ASTRAL

*A*ll Atlantic Ocean **S**ustainable, Profi**T**able and **R**esilient **A**quacu**L**ture

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Evidence of accomplishment

Report

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Summary

This document was created as part of Work package 6 of the Horizon 2020 project All Atlantic Ocean Sustainable, Profitable and Resilient Aquaculture (ASTRAL). Work Package 6 focuses on business development, profitability, and exploitation, addressing one of the primary objectives of ASTRAL, namely, to address IMTA value chains from the point of view of profitability and socio-economic factors; these aspects are crucial to large-scale promotion and deployment of the IMTA approach.

Deliverable 6.3 consists of business model analyses of eight use cases. It includes existing commercial farms and prospective IMTA systems (ASTRAL Labs), showcasing monoculture, co-culture, and IMTA systems with diverse value chains and species. This report used the Business Model Canvas (BMC) tool to describe and analyse each business model's essential dimensions. A crossed analysis is also used to highlight intrinsic and external factors affecting each business models, using SWOT and PESTEL approaches.

Environmental performances of IMTA systems are considered with key inputs from the life-cycle assessment deliverable of ASTRAL. This deliverable provides a comprehensive analysis of IMTA's economic aspects, business models, and factors influencing their development, compared to monoculture and co-culture use cases. This report faces limitations in extrapolating data and scarcity of economic information for experimental IMTA pilot sites (Labs). It emphasizes main drivers for IMTA that stakeholders can leverage.

Economic benefits include economic growth in coastal areas and income diversity, while changing consumer habits favour sustainable and premium aquatic products. Emerging markets, particularly in seaweed-based products, offer growth potential. The high quality of IMTA products, coupled with traceability, provides a competitive advantage. Research and development, along with skilled human resources, are essential for navigating the complexities of IMTA systems. Political and financial support are crucial due to substantial installation and operational costs. Producers need to develop effective marketing strategies, explore new markets, and enhance product branding to raise market value. Building a positive brand image can capitalize on international perceptions and increase market penetration. Additionally, exploring ecosystem services adds another layer of potential benefits to IMTA business models. In summary, while IMTA holds significant promise, addressing challenges in funding, expertise, and market strategies is essential for sustained profitability.

NB : This deliverable is supplemented by a compendium focusing on the IMTA cases analyses (see Appendix 3: IMTA case study compendium).

Introduction

Integrated multi-trophic aquaculture (IMTA) is a sustainable type of farming where multiple aquatic species from different trophic levels are farmed together. The IMTA principle is based on the co-cultivation in the same site of higher trophic level species with extractive species. Those extractive species will use and assimilate the wastes (organic and inorganic) produced by the fed species; one species' waste becomes another's food input (Hughes and King, 2023).

IMTA can be a solution to reduce the ecological impacts on the surrounding environment but can also increase the social acceptance of aquaculture by presenting a more sustainable system. The economic benefits could also be highlighted, with income diversification for the producer, greater market value for IMTA products and possible faster production cycles (Knowler et al., 2020).

To support the development of IMTA, one of the objectives of the ASTRAL project is precisely to address IMTA value chains from the socio-economic and profitability point of view; these aspects are crucial to promote and deploy the IMTA approach widely.

The deliverable 6.2 of ASTRAL outlines the macro socio-economic assessment and the macro and meso cost and benefit assessment of IMTA cases by highlighting major trends and impacts.

Based on these assets, the deliverable 6.3 aims to identify the right skills and requirements needed for IMTA application, notably, from an economical point of view. To do so, a business model analysis was carried out for existing monoculture, co-culture and IMTA farms. The same work was done on prospective use cases based on the ASTRAL IMTA Labs. Those IMTA labs are still at an experimental stage: each site manages a production on an experimental scale, with no post-production facilities, neither market channels nor defined target, so they are not at a commercial scale.

A business model is the description of how an organisation creates, delivers, and captures value. It defines how the company organises itself to deliver a value proposition to customers (a promise) and how it earns money and balances expenses and revenue flows (Knowler et al., 2020).

This deliverable aims at demonstrating the economic benefits and constraints of integrated multitrophic productions, defining the processes used and identifying market requirements and opportunities. This deliverable is intended to be a tool for existing or future producers and also as a decision-making tool by providing an overview of best practices, relevant economic frames, value chains and external impacts of IMTA farms.

This report follows some of the conclusions from deliverable 6.2:

- There is no single model or profile for IMTA farming, but a diversity of possibilities, depending on the species produced, the location or the type of cultivation (offshore or land based), amongst other variables.
- Current IMTA producers are either in an experimentation phase or a scale-up one and are producing a wide variety of products, but their approach is highly focused on Research and Development (R&D).

The following table highlights influencing factors for IMTA development and de facto for business models:

Table 1: Influencing factors on the socio-economic model of the farm

Influencing factors for IMTA development	
Structuring factors	**Contextual factors**
Ignorance of markets for each species and distribution channels	Regulation
Increase of production costs	Societal acceptance
Optimisation of production costs	Regional development
New market opportunities for revenue diversification	Institutional support
Complexity of production system and technical challenges	Environmental groups objection
Improved species' growth rate due to IMTA	Access to equipment, technical maintenance and high value technologies
Link with the research community	Cost variability
Consideration of ecosystem services for environment	Uncertainty of national context

The economic operation of aquaculture businesses is determined by a range of internal and external factors, which influence the definition of the business models. It is key to consider a range of aspects, including specific geographical features, the infrastructure and facilities for the production and its impact on the environment, accessibility to resources, spatial appropriation, environmental protection areas as well as the validation of the market (regional, national, international), potential partners, and regulatory and legal requirements, amongst others.

Methodology

Deliverable 6.3 consists of a detailed main report and an executive summary. The executive summary is a synthetic, more operational document that summarises the analyses, focusing on the IMTA approach.

1 Deliverable 6.2: cost-benefit analysis and socio-economic assessment

This deliverable is based on previous work: the deliverable 6.2 of ASTRAL, which provides an in-depth description of the socio-economic aspects of aquaculture and IMTA, as well as of the existing challenges and includes a preliminary cost-benefit assessment. To produce deliverable 6.2, 39 interviews with producers (IMTA, co-culture and monoculture) were conducted to collect economic and qualitative data in the 10 countries included in the ASTRAL project, from January to August 2022. Additional data were collected from literature and websites of companies. This previous work was a key input for the deliverable 6.3, especially to fill the Business Model Canvas (see section 3) for existing farms.

2 Definition of case studies

Eight case studies have been identified for this deliverable, located in different countries within the Atlantic Area.

Within those eight use cases, four are existing commercial farms and four prospective IMTA systems which correspond to the ASTRAL IMTA labs. As mentioned before, those pilot sites produce different species but have not yet reached the commercial stage and are not selling their products.

Table 2: Presentation of the eight use cases

Aquaculture model	**Species**	**Location**
Monoculture farm (X1)	Kelp	Norway
Co-culture farm (X1)	Kelp and mussels	Ireland
Existing IMTA commercial farm (X2)	Oysters and winkles	France
	Abalone and *Ulva*	South Africa
Pilot sites (ASTRAL - IMTA labs) (X4)	Fish (Atlantic salmon) Seaweeds Oysters Sea urchin	Ireland
	Native oysters and seaweeds	Scotland
	Sea urchins and seaweeds	South Africa
	Tilapia Shrimp Seaweeds Oysters	Brazil

The choice of use cases was made regarding:

- A geographic representativeness among the ten countries involved in the project
- Plurality of aquaculture models for comparison purposes (monoculture, co-culture and IMTA farms)
- A variety of value chains, size of farms and species produced to analyse a broader range of models
- The availability and relevance of the information we collected through interviews

3 Business Model Canvas

The business model is a decision-making tool for an organisation to identify the right economic strategy to implement, stand out from the competition and highlight the added value. This concept is using a visual approach to identify the core elements needed to create value.

It defines the four essential dimensions of a company:

- Offer: the promise to the customer – the value proposition
- Customers: the targeted users/consumers and the relationship with them
- Infrastructure: the key resources, activities and equipment needed to run the company
- Financial viability

To describe each business model, the Business Model Canvas (BMC) tool was used. Introduced by Alexander Osterwalder and Yves Pigneur, the Business Model Canvas is a matrix to describe, represent and analyse the basic elements of a business model (Osterwalder et al., 2010).

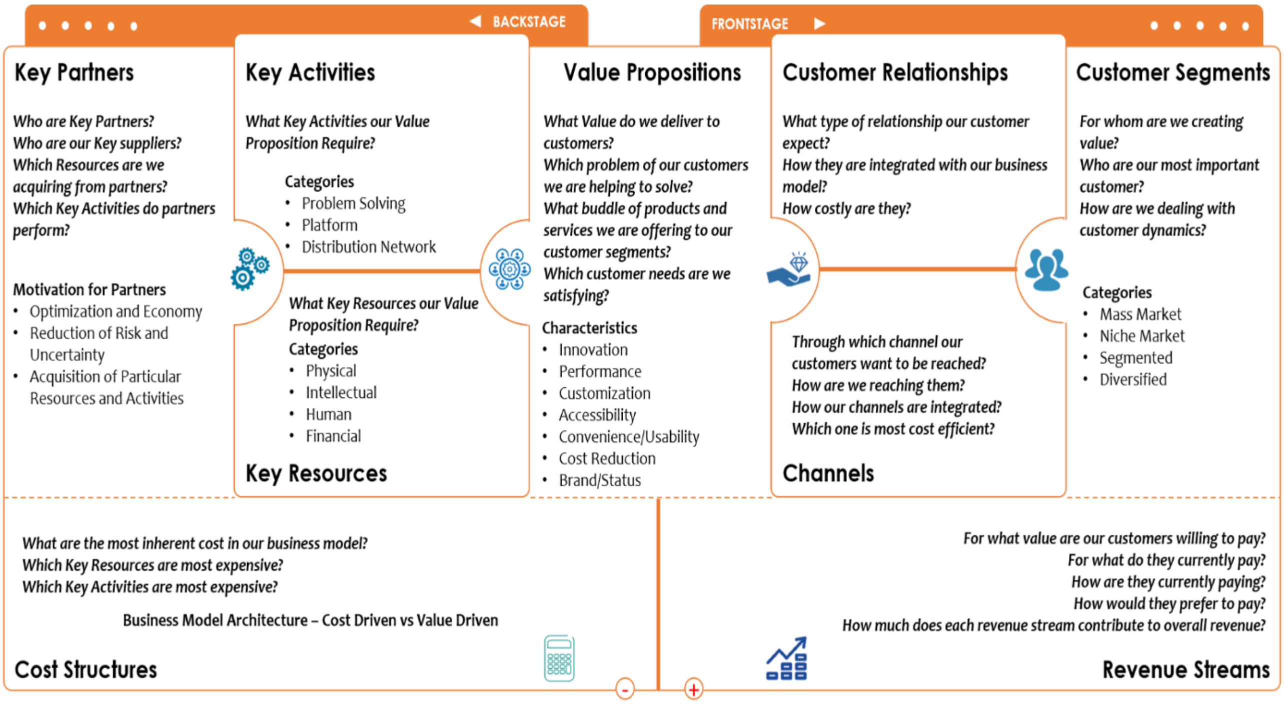


Figure 1: The Business Model Canvas matrix (Source: Osterwalder et al. 2010)

This template includes nine boxes broken down as follows:

- Value propositions: it is the expression of the offer, the problem that the company tries to solve. A potential customer must be able to clearly identify how the product is more interesting than another in the competitive field.
- Customer segments: it represents the company's target audience, the different profiles that the product is designed to appeal to and that the offer must reach.
- Channels: this box identifies the distribution channels, all the means used to get in touch with and to reach the targeted customers.
- Customer relationships: it presents the customer management strategy and how the company will attract customers and build their loyalty.
- Revenues streams: it outlines the company's main sources of income and how income will flow.
- Key activities: it describes the actions needed to achieve the value proposition and that will stimulate the offer.
- Key resources: it refers to all the elements needed for the company to create the service or product. There are four types of resources: financial, human, physical and intellectual.
- Key partners: it describes the various strategic players involved in the company's environment, such as subcontractors, public institutions, transport companies, etc.
- Cost structure: it identifies the main expenses as well as in which stages of the value chain we can find them, which are the highest and the lowest.

4 Intrinsic and external factors of the business models

For the description of the business models, we have used the Business Model Canvas (BMC) approach (described in section 3). An analysis of each case was done to identify how each production site operates. To do so, three different types of data were used: guided interviews with the responsible people of each site (producers and/or researchers), bibliographic review and all the complementary work done within the ASTRAL project through other deliverables.

For the prospective business models, deeper interviews were made with the IMTA Labs (Scotland, Ireland, South Africa and Brazil). Those interviews were used as key inputs to thoroughly understand the production phase of the systems and therefore allow us to generate hypotheses for the commercial aspects of the BMC. Notably, because as mentioned before, the ASTRAL labs are not at a commercial scale (the production is not sold), hence, a prospective work was required for the commercial aspects. Based on production details, a value proposition of each IMTA lab was drawn; possible markets, distribution channels and sources of revenue were proposed.

The BMC enabled the description of each model with the key information on the different aspects that the business performs to create value.
To complete the business models case studies, an analysis of all internal and external factors impacting each model was required, therefore a crossed analysis of two different methods was used: a SWOT and a PESTEL. Based on a standard SWOT analysis, internal strengths and challenges/weaknesses were identified for the business's development; these factors are intrinsic to the business model and to the system used by the producer.
Moreover, a Life Cycle Assessment (LCA) was conducted in ASTRAL for the IMTA Labs (deliverable 4.3). One of the aims of this work was to highlight the environmental performance of IMTA systems comparing to monoculture conditions. The relevant data from this deliverable on LCA was thus used to fill the intrinsic analysis of prospective business models (IMTA Labs).

For the external factors, a PESTEL analysis was used to identify the external opportunities and threats influencing each model. The PESTEL analysis is a strategic framework commonly used to evaluate the business environment in which a company operates from a political, economic, social, technical, environmental, and legal point of view.

