaken. A review of in-farm sensors was undertaken to give an indication of how sensors are currently deployed to capture data.

## Findings & Recommendations

The findings from this research provide insight into both traditional and alternative markets for the Scottish shellfish sector which could contribute to sector growth. Recommendations are framed against a SWOT analysis of the current situation in the bivalve industry in Scotland. Opportunities identified in this report offer a mixture of potential short to medium returns, and longer-term prospects. In particular, the alternative market opportunities identified are not necessarily quick wins and will rely on sector ambition, investment, scale and infrastructure. These alternative market opportunities may be dependent on entrepreneurial players in the sector who are prepared to diversify their business model or who have the investment to manage the risk in developing the market opportunity. In summary, the research indicated that:

- There is considerable scope for further growth of the Scottish industry, both from existing markets and products, and from diversifying into new areas, such as green investment opportunities. Market opportunities for bioactives will rely on bioprocessing capabilities being accessible
- Significant investment will be required to achieve growth in research and in the development of supply chains and facilities
- Scottish provenance and its associations with quality and sustainable production may provide a benefit/ competitive advantage over more industrial-scale producers. Competitor countries with similar values, such as New Zealand, have based their brand on similar messaging
- Certain products for alternative markets require the same high quality material, e.g. mussel powder and oils. These are not seen as waste stream routes from mussel processing, unlike shells which can be used for other purposes
- There are currently no obvious biorefining capabilities of scale in Scotland that would be relevant for the extraction of bivalve bioactives for the nutraceutical value chain. In addition, 'green' extraction processing systems need to be considered to protect the reputation and 'brand'. Sustainability credentials are key drivers for growth
- New business models and partnerships will need to be supported and developed to address the opportunities identified in this research



## SWOT

As part of the research a SWOT analysis of the sector and associated infrastructure was undertaken and summarised below.

<p style="text-align: center;"><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• Capacity to scale up within existing production sites</li> <li>• New production sites available</li> <li>• Reputation for quality associated with Scottish provenance</li> <li>• Established routes to market in UK retail and foodservice</li> <li>• Defined industry growth strategy</li> <li>• Some production and research innovators collaborating</li> </ul>	<p style="text-align: center;"><b>Weaknesses</b></p> <ul style="list-style-type: none"> <li>• Fragmented supply chain</li> <li>• Lack of necessary processing/ extraction facilities in Scotland/ UK for nutra/ pharma routes</li> <li>• Historical lack of investment in industry focussed research compared with other countries (e.g., New Zealand)</li> <li>• Lack of entrepreneurial culture in the industry</li> <li>• High levels of investment required in scale-up phases of growers</li> </ul>
<p style="text-align: center;"><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• Maximise potential from current production sites and open new sites in new locations including East Coast</li> <li>• Increase revenue from the whole bivalve, including co-products</li> <li>• Increase penetration of retail and foodservice markets</li> <li>• Increase consumption by existing shellfish consumers via NPD – focus on convenience and ‘on the go’</li> <li>• More targeted communications re sustainability and health credentials of Scottish bivalves compared with other proteins</li> <li>• High growth premium pet food market in UK/ export (China?)</li> <li>• High value nutraceutical/ supplement products such as mussel oil</li> <li>• Valuing ecosystem services to add new revenue streams</li> </ul>	<p style="text-align: center;"><b>Threats</b></p> <ul style="list-style-type: none"> <li>• Entry by low-cost, large scale producers from, e.g., Chile/ China</li> <li>• Price/ market volatility</li> <li>• New post-Brexit trade deals which may benefit competitor countries</li> <li>• Climate change</li> <li>• Complacency / comfort with the status quo</li> <li>• Dredged mussels v rope grown</li> </ul>

From the three diverse areas of this research and the SWOT analysis, opportunities within each were prioritised on the basis of foreseeable market trends, existing infrastructure as well as a more visionary outlook over a five to ten year timescale. Each has the potential to contribute to the proposition for growth and investment of the sector.

## Short to Medium Term Priorities

The key priorities are highlighted here. Further insight is provided within the specific sections of the report along with more detailed summaries at the end of each section.

### Consumers and Food Markets

- **Increase Consumption** - UK market penetration remains low. Use promotional opportunities and ongoing awareness-raising to existing and new retail and foodservice customers to grow this market. Potential exists to sustainably triple sea production and overall sales of mussels alone to £60m by the 2030s
- **Innovation** – continue innovation in flavours, formats and sustainable convenience packaging
- **Sustainability and Health Credentials** - invest in targeted campaigns to raise awareness of sustainability and health benefits of Scottish bivalves vs other protein sources. This should be aimed at key consumer groups – existing consumers of bivalves, regular consumers of fish & seafood, fitness/ sports/ diet enthusiasts, etc. This should equally apply to added value ingredients e.g., sauce ingredients
- **Collaboration** – encourage the supply chain and its supporting organisations to work together to achieve maximum commitment and impact
- **Import Substitution** – with the potential to sustainably triple outputs by the 2030s, the opportunity to displace imports should be explored
- **Explore Export Opportunities** - to non-EU markets, particularly China/ Asia
- **Frozen Products** – the frozen mussels category offers an opportunity for future growth both at home and internationally
- **Technology, Research and Academia** – technology, knowledge and skills will be required to support the prospective growth of the sector to optimise cultivation techniques; share best practice and make best use of data and digital information systems

### Alternative Markets

Potential areas of opportunity are identified as follows, i.e.:

1. Human health particularly from derivatives of mussel oil
2. Pet health/pet food ingredient
3. Plant and soil health

Mussel oil now accounts for 12% of the mussel export market for New Zealand and contributed NZ\$51m in 2020 (£25.9m).

- **Nutritional Profile and Bioavailability of Key Compounds** - research into blue mussels vs New Zealand green lipped mussels is recommended to understand whether or not comparable claims can be made. If this is the case, it will be easier to expand on the link already present in the minds of certain consumer groups between mussels and health benefits, such as joint health associated with humans and pets
- **Bivalve Waste Streams** - compile a detailed picture of the current Scottish output – by species, type of waste and geography. This will be necessary to fully evaluate the scope for bioprocessing/ nutraceuticals
- **Mussel Oil Opportunity** – given the potential for a premium product to compete in the marketplace, further investigation into the commercial opportunity for a Scottish mussel oil product should be undertaken
- **Plant and Soil Health** - research other opportunities for shellfish by-products as sources of blue bioactives. The inclusion of shellfish shells in compost is an example of a circular economy outcome where chitin can help control Potato Cyst Nematode
- **Business Models** – further consideration and consultation is required with high profile Scottish shellfish players as to whether partnerships with biorefining enterprises offer a commercial opportunity to explore alternative markets
- **Sector-wide Investment to Expand Production and Processing** – growth will require an expansion of production particularly in mussel farming for both the food and alternative market opportunities. Mainstream and alternative markets processing will require significant investment for growth
- **Collaboration** – is required across research, marketing and communications to maximise impact in reaching alternative markets

### **Carbon and Sustainability**

- **Carbon Capture** - Conduct definitive research on the carbon capture potential of mussels in Scottish production systems in order to support market claims and the potential to access blue carbon finance. Sequestration may be comparable to seaweed and forestry and as mussels have, by far, the lowest carbon footprint of any animal protein, there is a story to be told. SAIC could be encouraged to provide funding to help develop the evidence required to support this approach. Discussions with blue financiers should be initiated immediately because there is already a strong, positive story to tell

- **Payment for Ecosystem Services (PES)** – consider the option to develop a clear set of criteria for PES payments to reward shellfish farmers for making improvements to their systems and, in turn, enhancing environmental quality or gathering data to contribute to wider environmental management systems
- **Policy** - ASSG, Seafood Shetland, SSMG, CES, Marine Scotland and others need to continue to push the shellfish agenda strongly, particularly in the development of local marine plans and in the roll-out of the Blue Economy Action Plan. They also need to demonstrate the value of shellfish farming and initiate discussions with wind farm and other marine-space operators, including salmon farming, for co-location and to have discussions with the same users to explore data needs
- **Collaboration** - Identify researchers and funders to develop the evidence to support the collaboration that will be required to achieve these actions
- **New Sites and Pre-licensing** - Crown Estate to explore with legislators and potential new investors, the prioritisation of new sites and the value of pre-licensing sites to help expansion happen more easily. Work closely with all sectors and interest involved in marine spatial planning to encourage a smooth process

## Longer Term Priorities

### Consumers and Food Markets

- **Sustainable Growth** – continuously assess, amend and deliver on the priorities established in the short to medium term highlights
- **Sustainability and Provenance Drivers** – integrate sensor-based data capture through supply chain and at point of packaging, to validate provenance characteristics to the consumer
- **Smart Shellfish Farming** – support uptake of smart farming practices and infrastructure that will add value and contribute towards growth ambitions of the sector

### Alternative Markets

- **Investment Opportunities** - explore investment options for extraction/ processing facilities in Scotland. This may involve partnering with other industries such as salmon/ pelagic fish processors to maximise usage. Research suggests the costs of establishing new bioprocessing capacity are relatively high and are dependent on the type of extraction involved, the scale and location. Estimates range from £4m to £15m
- **Investigate Best-fit Extraction Techniques** – freeze-drying/ HPP/ snap drying/ supercritical fluid extraction – for blue mussels and target products
- **New Business Models** - develop and support new business models through actioning progress in the various components of this research. It may be that the companies who will attract investment, or operate future farms, will be very different from the make-up of the industry at present, especially if the drivers and scales shift significantly

### Carbon and Sustainability

- **Sensor-Based Data Collection Opportunities** – given the emerging technology solutions and limited uptake, a robust value proposition (for both PES and farm decision making) for farmers needs to be developed and trialled with Scottish shellfish farms
- **Low Carbon Additional Incentives** - The low carbon value of Scottish Shellfish has the potential to provide investors with additional incentives such as the opportunity to develop market opportunities for the payment of ecosystem services which a view to grow and increase returns in the longer-term vision of the sector

The research identified that each of the three development areas (traditional markets, nutra /pharma and carbon capture) offer opportunities for the development and growth of the Scottish bivalve sector, but the lack of bioprocessing capacity in Scotland presents significant challenges. Evidence from the examples explored in other countries, suggests that the most robust, sustainable model for Scotland would include all three elements. This would strengthen the long-term prospects of the sector by reducing risk and creating a more market-responsive industry with a diverse portfolio of income streams and better able to withstand economic shocks (such as the closure of the foodservice market during the COVID-19 pandemic). Accordingly, we would strongly recommend developing a strategy which harnesses all three aspects.

## Recommendations

### Market & consumer perspective

1. Investment in activity to drive new shoppers into the category through a combination of:
  - ✓ marketing activity in store and with customers to raise awareness and encourage trialling
  - ✓ adding to this the importance of innovation to keep the added value product relevant to today's market, consumer, emerging flavours and convenient easy to cook products
  - ✓ specifically communicating the sustainability benefits of Scottish grown mussels and telling the story of the natural product and its positive impact on the environment
  - ✓ climate friendly packaging to reinforce these credentials right through to fork
2. There is potential to develop frozen capacity to target new sales in the UK foodservice market, particularly in restaurants and bars.
3. Building on the provenance and sustainability credentials of Scottish grown mussels there is an ongoing opportunity to explore new opportunities in export markets.

### Nutra / pharma products

1. Undertake a research project into the comparative nutrition profiles of *Mytilus edulis* (blue mussel) and *Perna canaliculus* (NZ green-lipped mussel). This should encompass the nutrition profiles both in the raw state and after various extraction methods. This will provide baseline comparative data which can be used to establish the health credentials of the blue mussel, which can then be used as a basis for NPD and communications for human and animal nutrition products. This is likely to highlight further research projects to underpin industry development and ideally leading to a working group whose role it is to oversee a rolling programme of industry focused research projects similar to the existing New Zealand model.
2. Establish a working group, led by the shellfish industry and possibly with representation from other interested industries (seafood, salmon, soft fruit) with the purpose to explore levels of interest in extraction / biorefining facilities for the production of high value nutritional products possibly from second grade raw materials. This group should also include industry organisations and public sector (HIE, SE) particularly SDI as this may present an opportunity for an inward investment which will have significant benefit for the Scottish food and drink landscape. Access to funding will be key to building capacity in biorefining. Any extraction facilities established should be targeted at producing the highest quality extract possible and have access to the very latest technologies which may offer a competitive edge.