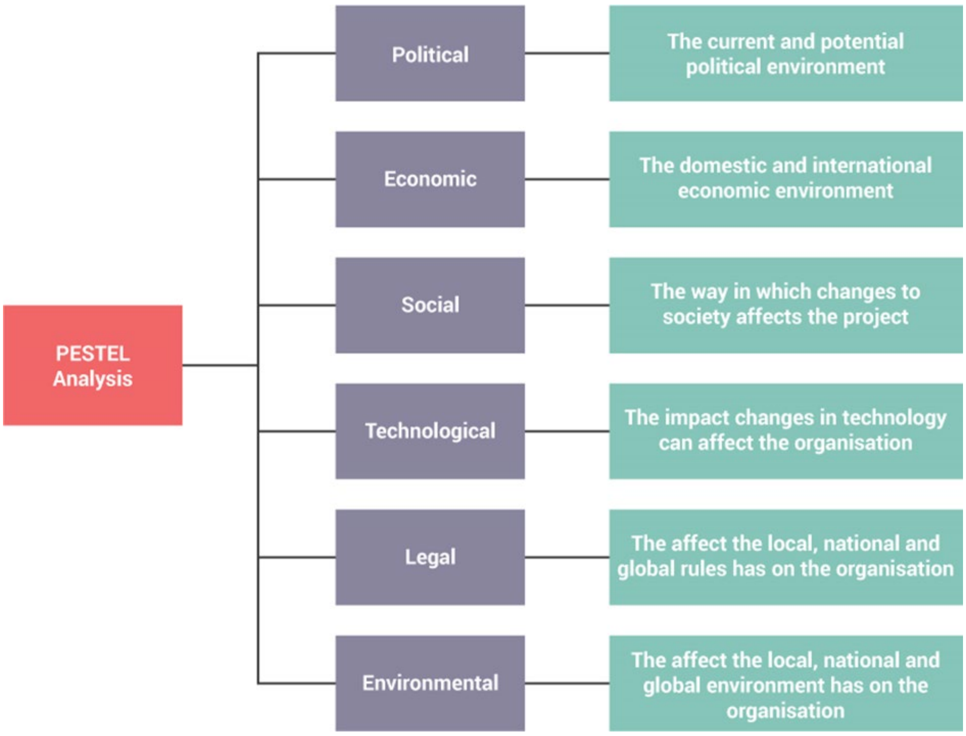


Figure 2: The PESTEL analysis (Source: planiumpro.com)

1 Classic aquaculture use cases

1.1 Monoculture case study – Norwegian farm

Offshore – Seaweed (Norway)

This production site is a subsidiary company of a corporate (leader group) which is a world-leading seafood corporation with 4,500 employees, established over 100 years ago. The Group's core business is production of salmon and trout, catches of whitefish, processing, product development, marketing, sale and distribution of seafood.

The monoculture farm, created in 2018, is producing and processing macroalgae offshore for feed (98% of the market), food and other valuable products from seedlings to finished product.

1.1.1 Business model presentation

Value proposition

Macroalgae absorbs excess nutrients from the sea such as nitrogen, phosphorus, and CO_2. It does not require any feed input or fertiliser addition, which makes it a species with interesting environmental ecosystem services.

One of those seaweed is sugar kelp (*Saccharina lattissima),* a brown alga which is common in Norway and is characterised by a blade with wave shaped edges and a sweet taste. It occurs naturally along the Norwegian coastline from the intertidal zone down to 30 metres and can reach five metres long.

Macroalgae are marine plants, and their nutritional content will vary depending on season, geographical location, and temperature.

Sugar kelp is seen as one of the most delicate of the edible seaweeds due to its sweet taste and natural content of glutamate, providing a rich and tasteful umami flavour.

This monoculture farm produces mainly sugar kelp (231 tonnes in 2022) and relies on high volumes to run machines for several hours and days in a profitable and practical way. This site can also produce winged kelp (*Alaria Escuenlata*) (15 tons in 2022).

The production capacity per species is 1,500 tons of *Sacharina* and 1,500 tons of *Alaria*.

Products can be sold in different forms:

- Dried sugar kelp: grounded (0-0.5mm or 0.5-2mm), leaves or box
- frozen sugar kelp: in bags of 100g, bits or bulk of 4 kg.

The produced seaweeds are organic as the farm is Debio-certified, an organic label in Norway.

Market customers, relationships & channels

This monoculture farm is using a Business to Business (B2B) approach by selling the whole production to international markets, especially industrial stakeholders.

Currently, 98% of products are sold for the feed market. Indeed, the company is selling kelp in bulk to a main customer, a Danish feed producer.

According to the producer, the part of seaweeds used for human consumption is currently representing small volumes and is mainly used for store-bought spice mix and smoked salmon seasoning (mixture of dried kelp and salt mixture).

The company mainly sells fermented kelp for feed, especially cows and pigs. This input reduces methane emissions from cows, increases milk production, and reduces the problem of milk fever in cows, reducing the use of antibiotics. For pigs, piglets are the target species: it is demonstrated that feed added with kelp (1-2%) improves the intestinal flora of pigs and provides better survival for the piglets, which represents an added value for the farmer.

The identified challenge is that cows' farmers do not have any tax on methane gas emissions, nor any reward for reducing methane gas emissions. Dairy farmers are therefore sceptical about taking on extra costs by adding a little fermented kelp to the feed.

For pig farming, economics are somewhat better due to the increased survival rates of piglets, covering the additional cost of adding kelp to the feed. Since methane is harmful for the environment, being about 19 times worse than the effect of CO_2, it is necessary to seek a reduction of methane emissions from agriculture.

This production site could use hybrid distribution channels: direct method and indirect method using a distributor. The farm is relying on the resources of the parent company to benefit from their large sales force.

Key activities

The size of the production area is around 100 to 500 hectares in an offshore site, ideal for kelp.

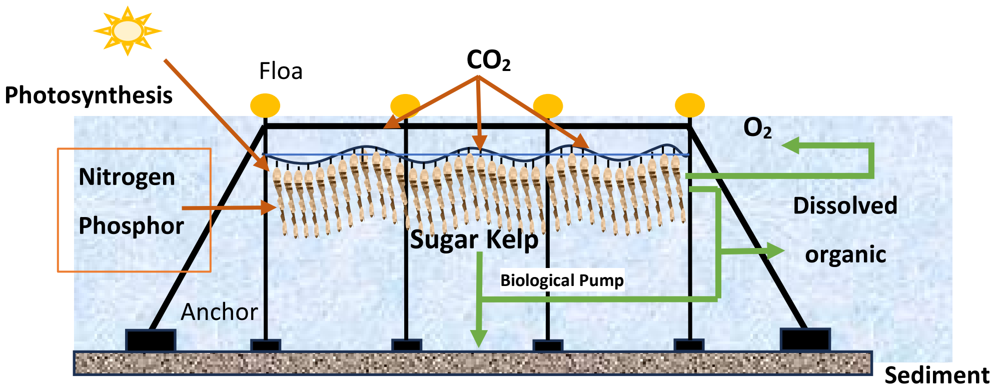


Figure 3: Kelp production process scheme (Source: producer; creation: Technopole Quimper Cornouaille (TQC)

They control all the production process, from harvesting to processing. The company has full traceability on the whole production chain by using the salmon industry's traceability system, processes and experiences which has been adapted and implemented in kelp farming.
They are doing daily environmental monitoring, for sunlight and temperature parameters for example, using sensors and their development is based on a strong R&D approach.

Key Resources

The company is one of the largest seaweed farms in Europe, possessing an extensive know-how about seaweed cultivation, research and development, marine biology and marine engineering. By producing their own seaweed seedlings from indigenous plants at their hatchery facilities in the Southwest of Norway, they can control the quality of the seaweed production through the entire value chain, from seedlings to finished product.

The farm is strongly linked with a research and development organisation; 50% of whose capital is held by the parent farm company (main company) and 50% by a Norwegian environmental protection organisation. As legally divided into different companies, this seaweed farm and the parent company operate roughly as one company in a practical way.

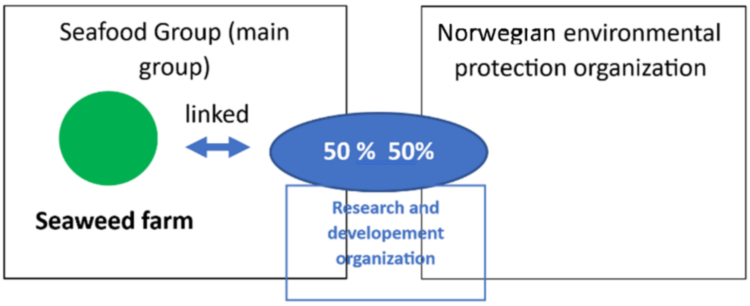


Figure 4: Administrative organisation of the Norwegian seaweed farm (creation TQC)

The main company was established in the first place and now conducts research, development, and industrialisation. The monoculture farm operates commercial production, currently only kelp. Both two companies are working using kelp and the human resources are shared between the two structures.
They employ 7 people year-round and hire 5 additional people during harvest periods (15 harvesting days) and 10 people including the boat crew. Additional people are hired internally from the seafood group using staff from the group's salmon farms, which are fallow during this period.
The seaweed farm has invested on R&D approach and on equipment, which is mainly specific equipment adapted to kelp production.

Key partners

30% of partnership and co-operation is performed with R&D institutions and 70% with other companies.

The company works with research organisations on kelp like SINTEF and Møreforsking, in upstream activities, but much of the R&D is downstream activity once kelp is produced.

They also work with business companies, both locally and internationally, with the development of equipment and technology. The companies are developing equipment either alone or directly with them because there is extremely little off-the-standard material available.

The farm is working with suppliers for cuttings or kelp seeds and with buyers for product development because kelp is a relatively new product, and they have clear requirements for how products should be.

These partnerships favour their optimisation process and economies of scale, enabling a reduction of risks and uncertainty. A key activity is development work, which consists of in-house trial and error management.

Cost structure

The production costs are distributed as follows:

- 50% harvesting costs
- 20% purchasing / processing / cutting
- 30% Human resources

Costs are mainly fixed. Sizeable investments have been made (€251,400) to optimise the process thanks to specialized equipment (frame mooring, rope work, sensors).

Revenue Streams

Thanks to sales of products (kelp), the company achieved 4,3M NOK of income on the last two years (€360,340). The price is variable, determined by the market and negotiated.

The company faces a significant deficit due to high R&D costs. R&D is necessary because the company is in a development and scaling up phase. According to the producer, it is important to separate operating and R&D deficits. If the farm only produces and harvests kelp and is not engaged in any R&D nor product development, they will have a break-even result with a production volume of 300 tons. But when including the costs of the R&D activity, they would need a production volume of 500 tons.

1.1.2 The Business Model Canvas

The Business Model Canvas

MONOCULTURE- OFFSHORE

SEAWEEDS (KELP)

NORWAY

Key Partners

- **Upstream partner**

Leader group (seafood corporation)
Research and development organization
Norwegian environmental protection organization
SINTEF and Møreforsking AS
R&D institutions working on kelp culture
Business companies for equipment and technologies
Buyers for product development
Boat company

- **Downstream partner**

Buyers (feed producer)

Key Activities

R&D

Production process : all the value chain (from hatchery to commercialisation)

Monitoring

Sales & marketing

Key Resources

Offhore production area with permits (trust and permissions)

Leader group

Shared HR with the leader group and skilled resources : for R&D and sales/marketing

Scientific knowledge (on aquaculture and kelp) and norwegian seaweed network

Specific equipment & technology including boat

Control of the value chain : quality & tracability approach

Value Propositions

Kelp production : *Alaria Esculenta* and *Saccharina Latissima*

- Environmental added value
- High nutritional components
- Wide range of application

Fermented, dried or frozen products in various packaging

100% organic products : is Debio-certified

Customer Relationship

Promotion by Bord Bia (State agency)

Promotion through representative bodies (IFA)

Channels

BtoB model :
Sales directly to 1 feed producer

Customer Segments

International market :

- For animal feed (98%)
- For human consumption (2%)

Feed producer : 1 main customer in Denmark

Potential markets segments especially on food and agriculture

Cost Structure

Incomes : 4.3M NOK (about 370 000€)
Contribution to the capital by the Seafood group (main company)

Distribution of production costs : 50% harvesting costs
20% purchaising, processing cutting
30% human resources

Deficit linked to continuous high R&D costs
Boat renting: about 60 000€ per year (during harvesting period especially)

Revenue Streams

Sales of products (kelp)

Income last 2 years : 4.3M NOK (about 370 000€)

Critical mass : 500tons per year (300tons when R&D costs excluded)

1.1.3 Synthesis

Perspectives for the company

- The Seafood Group Board's strategy is to reduce the environmental footprint of CO2, phosphorus and nitrogen emitted by farmed fish and the footprint of the Group's overall activities, as well as to establish a new species in the Norwegian profitable aquaculture industry.
- The farm wishes to double the production every year by 2030. As a productivity goal, it aims that the amount of kg/kelp per meter of cultivation rope must be up to 12 kg.
- They will pursue the R&D and innovation projects (cutting, product, equipment). The company also need to develop and diversify the market to finance their R&D projects.

INTERNAL FACTORS

STRENGTHS
• Performance of value chain: control of full production process and know-how • Strong R&D and knowledge development to innovate • Know-how and background of managers in macroalgae production • Large business that can seek new opportunities, undertake research and development and capitalise new business • Shared Human Resources (such as sales force…) = economies of scale (with the seafood group) • Access to patient capital from a robust owner • Added value of products developed based on performance, cost reduction and risk reduction
WEAKNESSES/CHALLENGES
• Labour intensive & very seasonal (April/May) activity • Technical equipment: need of robust sensors that can withstand being out in the sea for a long time without supervision and that have an acceptable cost. • The boat use: it needs a lot of deck space / complex manoeuvring / risk consideration (especially compared with other aquaculture production) • High cost of boat renting to harvest • Dependence on 1 feed producer (buyer) for the moment

EXTERNAL FACTORS

	Opportunities	Threats
Political	• Very positive attitude from municipalities towards kelp cultivation compared to salmon farming / sea area access • R&D funding from Norwegian Research Council (NRC)	• Access to relevant sea areas, competes with other activities and species
Economic	• Kelp has high potential market development and areas of application: for bioactive components + low footprint = environmental and nutritional properties for food (direct food, food ingredient or taste enhancer) / feed / fertilisers even energy (NTNU, 2018) • The selling price of farmed kelp is quite high: domination of the high-end market (NTNU, 2018)	• A market of kelp for human consumption not yet mature in western countries • Competition with Asia on seaweeds market • High price of seaweed-derived compounds (FAO, 2023) • Costs for processed kelp products: drying, freezing… (energy) • The market for kelps as food is limited in Norway (NTNU, 2018)
Social	• A growing demand for sustainable & alternative proteins, for vegetarian consumption, for novel sustainable source of products, material with carbon neutrality goals… • Seaweed for Europe foresees a potential market value at €9.3bn by 2030 for seaweeds (Seaweed for Europe, 2023)	• It represents an extra cost for feed: a change of behaviour needs to take place in agriculture: more sustainability-focused suppliers who choose health- and environment-friendly raw materials for the food they buy. However, the change is slow / agriculture is not ready to pay more.

	Opportunities	Threats
Technical	● Cutting-edge technologies and development of innovation to optimise the production processes	● Strict seasonality to harvest kelp (NTNU, 2018) ● Due to their high moisture content, kelps degrade relatively quickly after being harvested (Cabrita et al., 2017): storage and conservation issue ● High quality kelp is needed for human consumption. Avoid biofouling and minimise the degradation of the kelp (NTNU, 2018) ● Feed: methods for protein production from the carbohydrates requires comprehensive and complex processing. Need of high investments in facilities for processing. Need of a steady supply of kelp through the year for year-round processing for the production to be profitable (NTNU, 2018) ● Sea area & land facilities access: request space to produce (more than salmon) ● Labour: intense operations
Environmental	● Kelp contributes to absorb emissions of nitrogen, phosphorus and CO_2 ● Potential of kelp to provide ecosystem services	● Dependence of quality water: risks of natural (turbidity, swell) or accidental hazards and the impact of climate change (pH of water, amongst others) ● The monetisation of ecosystem services is not mature, it will require the further development of certification and credit schemes, along with robust monitoring, reporting and verification (FAO, 2023)
Legal	● Kelp concession is permanent, not temporary, in Norway ● From 1 July 2023, the Fish Export Act was expanded: seaweed and kelp are now considered seafood, lifting these species under the aegis of the Norway's Seafood Council, and the Fisheries and Aquaculture Industry's research funding. Provide better access for producers to 20-30 international markets through Norwegian Seafood Council offices around the world.	● Regulation obstacles on some added value markets (e.g., novel food)

2.1 Co-culture case study – Irish farm

Offshore - Mussel and Seaweed (Ireland)

Based in the west of Ireland, this company began its activity in the 1980s, first with spat collection of mussels (*Mytilus edulis*). The full production cycle began the year following the company launch.

This co-culture farm is now producing two species in an offshore cultivation site: mussels and seaweed (*Alaria esculenta*). The seaweed production started on a small scale, in the early 2000s.

2.1.1 Business model presentation

Value proposition

This farm has produced mussels (*Mytilus edulis)* in a range of 900 to 1,200 tons per year for the past three years. Mussels are a low-fat, low-calorie food and an excellent source of nutrients: sodium, selenium, vitamin B12 and zinc. Currently, the company is only selling fresh mussels.

The farm has had organic certification since 2010. Launched in 2009 and now governed by EU Commission Regulation 710/2009, organic production of seafood in Europe is interesting for adding value to products. Production requires quality products coming from a sustainable production system, which respects natural equilibrium and biodiversity, human health, and animal welfare (stocking density, seed collection sustainability, sustainable management…).

The company is also producing *Alaria esculenta*. Two tons of seaweeds were produced each year for the past three years.

The certification for seaweed is not established yet, but those raw products are still high value products regarding its biochemical composition and properties with many sustainable low carbon and less noxious application areas offering environmental and health benefits. Potential uses of *Alaria esculenta* are multiple: the seaweed can be sold fresh, dried, powdered, dried extract or dried liquid.

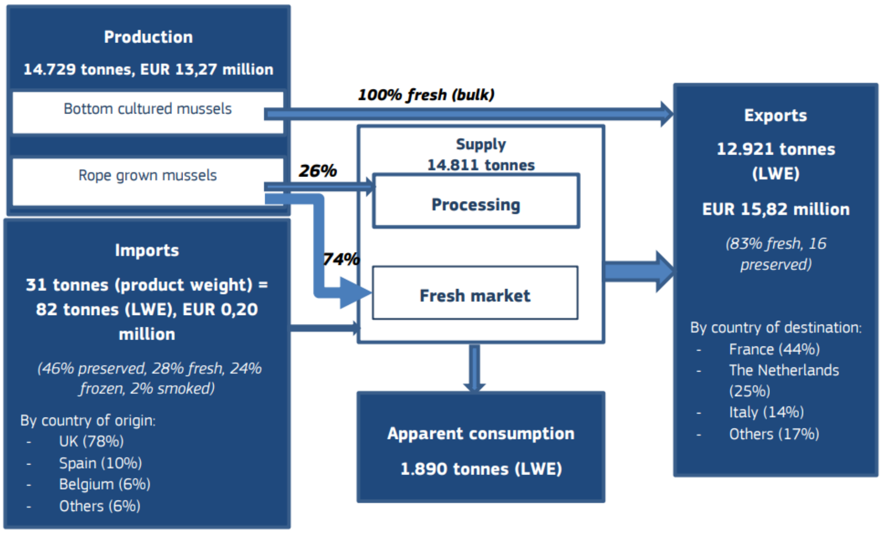
Market customers, relationships & channels

The main part of the production is sold on the national market: mussels are sold in bulk to national processors for 80% of their sales and the company is not processing the products.

The remaining production (20%) is sold in the European market, mainly exported to Italy, France and the Netherlands. Export fresh products are sold to distributors for restaurants and the HORECA[1] sector. The company is based on a B2B approach. New customers are brought by Bord Bia, the State Agency promoting Irish agricultural and aquaculture products.

[1] Hotels, Restaurants and Catering.

The company's sales organisation follows national trends regarding the Irish supply chain for mussels (see figure 5) as most of the Irish rope-grown mussels' production is sold for national consumption (74%).



Source: EUMOFA elaboration based on national statistics, EUROSTAT-COMEXT and interviews with stakeholders

Figure 5: The Irish supply chain for mussels

Markets for seaweeds are not fully established yet as this is a start up on a trial basis. The company is not selling the seaweed production yet but *Alaria esculenta* is particularly interesting and used on a commercial basis in Europe as food and feed ingredients (for human and animal consumption), as well as in cosmetics segments (BIM, 2023).

Key activities and key resources

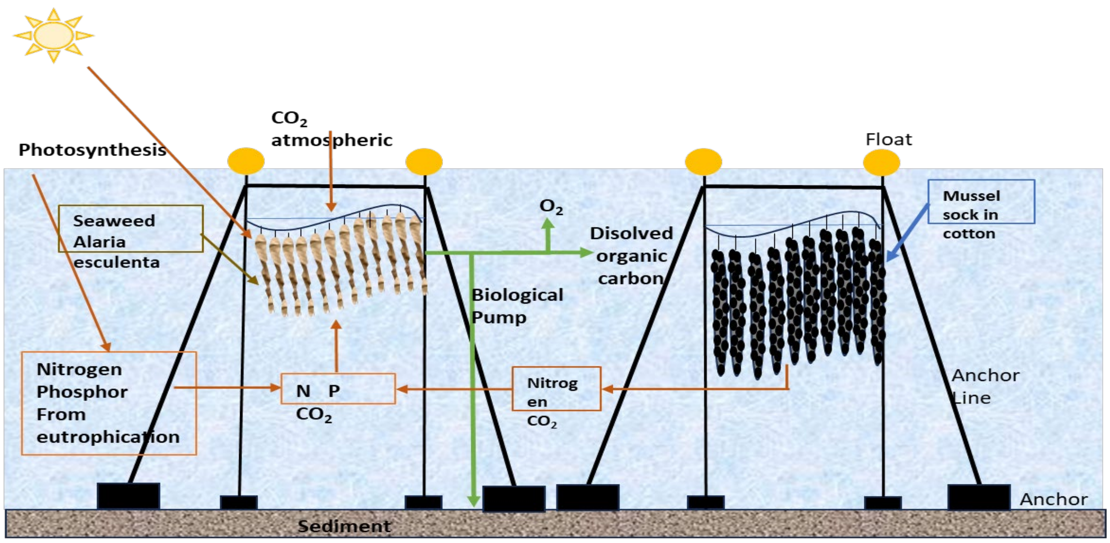


Figure 6: Co-culture system farming process (Source: producer; creation: TQC)

The open water marine production site is in a sheltered area of an inner bay. The water quality is pristine and is classified Class A (shellfish classified areas).
Mussels and seaweeds produced on this site are not fed with external inputs; those species assimilate the nutrients from the surrounding environment, improving the water quality.

To carry out the grow-out phase of seaweeds at sea, the company has a seed supply contract with an Irish seaweed production company which specialises in the hatchery of seaweed seed.
The company handles the entire production chain and employs seven full-time persons (4.5 working at sea, 1 in administration, 1.5 is shore based) and one seasonal contract (during summer). The farm uses automated processes, adapted boats and technical equipment.
The production of mussels and seaweeds together is complimentary: the busy season for mussels is during summer whereas the busy season for seaweed is winter.
The staff are employed all year round and similar skills are used for both types of production.
Assets (e.g., equipment, staff) are shared for both species and used throughout the year.

The farm is also actively involved in R&D by trying to increase the circularity of the mussel production. They are using more sustainable equipment by switching from synthetic rope to cotton and are cultivating rope grown mussels with this cotton mussel mesh, a biodegradable material that helps mussel growth.
They critically assess their production methods continuously and are using bespoke equipment, which is vital for the ease of husbandry of species for seeding, growth and harvesting.

Key partners

The farm is active in networking with the European and international research communities.
Main upstream partners are suppliers: for technical equipment, boats and consumables.
The seaweed hatchery is also a key partner to provide seed, necessary for the production.

Moreover, this company is involved in the IFA Aquaculture, which is a consolidated representative body made up of representatives from each sector of the Irish aquaculture industry, including stakeholders that farm fish, shellfish, seaweeds and other novel species that may be produced around the Irish coastline.

Cost structure

For mussel production, human resources costs and infrastructure costs are the most important ones. The total running costs are estimated at around €500,000 per year, of which 60% is for salaries and 40% for equipment depreciation and consumables.

As the seaweeds production is at an initial stage and is not yet fully established, costs are shared with the mussel production. However, one of the main costs for seaweed is coming from the seed purchase. €75,000 was invested in equipment and €150,000 was used to purchase a building. The set-up costs for the seaweed have amounted to €35,000 over the past three years.

Revenue streams

The main revenue for this co-culture farm is coming from the sales of products, especially mussels as the seaweed production is at a pilot scale. The company is estimating approximately €100,000 profit per year for those sales.

The farm also relies on funds from Europe and from the Irish State, especially EMFF funding, FLAG grants and BIM funding Schemes.

2.1.2 The Business Model Canvas

The Business Model Canvas

COCULTURE - OFFSHORE

MUSSEL / SEAWEEDS

IRELAND

Key Partners

- **Upstream partners :**

Public funders

European and international research communities

Representative body: Irish Farmers Aquaculture

Seaweed : hatcheries for seeds (Seaweed Production Company)

Suppliers for seaweeds & mussels (equipment, boats, consumables)

- **Downstream partners :**

Processors and distributors

Key Activities

R&D

Production process

Monitoring

Sales & marketing

Management

Key Resources

Open marine production site: Quality water classified Class A) and inner bay

Automated processes, adapted boats and equipment

Skilled human resources : 7

Cotton mussel mesh and be-spoke equipment

R&D

Value Propositions

Production of **fresh mussels** (*Mytilus edulis*) (900 – 1200 T/Y) :

- High nutritional potential (low-fat, low-calorie food and nutrients source)
- Sold fresh & in bulk

Spat collection

Certified organic mussel farm (2010)

Production of **seaweed** (*Aleria esculenta*) (2T/Y) :

- Environmental benefits
- Health benefits

Complementary seasonal activities (seaweeds / mussels) to optimize production capacity.

Customer Relationship

Promotion by Bord Bia (State agency)

Promotion through representative bodies (IFA)

Channels

BtoB model :
Bulk sales go to the local processor.
Fresh sales go to distributor for restaurants and European markets.

Customer Segments

Mussels : 100% fresh

National market : 80%
To national processors

Export European market : (20%)
Italy, France & The Netherlands

Distributors for HORECA

Cost Structure

Production costs : €300 000 salary / €200 000 depreciation of equipment & consumables
Seeds for seaweeds.
Shared costs between both activities : seaweeds & mussels

Investment : €75 000 of equipment / €150 000 building
For seaweeds = €35 000

Revenue Streams

Sales of products

Profit = Around €100 000

Public fund like EMFF funding, FLAG grant, BIM Schemes

Seaweed : not fully commercial yet / small scale

2.1.3 Synthesis

Perspectives for the farm

- Development of seaweed production: testing new methods and equipment with a view to increasing production in the future and continuing R&D activities
- Co-culture can promote a more circular approach and would improve consumer perception and demand (sustainability – environment friendly food promotion as a marketing strategy). Currently, co-culture production is not seen as an added value for the farm, but there may be potential in the future as the seaweed aspect of the business grows. (see figure 7).