3. Any nutraceutical opportunity, such as mussel oil or any other high value extract should be focused on quality rather than quantity, as Scotland is unlikely to be able to play successfully in commodity markets with large industrial producers.
4. Further research into the requirements of the pet/ animal feed opportunity as this has the potential to generate significant income from opening up a lucrative growth market in the UK. Research is required to:
  - ✓ establish baseline data on quantities, quality specifications, formats, etc.
  - ✓ develop a strategy and roadmap for the mussel industry in targeting this growth industry

### **Markets for carbon off setting and other green investment opportunities**

1. Findings from the Critical Mass Study and earlier CES Payment for Ecosystem Services Report should be combined with the low/blue carbon story and data opportunities to input into further, detailed modelling that would support the pre-approval of sites that could attract new investors and bring new business models in new areas.
2. At a policy level, ASSG, Seafood Shetland, SSMG, CES, and Marine Scotland need to continue to push the shellfish agenda strong, specifically highlighting the low-carbon nature of the sector, particularly in the development of local marine plans and in the roll out of the Blue Economy Action Plan.
3. The Shellfish Aquaculture Growth Plan of the Shellfish Working Group should include specific actions around Payment for Ecosystem Services research and roll-out, alongside blue carbon opportunities and the need for greater data to support industry sustainability and growth. This also builds on increasing Scotland's reputation for clean waters.
4. SAIC could be encouraged to provide funding to support the detailed development of the low carbon and Payment for Ecosystem Services aspects of this report, including through innovative systems for greater collection and use of data, to support the shellfish farming sector to produce effective communication materials that will support input into policy and industry development work.



## Prospects for existing and alternative products and services in UK retail and food service sectors

### Introduction

The potential for growth of mussels in UK retail is significant, considering that only 15% of the population currently buys mussels at least once a year. This number has steadily grown over the last ten years from around 10%, through a mix of promotional and marketing activity. The marketing credentials around the sustainability of Scottish rope grown mussels and their healthy nutrition provide a real opportunity for future growth as pressures to eat better and environmental sustainability become stronger purchase drivers. This collateral is equally important for retail and foodservice markets and, when combined with local Scottish provenance, the industry is in a strong position to capitalise.

Product format is key to maintaining and growing the market opportunity. For instance, where convenience is a key driver of the purchasing decision, then added value product packs will be important. This trend will continue to improve profitability in the processing sector given its greater margin over live product. Live mussels will always have a place with customers, but their supply will also require innovation to ensure they remain relevant to a younger customer. While Shetland mussels dominate the UK retail and wholesale markets, there is still much potential to drive sales through increased listings in restaurants, particularly the national chains.

Further insight is available in Appendix 1. Reflections from SSMG customers (e.g., ALDI, Morrisons and M&S) have been captured as part of the insight gained in this research.

### Key Findings

#### Market Background

Grocery and foodservice markets have been particularly impacted as a result of Covid-19 and as these markets enter a pandemic recovery phase, identifying the key insights associated with these channels provides a relevant backdrop for commercial activity.

- Covid-19 has impacted sales of food and drink in both the grocery retail sector as well as out of home/foodservice with the market contracting from £200bn in 2019 to £174bn in 2020. Foodservice's share of the market has dropped from 36% to 19%. Grocery sales have grown as the impact of lockdowns has driven in home dining and eating; however, we are now seeing a slowing of sales in grocery as shopping habits begin to return to pre-Covid times
- Online sales have grown during 2020 and are now worth around 13% of grocery sales. This growth was driven by lockdown restrictions on movement and shoppers' reluctance to visit stores in person. Whilst growth has now slowed, the channel will remain a popular option and has almost doubled in size over the last 15 months. The convenience sector and high street also saw growth during 2020 as shoppers shopped local

- Home deliveries from takeaway restaurants and other foodservice outlets who pivoted their offering in 2020 have grown in popularity as consumers treated themselves. It is forecast that this trend will continue and with penetration sitting at 43% there is still more room for this channel to grow
- As the world emerges from lockdown in differing stages and the recovery begins, it is unlikely that the out of home market will return to 2019 levels until well into 2022
- As the markets begin to return to normal, we expect that the trends that were emerging in the pre-Covid marketplace will begin to re-appear including – Health, Digitalisation & Technology, Sustainability and Provenance
- Brexit has had an impact on UK exports with additional paperwork and costs being cited as two of the major issues. The seafood sector in particular has experienced major problems associated with the time taken for products to reach markets and the paperwork complications associated with groupage orders (orders containing different boxes of fish for one customer but from several suppliers each needing their own paperwork).

The road to recovery in the UK has now begun and with that we will see a re-balancing of where consumers spend their discretionary income, switching some back from grocery to hospitality. It will, however, take time for hospitality to rebuild and for consumers to have confidence in re-engaging with this sector which still has an impact on revenue generation for operators. Grocery sales are beginning to slow as we see an annualisation of sales versus the peak of 2020 and Covid imposed lockdowns and restrictions. Sales remain higher than 2019 levels demonstrating the continued importance of the grocery sector for food shopping in the UK.

### **Seafood Market Background**

An insight into the UK seafood market provides evidence for habits resulting from lockdown phases and how this impacted on in-store points of sale. Key highlights (slides 17-22, Appendix 1) include:

- The seafood market in the UK is made up of Grocery sales (£4.2bn) and Foodservice/Out of Home sales (£4.8bn). We export £944m and import £3.5bn.

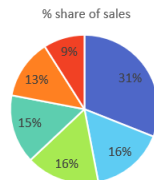
The seafood supply chain is comprised of many parts – consumption, processing and imports and exports. Sales of seafood in the UK total £9bn and we export £944m of which c.60% is salmon, it is also our biggest food export. We also import £3.5bn of seafood



**Grocery Retail:**  
**£4.2bn**



**Out of home:**  
**£4.82bn**

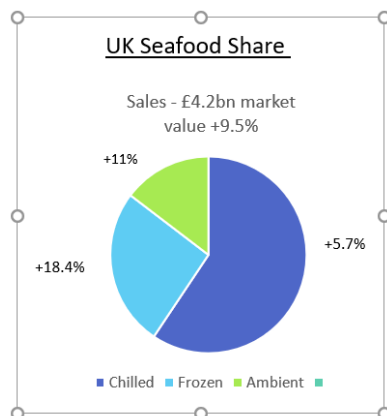


■ Quick Service Restaurant ■ Full service restaurant  
■ Fish & Chip Shops ■ Pubs  
■ Travel & Leisure ■ Worplace & Education

Source: Seafish Factsheets – Seafood Supply Chain

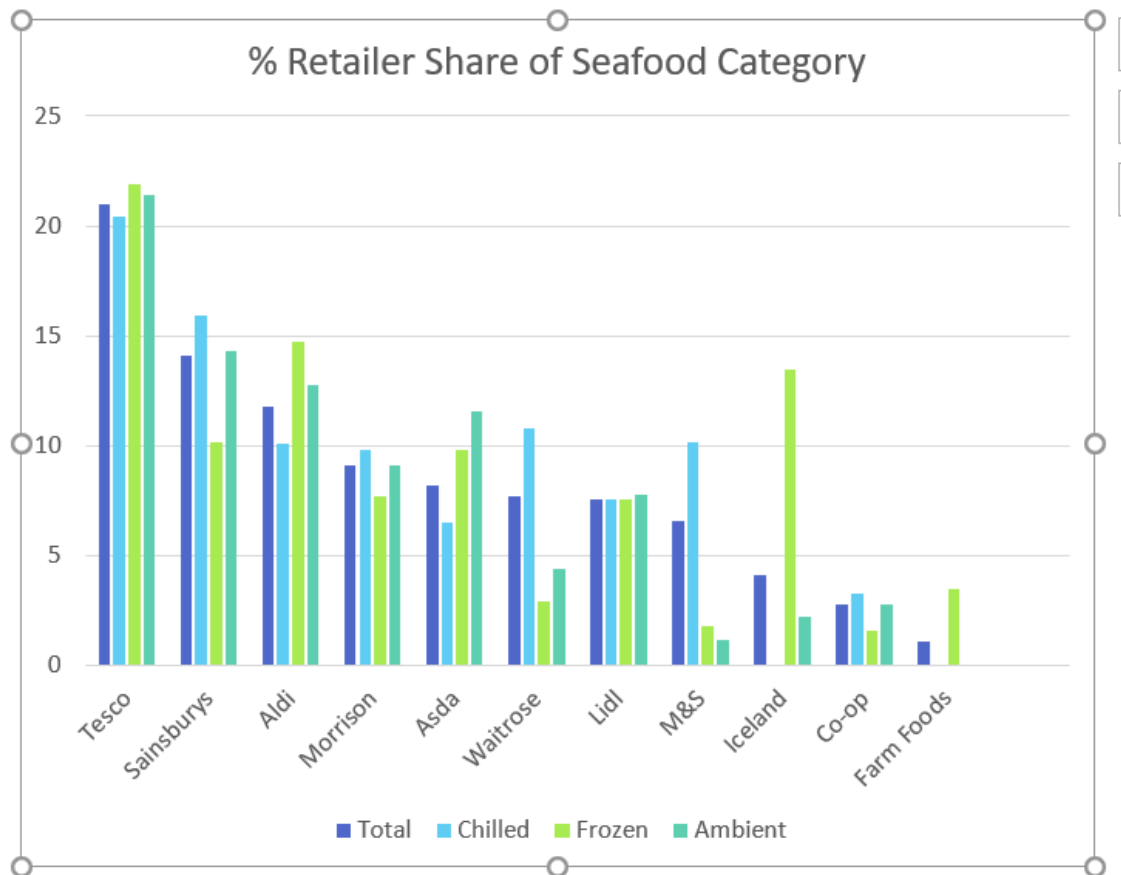


Sector	Estimated Scottish Exports Value in 2018
Drinks	£4.36bn
<b>Fish</b>	<b>£944m</b>
Cereals	£179m
Animal Feed	£174m
Meat	£99m
Fruit & Veg	£62m
Dairy & Eggs	£49m
Misc.	£41m
Sugar	£23m
Coffee, Tea	£21m
Oils & Fats	Negligible



- Sales of seafood in grocery were +9.5% when comparing 2020 sales with those in 2019. Chilled sales account for 59% of all sales (+5.7%), frozen account for 26% (+18.4%) and ambient sales are 15% (+11%). Some of the strength in frozen and ambient sales will be attributed to shopping habits during lockdown where shoppers stocked up on frozen and tinned goods at the beginning of Lockdown 1.

- Two retailers (Tesco and Sainsbury's) closed some of their fish counters during lockdown to re-deploy staff elsewhere and due to lower footfall in stores as some shoppers switched to online food shopping. The growth in pre-packed fish helped to compensate for loss of sales, however there is a realisation that in many stores, these counters will not re-open
- Tesco is the biggest retailer of seafood in the UK with a 21% share



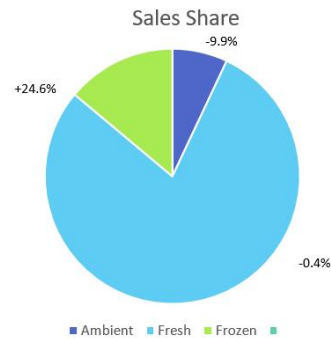
- The top 3 species – salmon, cod and tuna account for £2bn of sales in grocery
- Mussels is the 18<sup>th</sup> placed seafood species in grocery with sales worth £25.4m
- Scallops are in 21<sup>st</sup> place, with £18.8m of sales
- Oysters are the 38<sup>th</sup> most popular with only £1.4m of sales
- When comparing sales of mussels in 2020 with 2019, growth was up +1.7%, but all of it was from frozen sales (+24.6%), with ambient sales falling (-9.9%) and fresh mussels' sales flat. Looking at the volumes sold in 2020 versus 2019, sales have grown by +12% driven by sales of fresh mussels (+13.9%) and frozen mussels (+5.5%). This could suggest that prices have dropped and/or there are bigger packs being sold.