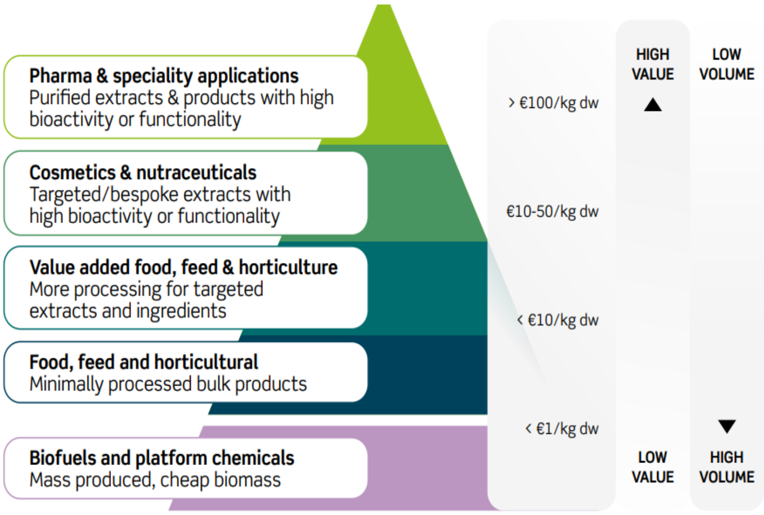


Figure 7: Value pyramid for seaweed derived products (BIM)

<u>INTERNAL FACTORS</u>

STRENGTHS
• Actively involved in R&D for the production process & methods, circularity. • The production site is not suffering from biotoxin closures, so it can fill a gap in the market for a few months each year • The circularity approach: they have diversified to use better materials and have ceased the use of plastic consumables in the production system. They continue to research better materials. Switch also from synthetic rope to the use of cotton • Low impact of both production systems on the surrounding environment • Optimisation of costs & resources: the commonality between the systems means that the skills of staff are complementary, and the use of equipment is maximised. • Mussels = Organic certified • Potential market for seaweeds (*Alaria Esculenta*) • No need of feed for both species: no feed costs
WEAKNESSES/CHALLENGES
• Decreases in production of mussels may occur following a period of low spat collection • The company has been waiting 2.5 years to get the licence to increase the seaweed tonnage: and it is still waiting in 2022. • Biosecurity: major threat to mussels

EXTERNAL FACTORS

	Opportunities	Threats
Political	• Favourable national and EU policies support seaweeds cultivation	• A change to the Classification of the shellfish production waters would have a detrimental effect to the species at this production site: A or B = open/closed status of any production area
Economic	• Potential of *Alaria esculenta* valorisation thanks to its functional and nutraceutical properties and existing growing demand: food, feed, cosmetics and agriculture (Seaweed for Europe, 2020)	• Increasing fuel price • Strong competition for mussels with Spain / France, Italy (high producer & market) and with suppliers from Chile (low cost): Irish mussel unit value remained low (EUMOFA 2022) • Ireland is a small market for mussels. In 2020, it was the seventh largest producer in the EU (with 3% of EU production) and had a low consumption of mussels per capita (0.38 kg/year) (EUMOFA, 2022) • Cost of labour and difficulty to recruit • Mussels: Vulnerable profitability with high cost of labour and low unit value despite of certifications (EUMOFA, 2022)
Social	• Seaweed: A growing demand for sustainable and alternative proteins, for vegetarian consumption, for novel sustainable source of products, material with carbon neutrality goals… (Seaweed for Europe, 2020) • Public acceptance of seaweed aquaculture is generally positive against finfish	• Possible lack of spats for mussels • Limited knowledge on co-culture: need more research on hatchery, grow up phase, processing, market & sales • Development of new technologies – adaptation needed by producers

	Opportunities	Threats
Technical	● Complementarity of the species production in terms of seasonality	● Strict seasonality to harvest kelp: limited harvesting periods (NTNU, 2018) ● Due to their high moisture content, kelps degrade relatively quickly after being harvested (Cabrita et al., 2017): storage and conservation issue. ● High quality kelp is needed for human consumption. Avoid: biofouling and minimise the degradation of the kelp (NTNU, 2018) ● Feed: methods for protein production from the carbohydrates requires comprehensive and complex processing. Need of high investments in facilities for processing. Need of a steady supply of kelp through the year for year-round processing for the production to be profitable (NTNU, 2018) ● Sea area & land facilities access: request space to produce (more than salmon) ● Labour-intense operations
Environmental	● Seaweeds contribute to absorb emissions of nitrogen, phosphorus and CO_2	● Dependence on the environment: constant water quality, weather conditions, bio-toxins caused by phytoplankton blooms are part of threats for the farm, the impact of climate change // acidification & pH variation of water… ● Distance from landing & processing companies
Legal	● Minimal regulations exist for seaweed-based food products	● The complexity of licensing: the lack of timelines for the approval of licences

3 IMTA Commercial farms

3.1 Commercial IMTA farm – French farm

Offshore - Oysters and winkles (France)

The farm was founded in 2017 by two engineers in agronomy who wanted to produce high-quality aquaculture products by using innovative production processes. In 2023 they split up and one of them continued the business.

Located in the northwest of Brittany, the company is focused on spats and high value half-breed oysters. For five years, the company has been growing oysters in an IMTA offshore farm, collaborating with private companies and research organisations through innovation projects.

After three years, the company aims to maintain profitability through oyster production.

3.1.1 Business model presentation

Value proposition

Since 2008, the emergent virus OsHV-1 has caused massive mortality events in *Crassostrea gigas* spats and juveniles in France. Since 2012, mortality driven by the pathogenic bacteria *Vibrio aestuarianus* has been hitting market-sized adults. Successive disease outbreaks in oyster beds in France have caused dramatic production losses, and subsequent decline in the oyster-farming industry. Oyster farming also requires more manual labour to move and clean the oyster bags. It is becoming increasingly difficult to find young skilled people to work in aquaculture. Finally, there is no new land available to expand oyster farming.

Concurrently, winkles are mainly imported from Ireland and Scotland where they are harvested. In France, they are also produced in Brittany but there are no monoculture winkle farms, only a few co-cultures and IMTA farms.

The aim of this IMTA commercial site is to secure oyster production and diversify its production. They lead several innovation projects focused on the IMTA system to develop a more sustainable and profitable aquaculture.

The farm produces species from two trophic levels: oysters and winkles. They are using an offshore IMTA system. With this approach, species at a lower trophic level (winkles) use uneaten feed from the higher trophic species (oysters) as a nutrient input. The lower trophic species can then be harvested in addition to oysters to diversify farmers revenues.

They are using oyster bag farming with the help of periwinkles to reduce the fouling on bags. The winkles are feeding on this fouling allowing a better aeration of bags and a more effective water and nutrients circulation. This has a direct impact on the growth of oysters by increasing the growth rate by 15% compared with a farm growing only oysters.
On the other hand, the winkles increase the survival rate of oysters by eating dead oysters and thus decreasing the bacterial load. Moreover, the use of the fouling by winkles as a feed reduces the manual work needed to clean the oyster bags.
The natural ability of winkles to eat phytoplankton within and around oysters' farms can help producers to improve the environmental performance of their farm. In addition, those extractive species are marketable products and have an attractive commercial value, providing economic benefits to farmers.
The farm produces high-quality oysters and winkles: in 2023, they produced 200 tons of oysters (*Crassostrea gigas*) and 8 tons of winkles (*Littorina littorea)*. The winkle production has doubled between 2021 and 2023.
The company also produces spats and semi-rearing oysters (18 months) targeted for oyster farmers.
Winkles are raised to jumbo size (maximum size is around 3-4 cm), a rare size for these products: they do not reach this size on natural conditions (or they have been harvested before to reach this size). The way they grow the periwinkles and oysters does not require any artificial feeding or antibiotics and does not have any negative impact on the surrounding environment.
Growing oysters in offshore areas gives them distinctive characteristics: a marked iodized tasty and meatier oyster.

Market customers, relationships & channels

The farm focuses its production on high-quality non-processed products.
Oysters' production is mainly sold internationally, especially on the European market (80%). Their customers are from Italy (luxury fish shops), from Switzerland (3-stars restaurants) and from Ireland (oyster farm).
The farm has different customer segments for oysters mainly based on a B2B approach:

- The company sells oyster spats and half-farming (18-month oysters) to oyster farmers.
- It sells non-purified 3–4-year oysters to wholesalers and to oyster farmers.
- The remaining oysters' production is sold directly to consumers (B2C) and gastronomic restaurants.

Winkles are sold fresh to consumers, sold at the same time as oysters to the same customers (restaurants and direct consumers). The company is also selling the winkle production to oyster farmers (market diversification) and to a distributor. This distributor is a French national network (Poiscaille) proposing fresh and sustainable seafood baskets (local distribution channel). The network is buying winkles at a fixed and stable price, without intermediary.

The farm prospecting is low, customers contact them directly thanks to their established reputation (trusting relationship) and the high quality of their products. They do not have any internet website nor direct sale point yet.

They have several products to offer to one buyer: by selling oysters, it is also an opportunity to propose high value jumbo winkles. They reach customers better with multiple products, and demand is finally more important than supply.

Key activities

Founded in 2017, they have developed an oyster farm for spat and half-breed oyster (12 months) in pooling facilities with another farm, the time required to develop their own farm and production capacities in 2019 (investment).

They are one of the first companies to grow oysters in an open-sea farm, rather than producing them on the bottom of estuaries in oysters' beds. They control all the production process from R&D, hatchery to commercialisation.

The winkles and oysters are graded and packed for shipment to customers.

The core business is divided in fields:

- Production of high-value oysters for the French and European wholesale market and production of high-value foreshore oyster in spat and half-farming by their own funds. This aquaculture production maintains the R&D activities on marine culture. 70% of its business model corresponds to half breed oysters (18 months).
- The R&D on genetic issues between oysters.
- The R&D to develop the IMTA system in offshore areas. They work on several projects:
  -offshore production in the IMTA system with 4 species: seaweed, oysters, abalones and winkles.
  -foreshore and offshore production in IMTA with 2 species: clams and oysters.
  -double production of oysters and winkles (figure 8).

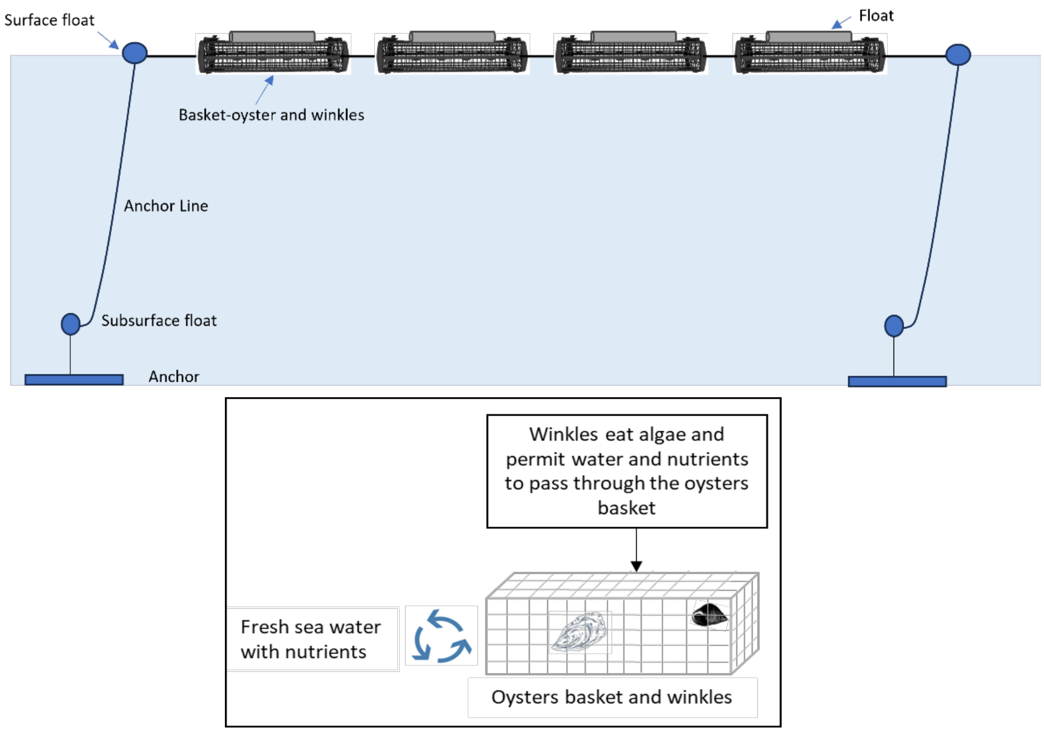


Figure 8: Winkles-Oysters IMTA farm example in France in an offshore area (Source: producer; creation: TQC)

Key resources

The farm is developed on an 8,5 hectares production site with 40,000 places in operation.

The team is made up of 6 full-time, permanent employees who grow oysters (90% of the time) and winkles (10% of the time), with one seasonal job. Winkles are grown in spring and autumn and harvested in September and February respectively.

In order to develop the open sea IMTA system, the company has to purchase juvenile winkles from hatcheries (mainly in Ireland). For this reason, the manager has a doctorate in this field. He wrote his thesis on abalone and worked for a French abalone farm. The company develops and relies on valuable scientific knowledge and know-how to constantly adjust the optimal species for the IMTA system and parameters (optimal density, temperature, salinity, area, technical process, etc.).

One of the most important stages for farms is the regulatory phase. The diagram below (figure 9) shows the different steps and related actions to be considered and/or overtaken.

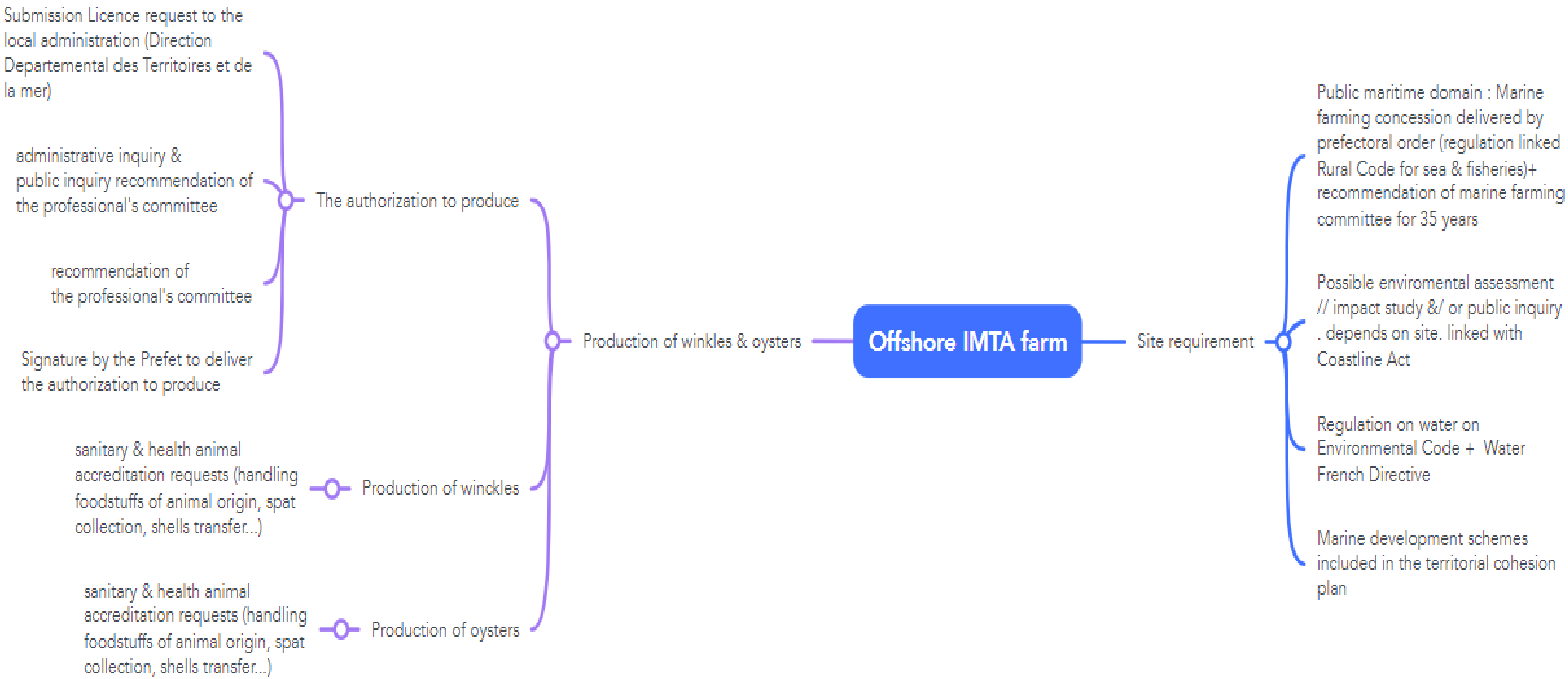


Figure 9: Reglementary steps to implement IMTA offshore systems in France (source: Integrate project)

Key partners

The company has strong links with research organisations (including the Agro Institute of Rennes and Angers). As an oyster farming start-up, they are involved in the innovation ecosystem and with professional representatives: members of the Blue Economy cluster Pôle Mer Bretagne Atlantique and the committee of the Bivalve Professional Association in Northern Brittany.

They work with SYSSAAF (Syndicate of French Poultry and Aquaculture Breeders) (genetic expertise).

Another main upstream partner are the winkles' hatcheries in Ireland.

They are also supported by private and public funders who help them to develop the company.

Main key downstream partners are gastronomic restaurants and distributors.

Cost structure

Human resources are the costliest activities for this company, just as R&D, especially on IMTA.

Production costs are structural costs for 5% (buildings, oyster farming equipment, boats, water energy) and wages (60%). There are also high cultivation costs, as they need to buy raw materials (winkles from Ireland) (35% of production cost) and to invest in new equipment to adapt their production with an IMTA approach. In 2021, they bought a farm and a second-hand barge (€150,000).

Using an IMTA system, the manual work with oyster bags is reduced. In fact, winkles act as cleaners on the oyster bags (anti-fouling action). However, there is an extra cost (+1h labour per handling) during the grading and cleaning phase; winkles are falling first and need to be separated from the waste in the sorting chain. During rearing, it is easier to handle because the bag is lighter; there is no significant difference in terms of production costs compared to monoculture.

Revenue

In 2022, the company obtained public funds (€80,000) through an innovation project on a new IMTA system (seaweeds and abalone).

Public funds, such as the European Maritime and Fisheries Fund, are important at the starting phase (around 25% of turnover) and then decrease thanks to sales to customers. On the other hand, the company has contracted loans and has made a private fund raising (€350,000) in spring 2023.

Now the company is profitable by selling fresh oysters and winkles.

With their offshore IMTA system, they grow very special oysters that they can sell three times the price of a classic oyster. Jumbo Winkles are sold around 30€/kg against 20€/kg for normal winkles on the French market.

The turnover evolved from €360,000 euros in 2021 to a desired €420,000 turnover by 2022. In 2023, the turnover reached €520,000, where winkles represented a 10% of the turnover.

3.1.2 The Business Model Canvas

The Business Model Canvas

IMTA FARM – OFFSHORE

WINKLES / OYSTERS

FRANCE

Key Partners

- **Investors**

Private and Public funders

- **Upstream partners :**

R&D and professional organizations : Institut Agro Rennes Angers, Member of Cluster Pôle Mer Bretagne Atlantique, Comité régional Conchylicole Bretagne Nord
SYSSAAF
Scientific network
Winkles hatcheries (Ireland)

- **Downstream partners :**

Distributors and gastronomic restaurants

Key Activities

R&D

Production process: all the value chain (from hatchery to commercialization)

Grading

Sales & marketing

Management

Key Resources

Juveniles from hatcheries

Technical process from research institutions

Scientific knowledge

Offshore oysters' production area
Skilled human resources: 7 people (6 permanent staff)

Value Propositions

IMTA Offshore production of **oysters** (200 tons) :

- High nutritional potential
- a marked iodized tasty and meatier oyster
- Increased growth rate by 15%
- Increased survival rate
- Offshore products : higher quality

Spat/**semi-rearing (18 month) oysters** (foreshore)

IMTA Offshore production of **winkles** (8 tons):

- Jumbo size products
- Use fouling as feed
- Increase the water and nutrient circulation in bags
- Reduce bacterial load by eating dead oysters
- No antibiotic or artificial feeding
- Offshore products : higher quality

Winkles sold in bag of 100g

Customer Relationship

Customers contact them directly for their high-quality products.

Distribution based on the company's reputation.

Several species to offer to the buying consumer.

Channels

BtoB model: directly to restaurants, oyster farmers or distributor

BtoC model: directly consumers

Customer Segments

Oysters (fresh products):
Mainly European market (80%)
(Italy/Switzerland/Ireland)

National market

Customers :
Oyster farmers for spat and semi-rearing (oysters of 12 month)

Offshore IMTA oysters :
Wholesalers and Oysters farmers for non-purified oysters of 3 or 4 years
Gastronomic Restaurants and end consumers (food industry)

Winkles (fresh products):
Consumers
Oyster farmers
Distributor (Poiscaille)

Cost Structure

Cost production: structural costs (buildings, oyster farming equipment, boats) and mainly human resources (60%)

R&D costs

Cost of a farm and of a second-hand barge: €150,000

Revenue Streams

Sales of products (fresh oysters and winkles) : Winkles prices: around 30€/kg
Oysters prices: 3 times the price of a classic oyster

Public & private fundings
Turnover: €360,000 . Desired €420,000 turnover by 2022. €520,000 in 2023.
Winkles: 10% of turnover

3.1.3 Synthesis

Perspectives for the company

The company has several ambitions for the future:

- be able to produce their own winkles (hatchery)
- be able to guarantee 100% traceability of the products in the future
- pursue R&D on IMTA projects and diversify their production with other species
- pursue the development of the abalone hatchery pilot

INTERNAL FACTORS

STRENGTHS
• Growing winkles combined with oysters requires less R&D because the combination of species is quite easy and the profitability is quickly reached • A strong internal R&D and close partnerships with research organisations (shared knowledge) • The control of the production process and oysters' life cycle • IMTA reinforced their business model, especially as this type of farming should enable them to fight against oyster mortality. • Capacity to adapt the harvest and sorting process with the mix species • Offshore system reducing the pollution risk from coastal areas (agriculture effluents discharged into the sea…) and optimising farming. • An assertive entrepreneurial & business approach • The value proposition: producing high-quality oysters and winkles in offshore farm (unique case). • Several sales segments to make sure that they can sell all products. • A competitive advantage on competitors: winkles are a high-value species, but not many farms invest in R&D to produce them at large scale + an open sea oyster production = rare + high quality and distinctive taste. • The use of an IMTA system is also positive for their image and their dynamism
WEAKNESSES/CHALLENGES
• Reliability on robust equipment because of an open sea system • The need to develop and to finance regular R&D projects on the IMTA system (strong effort: funding watch, set up applications, administrative costs…)

EXTERNAL FACTORS

	Opportunities	Threats
Political	• Support from supranational organisations and policy makers to develop the booming aquaculture industry (Ahier, 2018)	• Complex and long regulatory process for setting up aquaculture farms (minimum 12 months)
Economic	• The support of investors who share this same sustainable vision • A growing market for French high-quality winkles (doris.ffessm.fr) • Local production of seafood products is only covering a quarter of the overall consumption • Development of rural/coastal areas by providing employment and stimulating economic activities.	• Need to buy winkles spat (from Ireland) and risk of price fluctuation • Lack of knowledge about IMTA in France and doubts about their profitability. • Public distrust of the environmental risks caused by aquaculture farms
Social	• Producing oysters in the open sea gives consumers a good image of natural farming, with no artificial feed or pollutants => respect of the environment • Good French stakeholders' perception of IMTA as a means of limiting environmental impacts (Ahier, 2018)	• Lack of visibility and understanding of IMTA. • Aquaculture in France is facing a lack of attractiveness (difficult working conditions, low social acceptance)
Technical	• Development of R&D in aquaculture • Raising of offshore wind energy zones in France: an opportunity for the offshore aquaculture site	• Strong resistance of the equipment on open sea environment to resist to swells, storms • Difficulty to recruit with adequate skills, to attract or to maintain because of tight labour
Environmental	• Better water quality offshore because there's less land-based pollution risks (fertilisers, pesticides, etc.). • Seafood products are a source of protein intake	• Adequacy between the open sea production site and a sufficient and continuous nutritional input: difficulty to guarantee (dependence = a risk) • The risks of natural (turbidity, waves, winds, swell), diseases, or accidental (oil) hazards and the impact of the climate change
Legal		• Necessary sanitary authorisations to be able to sell their own products resulting from their innovation. • Complexity to encourage IMTA farm: multiplicity of authorisations (per species) • Maritime safety policies in the implementation of offshore production site

3.2 Commercial IMTA farm – South African farm

Land based and semi closed system- Abalone – *Ulva* (South Africa)

The farm was established in 2011 in two main sites in South Africa: Buffeljags on the Cape South Coast and at Kleinzee, near the Namibian border. The company's core business is the production of local abalone species, Mediterranean mussel, Pacific oyster, and rainbow trout.

The IMTA system, located on the Buffeljags site, is used to produce abalones and *Ulva*.

3.2.1 Business model presentation

Value proposition

The farm's main activity is the production of abalone (*Haliotis midae)* and its commercialisation. They are using an IMTA system in an onshore area: abalone are grown on land, placed in baskets in tanks and water supply is done via 50% recirculation using *Ulva* paddle raceway.

The abalone produced is known as the second most valuable abalone species.

With this IMTA system, on the Buffeljags site, they produce an average of 300 tons per year of abalones and 600 tons of *Ulva*.

Most of the abalone production is marketed as fresh products (80% of the total production) and the remaining percentage is sold frozen (around 8%), canned (10%) and dried (around 2%).

The farm is also producing *Ulva*, a seaweed with high nutritional potential that can be used in a wide range of applications: for human consumption, used as a feed input, in biosecurity, for food preservation and in industry (Bolton et al., 2016).

IMTA is a focus for the company for providing several benefits including an efficient recirculation using *Ulva* as a good bio-filter and mitigation support against red tides.

This system is also improving the quality of the water returning to sea; the quality of the effluent is almost equal to the extracted seawater, reducing the negative impact of the system on the surrounding environment.

From an economic point of view, it also reduces the farm's electricity costs by about 40% and its feed cost by about 20%, as they are using *Ulva* as feed material for abalone. This input is also reducing the pressure on the kelp resources in the area, which is a significant environmental benefit.

IMTA is significantly increasing the growth rates of abalones by raising the water temperature and using the high protein-based *Ulva* seaweed (Cyrus et al., 2015).

The IMTA production is done in clusters: the aim is to mitigate disease spread by having a certain ratio of abalone tanks to an *Ulva* system. The *Ulva* from each cluster feed only abalone on that cluster. Each IMTA unit is confined and will restrict any disease or any other biosecurity risks.

The IMTA system implemented in the farm has led them to new species development. Since IMTA has been successful for the abalone production, they are assessing if they can use the same IMTA system to grow high-value sea urchins.

Market customers, relationships and channels

The IMTA farm is focusing on the production and sales of high-quality abalones, the most expensive shellfish. There is no commercial use of the produced sea lettuce; the farm is using it to feed abalones and as a biological filter system. The statement is that sea lettuce is an excellent bio-filter and has high performance in recirculation units.

The whole production of abalone is sold internationally as the consumption of shellfish in South Africa remains low. Generally, the consumption per capita of seafood products (fish and seafood) in the country declined, which is contrary to the global trend (FAO, 2020).
As the local market is almost non-existent, 100% of the abalone production is exported to Asian food markets, mainly Hong Kong, China and Taiwan, where this product has a high value and is sought-after.

The farm has three sales segments, depending on the form in which the abalone is packed:

- Fresh products (80% of the production) are sold directly to wholesalers (Hong Kong, Taiwan, China, Malaysia or Singapore) specialised in fish markets, in hotel chains, or restaurants. An average grow-out period for a live export abalone is about 38-39 months.
- Canned products (10%) and frozen products (8 to 9%) are mostly sold to wholesalers and in specific cases, directly to small retail chains.
- Dried products (1 to 2%) are sold to specialised dried wholesale houses.

The company has two main distribution channels, both on a B2B approach. On the one hand, they are working with an Irish agency, specialised in shellfish in Asian markets and are, on the other hand, they are using the normal wholesalers' channels in Hong Kong and Taiwan for the other 50%.
To maintain a trusting relationship and to fit the supply and specific needs of the Asian markets, they are visiting their customers regularly and are attending fairs where they represent the company and their branding. Prospecting is low but they rely on their reputation, the high-quality of their products and high export quality conditions.
The Abalone Association of South Africa has obtained permission to collude on price from the Competition's Commission as all abalone is exported and does not affect the local consumers. This enables the South African Industry to collectively increase their prices.

Key activities

The company is a vertically integrated, sustainable abalone production and the abalone/*Ulva* farm covers 10 hectares, 7 of which are being used for production.