## Mussels

Slides 23 to 31 provide further insight into this category in Appendix 1:

Mussel sales in GB grocery total £24m, with fresh accounting for 79% of total sales

- 2.9m mussel shoppers
- £24m category values
- 4.6m kilos of mussels
- 3 sub categories – fresh, ambient and frozen
- Added value products are the most popular



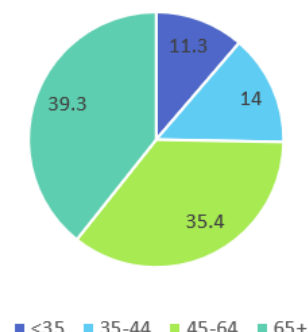
Source: Nielsen Scantrack and Homescan 2020

- In 2019 there were 6,700 tonnes of mussels grown in Scotland with a £6.8m value at farmgate. 71% of production comes from Shetland. Most Scottish production is destined for the UK market
- The UK produces 25-30,000 tonnes annually of which one third of this volume is used domestically and the rest mainly exported to the EU. There are 550,000 tonnes of mussels grown in Europe – Spain is the largest producer with 200k annual tonnage, France produces around 80,000 tonnes and Italy 65,000 tonnes
- We import 3,600 tonnes of mussels into the UK (2018) in the main from EU, Chile and New Zealand ranging from occasional live imports from Holland and Ireland to frozen, marinated and pickled mussel meat formats from Chile and EU
- Mussel sales account for £24m of sales in UK grocery
- Sales and volumes in grocery retail both increased in 2020 with sales +1.7% and volumes +12%. However, the number of shoppers buying have decreased in the last year, meaning existing shoppers were buying more at lower prices
- Sales of chilled mussels dominate the category accounting for 59%, followed by frozen accounting for 26% and ambient 15%
- 2.9m people bought mussels in the grocery channel. The majority of shoppers buy fresh mussels (2.2m shoppers). In the last year the number of shoppers buying fresh mussels

decreased by almost 6%. There was a small increase in the number of shoppers buying ambient (+0.3%), whilst the number of shoppers buying frozen mussels increased by 15% to 739,700. It is thought that changes in buying patterns will have been impacted by Covid purchasing in grocery where there was an element of stockpiling ambient and frozen goods in the early lockdown phase

	No. of Buyers 28/12/19	No of Buyers 26/12/20	Buyers Change %
Total GB	3,019,834	2,913,539	-3.5%
AB	33.0	33.1	-3.1%
C1	24.8	24.4	-5%
C2	21.7	22.2	-1.7%
D	8.0	9.6	+15.1%
E	12.5	10.8	-16.8%

Age of Buyer



- The socio-economic group AB (typically higher income workers) account for 33% of mussels' buyers in the grocery channel. It is however the socio-economic group D (typically classified as lower income who have seen their numbers grow most in the last year and by 15% whilst all other groups have fallen. This could be attributed to the success of mussel sales in Aldi and Lidl
- Mussels are sold in a variety of ways in grocery retail including fresh in a net, fresh in other packaging (MAP) fresh in a sauce (vacuum packed), in tins and jars and as frozen mussel meat (with shells off)

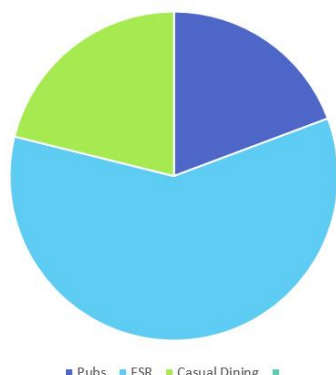


- In the UK there were 7.3m packs of cooked mussels in a sauce sold in 2020 representing c.£15m of sales and representing the most popular pack format type
- SSMG are the leading manufacturer of added value mussels in the UK producing both branded and own label products
- Live mussels account for 858,000kg in grocery. These sales will mainly be driven via counters and innovative packaging solutions that allow the fresh product to be sold in

packaging that is environmentally friendly and easy to handle, being developed for counters in selected retailers

In the out of home market, consumers are most likely to eat mussels in a restaurant which account for 60% of portions consumed or 4.67m meals. This equates to penetration of 0.35% and tonnage of 2.3k – 3.5k\*

No of Portions in Out of Home Market



\* Source Seafish research. Tonnage estimates are based on 500b portion and 750g portion and 4.67m meals

- Within the foodservice sector, the majority of mussels are eaten in restaurants (60%), followed by casual dining (21%) - a full-service restaurant with a fun, comfortable, laid-back atmosphere and affordably priced menu - and pubs (19%). It is estimated that there are 4.7 million mussel meals portions eaten in this sector annually equating to between 2,300 tonnes to 3,500 tonnes, with a penetration rate of 0.35%, which is considered to be low

## Current Scottish Supply

Scottish rope-grown mussels are a healthy and nutritious food that are farmed in an environmentally sensitive, sustainable and low carbon manner.

The Scottish shellfish sector is ambitious – the overarching view of the ambition / opportunity relies on growth and structure both at a farming level and through the supply chain. The insight highlighted for existing and alternative products and services in UK retail and food service sectors provides a selection of market drivers which will contribute to achieving growth across the sector.

SSMG is the UK's leading producer and processor of mussels. It is a marketing co-operative of nineteen mussel and oyster farmers (including eleven farms in Shetland and two farms in the Western Isles), with a processing site in Bellshill which is well situated to service the needs of its grocery retail and foodservice customers. As a co-op, its primary aim is to ensure a reasonable return for its members' produce, benefiting the communities in which the rural farms are located and helping to provide a long-term sustainable basis for future growth and



investment in the sector. Over the last decade the business has grown to a turnover of around £25m and it has ambitious plans to grow mussel sales by 40% over the next five years.

SSMG is viewed by its customers (all major multiple grocers in the UK and including Tesco, Asda, M&S, Morrisons, Aldi, Lidl) as the market leader and go-to business for domestically grown mussels. It currently supplies over 95% of UK multiple retail mussels in sauce and 100% of live mussels in the same market. It also has an increasing presence in the wholesale and foodservice markets, primarily from its facility in Shetland. The coop sells circa 1,200 tonnes of member's live mussels to these markets and is a critical player in delivering new and existing market opportunities to achieve the retail, wholesale and foodservice growth ambition of the sector.

### **Growth Potential of the Supply Chain and Support**

As experts in the sector, SSMG's own analysis of the market and production growth potential confirms that, to meet the Aquaculture Growth to 2030 strategic vision, there is sufficient sea site capacity to more than double output by the 2030s to 21,000 tonnes of mussels per annum. Additionally, there is an associated increase in the value of all shellfish (following processing) farmed in Scotland from c£30m to c£60m (at current prices).

Significant progress towards these targets, however, will require sector-wide investment: notably in data capture and analysis; upgrading of current mussel boats to build capacity; and improving skills resource across the supply chain. To a lesser extent, upscaling production/ added value processing capability will be required, although capacity mostly already exists in the Scotland, the UK and beyond.

Effort and resource are planned by SSMG for the near future to enhance smart production through facilitating a unique matrix of exciting collaborative research and innovation strands. The business has ambitious plans to expand mussel sales by 40% over the next five years.

Capacity and capability will also be developed in the tertiary education sector in Shetland and elsewhere, whilst simultaneously transforming and evolving mussel production into a knowledge-based sector.

Understanding will be developed in three critical areas that will contribute to the growth of the sector through:

1. Improving the security, reliability, and survival of spat (juvenile seed) inputs
2. Optimising cultivation techniques that will include the modelling of production environments to improve farm yields efficiency and raw material quality
3. Identifying and sharing best practice to drive farm and quality improvements through analysis of farm-generated data and processes



Developing and delivering these assets and capabilities will provide a solid foundation to grow the sector both organically and exponentially by winning a larger market share of current competitor activity, encouraging more consumers to eat mussels. SSMG believe this direct food market opportunity is achievable.

## Conclusions – Key Points

The prospects for existing and alternative products in the UK retail and foodservice sectors are key when considering the growth potential of the Scottish shellfish sector. Consumer trends, as always, drive innovation and add value in product lines. Meeting consumers' aspirations around sustainable sourcing lends itself to both messaging and the use of technology to verify provenance (Slides 33-40, Appendix 1).

### Consumer Mediated Trends

- The biggest opportunity to grow the mussels category in the UK is to encourage existing consumers to consume more (either at home or out of home) as well as attracting new consumers to the category both in grocery and in the out of home sector
- UK market penetration remains low in both retail and foodservice leaving significant potential to grow. Only 15% of the population currently buy mussels at least once a year. Consumer education to encourage consumption of more shellfish would be greatly beneficial to encourage consumers not familiar with the product to indulge. For every 1% increase in penetration in grocery, this adds an additional 29,000 shoppers to the category
- The success of meal deals offers an opportunity to attract new consumers to the category
- Continued innovation in flavours for the cooked mussels in sauce sub-category will also be key to match the flavour trends that are impacting our menus and pallets. New flavours will also help to attract new consumers
- Convenience both in packaging and cooking formats will also be key in the take-home market
- Consumers have become more accustomed to treating themselves at home and event marketing offers an opportunity to capitalise on this going forwards, e.g., St Valentine's Day, Mother's Day, Father's Day, 'Mussels and Frites Day'

### Sustainability and Provenance Drivers

- Messaging around sustainability and the climate friendly values of mussels needs to be continued and strengthened to match the mega trends that are developing. This could be achieved by marketing in store, on packaging, on menus, above the line media and social media. The maximum benefit would be achieved by growers, suppliers and customers working collaboratively, including enlisting the support of Seafish and other relevant trade organisations
- Continued focus on sustainable packaging will be core as will ongoing evolution of convenient formats

- Sustainable sourcing of added value ingredients will be important as will a focus on net zero in farming and manufacturing whilst communicating this to customers and consumers

## **Trade**

- The opportunity to displace imports should be explored
- Exports also offer future potential for growth. Most European countries consume more seafood than the UK. Scottish mussels have a fantastic provenance which will appeal to seafood consumers not just in Europe but further afield. An exploration of products consumed in international markets and routes to market should be investigated further
- The frozen mussels category offers an opportunity for future growth both at home and internationally
- The success in Aldi and Lidl demonstrates the opportunity to further grow the category with a consumer/shopper who might not typically have considered buying mussels
- Brand/product growth can be stimulated by being available everywhere and being front-of-mind and innovative
- Selling online has grown and has almost doubled in size over the last 15 months and has established itself as an important shopping channel with subscription boxes; direct to consumer sales; and through multiple retailers which is the main route to market for this category. It is important that suppliers into this channel maximise the selling opportunity through effective positioning within customer websites, dealing with direct consumer orders in a timely way and ensuring the product reaches the customer in first class condition in safe and robust packaging

## Market Prospects for nutra / pharmaceutical products and bioprocessing of Scottish shellfish

### Introduction

Bivalves such as mussels and oysters are good sources of:

- Omega-3 EPA/DHA
- Potential anti-inflammatory agents (E and D resolvins)
- Protein (complete protein)
- Several minerals and vitamins
- Extraction of collagen is also possible from bivalves although not cost-effective with current technologies

Of all bivalves, mussels are the most recognised source of nutraceutical/pharmaceutical extracts thanks to decades of activity by the New Zealand green lipped mussel (*Perna canaliculus*) industry and there is a strong consumer association between green lipped mussels and joint health. New Zealand has successfully capitalised on the health properties and provenance of this species to secure a premium point of difference in nutra and pharmaceutical markets and developed a robust supporting supply chain. The predominant species in the UK is the blue mussel (*Mytilus edulis*) which is a much less researched species, although the nutritional profile in many respects seems very similar to the green lipped mussel.

Mussels can be fractionated into shell, meat, byssal threads and extracellular fluids with the shell accounting for 70-80% of this mass whilst the extracellular fluid is minor but contains very niche bioactives. As with fresh mussels for food, mussels diverted for the extraction of certain value add components have to be processed rapidly to avoid deterioration of the required bioactive components, although deteriorated components may still have value in low value applications.

The shell contains a complex bio-composite that includes protein, glycoproteins and minerals and pigments which through extraction may have niche high value applications but has potential for low value markets such as composting (with adherence to time / temp protocols as determined by legislation). Mussel meat contains a mix of protein, carbohydrate and lipids. The latter is attribute to the potential anti-inflammatory properties associated with green lipped mussel extracts for bone health applications. To date, blue mussels' meat is used for culinary purposes and no functional food extract for blue mussel meat fractions exist.

To investigate the potential alternative market opportunities, the approach undertaken by NNB in this study focussed on:

- A combination of both primary research (interviews with trade organisations, companies and industry experts in the international shellfish industry)

- Secondary desk research
- Best practice case studies from the leading globally recognised New Zealand green lipped mussel (*Perna canaliculus*) industry (Although a different species from the blue mussels (*Mytilus edulis*) cultivated in the UK, the development of the New Zealand industry provides much relevant insight for any plans to expand the Scottish mussel industry).

The methodology was designed to provide insight as to the prospects and considerations associated with this route to market including:

1. An assessment of nutra and pharma market opportunities available, including any barriers identified, and recommendations for best fit for the Crown Estate
  2. An assessment of the competitive landscape including key company case studies
  3. Any opportunities presented by Scottish provenance which offer potential for premiumisation
  4. An estimation of the value of the opportunity in the key markets where possible
- Any growing or emerging product categories or trends which offer opportunities for new entrants
  - An overview of consumer segments where applicable, including drivers, purchasing behaviour, consumer beliefs and any barriers or other issues
  - An overview of the main purchasing channels in key markets
  - An assessment of Scotland's bioprocessing capabilities to support this

## Key Findings

### Key Attributes of Shellfish for Nutraceutical Value Chain

The market prospects of bivalves as candidates for successful nutra / pharmaceutical products relies heavily on their nutritional value and the ability to extract these nutrients for a health-based value chain. The following narrative is supported by the slides in Appendix 2:

#### 1. Nutrition Overview of Mussels and Oysters

Bivalves such as mussels and oysters are recognised as good sources of nutrients, essential amino acids, Omega-3 EPA/DHA, complete protein, several minerals and vitamins and a range of potential anti-inflammatory agents (E and D resolvins). Although lower in protein than other animal foods, mussels may be a more sustainable animal source of protein.

## Nutritional comparison of raw oysters and mussels (from Slide 11 and 12, Appendix 2)

	Oysters	Mussels
<b>Energy (kcal)</b>	65 - 81	74 - 86
<b>Protein (g)</b>	9,45 - 10,8	11,9 - 12,1
<b>Fat (g)</b>	1,3 - 2,3	1,8 - 2,24
<b>Polyunsaturated (g)</b>	0,4	0,6
<b>Monounsaturated (g)</b>	0,2	0,3
<b>Saturated (g)</b>	0,2	0,4
<b>Carbohydrates (g)</b>	4,9	2,5 - 3,7
<b>Sugars (g)</b>	Trace	Trace
<i>Vitamins</i>		
<b>Vitamin A (µg)</b>	75	0
<b>Vitamin E (µg)</b>	0,9	0,5 - 0,7
<b>Thiamin B1 (mg)</b>	0,06 - 0,2	0,1
<b>Riboflavin B2 (mg)</b>	0,2	0,21 - 0,4
<b>Niacin (mg)</b>	1,8	1,6
<b>Vitamin B6 (mg)</b>	0,05 - 0,2	0,05 - 0,1
<b>Vitamin B12 (µg)</b>	17	12 - 19
<b>Folic acid (µg)</b>	0	37

	Oysters	Mussels
<i>Minerals</i>		
<b>Sodium (mg)</b>	510	290
<b>Potassium (mg)</b>	260	320
<b>Calcium (mg)</b>	140	26 - 38
<b>Magnesium (mg)</b>	22 - 42	23 - 34
<b>Phosphorus (mg)</b>	162 - 210	197 - 240
<b>Iron (mg)</b>	5,7	3,9 - 5,8
<b>Copper (mg)</b>	7,5	0,2
<b>Zinc (mg)</b>	59,2	2,5
<b>Chloride (mg)</b>	820	460
<b>Selenium (µg)</b>	0	51
<b>Iodine (µg)</b>	60	140

## Nutritional comparison of cooked green lipped and blue mussels (from Slide 13, Appendix 2)

	Green-lipped Mussels	Blue Mussels
Energy (kcal)	105	172
Protein (g)	18,8	24
Fat (g)	3,1	4
Calcium (mg)	173	33
Omega-3 Fatty-acids (mg)	850-900	850-900
Copper (mg)	0,19	0,1
Iron (mg)	10,9	6,7
Magnesium (mg)	82,5	37
Manganese (µg)	898	680
Niacin (mg)	5,6	3
Phosphorus (mg)	330	285
Selenium (µg)	75,6	89,6
Zinc (mg)	16	2,7

The nutritional profile of green lipped and blue mussels is broadly similar, suggesting that there is scope to develop similar messaging for Scottish mussels.

## 2. Mussel Extracts and Compounds Relevant to Pharma/ Nutraceuticals

The evidence supporting health benefits of mussel-based supplements or extracts is limited and sometimes inconsistent, but bivalves offer a source of different compounds with potential health effects (e.g., anti-inflammatory, anti-viral, antioxidant, antihypertensive) that can be relevant to both pharma and nutraceuticals (Slides 19 and 20). Several cellular, animal and human studies have been carried out looking at the potential effect of green lipped mussels on bone health, particularly arthritis and joint health, acknowledging improvements with the caveat that some studies have serious limitations (such as lack of control/placebo group) (Slide 26).

**Omega-3 fatty acids** have been shown to have multiple health benefits, from promoting brain health, to improving risk factors for heart disease. Omega-3 from mussels has been mostly studied for its anti-inflammatory properties that help manage inflammation and reduce the pain and swelling associated with arthritis and other painful joint conditions, hence may improve bone and joint health (Slide 21).

Green lipped mussels (shell or meat) are a source of **Glycosaminoglycans** (GAGs) (Slide 24-25), and these are considered as having anti-inflammatory properties although it is likely that it is a range of bioactives that exert their effect on arthritic joints. GAGs are principal components of cartilage and the synovial fluid found in joints and cartilage is continually broken down and rebuilt in response to the stress placed on the joint. Collagen turnover, including adequate synthesis, is key to proper joint health and function. Awareness of green lipped mussels for joint health is high amongst pet owners possibly due to their being fewer brands and ingredients competing for consumer attention.

Mussels are a source of cholesterol-lowering **phytosterols**. These are cholesterol like compounds which form a key component of plant cell membranes. Phytosterols are found in almost all plant foods but are particularly high in plant-based oils. Due to their similarity to cholesterol, phytosterols inhibit the absorption/reabsorption of dietary cholesterol/bile cholesterol and as a result can lower serum cholesterol levels. Slides 27 and 28 consider one study where mussels could be capable of altering blood lipids and cholesterol but it's not conclusive.

**Collagen** in mussels is considered as a compound of interest (Slides 29 and 30) particularly as global consumer interest in the health benefits of collagen is increasing rapidly. Mussel byssus is a good source of high quality collagen, but extraction techniques are fairly early stage and not yet of a truly commercial scale. This is an industry which is likely to develop over the next 10 years as techniques are developed and refined and is therefore a relatively whitespace opportunity for Scotland.

Insight into the dietary supplements launched on the basis of these bioactives or health targets is given in Slides 51 - 60.

### 3. Extraction Methods and How These Impact on Nutritional Quality

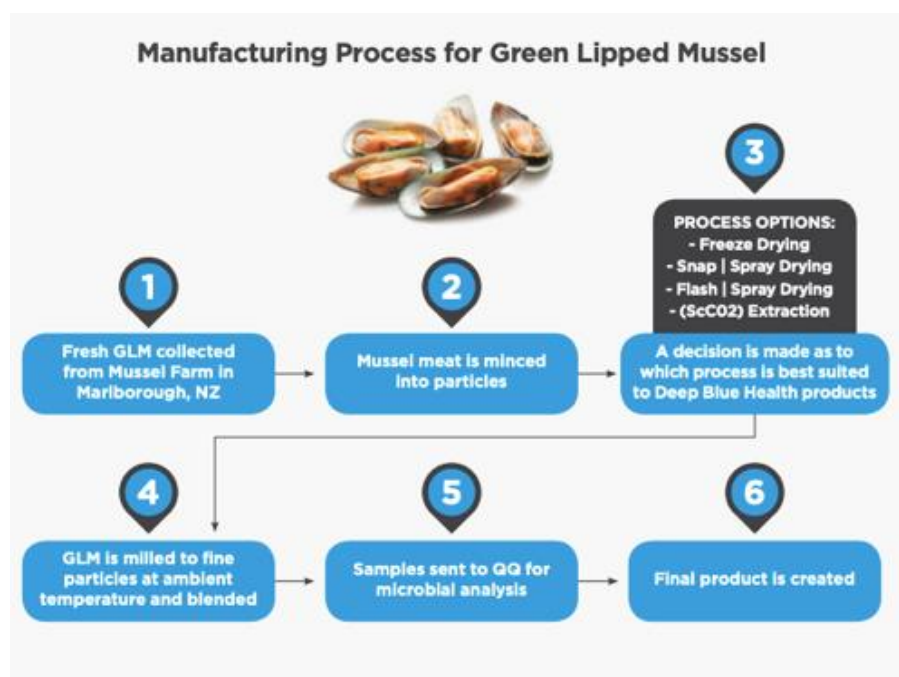
Conventional processing of mussel extracts the meat by using steam-based and other established methods but can denature much of the mussel bioactive compounds which are associated with anti-inflammatory activity. Consequently, the development of cold processing techniques has been important for processing components of the mussel extracts in terms of maximising the derivatives' value.

There are several methods of extraction currently utilised for bivalves globally:

- Freeze Drying/Lyophilization after harvesting: the mussels are removed from their shells and powdered in a purpose-built extraction plant. The mussel meat is freeze dried to ensure the stability of the nutrient content
- Snap Drying in a drying operation: liquid, slurry, or puree material is applied as a thin layer onto the outer surface of revolving drums that are internally heated by steam to dry the product
- Flash Drying/ Spray Drying Flash: dry processing uses fresh uncooked mussel meat mixed in a liquid suspension. Particles of the mussel meat are sprayed into a current of hot air, and then evaporated to create a nutrient rich mussel powder
- Supercritical carbon dioxide (ScCO<sub>2</sub>) extraction Oil Extraction (or Supercritical Fluid Extraction): separating an active component (the extractant) from another (the matrix) using supercritical fluids
- HPP processing: MacLab in New Zealand has developed a high-pressure processing (HPP) technology to extract the mussel meat from the shell without using heat



An example of the process from the brand Deep Blue Health New Zealand is shown here (Slide 35).



### Overview of Mussel Derived Nutraceutical Markets

The global dietary supplements market size was valued at US\$140.3bn in 2020 and is expected to expand at a compound annual growth rate (CAGR) of 8.6% from 2021 to 2028. The increasing consumer awareness regarding personal health and wellbeing is expected to be a key factor driving the market for dietary supplements over the forecast period. The working population around the globe is struggling to fulfil the daily nutrient requirements owing to hectic work schedules and changing lifestyles. This is increasing their dependency on dietary supplements to fulfil the nutrient requirements owing to their high convenience, which, in turn, is expected to drive the market over the forecast period.

The global market for Bone and Joint Health Supplements estimated at US\$9.9bn in the year 2020, is projected to reach a revised size of US\$14.7bn by 2027, growing at a CAGR of 5.8% over the period 2020-2027<sup>2</sup>. The Joint Supplements market is projected to record 5.0% to 6.4% CAGR and reach US\$9.5bn by the end of the analysis period.

The Bone and Joint Health Supplements market in the U.S. is estimated at US\$2.7bn in the year 2020. China, the world's second largest economy, is forecast to reach a projected market size of US\$3.1 Billion by the year 2027 trailing a CAGR of 9% over the analysis period 2020 to 2027. Among the other noteworthy geographic markets are Japan and Canada, each forecast

<sup>2</sup> Bone and Joint Health Supplements - Global Market Trajectory & Analytics, Research and Markets, April 2021

to grow at 3.2% and 5.3% respectively over the 2020-2027 period. Within Europe, Germany is forecast to grow at approximately 3.7% CAGR.

In the US, the dietary supplement market value was over US\$36bn in 2020 and tablets and capsules accounted for over 50% of the market. Glucosamine and chondroitin are traditional go-to supplements for joint health, and products featuring this popular ingredient combination have a 57.8% share of the joint health segment and the highest dollar volume of the segment's sales in the US (SPINScan Data, 2019). Despite their popularity, they have shown consistent decline over the last three years as the market diversifies with more options to address joint support.

Slides 42-44 provide more detailed information on mussel extracts. Glucosamine and chondroitin are traditional go-to supplements, but recent market analysis has shown that although this combination has the largest share of the joint health market, their position is showing a decline as the market diversifies with alternative options to support joint health.

There is an increase in the number of online articles mentioning mussels and health (Slide 46) which suggests increasing consumer awareness and interest, which is a positive. All articles specifically on joint health, focus on green lipped mussels. Two of the biggest online health platforms in the US – WebMD and Healthline – have dedicated articles to green lipped mussels and its benefits (Slide 48).