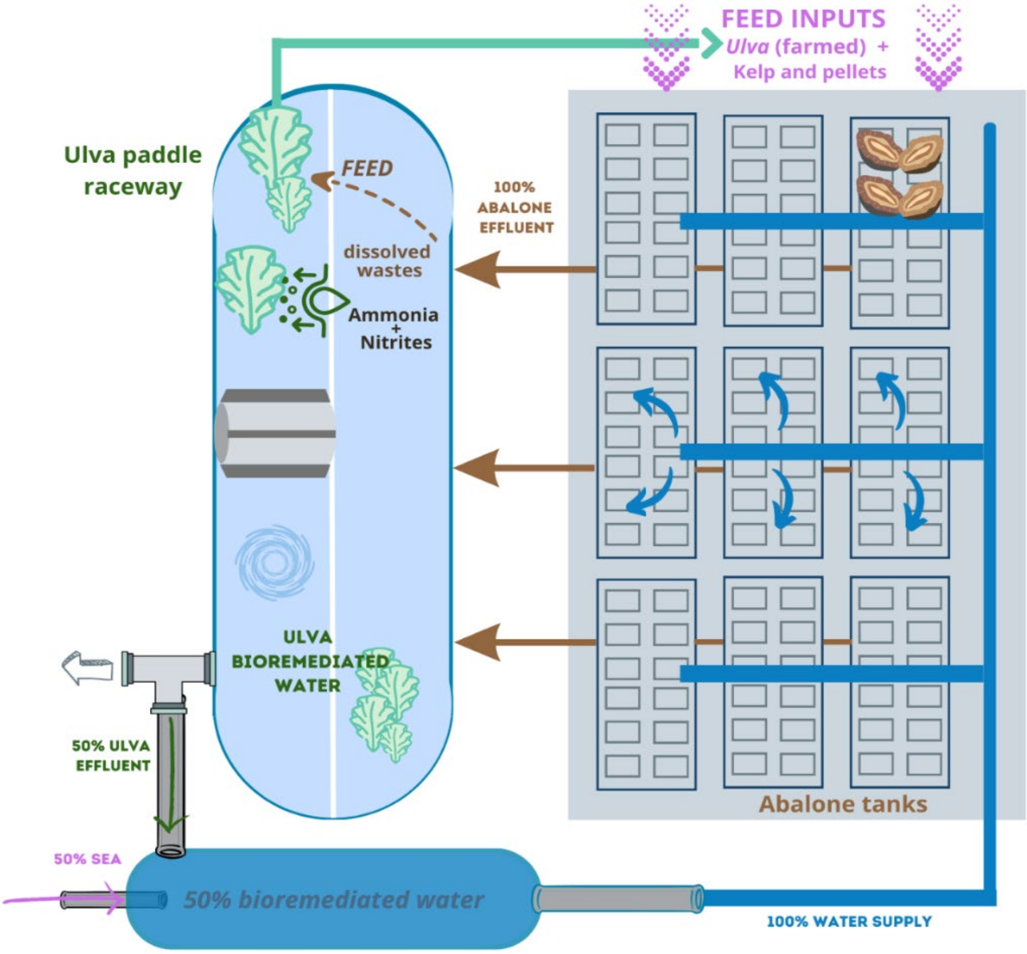


Figure 10: Abalone-Ulva IMTA farm example in South Africa (Source: producer, creation: Pôle Mer Bretagne Atlantique (PMBA)

Each platform of the production site is made of an *Ulva* paddle raceway and Abalone tanks. *Ulva* are grown in circulated water using a paddlewheel to allow equal distribution to sunlight and keep the *Ulva* suspended.

Ulva ponds are supplied with 100% of the abalone tanks effluents, filled with dissolved wastes from dissolved abalone excretions. *Ulva* is using the dissolved wastes from abalone as feed and are extracting and absorbing dissolved nutrients by transforming toxic ammonia and nitrites.

Ulva are used as a biofilter in this system but also as a feed input for abalone, which are going to be fed with a combination of fresh *Ulva*, wild harvested kelp, and pellets.

Seaweeds are filtering the abalone effluent and is re-injected for 50% in the water supply of abalone. Indeed, the water supply used for the production is provided with 50% of pumped water from surrounding sea and 50% from the recirculation, so from the effluent itself.

Producers control all the production process for *Ulva* and abalones:

- hatchery with algae culture process and abalone larval rearing
- nursery in shallow trays to reach 15mm
- grow-out in baskets in tanks with vertical substrate as habitats, moved to bigger size classes gradually (to reduce the stocking densities and adjust the feeding programs).

As they are using 50% recirculation using large *Ulva* ponds as biofilters, monitoring parameters is also a key activity of the farm.

Live abalone exports are packed on the farm and exported using airfreight (abalone stay alive for up to 36 hours). The production harvested for canned and dried products is sent to a sister company for processing and export: dried product is exported via airfreight and canned product via ships.

R&D is also led by the company including research on the different feed ratios and the mix between different seaweeds (kelp, pellets and *Ulva*) to feed abalones and give them a balanced diet to obtain better growth rates. They are also involved in partnerships with universities and university/research funding and projects.

With this IMTA system, the farm is producing an average of 450 tons of abalones every year, and 900 tons of *Ulva* (on both sites).

Within this Abalone-*Ulva* production site, they produce an average of 300 tons per year of abalones and 600 tons of *Ulva*.

Key resources

The localisation of the farm is playing a major role on the production sustainability: the site is in an abalone hotspot, where wild abalone occur and are harvested. The water quality is ensured as the farm is far from any agricultural or industrial activities.

A kelp concession is available in the area, allowing direct access to a source of natural feed. Feed production is also a key resource, as abalone are fed with more than 50% natural material: kelp (harvested) and *Ulva* produced in the IMTA system (ponds).

The recirculation system is highly dependent on electricity supply: the farm sets up wind turbines to produce about 50% of the farm's electricity requirement. The wind turbines generate power for pumping fresh seawater through the farm used as water supply for the IMTA system (50% of seawater) and aerating the abalone tanks. It is the only company in South Africa to do it. Using the *Ulva* as a biofilter for the semi-recirculation system, the farm saves a further: they are saving electricity costs of up 40 % of the traditional flow-through systems.

The abalone farm is using mostly manual technology to harvest, clean, feed and grad. Qualified human resources are thus a key resource for those activities. For the abalone production only, the main part of human resources is employed on the production/grow-out task (80%). The technical team makes up 10% and management makes up about 5% of the labour force. They are supported by two production managers, two senior managers, 13 technicians, 5 administrative employees and 5 engineers.

Key partners

The founders have strong relationships with academic partners (foreign universities in Australia, New Zealand, Sweden and the University of Cape Town) and the company is involved in like-minded research projects. The company's development had been facilitated by this strong partnership with the research community. Part of the company’s activities are thus devoted to R&D.

They are part of The Abalone Association of South Africa, a professional organisation, and the company is in the process of obtaining the ASC accreditation (Aquaculture Stewardship Council).

Feed is one of the farm's key resources and feed suppliers of processed food are therefore major upstream partners in the production process.

Public funders are helping them to develop (7% of the funds) but the farm is mainly funded by private shareholders.

Processing, sales and marketing are led by a sister company for the whole dried and canned products.

Cost structure

Human resources and production costs are the main costs of the company and have been increased by the implementation of IMTA regarding needed labour and R&D. In 2023, R&D costs for this system represent 3.5% of the total cost.

Within the production costs, raw materials are the most expensive ones (32%), before wages (27%) and structural costs (infrastructures, fluids, technical facilities) (24%).

Main investments have been made over the past three years on infrastructures (+/- €447,000), farming system (+/- €248,000), marketing (+/- €74,000), processing (+/- €25,000) and environmental assessment and sustainability (€20,000).

Using the IMTA system (recirculation) and through wind turbines, the pumping costs are decreased by around 65%. On the other hand, regarding the technicity of the system (IMTA) and the species produced, the farm needs more investment on R&D.

Processing and transport are also significant costs, which have increased over decades, in particular, since COVID. Indeed, the fresh market was affected, and their transport costs have more than doubled.

Revenue

The farm needed a massive capital investment, so strong financial partners or good access to funds is very important, especially to private fundings.

5 to 7% of the investment was covered by public funds; the abalone farm has been beneficiary of ADEP (Aquaculture Development Enhancement Program). As an example, 30% of the wind turbines were financed with this program. They also benefited from the CASIDRA (agricultural fund in the Western Cape).

The farm is funded by private shareholders and more than 90% of the investment is coming from private funds. It is a South African company that is made up of a couple of shareholders: a major South African seafood industry company has 51% and various small South African based shareholders hold the remaining 49%.

Sales of products are providing them profitability. For abalone, current sales prices are:

- Live: 29€/kg
- Canned: 440€/box
- Dried: 320€/kg

To be economically viable, this IMTA system needs a minimal production of 200 tons of abalone.

3.2.2 The Business Model Canvas

The Business Model Canvas

IMTA FARM – LAND BASED AND SEMI CLOSED SYSTEM

ABALONE / ULVA

SOUTH AFRICA

Key Partners

- **Investors :**

Private / shareholders
Public funders (7%)

- **Upstream partners :**

Feed manufacturer
Representative bodies and professional organizations (The Abalone Association of South Africa)
R&D academics (university in Australia, New Zealand and Sweden, University of Cape Town) and like-minded research projects
Governmental organization (i.e. Ministry of Environment, Forestry and Fisheries, Department of Trade and Industry)

- **Downstream partners :**

Sister company of the group :
100 % processing for canned and dried products)
100 % : sales and marketing
30% feed pellet production

Wholesalers
Intermediate in the retail sector

Key Activities

IMTA production

Production process: all the value chain (hatchery, parameters monitoring, and processing)

Monitoring and maintenance

Logistics ; packaging and transport (for live products)

Management / human resources

R&D

Key Resources

Private land and suitable localization

Feed for abalone

Qualified human resources

Electricity (for recirculation system and aeration)

Wind turbines

Access to processing/live packing for exports

Species & producer reputation: second most valuable abalone species in the world

R&D support and scientific knowledge

Value Propositions

IMTA production system

Production of **Abalone** (*Haliotis midae*)

- High quality product (second most valuable abalone species / fed 75% or more on natural feed)
- Partially fed on natural food
- Significantly increased growth rate
- Fresh products, canned, frozen and dried

Production of ***Ulva spp***

- Environmental and quality benefits (enhance the growth, health, product quality and sustainability / Improved water quality of the water returning to sea / reducing the pressure on the kelp resources / reduce disease propagation)
- High nutritional and environmental potential

Customer Relationship

Frequent customer visits (international travels) and fitting the supply by identifying their specific needs

Attending fairs: i.e.food expo's (China, Hong Kong, Singapore and Taiwan)

Distribution based on the producer/country reputation (consistent supply and quality)

Channels

BtoB (indirect distribution channels) :

50 % : specialized agency located in Ireland (specialized in shellfish in Asian markets)
50 % : wholesalers in Hong Kong and Taiwan

Customer Segments

Abalone :

Export market

International customers (mainly Asian customers) (100% of the abalone production) :
Wholesales in Hong Kong, Taiwan and China
Retailers in Singapore and Malaysia

Fresh products (80% of the production):
wholesalers to restaurants
wholesalers specialized in fish markets or in hotel chain.
Canned products (10%) : sold mostly to wholesalers and then to retail chains

Remaining 10% exported for specialized wholesale houses : 1 – 2% dried abalone and +-8 % frozen

Cost Structure

Human resources (30%)
R&D costs (3.5% of the total cost)
Production costs : Feed / raw material (32%) / Environmental assessment/sustainability
Structural costs : (infrastructures, fluids, technical facilities) (24%) / Wages (27%)
Processing and packaging for transport
Subcontract costs (for dried and canned products)
Transport cost (airfreight or ship)

Revenue Streams

Public grants (5 to 7% of the investment) : Aquaculture Development Enhancement Program for 30% of the capital investment and CASIDRA (agricultural fund in the Western Cape)

Private fundings (>90% of the investment)
Shareholders (direct transfers)

Sales of products (abalone) : COD (on delivery for fresh) and COC (on command) for canned)
Average per kilogram : Live - $ 30 €/kg ; canned - 450€/box ; Dried - 330€kg

3.2.3 Synthesis

Perspectives for the farm

- Development of the local market:

Population of South Africa is going to increase and the demand for fish and seafood products will extend. However, local consumption of abalone needs to be valued, as it is not a traditional product.

→ valorisation of the product to raise a new domestic niche market: only few high-end specialised restaurants will be able to afford it. The industry has tried lower-valued canned products in the retail sector without much success for now.

To develop the aquaculture sector, relevant policies/programs need to be developed with all concerned stakeholder (producers and environmental groups), other local actors (e.g. tourism agencies) and the general public:

- Less harsh legislation required
- More start-up venture capital required
- More local R&D funding required.