- The conclusion is similar: early research shows promising effects, but often studies are inconsistent, and more studies are needed for stronger recommendations
- Most consumers in the UK and other Western markets are aware of mussels as a seafood and associate it to culinary usage
- Interest in health benefits is growing significantly in Asia, particularly China
- More health-conscious consumers possibly connect general seafood benefits with mussels, but not necessarily the specific studied benefits so far
- Consumers suffering from bone health issues and joint pain are the most likely to have heard about mussels' potential benefits for such conditions
- Competition is already significant in the market and may not offer appropriate return on investment for new entrants

Most of the commercialised mussel extracts are from New Zealand green lipped mussels.

- The key benefit studied for these extracts and offered by the products that incorporate them is joint health, connected to potential anti-inflammatory activity
- Mussel extract supplements are available in a whole range of formats, with capsules, tablets and powders the most common

### Companies/Products Examples

Examples of commercially available mussel extracts in dietary supplements are highlighted in Slide 62. Four antipodean case studies - Sea to Me, Biolane Green Mussel Extract, Kordel Musseltone and Blackmores Lyprinol Green Mussel Extract are shown in slides 64-71. Sea to Me also relies on traceability and sustainability in their marketing.

### Mussels in sports nutrition products

Slides 73–80 demonstrate that there are currently almost no products using collagen from mussels or even combining mussels and collagen on the same product. This research identified just one example in the UK from Power Health. However, sports nutrition is a fast-growing market, and there are obvious connections between the primary benefits offered by mussel extracts (joint and bone health, anti-inflammation, collagen), which suggest that there are opportunities for further development.

### Mussels in pet food products

Slides 83-92 demonstrate that:

- Petfood is currently one of the fastest-growing segments in the global food industry. According to Euromonitor, the petfood market was worth £67bn in 2018, but is forecast to grow to £102bn by 2024
- In the UK, pet food sales totalled £2.9bn in 2020, growing 16% since 2015. Volume sales also grew in that period, but only by 3%, reflecting the growing trend towards premiumisation in the UK market
- Growth is particularly notable in China, where the petfood market was worth more than £5bn in 2019 and growing is growing by 30% per year. It is set to be 10% of the global market vs 1% a decade ago
- 42% of pet food buyers consider their pet a “foodie” according to Mintel. Brands using human grade food, and homemade-style recipes featuring gourmet ingredients are growing significantly – this offers strong potential for mussels, possibly from outgrades or areas of production designated as not suitable for human consumption
- The number of pet food products launched with “chondroitin” and “omega 3” increased in 2020
- Green lipped mussels and joint health are strongly connected in consumers’ minds when it comes to pet food products
- Most active regions are Asia and Europe

- Most products don't specify the source of chondroitin but omega 3 is often listed as coming from mussels or salmon
- There are a few brands which sell cooked and freeze-dried mussels as a single product, aimed at cats or dogs
- In the UK, the Healthy Pet Store sells cooked mussels which can be mixed with other raw, wet or dry dog food or given individually as a health treat

Given the trend towards humanisation in pet food, there is certainly scope for Scottish mussel producers and brands to develop this market further, possibly with product, which is not suitable for the human retail market, **but price will be key** as competitor ingredients are often derived from waste streams and therefore very low priced.

### New Zealand – Case Study

The New Zealand green lipped mussel industry has been a pioneer of the marine extracts and nutraceuticals industry since the 1970s and is a global success story. There are a number of factors which have led to New Zealand's success in nutraceuticals from mussels including:

- Focus on value add products and export markets as primary drivers of growth
- Early identification of the potential link between green lipped mussels and joint health benefits
- Mussel powder and oils are not seen as waste stream routes from mussel processing -the two markets have developed in tandem, and both use the highest quality raw material
- A variety of commercial uses have been found for the waste shell from the half shell product – use in concrete in the construction industry, as a soil improver for vineyards, and as an ingredient in chicken feed
- Investment in long-term research programmes
- Effective collaborative marketing using the industry trademark **Greenshell™** and focusing on unique health benefits and production from pristine environment

Key insights into the structure and dynamics of the New Zealand industry are given in Slides 94-99. Green lipped mussel aquaculture in New Zealand provides one of the highest value returns per hectare in their cultivation, surpassed only by salmon farming.

Comparison of the approximate annual value per 10 farmed hectares for different primary products	
Salmon	\$140,000,000
Mussels	\$850,000
Oysters	\$800,000
Kiwifruit	\$800,000
Dairy	\$77,000
Sheep and beef	\$8,500

Source: Zespri, Beef+Lamb, DairyNZ, AQNZ

(Taken from The New Zealand Government Aquaculture Strategy to 2025)

Another notable feature of the New Zealand supply chain is how integrated the production of mussels and other bivalves is with the wider seafood industry. Their largest companies have a broad portfolio of interests encompassing shellfish and salmon farming, wild sea fishing, fish and shellfish processing and extraction of nutritional compounds.

The number of aquaculture businesses has declined over the last 15 years in New Zealand, as the industry has consolidated, and supply chains have become more fully integrated. Larger companies such as Aroma NZ and MacLab/Pharmalink are working towards enclosed supply chains encompassing processing and production of extracts and supplements. In recent years, much of the investment in the mussel industry has come from these large conglomerates and there have been several high profile investments in the New Zealand seafood industry by Asian companies in the last 5 years (Slides 99–100).

New Zealand is a long term public sector investor in scientific research and technological development with projects selected in consultation with industry bodies such as Aquaculture New Zealand and this has underpinned the growth of the mussel industry. They also provide research funding for individual companies and consortia on a 50:50 basis.

Current research priorities and ongoing projects include :

- Clinical trials into benefits of green lipped mussel oil on inflammatory diseases
- Breeding programme for improved characteristics such as increased growth, higher levels of bioactive compounds, increased nutritional value and resilience to pests and climate change
- Improvement in extraction techniques to capture the maximum nutritional value from the raw material
- Production of spat on land-based farms, to reduce reliance on gathering from washed up seaweed
- Research into open ocean production techniques and scale up

- AI applications for waste reduction and improvement in product quality

### **Mussel Oil – adding value to nutritional extracts**

Over the last 10 years the development of mussel oil has been critical to the growth and security of the New Zealand mussel industry, whilst mussel powder has become something of a commodity product with large producers such as Chile also entering the market. Mussel oil however is currently only produced in New Zealand where the technology was developed and is the highest quality mussel extract available. During the COVID-19 pandemic, the global price of mussel powder has fluctuated significantly, but the price of the higher quality mussel oil product remained stable at NZ\$ 3000 per kilo (£1521 per kg). Mussel oil now accounts for 12% of the mussel export market for New Zealand (Slide 96) and contributed NZ\$ 51m in 2020 (£25.9m).

### **The importance of environmental sustainability and the indigenous value chain in New Zealand to brand values and provenance**

The role of enterprises that have health platforms that can develop and market bioactive products are critical in the value chain. Four examples of New Zealand brands showcase the importance of both environmental credentials and extraction methods for their product and brand development.

**Deep Blue Health New Zealand** <https://www.deepbluehealth.co.nz/> is a fast growing natural health supplement company that has within its portfolio marine sourced health supplements for joint, immune and skin health and service a global market. They rest their marketing on the reputation of New Zealand's reputation as a 'clean and green' environment and that the active ingredients in their products are of pure and high quality (Slides 32-34).

**Aroma NZ Limited** <https://aromanz.nz/pages/about> is a vertically integrated company, with over 30 years in the GLME industry. Aroma NZ own mussel farms throughout the Marlborough Sounds and Banks Peninsula and this ensures stable supply of the raw material for processing into powder and oil. Aroma NZ Limited acquired the Biolane GLME brand in 2020 (Slide 35)

**MacLab** <https://www.maclab.co.nz/> is a New Zealand biotech company that extracts bioactives from green lipped mussels for the biopharmaceutical market and they have developed two extraction processes (including high pressure processing) that protects the bioactive for anti-inflammatory activity from degradation and which also eliminates the use of solvents. MacLab rely heavily on the environmental sustainability credentials of the mussels' farms (Slide 36).

**Trade Ingredients** market their Green Lipped Mussel Powder as having been harvested from the Marlborough region of New Zealand and they supply their powder to some of the largest pet-food manufacturers in the UK. They cold process the raw material (Slide 37).

## Bioprocessing and circular economy market considerations

Historically there has been a wide range of EU funded projects aimed at shellfish valorisation routes although commercial outcomes from these are difficult to ascertain. Recent programmes involve recognised regions and players and cover topics from maximising output and quality from mussel farming (e.g., MusselAlive); valorisation of bivalve shells (e.g., GAIN Green Aquaculture Intensification) to exploring the potential for bioactive extraction (e.g., Blueshell). The latter focussed on screening shellfish by-products as sources of blue bioactives which could be targeted at a number of market opportunities including plant health. It is of interest to a Scottish composting operation who are actively looking at the inclusion of shellfish shells in compost given the role of chitin in controlling Potato Cyst Nematode – a major pest that threatens the Scottish potato sector.

A consortium of Danish partners addressed the need to boost sustainable mussel production in Danish coastal waters to capture the opportunity for mussel harvesting to supply animal protein feed ingredients for pig and poultry production. MumiPro was established in 2017 <https://www.mumipro.dk/about/overview> and covered mussel production, processing and mitigation work packages through a range of research and industry partners.

As with all potential applications associated with shellfish waste streams there are challenges with scale, availability, logistics, business economics and regulatory considerations. In addition, from a supplier perspective, players in shellfish sector have to evaluate the opportunity both from a business case and a value chain proposition as to what, if any, alternative markets can be serviced. In order to address these markets either entrepreneurial bioprocessing businesses need to see the end market opportunity or the shellfish sector itself has to create / invest in the partnerships who can create value from the raw material.

As noted earlier, an integrated supply chain was vital for the New Zealand green lipped mussel sector to benefit in the nutraceutical market opportunity. This was reinforced by Naik & Hayes (2019) Trends in Food Science & Technology 92 111-121 (Bioprocessing of mussel by-products for value added ingredients and applications). It also concluded that an integrated supply chain at scale is necessary and requires a sustainable supply and scalable technologies for conversion from raw material to ingredient. These are important considerations when evaluating whether there is scope for Scottish mussels to enter this alternative market opportunity.

## Business Models for Shellfish Bioprocessing

In considering the key components required to successfully establish a business case in respect to shellfish bioprocessing, reviewing overseas examples and comparing that to the existing infrastructure in Scotland, provides practical insight.

### *The Infrastructure Required for Bioprocessing*

In order to exploit a commercial route to market for mussel derived nutraceutical bioactives with proven efficacy, specialist extraction methods and access to intermediary bio processing capabilities are required. In addition, 'green' extraction processing systems need to be



considered if mussels are to have a true circular economy impact. Many of these technologies remain at laboratory scale and not yet at a stage for industrial application.

The research suggests that costs of establishing new bioprocessing capacity are relatively high and are dependent the type of extraction involved, the scale and where the plant is located. Estimates range from £4m to £15m and much of this information is held by individual businesses and is commercially confidential. As a very broad example, a New Zealand based company, MacLab, has a rolling programme of investment in its processing and supply chain facilities, amounting to around £10m over the last 3 years.

New Zealand has established enterprises that are critical to a supply chain targeted at the supplement market on a global scale. Having access to appropriately scaled bioactive extraction processes and facilities will be key if Scotland's blue mussel farming sector is to extend into commercial opportunities associated with nutraceutical markets as part of any growth and investor strategy. An example of this is High Pressure Processing which can be deployed to remove meat from bivalve shells. This technology has been adopted and semi-automated by New Zealand processor Future-Cuisine Export LTD whilst MacLab in New Zealand employ this process as part of their extraction process for mussel bioactives. Having access to processing capabilities like these are key in a bioprocessing context.

Linked to this, and as part of evaluating the growth strategy potential of Scottish shellfish industry, it is also worth considering how entrepreneurial talent can be nurtured in this space to support alternative opportunities for seafood, ecosystem service opportunities or bioprocessing capabilities. Integrating this talent into traditional bivalve value chains has the potential to enhance investor confidence in shellfish farming and its growth potential as has been seen in New Zealand.

An example of such an innovation ecosystem is Hatch Innovation Studios <https://www.hatch.blue/> which is an accelerator programme that links to an investment fund – one of their investments is in SmartsOysters, an Australian start up with global reach <https://smartoysters.com/about> that offer a digital platform for smart management of bivalve farms and analytics that track farm performance. SmartOysters is an example of where sensors that capture data are integrated into a platform that will not just inform decision making but provide certifiable quality and provenance for shellfish production. As long as Scottish shellfish stakeholders can connect with emerging tech solutions across the globe then the sector can build on growth opportunities that will, in turn, contribute to investor confidence.

As seen in New Zealand there are markets for shellfish and their co-products which rely on bioprocessing prior to entry into value chains that both support the circular economy proposition and creates an investment opportunity for sector growth. Alongside that is the investment by New Zealand government into long established funding for bivalve strategic research programmes to support, not just opportunities for entrepreneurial talent, but knowledge hubs for the sector.

As part of evaluating whether there are growth opportunities for Scottish shellfish in non-food markets access to relevant bioprocessing infrastructure and capacity needs to be



considered and this could include ascertaining whether established shellfish bioprocessing entities would want to licence in technology or build a business base in Scotland should blue mussels prove to provide an advantage and market opportunity.

There are examples of how creative business partnerships can evolve in this sector – one such example is seen with Aquaproducts. It is a French owned company active in the field of marine bio-processing and sales of marine extracts and they formed a joint venture with an Indonesian bioprocessor to process fresh and sustainable by-products from marine resources for functional ingredients for the food and feed industries. This type of approach <https://www.magprobiotech.com/about-us> is potentially critical if Scottish shellfish sector is to consider routes into nutraceutical value chain.

In Norway, there is a national facility that supports marine biodiscovery and bioprocessing capabilities. Nofima - <https://nofima.no/en/research/marine-biotechnology/> - is an example of an R&D infrastructure that can support on a project basis how value can be extracted from residual marine raw materials and potentially be scaled up. By working in partnership with the R&D base, solutions can emerge that have industrial application.

### **The Scottish Research and Innovation Landscape Relevant to Shellfish**

The capability of the research and innovation ecosystem in Scotland, and the commercial bioprocessing sector, is crucial in supporting potential investor confidence in growing the bivalve farm proposition.

In Scotland there is a wealth of knowledge assets around aquaculture and marine bioactives spread across different centres: Scottish Association of Marine Science (SAMS), University of Stirling Aquaculture Centre, International Centre for Aquaculture Research and Development and Marine Biodiscovery Centre (both at University of Aberdeen). In terms of innovation players, Scotland's Sustainable Aquaculture Innovation Centre (SAIC) focuses on 'unlocking sustainable growth through innovation excellence'. Both have potential to drive growth within a sector of key economic importance. SAIC commitment to an aquaculture academy could also have a part to develop the skills which will be required to meet new market opportunities.

In terms of support for the bioeconomy the Industrial Biotechnology Innovation Centre (IBioIC) is a resource which connects knowledge relevant to the bioeconomy through harnessing the expertise in bioprocessing across Scottish Universities. Their Bioeconomy Cluster Builder has a remit to include food and drink sectors to create bioeconomy value chains. Processing by-products from food sector have been identified in the National Plan for Industrial Biotechnology (2019) as having great potential for the development of Scotland's bioeconomy.

An example in Scotland of an early stage enterprise operating in this space is Cuantec based in Oban; initially launched on the technology platform of extracting chitin from shellfish shells and developing antimicrobial compostable films for food applications and eliminate the need for single use plastics. Recently the business has taken a change in direction and the strategy is to scale up its proprietary processing technology and licence it and onward product development to partners in value chains. It is feasible to future think this approach and assess

whether small scale processing units at point of waste streams could be viable within a Scottish bivalve farming context.

The Blue Economy Cluster Builder is an initiative funded by Scottish Enterprise and delivered by Aquatera based in Orkney. The initiative communicates and raises awareness of the blue economy in Scottish SMEs and enables these organisations to take advantage of new market opportunities and to support the sustainable growth of the blue economy in Scotland. Whilst the focus of this initiative is around building the capabilities associated with the blue economy it verified that currently there is no obvious biorefining capabilities at scale in Scotland that would be relevant for the extraction of bivalve bioactives for the nutraceutical value chain. However, they were keen for CES to engage with them further to explore whether indigenous capability and capacity could be built in this thematic area.

Although biorefining potential of waste and co products from food sector in Scotland has been the subject of several reports over the last decade (including the report undertaken on behalf of ZWS in 2017 by Ricardo Energy and Environment, Circular Economy report Sector Study on Beer, Whisky and Fish 2015), the detail on shellfish as the starting material is sparse and historic.

SSMG provided insight into current levels of waste in the mussel sector (750–800 tonnes) with costs associated with rendering that material estimated at £40 per tonne. That alone represents a cost of up to £32,000 per annum. Waste is generated at the processing site and there would appear to be significant discrepancies with that identified in the 2015 data.

## Conclusions – Key Points

### Markets

Three potential areas of opportunity have been identified, i.e.:

1. Human health particularly from derivatives of mussel oil
2. Pet health/pet food ingredient
3. Plant and soil health

More health-conscious consumers possibly connect general seafood benefits with mussels, but there remains limited understanding of particular benefits. There is an opportunity to raise greater awareness of these benefits.

Specific segments of the market for nutraceuticals for human and animal health derived from mussels, particularly mussel oil, would appear to offer significant opportunities for Scotland. However, this will require considerable investment in two areas:

- Research into the nutritional properties of blue mussels and how these compare with the green lipped mussel in terms of offering similar benefits for joint health, or any other health benefit. This would apply to both human and pet health.
- Production and extraction facilities for the preparation of nutraceutical extracts.

Plant and soil health present other opportunities for shellfish by-products as sources of blue bioactives. The inclusion of shellfish shells in compost is an example of a circular economy outcome where chitin can help control Potato Cyst Nematode – a major pest that threatens the Scottish potato sector.

### Value of Insight

The New Zealand green lipped mussel industry has pioneered the development of the nutra/ pharmaceutical market for bivalve extracts, and provides valuable lessons, i.e.:

- A strong focus is required on nutra/ pharmaceutical routes as a value-added industry in its own right
- Integrated supply chains are essential, from primary products through to extraction and final product
- Significant investment is required in research over a long period
- Collaboration in research, marketing and communications is beneficial. New Zealand is a long-term public sector investor in scientific research and technological development with projects selected in consultation with industry bodies
- Strong industry bodies help provide a focus for development, communications and funding
- Investment in infrastructure is financially significant as is state of the art facilities to build and protect reputation

- Investment in the development of extraction techniques is critical to enable the extraction of highest quality compounds
- Environmental credentials are now key drivers for reputation and brand
- Mussel powder and oils are not seen as waste stream routes from mussel processing -the two markets have developed in tandem, and both use the same high quality of raw material
- Mussel oil now accounts for 12% of the mussel export market for New Zealand and contributed NZ\$51m in 2020 (£25.9m)

### **Challenges**

The business model and the market that a blue lipped mussel extract could capture would need to be validated further and clearly articulated if it's going to be the driver for investment in the sector.

Currently there is no obvious biorefining capabilities at scale in Scotland, that would be relevant for the extraction of bivalve bioactives for the nutraceutical value chain. In addition, 'green' extraction processing systems need to be considered if mussels are to have a true circular economy impact.

The costs of establishing new bioprocessing capacity are relatively high and are dependent the type of extraction involved, the scale location. Estimates range from £4m to £15m.

Competition is already significant in the market for biorefined mussel extract products and may not offer appropriate return on investment for new entrants. As outlined, given the potential for a premium product to compete in the marketplace, Scottish mussel powder and oil products may hold the best prospects in the market and may be worthy of further investigation as a commercial opportunity. Either entrepreneurial bioprocessing businesses need to be convinced of the market opportunity or the shellfish sector itself has to create or invest in the partnerships that can create value from the raw material.

## Alternative income and investment proposition based on environmental credentials of shellfish farming

### Introduction and Background

The focus of this section spans across two pillars which provide insight on innovative opportunities for the sector beyond producing a high quality food product. Through a combination of desk-based research and informed interviews an insight into the following was undertaken:

1. Payment for ecosystem services including sustainable financing for low-carbon footprint food production
2. Payment for sensor-based data collection which would also contribute to regulatory and market requirements

The qualitative research results were considered in terms of practicality with respect to the current supply chain, its capacity to meet alternative markets and any implications for quality standards. The findings from this approach will enable CES and the Scottish bivalve industry to have insight on how additional value could be achieved through supplementary income streams which could contribute to the competitiveness of the sector and its growth.

Shellfish farming in Scotland relies on the natural availability of plankton in the coastal environment to feed mussels and oysters. The majority of them are produced either on or close to shore, requiring only the use of small boats for regular monitoring. Larger boats are used in the mussel sector at harvest time and other intervals when the ropes need to be lifted. There is some waste deposition below mussel lines, but overall, the product is understood to represent a very sustainable animal protein option. They are seen as a naturally low-carbon food product, although this isn't always highlighted as part of the provenance.

Further positive attributes arise because the plankton that shellfish filter feed from the sea grow on nutrients in the water. Extraction of plankton by shellfish represents an extraction of nutrients from coastal waters, especially when we remove the shellfish to eat. As shells develop they also lock-up carbon. The presence of farming infrastructure in the coastal environment may also provide additional benefits related to coastal protection.

A recently published paper by Suplicy (2020) '*A review of the multiple benefits of mussel farming*' included various insights such as the environmental impacts of mussel farming and opportunities around ecosystem services; mussels as a sustainable alternative to fishmeal in fish and animal feeds; the contribution of mussel farming to absorb atmospheric CO<sub>2</sub> as well potential use of mussel by-products.

Here we explore how these positive attributes could be capitalised upon to provide added value that could stimulate investment in the sector; particularly looking at the ecosystem services provided by farmed shellfish; and how the presence of shellfish farming infrastructure itself could be of value to other sectors interested in data from coastal waters.

During the study period 18 consultations were held with Government, research, producers, buyers and associated sectors almost exclusively through email and virtual meetings (see Appendix 3). The consultations primarily aimed to understand:

- If any discussions had taken place within government and industry with regard to a payment for ecosystem services system in the marine environment.
- What demand there is for data both within the shellfish sector and from other industries, as well as financiers and the market.
- What appetite there is for the development of such areas.

### Payment for Ecosystem Services

Crown Estate Scotland has previously commissioned a study of Payment for Ecosystem Services (PES) approaches that could be applied to shellfish. PES approaches have become more familiar in terrestrial systems, with pilots reported across the UK and around the world. Some examples of marine PES approaches are reported by the likes of OECD ([https://www.oecd.org/stories/ocean/payments-for-ecosystem-services-programmes-540de426#:~:text=Payments%20for%20ecosystem%20services%20\(PES,incentivise%20higher%20ecosystem%20service%20provision\)](https://www.oecd.org/stories/ocean/payments-for-ecosystem-services-programmes-540de426#:~:text=Payments%20for%20ecosystem%20services%20(PES,incentivise%20higher%20ecosystem%20service%20provision))). Current rural payments to land-based farmers in Scotland contain an element of payment for ecosystem services in terms of good stewardship. However, at present there is no structure or pilot for a PES approach in Scotland's marine environment. Here we set out some ideas on how such a scheme could be piloted and outline the potential value to the shellfish sector and to Scotland.

The two primary areas where payments could be considered are removal of nutrients (for example nitrogen and carbon) and environmental protection by production infrastructure. As well as the provision of services we also need to consider who benefits and therefore who would pay. There are opportunities for less formalised peer-to-peer systems where one entity sees value and will provide incentive for the provider – in Scotland that could be the salmon sector who may value the opportunity to expand production if nutrients are removed, however research to date indicates this would only really have value at a whole-loch scale rather than site-by-site integration.

Alternatively, developing a more formalised, regulated system where the value may be broader – for example, if shellfish farming infrastructure protected an area of coast the Government may consider incentivising the farming based on a payment per tonne of production from a specific type of infrastructure. If the presence of farmed shellfish effectively created no-fishing zones or the infrastructure provided a nursery for fishery species there could be consideration of a PES from the revenues of a particular fishery. A Government-backed PES for shellfish farmers in Chesapeake Bay has led to significant industry growth and a resulting improvement in overall water quality. Suplicy (2020) highlights that each mussel can filter between five and ten litres of seawater and from 15 mg to 150 mg of particulate organic and inorganic material per hour.