INTERNAL FACTORS

STRENGTHS
Technical • Electricity production with wind turbines: optimisation of production costs + stabilise the voltage • Significantly increasing species growth rate (Cyrus et al., 2015) • Strong partnerships with research organisations (shared knowledge) and R&D stakeholders • Improvement of farm efficiency by the circularity process • More than 50% of natural feed using *Ulva* **Environmental** • Traceability: 100 % control of the production process • IMTA cluster system: reduces the probability of experiencing losses due to HABs by over 90% and mitigate diseases • Reducing environmental impacts (improves the quality of water returning to sea) • Biosecurity: it's a major threat for abalone and IMTA is reducing parasite loads **Economic** • High-value and quality products (sought-after by the Asian markets) • High reputation: second most valuable abalone species • Strong private shareholders and direct transactions: no pressure on cash flow • Production of *Ulva* as a feed material: decreasing feed costs • Production and use of *Ulva* as biofilter: water recirculation decreasing water supplies • Marketing advantage by using IMTA: by using a greener production system and natural feed • Market and wholesaler faith • Private lands: autonomy of the farm • Diversification: the farm is developing new species like sea urchins
WEAKNESSES/CHALLENGES
Technical • R&D: Continued research to manage the IMTA system to go onto 100% recirculation reducing the risk of losing stock due to Harmful Algal Blooms. • Skilled human resources **Economic** • Marketing to face competitors: Australian, Chilean, and Californian species are also high-quality products, so putting efforts in marketing and brand image is key to keep the status (country and species reputation) • Valorisation with a certification of the product to increase the market differentiation, traceability, easiest profit margins and profitability • High investment costs (infrastructure)

EXTERNAL FACTORS

	Opportunities	Threats
Political	• Strong group dynamic in SA within producers • South African government prioritising aquaculture in its National Development Plan to 2030: support investment in the development of aquaculture with aid	• Kelp resource management: political resource; (take it away from current concession holders to give it to community fishers) • Minimal research on aquaculture socio-economic dimensions and minimal technical data to communicate to communities (Morake, 2015) • Restricted access to public and private land and water bodies for aquaculture purposes
Economic	• Private fundings • New market opportunities for revenue diversification • Asian market is looking for eco-labels, especially in the high-end market: increasing the value of IMTA products	• Long return on investment: 4 years for a small/family farm / higher for a larger farm • Increasing transport costs (COVID, higher fuels costs…). • External funding dependency
Social	• Local benefit: Increasing the coastal areas and communities: job creation, environment preservation, economic benefits • Partner dynamic: professional organisations, research partnerships, local dynamic •	• Low general awareness of South African communities on aquaculture • IMTA misreading • Criticism of marine aquaculture due to the negative perception of the environmental impacts and a lack of knowledge and data on the socio-economic impact (Morake, 2015)
Technical	• Innovations in aquaculture to reduce risks and to develop markets: R&D	• Skilled human resources • Growing demand for technological skills (digital technologies) • Slow adaptation of producers to new technologies and slow integration of new technology due to the costs • Lack of technical data on environmental effects of IMTA • Lack of knowledge within the public and producer community regarding the IMTA model benefits • Degradation of electrical infrastructure in South Africa

	Opportunities	Threats
Environmental	• Market demand for eco-certified seafood in sustainable aquaculture system • Circularity and waste management • Social perception on natural feed inputs • Reduced pressure on wild stock populations of abalone and kelp	• Impact of climate change on seawater supply and temperature • Biosecurity and disease spread
Legal	• Labelling products and branding	• Administrative slowness • Authorisations and permits delivery processes Weak feedback and/or support from sector representatives and associations on IMTA

4 ASTRAL IMTA Labs: Prospective business model analysis of pilot sites

4.1 IMTA Scotland - case study

Offshore IMTA - Seaweeds and Oysters (Scotland)

Located along the western coast of Scotland, this system integrates seaweeds and oysters within an open-water, low-trophic aquaculture site.

It operates a submerged tensioned grid system which provides the infrastructure to develop and validate a wide range of cultivation approaches seeking to efficiently combine the cultivation of seaweeds (*Saccharina latissima* and *Alaria esculenta)* and European flat oysters (*Ostrea edulis*).

4.1.1 Business model presentation

Value proposition

This IMTA system focuses on cultivating two species: seaweeds (*Saccharina latissima* and *Alaria esculenta*) and European flat oysters (*Ostrea edulis*). In this pilot site, the IMTA approach is providing several benefits:

- Additional income generation outwit the seaweed production cycle (production of two trophic groups)
- Creation and exploitation of ecological synergies (if scaled up) i.e. efficient use of nutrients through stronger trophic linkages between cultivated products
- Cost reductions: using a low-cost cultivation infrastructure for oyster production (one system for two trophic groups).

Enhancing the value proposition hinges significantly on product quality and traceability. While this system lacks organic certification, obtaining it would be valuable for many existing seaweed products. Product certification serves as a crucial factor for differentiation, streamlining profit margins, and ensuring overall profitability.

The potential value of seaweed is extensive, attributed to its specific biochemical and nutritional properties. Laden with vitamins, essential minerals, proteins, and carbohydrates, seaweeds provide the raw material for a wide range of applications (see table 3).

Seaweeds, as oysters, are marketable in various forms: fresh as live in-shell products, smoked, salted, frozen, or as ingredients in processed foods. Additionally, juvenile oysters, known as spat, can be provided to local rewilding initiatives, aiding in the restoration of wild oyster beds.

Moreover, oyster shells, a by-product of processing, serve multiple purposes, including soil enhancement (as a liming agent), applications in civil engineering, and utilization as biomaterials.

The seaweeds and oysters cultivated within this IMTA system contribute to providing ecosystem services, referring to the benefits people derive either directly or indirectly from ecosystems (Clark et al., 2021). In addition, both seaweeds and oysters offer a broad spectrum of other ecosystem benefits that remain underutilized and not fully capitalized upon commercially. Establishing an industry-wide consensus on standardized monitoring and adopting best practice measures becomes crucial to substantiate claims related to ecosystem services.

Prospective market customers, relationships & channels

- **Seaweeds**

The seaweed industry in Europe presents a significant economic, social, and environmental opportunity. By 2030, the European market for seaweed could burgeon into a multi-billion-euro industry, potentially reaching up to €9.3 billion. Currently, only 30% of this market is met through European production, while the remaining 70% is sourced from imports (Seaweed for Europe, 2020).

This growth trajectory is driven by the expanding markets for seaweed-based foods and additives, particularly phycocolloids. In 2019, 77% of seaweed produced globally was used for application in human consumption applications (Grand View Research, 2020).

Table 3: Range of possible applications for seaweeds (Source: World Bank, 2023)

Market segments	Main Value proposition
Biostimulants, fertiliser	● Gain crops production and resistance ● Biological agricultural input
Feed	● Improve nutrient absorption ● Animal performance benefits ● Protein source and support digestive health ● Methane reducing
Ingredients	● Rich mineral and bioactive compound ● Improved well-being and health benefits (antioxidant, antimicrobial, antiviral properties…) useful in Nutraceutical and pharmaceutical ● Phycocolloids: Seaweed extracts composed of sugar polymers (agar, carrageenan, alginate). ● Gelling properties applied in food, biotechnology, pharmaceutical, and cosmetic applications.
Food	● Alternative proteins, healthy food ● Texturing and stabilising function for food product
Material	● Eco-friendly and biodegradable ● Strength and sustainability
Biofuel	● High carbohydrate content beneficial for anaerobic digestion and ensiling processes. ● Bioethanol and methanol production (although this requires large seaweed production volumes to be suitable/productive)

Based on the Global Seaweed New and Emerging market report of 2023, the World Bank has drawn out predictive seaweeds market development (see figure 11):

- Short-term markets (before 2025): biostimulants and feed
- Medium-term markets (2024-2028): nutraceuticals
- Long-term emerging markets (after 2028): pharmaceuticals and building material

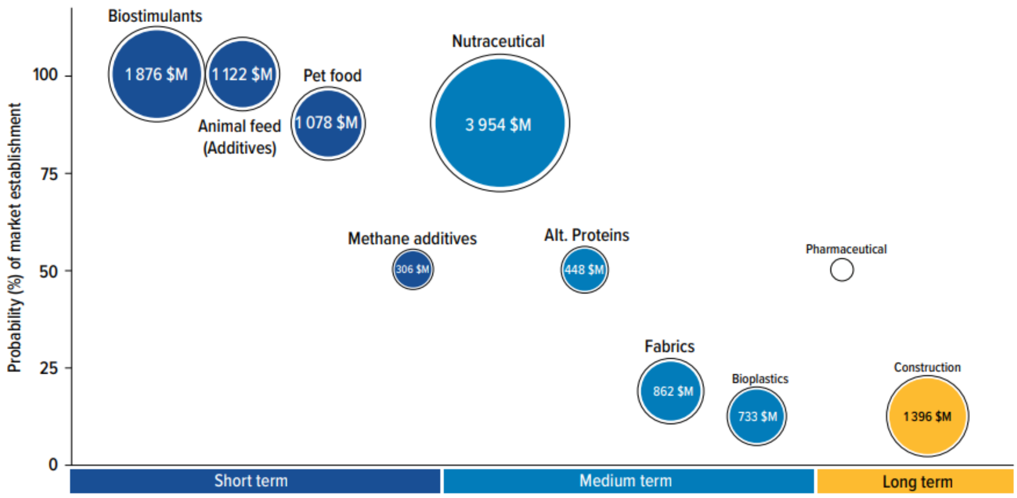


Figure 11: Predictive seaweed market development (Source: Global seaweed: new and emerging markets report 2023)

For future development, here are some figures of the projected seaweed market in Europe in 2030.

Component	Ambition Level			Units
	Conservative	Moderate	High	
Animal Feed	539	1,192	2,218	€ million
Food	688	1,375	2,094	€ million
Biostimulants	607	764	1,824	€ million
Bio-packaging	182	569	1,283	€ million
Pharma & nutraceuticals	195	528	771	€ million
Additives	609	676	749	€ million
Cosmetics	149	215	291	€ million
Biofuels	6	12	22	€ million

Figure 12: European seaweed market in 2030: conservative, moderate, and high ambition cases (Seaweed for Europe 2021)

In some cases, seaweeds could also be sold to seaweed producers that struggle to achieve adequate supply from natural populations. The Scottish Government recently made a statement regarding the seaweed review, highlighting specific points: *"Following an amendment to the Scottish Crown Estate Act 2019, which prohibits the wild harvest of certain kelp species inhibiting the growth or recovery of the plant, Scottish Ministers committed to a review to gather evidence on the implications of seaweed* *harvesting by any method and consider the sustainable development of the seaweed sector. There is a long history of harvesting wild seaweed in Scotland, and although the existing Scottish seaweed industry is small, there is a growing interest in further developing the commercial seaweed-based industry, for example through creating new high value products from wild seaweed and through cultivating seaweed to supply various existing and emerging markets.*" (Statement on the Seaweed Review (www.gov.scot).

It should be noted that profitable and, in some cases, higher quality varieties of seaweeds can be obtained from natural sources, creating significant competition for supply to these industries. The main market sectors using European kelp, which has the potential to be grown on a commercial scale, are:

Table 4: Key market sectors where European kelp are used on a commercial basis (Source: BIM, 2023)

	Processed format			**Market segments**				
	Dried meal & powder	Dry extracts	Liquid extracts	Biostimulants	Feed	Biomaterials	Cosmetics	Foods & Ingredients
Saccharina latissima	✓	✓	✓	✓	✓	✓	✓	✓
Alaria esculenta	✓	✓					✓	✓

Seaweeds sales mainly follow a Business-to-Business (B2B) approach but could also involve Business-to-Consumer (B2C) relations.

- **Oysters (*Ostrea edulis*)**

Domestic market:

In recent years, there has been a noticeable rise in the local consumption of Native oysters. Scottish shellfish production data is annually documented, detailing production volumes for both the table market (direct sales for human consumption, typically around 4 years old and weighing approximately 70-80g in total wet weight) and the on-growing market (sales to other businesses for further growth, comprising juvenile oysters of ≤1 year old and 25g total wet weight).

European flat oyster production destined for the table has exhibited fluctuations in recent years, primarily attributed to the impacts of the Covid-19 pandemic. Notably, there was a significant increase from 8 to 109 tons between 2021 and 2022. The first-sale value of these oysters tends to vary

throughout the year, influenced by factors such as demand, production levels, and the geographical origin of the product.
For the rewilding market, oysters can be marketed at a growth size of 1 year (25 grams). For the table market (main domestic market), oysters are sold in both fresh and frozen states at approximately 4 years of age, requiring a span of 5 years from seed to reach the table market size (65-70 grams).

The domestic market in Scotland and the UK holds potential for acquiring highly valued products (SAOS, 2021). One of the key factors is the direct-to-consumer sales model adopted by many oyster farms. Through the utilization of online marketplaces and the establishment of strategic partnerships with retailers and seafood restaurants, oyster producers can broaden their market reach and provide sustainably farmed oysters directly to customers' residences. Benefits are:

- for consumers: freshness and sustainability
- for restaurants: significant opportunities for restaurants and distributors to enhance their offerings and meet the growing demand for premium seafood products

On the domestic market, oysters can also be sold to wholesalers and fishmongers (HORECA) fresh, or smoked as a luxury product, for a niche table market.

Export market:
In 2020, the EU's total oyster consumption reached an estimated 91,800 tons. The main export market within EU members are France, Belgium and Spain. France is the main producer and exporter (source EUMOFA, 2022) and has the largest apparent consumption within the EU member states. Main French imports are from Ireland and UK. The intense competition prevalent in the EU market signals the potential emergence of a lucrative high-value market for Scottish oysters.

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)”* (SAOS, 2021). There exists potential for their transformation into nutraceuticals, pharmaceutical products, and for bioprocessing. For this market, a high quality of the raw material and a rapid processing chain is needed to maintain the shellfish’s condition, biochemical composition and nutritional profile.
Furthermore, oyster shells or crushed shells offer a wide range of applications, such as soil enhancement in agriculture, utilization in structural engineering, and the creation of high-value biomaterials. Several companies and start-ups have developed their production process to upgrade these by-products.

Key activities

This system is located 200 meters off the mainland coast on the West coast of Scotland. The total lease area is 30 hectares with currently one production site of 1 hectare deployed, being composed of a 100 x 100m submerged and tensioned rope grid system. This is an experimental non-commercial site, and as such, the deployment layout is flexible and largely influenced by varying research project needs and requirements. In its current configuration the site offers growing space for up to 48x 50m-long cultivation lines, dominated by the production of brown seaweed species (*Saccharina latissima* and *Alaria esculenta)* in conjunction with small-scale trials for the co-culture with other extractive species such as shellfish (European flat oyster *Ostrea edulis* and King scallops *Pecten maximus*).