The value of both types of ecosystem services provided by shellfish is challenged in typical production areas for shellfish that are grown for human consumption. Designated shellfish growing waters are, almost by definition, clean waters. Indeed, that is a strong component of the marketing of shellfish, especially oysters that are consumed raw. Shellfish tend to be grown in sheltered bays too, where coastal protection is not such an issue. Therefore, a payment for ecosystem services may only become viable in areas with lower water quality or in more exposed locations, both of which offer challenges.

Producing shellfish in areas with lower quality would typically add a requirement for depuration; in more exposed areas more robust infrastructure would be required – both adding costs. The need for depuration could be removed if shellfish (primarily mussels) were not destined for human consumption, for example if processed for animal feed, given that recent studies in Denmark indicate little risk of bioaccumulation or toxicity transfer. As a protein ingredient for pet food the issue is essentially removed and pet foods are, as shown in this report, potentially a premium market. However, current producers for the human food market may also be concerned about potential risk to the brand of Scottish mussels if some were produced in less clean waters, regardless of their destination.

Producing shellfish (again with the primary expectation being mussels) in more exposed sites could provide coastal protection benefits generally but could provide additional value and positive marketing to other infrastructure projects, for example marina development. There is potential to explore co-location of shellfish with wind farms, perhaps by having submersed lines, which may help to protect the moorings of turbines. In the coming years there will likely be an increasing need for the multiple use of marine sites particularly as part of marine spatial planning processes.

Both water quality and exposure are risks on Scotland's east coast, but there is potential to expand shellfish production in these areas, especially if some of the additional risks and costs can be offset through a PES system.

The emerging areas of nutrient trading schemes and Blue Carbon Credits, which are progressing through academic assessments and initial political interest beyond Scotland, have not matured yet and still face many challenges.

### **Blue Carbon Opportunities**

Shellfish could also be packaged as the ultimate blue carbon animal protein source. The UK and Scottish Governments are exploring blue carbon credit schemes primarily focused on sedimentary carbon capture in salt marshes, kelp beds and seagrass beds. Although farmed shellfish are removed from the water, carbon is captured in shells that may be locked-up depending on the post-harvest use of the shells (e.g., aggregate) and, even when processed could provide a more sustainable, lower-carbon alternative, e.g., as cement, within a circular economy. There is scope for a proactive, data-driven case to be made for farmed shellfish to be included in the potential blue carbon credit schemes. Research by Filgueira et al in 2015 highlighted the potential for this at an ecosystem level and whilst other researchers have continued to develop the science around this there has been little uptake in policy. The

possibility of farmed shellfish being part of a blue carbon credit scheme would help to provide additional income for existing farmers as well as new entrants.

Jansen and van den Bogaart report carbon sequestration potential for Dutch farmed mussels of -43 to +86 kg C/tonne of mussels per year, depending on allowances for respiration and growth. Assuming an average of 8000 tonnes of production in Scotland (not including losses/mortalities during production) gives a potential of 86 tonnes C per annum at the upper end of this scale. This is equivalent to 1000ha of algae (based on estimates from Queiros et al 2019 quoted in a Marine Scotland case study). Managed forestry in a Scottish context has an average of around 2.5 tonnes C per ha per annum sequestration rate (estimating from various Forestry Research publications), meaning the mussel industry provides sequestration equivalent to 34ha of forestry. Confidence in the numbers from this initial desk-based research could be strengthened through additional academic research.

Suplicy (2020) highlights an overall production-side carbon footprint of 0.22-0.25 kg CO<sub>2</sub>e/kg for mussels (the higher value coming from a 2012 study by Fry, funded by the Scottish Aquaculture Research Forum.) This equate to

- 0.6 kg CO<sub>2</sub>e/kg of mussel meat
- 19–36.7 CO<sub>2</sub>e/kg for beef
- 6.4–8.6 CO<sub>2</sub>e/kg for pork
- 3–6.5 CO<sub>2</sub>e/ for poultry
- 4.2–5.4 kg CO<sub>2</sub>e/kg for salmon

This indicates that mussels have by far the lowest carbon footprint of any animal protein.

Spat collection is potentially increasing Scotland's carbon sequestration opportunities because that would have otherwise died are being grown up to produce food and trap carbon in their shells. If some of these spat survived and formed reefs it would take many years (potentially decades) to see similar returns because wild mussels put more energy into reproduction and take 6 years to reach an equivalent size to farmed mussels after 2 years (Jansen and van den Bogaart).

### Valuing Data

There is much buzz in the aquaculture sector about data tools for farmers. The salmon sector has been the main users of such systems for many years. However, the structure of shellfish sector, primarily independent owner operators relying on natural spat fall and plankton supplies, has meant very little interest or uptake in the use of consistent datasets for management purposes. Indeed, a study by North Atlantic Fisheries College called Shell-volution (<https://www.nafc.uhi.ac.uk/t4-media/one-web/nafc/research/aquaculture/shell-volution/Shell-volution-Consultation-with-Shellfish-Producers-Final-Report.pdf>) showed that very few farmers saw value in regular collection of environmental data. However, the same study indicated farmers were interested in better access to finance, which would likely require improved management and impact data collection.

In this report we aim to highlight the connection between better collection and use of data as a route to add value to farms (including access to finance and to feed into processes like



Blue Carbon Credit development), but also explore additional value from data collection for other users (gathering and selling data). Challenges of automated data collection and transfer in the remote areas of Scotland need to be highlighted but there is clear consumer / market appetite for data that could support the sustainability value of shellfish as a protein source.

There is a general consensus that greater volumes of data are required in key areas understood to be bottlenecks for the industry; issues around spat fall, plankton movements and volumes, climate impacts, harmful algal blooms. At present there is less obvious demand for significant amounts of farm-level management data and hesitation for any of that to be shared. However, this is, in part, an artefact of the development of the industry – pioneers who remain are still small-scale, crofting-type operations. Larger players are developing internal management systems more akin to salmon farming, but there is little corporate engagement driving the need for an internal valuation of data. There is little demand from NGOs or the market for much detail either, in part because of the low-carbon, sustainable story of shellfish farming generally. New entrants, particularly businesses of scale, attracted by the low-carbon sustainability view of shellfish and able to attract financing will likely require more data. In fact, in order to be attracted in the first place there may be the need to fill some of the bottleneck data gaps.

Strategic use of regional development funds and effective partnerships between industry and academia is already starting to address these issues. Some examples include (but are not limited to):

- NAFC provides analytical services, particularly to the Shetland industry.
- SAMS provides data on oceanographic risks on a regular basis.
- University of Stirling provides production innovation research.

These collaborations increase the volumes of data on particular aspects of the industry but there is a need for a broader, more holistic approach using modern technology. Satellite analysis could fill some of the gaps now, as piloted by ShellEye project, but there is also the opportunity for farms themselves to be key data collection points and potentially develop an additional income stream in the process.

Data has a real value itself. The world is increasingly data-hungry and the climate emergency requires use to understand even more about changes in our environment. Scotland has a Coastal Observatory already, see:

<https://www.gov.scot/binaries/content/documents/govscot/publications/factsheet/2019/11/marine-scotland-topic-sheets-ecosystems/documents/the-scottish-coastal-observatory-updated-february-2019/the-scottish-coastal-observatory-updated-february-2019/govscot%3Adocument/coastla-observatory.pdf>.

This is a network of stations around the coast, many of which provide data on a voluntary basis. At least one of these is already associated with a shellfish farm. However, the overall number of sites is limited. The shellfish sector already has a significant, permitted infrastructure presence around Scotland and could provide a network of locations for coastal data collection. This could be paid for by Government agencies, international foundations or

other industries, however no specific funder was identified during the study period. The ASSG could pursue this avenue further if it was of interest to members.

### **Sensor Based Data Collection Opportunities for Payment Streams and on-Farm Decision Making**

As part of this research an in-depth review was undertaken on sensor based data capture options as bivalve farms have a range of infrastructure in the water across a vast area with a low population density and this offers an opportunity for data collection via sensors. There are several data solutions emerging in the marketplace, particularly for farm management, including a handful specifically designed for shellfish farmers. So far uptake is limited because the value-proposition is not immediately clear to farmers – and internet connectivity can be challenging in remote coastal areas. The maintenance of sensors and the range of sensors required can also add additional management challenges. Data capture can be used for certification purposes as well as a valuable insight into the health of near shore coastal environments. In addition to benefiting the industry, data streams are relevant to regulators and scientists who recognise that it is costly and challenging to maintain data infrastructure in areas where bivalves are farmed, and they could be willing to pay shellfish farmers for data. It is therefore pertinent to explore these opportunities in the context of growing the Scottish bivalve sector and increasing its attractiveness for investment.

Remote sensing technology has a part to play in capturing relevant data streams and this study investigated the current and future needs, opportunities and challenges of farmers hosting data infrastructure (e.g., sensors) on their farms. Insight was gained through proprietary knowledge of remote sensing options and an understanding of the costs/ benefits and where the value would lie for farmers both individually and for the industry as a whole.

### **Sector Characteristics Relevant for Data Capture**

The main growing areas for shellfish are the West Coast of the mainland (typically smaller sites, more of a ‘crofting’ style, although some growth in site size) and Shetland where the industry is more ‘industrialised’. Typical production technology is a series of buoys strung together up to several hundred metres long from which one or two continuous ropes of mussels are suspended. Oyster production volumes are much lower and typically on trestles and baskets in the intertidal area. Mussels are grown in similar areas to salmon farming and some companies hold licences for both. Specific locations of farms can be seen in <http://aquaculture.scotland.gov.uk/map/map.aspx> - and there can be some areas where there are multiple sites in one loch/voe whilst on west coast the farms tend to be a little more dispersed.

### **What Type of Data may be Important and Who is it for?**

In salmon farming there are ‘management areas’ where all producers are supposed to collaborate on stocking and disease control, but these don’t really apply for shellfish as disease management is not such an issue. Although there are some concerns about algal blooms in Scotland this is more of an issue in other countries (e.g., Chile) and they are

attempting to establish a Harmful Algal Bloom monitoring program with series of sensors out at sea (and aerial imagery analysis) for both salmon and shellfish.

In Scotland, shellfish production waters are graded, depending on how much pollution there is typically from sewage, but sometime from sheep/cattle density as the measure is E. coli count. This is not such an issue for mussels that are usually cooked, but it is a consideration for oysters. Oysters from grade A waters can be consumed without further processing whilst those from B grade waters need depuration (flushing with clean water which in turn adds costs) or must be sold cooked. Waters can change classification throughout the year.

For mussel (and oyster) farmers we might expect measurements like dissolved oxygen, temperature, salinity and some measure of turbidity to be critical pieces of information, but the study by North Atlantic Fisheries College shows that many shellfish farmers do not place value on knowing this. Additional environmental criteria like wind speed and tidal force could also be interesting as that will place potential strain on infrastructure or could bring plankton (food) to the farms. Much of this data could also be useful for scientists, environmental specialists, or government – and shellfish farming infrastructure could provide a useful place for positioning sensors for data capture. There may also be requirements to understand losses due to predation by starfish or eider ducks and potentially impacts on the seabed communities immediately below farms (this is more of an issue in sheltered production locations where water movement is gentle). It is reasonable to assume that a network of data collection around shellfish farming sites would require a third party to provide that data in a format that would hold value in the environmental data market and to pay a return to the shellfish farmers.

In addition to data that could prove useful to shellfish farm management there is an opportunity that acquisition of data will be of value in the investment proposition. Investors seeking to increase sustainable seafood production would require data from farms as part of their measure of progress. The proposed UK-focused Blue Impact Fund will have some focus on environmental criteria that are included in the Turning The Tide measures published by UNEP (<https://www.unepfi.org/publications/turning-the-tide/>), but will include other key performance indicators that may link to the developing Blue Carbon Credit scheme for the UK (primarily focused on seaweeds). It is vital that the shellfish sector has input into the development of the Blue Carbon Credit scheme to ensure shellfish are included.

### **Use of Sensors and Artificial Intelligence (AI) to Support Water Quality Monitoring and Farm Management**

There are a range of data capture options using Internet of Things (IoT) devices applicable to shellfish operations. LoRaWAN connected IoT devices / sensors have the ability to capture relevant data and with the use of AI can provide meaningful insights for on farm decision making. LoRaWAN enabled sensors have the advantage of being able to be deployed over large distances, have long battery life, the infrastructure required is reasonably cost effective and the LoRaWAN sensor market is maturing making it a realistic proposition for at scale farming operations. An example of this is from Libelium which can capture all the parameters

previously identified as being relevant to shellfish farming. Libelium smart water technology is an example of IoT and sensors that has been adopted by mussel producers in New Zealand to meet standards of sustainability and quality and they have achieved this using real time salinity data to identify mussel harvesting compliance.

## IoT Sensors for Water Quality

Comprehensive water quality data can be collected over currently available LoRaWAN connected devices and sensors such as Libelium's Smart Water Xtreme device ([https://www.libelium.com/downloads/documentation/smart\\_water\\_xtreme\\_tecnical.pdf](https://www.libelium.com/downloads/documentation/smart_water_xtreme_tecnical.pdf))

This device allows the connection of up to six high-end factory calibrated sensors to collect data and is currently the 'gold standard' LoRaWAN device for monitoring water resources.

Currently available sensors to measure:

- Dissolved oxygen
- pH
- oxidation reduction potential
- conductivity
- salinity
- turbidity
- suspended solids
- dissolved solids
- redox (orp)
- temperature
- sludge blanket
- chlorophyll a – blue
- chlorophyll a –red
- phycocyanin
- ammonium
- CDOM/fDOM
- Nitrate
- Chloride
- Sodium
- Calcium
- Total coliform bacteria
- Pressure
- Bromide
- Refined oil
- Crude oil



This provides options for the remote monitoring of water quality that can be used to support decisions for farmers and regulators.



In Poole Harbour a company call UnifAI Technology (<https://www.unifaitechnology.com/>) have developed a water quality monitoring and risk assessment engine to support a lower cost approach by using predictive artificial intelligence (AI) capabilities to support advance warnings of water quality issues in the marine environment. UnifAI measure only a limited number of water quality parameters from which higher order/more complex parameters can be derived using their AI engine. This reduces the instrumentation cost for any given site.

Similarly, French start-up company Bioceanor (<https://www.bioceanor.com/en>) has developed an IoT/AI solution for monitoring and predicting water quality. The AI component uses an algorithm that proposes to offer predictive insights on dissolved oxygen, algal blooms and microbial contamination. This has the potential to provide data that will allow operators to demonstrate in real time whether sites are of Grade A or Grade B water quality. They have identified shellfish operations as one of the main beneficiaries of this technology and have

deployed a solution on an oyster farm in the Mediterranean. The IoT device element involves the collection of water quality data using LoRa connected sensors that capture a wide range of water quality parameters. The combination of IoT devices and an AI engine allows timely alerts to near real time and future changes in water quality that might impact shellfish operations.

The biggest challenge for marine instrumentation is fouling, hence why the use of simpler sensors and AI to derive the higher order insights may be the way forward. Developments in AI are promising to push down the cost of monitoring water quality parameters by using simpler instrumentation and leveraging an AI engine to determine other parameters that would otherwise require more complex and costly instrumentation.

Platforms that rely on sensors to provide the data that will inform farmer decision making are very relevant both in farm management but also in terms of their relevance to support supply chain assurance. However, the value and motivation for sensor based data opportunities for farm management purposes is likely to lie with larger enterprises. Two examples already deployed in shellfish farming are:



SmartOysters (New Zealand) offers an aquaculture farm operations platform that supports multiple aspects of farm management and integrates with sensor systems that may be deployed to capture various data points across all aspects of operations and environment. There are variants of the same platform that offer solutions for seaweed and mussel farming operations.



The Yield an Australian agritech business that also offers IoT (Internet of Things) and analytics services for agriculture and aquaculture. Sensors capturing weather and water data provide insights to shellfish farm managers to support harvesting decisions as well as insights that can predict the likelihood of POMS (Pacific Oyster Mortality Syndrome). The data can also made available to food safety regulators via a portal to support timely management decisions.

It is therefore possible that the Scottish bivalve sector can implement different types of data capture systems for their own farm management purposes and ecosystems services

## **Financing Opportunities**

Investment finance has not generally been available to enable the sector to scale up. Businesses that have grown have typically done so either with traditional bank financing or personal investment. There is promise of a new commercial investment fund called the Blue Impact Fund, specifically targeted to grow UK aquaculture. The fund has been developed in collaboration with WWF-UK with a particular focus on low-carbon production of shellfish and seaweed, although funding for improvements in salmon farming are included. Projects of between £1million and £15million will be of interest to the fund, meaning that tonnages will need to be significant.

In 2020 the Scottish Government also launched the Scottish National Investment Bank with a focus on a green recovery. Whilst shellfish projects are not specifically mentioned they could have potential for support, especially where they address key structural challenges, perhaps around coastal environmental quality. The Scottish Investment Bank (recently under Scottish Enterprise) has invested in the shellfish sector, although it is not clear how this will continue with the formation of the SNIB.

Investors seeking to increase sustainable seafood production would require data from farms as part of their measure of progress. The proposed UK-focused Blue Impact Fund will have some focus on criteria that are included in the United Nations Environment Program publication “Turning the Tide: How to Finance a Sustainable Ocean Recovery” but will include other key performance indicators. This need for data could provide further opportunity for new farms to contribute to industry-wide data requirements.

Another factor that will likely speed up investment by new entrants, or help current innovators to scale more easily, will be pre-approval of sites with sizable production volumes. The technology of (particularly) mussel cultivation is now fairly standardised across the industry and given the limited environmental impacts there should be the opportunity for CES to progress applications on behalf of future investors. This may be of particular value on the east coast where production would be seen as ‘new’. despite having historic shellfisheries. This would also provide Food Standards Scotland and SEPA with the opportunity to address any issues early and provide investors with confidence that farms will develop without major hurdles. Some of the cost of this pre-work could be built into leases.

## **Policy Considerations**

Blue Carbon opportunities and the value of data are both of relevance when considering the policy environment supporting growth of shellfish. Scotland’s National Marine Plan (2015) recognised shellfish as having a particularly low carbon footprint. SNMP has provided the overarching framework for the growth of shellfish aquaculture although additional instruments have also been developed, including Scotland’s Aquaculture Growth Strategy to 2030 and the Shellfish Working Group (SWG), which brings together industry, regulators and scientists to address challenges and identify opportunities for the sector. Shellfish aquaculture should also be a strong element of the developing Blue Economy Action Plan, which promises to encourage collaboration across the public sector, marine industries and

marine environmental interests to unlock cross-sectoral synergies that can support growth and jobs, benefit coastal communities and help deliver a just transition to net zero. Marine Scotland is also proposing an Aquaculture Shellfish Growth Plan, however this and the regular meetings of the Shellfish Working Group have been delayed whilst the government deals with the challenges of Covid-19.

## Conclusions – Key Points

### Payment for Ecosystem Services

There was no specific objection to the idea of a PES system in the marine environment from those interviewed. However, whilst shellfish farming is typically a low-impact, low-carbon food production option that makes sustainable use of Scotland's natural capital, a clear set of criteria would need to be developed to qualify for PES payments. It appears it would be challenging to consider a blanket payment to farmers simply for the process of farming shellfish using current norms despite the services shellfish farming already offers. A PES system could be used to reward farmers for making improvements to their farming systems that could further improve environmental quality, or for gathering and sharing data that would contribute to wider environmental management initiatives. PES payments could also be provided for farms developed in areas where they can specifically address issues like water quality or coastal protection, especially where it would otherwise be economically challenging to justify investment. The Scottish Government should consider these issues in the development of the Blue Economy Action Plan and Marine Scotland in the proposed Aquaculture Shellfish Growth Plan. The Scottish Aquaculture Innovative Centre (SAIC) could support a research project to explore these opportunities more deeply.

### The Low-Carbon Story

The Scottish shellfish sector has a real opportunity to capitalise on the low carbon story. Further research is required to confirm the desk-top findings in this report, but with sequestration potentially comparable to seaweed and forestry and mussels having by far the lowest carbon footprint of any animal protein there is a story to be told. Presenting the low-carbon story effectively and strongly will attract finance to the sector and support the growth ambitions of the sector, possibly providing additional value to increase production specifically focused on carbon capture and environmental improvement, perhaps not specifically for consumption. However, retailers will likely be interested too given increasing demands on reporting Life Cycle Assessments and other environmental impact indicators – and for attracting consumer categories increasingly selecting diets based on environmental credentials. SAIC could be encouraged to provide funding to support development of the evidence required to support this approach.

### New Sites

The development of new production areas and sites provides an exciting opportunity, but additional challenges. Sector representation in all regional marine spatial planning dialogues is challenging because of the time burden, with priority given to involvement in plans around existing production locations. It may be worthwhile for CES, Marine Scotland and industry bodies to consider bringing in potential investor representatives to participate in the dialogues, especially where there is an ambition to grow the sector in new areas. Another factor that will likely speed up investment by new entrants, or help current innovators to scale more easily, will be pre-approval of sites.



## **Data**

Increased data collection has multiple potential values and there are many opportunities to develop this area to strengthen farm performance, support successful industry growth strategies, support marketing initiatives e.g., around blue carbon, and attract investment. Linking the value of data for farm management to the delivery of wider industry strategies could provide a key driver for increased precision farming in the sector. Information that can increase the knowledge of factors influencing e.g., spat fall and growth in specific locations could help to increase the overall productivity of the sector from existing sites. This requires a concerted effort from multiple farms and partnership with agencies who can structure data collection and processing in a way that maximises the value for the sector. The collection of data from existing sites would further demonstrate the sustainability credentials of farmed shellfish as a low-carbon protein sources making sustainable, renewable use of Scotland's natural capital assets.

During the study no clear route for a payment for data was identified. However, there is clearly demand for greater understanding of the impacts of climate change on coastal waters, so we recommend that discussions between Government, research and industry stakeholders continue in this space, perhaps even as a specific topic within SAIC, the Shellfish Working Group, or more widely in the Scottish Forum on Natural Capital, for example.

Normalising regular data collection and analysis will reduce the gap between what investors are looking for in terms of strategic sector and business management and current industry practices. This should bring the potential of investment even closer, especially as the data should provide further validation of the sustainability criteria of shellfish farming in Scotland, including evidencing the low-carbon story.

In terms of the infrastructure that could be utilised in the Scottish context, SmartRural have piloted data collection from low-energy sensors with farmers on remote agriculture farms using a system called LoRaWAN (Long Range Wide Area Network). As well as seeing value in the data collected, farmers also liked that the system enabled worker safety devices in areas where mobile phones do not work. SmartRural already have infrastructure established in Argyll and Bute that could enable further piloting with shellfish farmers.

## **Policy**

ASSG, Seafood Shetland, SSMG, CES, Marine Scotland and others need to continue to push the shellfish agenda strongly, particularly in the development of local marine plans and in the roll-out of the Blue Economy Action Plan. In order to provide confidence for the arguments for expanding shellfish production, specific research evidence is required, particularly around carbon sequestration and other ecosystem services. Specific numbers and comparators to other sectors will further strengthen the case for active inclusion of shellfish in all marine planning and potentially grow interest from other marine users for greater co-location in an increasingly busy space.

## **Financing**

There are innovative finance opportunities on the horizon, but again a stronger shellfish story is needed to encourage the financiers to fully engage. The blue-carbon and other environmental services are clear points of interest given current dialogue in the finance industry. Once financiers truly understand the value of shellfish in terms that make sense to them they will become strong advocates on behalf of the sector to support growth, investing in structural requirements as well as farms.

## **New Business Models**

By actioning progress in the various components of this study together (alternative products, new markets, PES, low-carbon, pre-planning sites, data use) the sector will be starting to address many of the requirements of potential larger-scale investors. It may be that the companies who will attract investment or operate future farms will be very different from the make-up of the industry at present, especially if the drivers and scales shift significantly.

Any growth carries the risk of increasing volumes and decreasing market price unless the market continues to expand with sufficient demand. However, there is scope for growth in production to happen for alternative reasons, with the value for food not being the main driver. If the value of meat is lower for other uses than higher-end UK consumer rates, for example volume European markets or animal feed market then additional value will need to come elsewhere to maintain current income levels. Given the potential for value to be realised from oil extraction, for PES (including carbon) and payments for data an alternative value structure may be viable. Indeed, this new opportunity may provide greater returns if the additionalities can be realised.

## **Appendix 1**

Slide deck to accompany prospects for existing and alternative products in UK retail and food service sectors is provided in a powerpoint file

## **Appendix 2**

Slide deck to accompany market prospects for nutra / pharmaceutical products is provided in a powerpoint file

## **Appendix 3**

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## Appendix 4

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