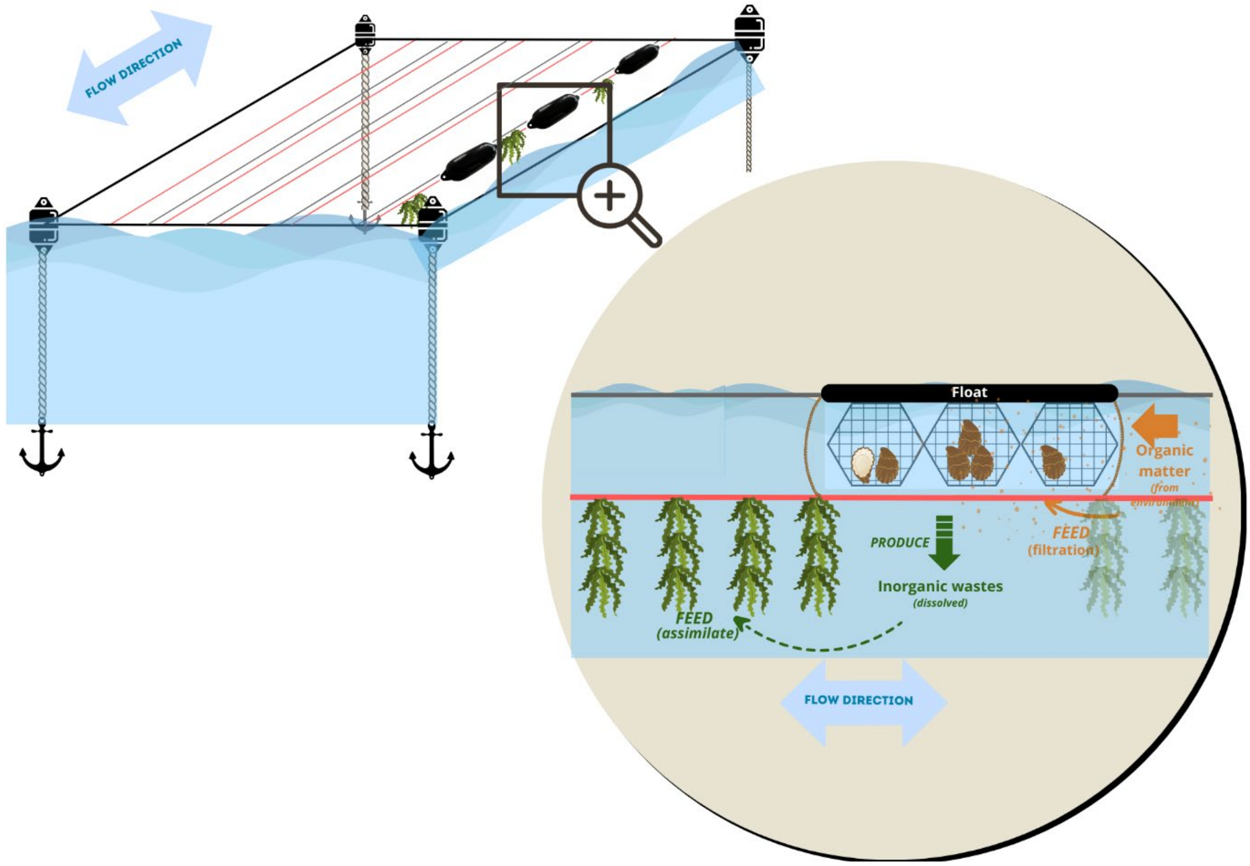


Figure 13: The IMTA Lab system organisation in Scotland (Source: SAMS, creation: PMBA)

The site is oriented parallel to the shore and the main current direction is NE-SW, leaving it moderately exposed to dominating surface currents and variable wave action. The tide is semi-diurnal with an annual range of 0.45m to 4.50m. The local climate is strongly influenced by the Gulf Stream and North Atlantic Oscillation, with the latter resulting in the predominance of westerly winds at this site. Across the year, seawater temperature varies from 6.1 to 15.7 °C and salinity from 19.5 to 33.3 PSU in the top 1.5m of the water column – the main growing space for both seaweed and shellfish.

Oysters are deployed in floating shellfish baskets attached to seaweed growing longlines and left to grow until they reach harvestable size (approx. 3 years from spat size of 20-25mm shell height).

Oysters are very efficient filter-feeders, filtering the surrounding water for particulate organic matter. As a result of their metabolic processes, oysters then release inorganic nutrients back into the water column thus adding to the nutrient pool available for seaweed to assimilate and grow.

Seaweed also requires buoyancy to keep it at the optimum cultivation depth: in this system the buoyancy is provided by the shellfish baskets rather than traditionally employed trawl floats. Thus, seaweed and oysters can be co-cultivated using the same infrastructure components and buoyancy aids used in seaweed monoculture can be replaced with floating shellfish baskets holding an additional potential income stream for the producer. The production process requires strong R&D aiming to optimise seaweed nursery, deployment, cultivation and harvesting methods following a cradle to farm gate principle. The goal is specially to reduce the operational costs of IMTA, improving efficiency (spatial and resource efficiency), circularity and product quality and yield for integrated low trophic aquaculture.

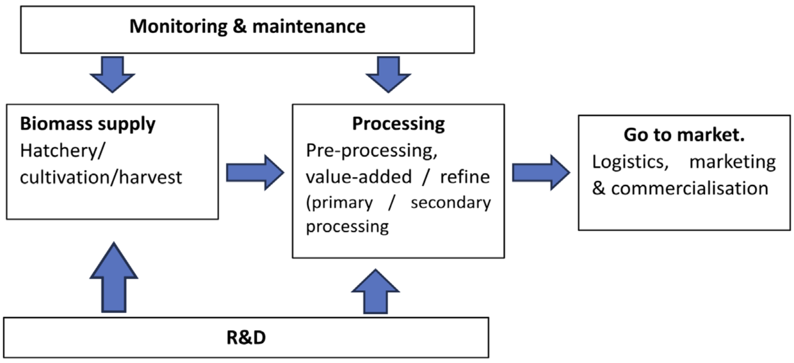


Figure 14: Simplified value chain of key activities for oyster and seaweed (creation: TQC)

Seaweed, especially brown seaweed (kelp), is a fast-growing crop, growing exponentially in March and April with biomass yields doubling every 11 to 17 days. The main harvest period is comparatively short with 3 to 4 weeks from late April to mid-late May.

During this time, seaweed growth will have slowed down or even stagnated and the product will be intact and free from on-growing biofouling organisms. Ultimately, the optimal harvest time is determined by the intended application and its requirements. For food and feed applications, an early harvest is needed to avoid spoilage from biofouling and the accumulation of heavy metals (e.g. inorganic arsenic, iodine) in the seaweed tissue causing food safety concerns.

For non-food/feed applications, harvest can be performed much later in the season providing overall greater yields and higher sugar contents (relevant for e.g. phycocolloids or biofuel production).
It is important to optimise cultivation trials for improved operational decisions according to the market: this depends on the product's intended application.
The system produces every year an average of 4 tons for each seaweed species.

Key resources

This system is highly dependent on the site location and prevailing environmental conditions as it is an open water system. Specific environmental requirements are needed for these species:

- Environmental factors: the production needs to be away from sewage outfalls and other sources of pollution, and in areas with stable marine salinities i.e. away from river mouths and large catchment areas
- For kelp: almost full-strength salinity seawater, need to avoid places that are likely to be freshwater influences
- The location of the farm needs to provide sufficient food quantity and quality for shellfish
- The good water clarity for light penetration as well as sufficient nitrate levels are needed to promote the growth of seaweeds

One of the first key resource needed is a suitable area to implement the production site. In this case, a production site of 1 hectare is required, to which a surrounding area for secure anchorage to the seabed is added. In addition, the right authorisations and licences for lands, seaweed exploitation and shellfish exploitation are needed (see figure 15).

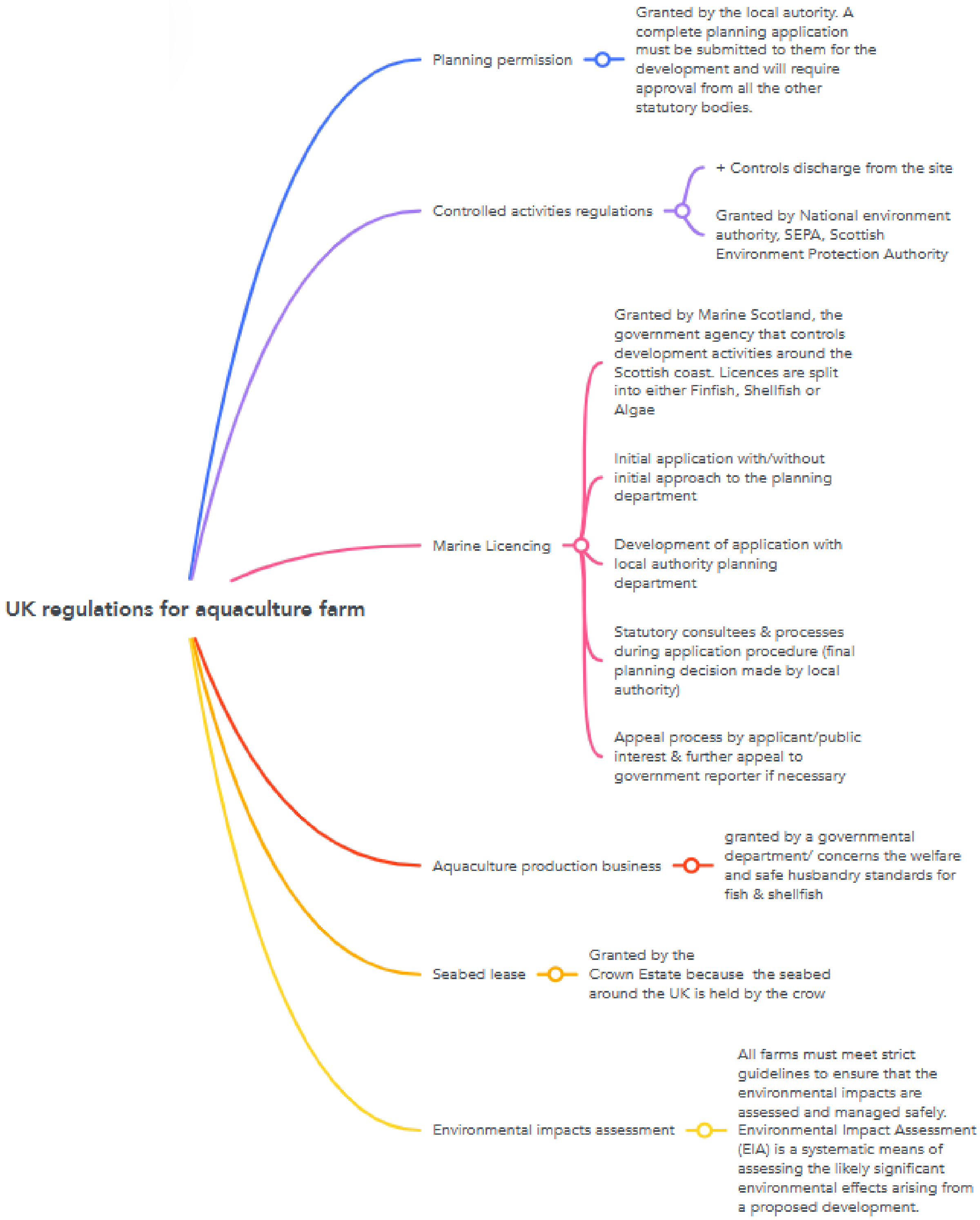


Figure 15: Reglementary pathway for aquaculture – Scotland (Integrate project & Scottish government/ Creation TQC)

For infrastructures, key criteria are low-cost equipment, easy to maintain, reliable in adverse weather and provided for high stocking densities of seeded materials and shellfish. To facilitate movements, especially during harvesting periods, the production area must be designed to allow boat manoeuvres.

A work boat is also required as well as a harvesting boat (landing craft); either can be owned or hired from local partners.

To start the production, main inputs are needed: hatchery-reared seaweed sporophytes (twine-seeded or direct seeding onto growing line) and shellfish spat equipment (trays, longlines, boat, anchor, buoys). To run activities, skilled human resources are key, with a higher labour intensity during the harvesting period:

- Recruitment and training of key staff/seaweed farm technicians.
- Business development activities / following sales and marketing.

In this system, the work is carried out by one seaweed nursery manager, one farm technician and two researchers.

Key partners

Key upstream partners in this system are funds providers. In Scotland, public and private fundings are relevant for aquaculture (see figure 16).

EU funds	National Schemes/Public grants	Private fundings
• European Maritime, Fisheries and Aquaculture Fund (EMFAF) • Horizon Europe	• Marine Fund Scotland • Seafood Producers Resilience Fund • Aquaculture Development Scheme • Aquaculture Industry Engagement Fund (AIEF) • Nephrops Programme Board • UK Seafood Fund • Scotland Food and Drink Export Plan • Opportunity North East (ONE) Seafood Transformation Project • BBSRC Biotechnology and Biological Sciences Research Council	• Sustainable Aquaculture Innovation Centre (SAIC) • Water Innovation Grant • Bank • Shareholders • Research Incentive Grants (Carnegie Trust)

Figure 16: Available grants/fundings for aquaculture in Scotland (Source: Europa, EMFAF, SAIC, Scottish government)

Governmental organizations play a pivotal role as key partners due to their involvement in issuing necessary permits and authorizations for the installation and operation of the production system. Additionally, trade associations, professional organizations, and scientific networks are essential for the production and commercialization of products within this industry. Main ones are the AlgaeUK Network, the Association for Scottish Shellfish Growers (ASSG), the Scottish Seaweed Industry Association (SSIA), as well as larger shellfish restoration initiatives such as the Native Oyster Restoration Network (NORA).

The installation process makes the producer dependent on suppliers:

- for equipment especially the boat used to harvest, maintain the installation, monitor
- for juveniles and seeds to start the production

Within the production process, transport companies and processors are key partners since they enable the producer to reach markets and consumers.

Key downstream partners are focused on R&D. Research organisations are also key for collaborations related to seaweed compounds as well as seaweed/shellfish health based in the UK and Europe.

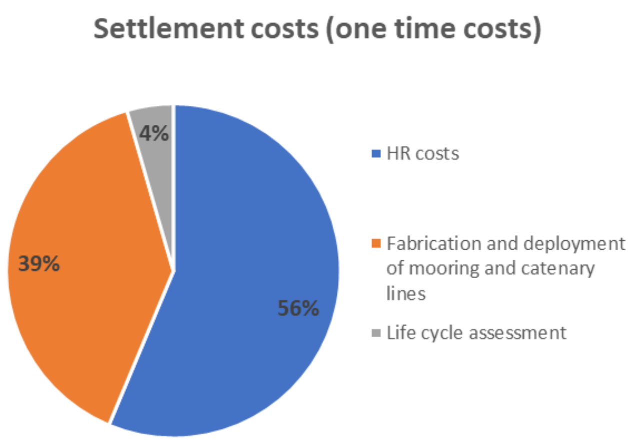
Cost structure (pilot scale)

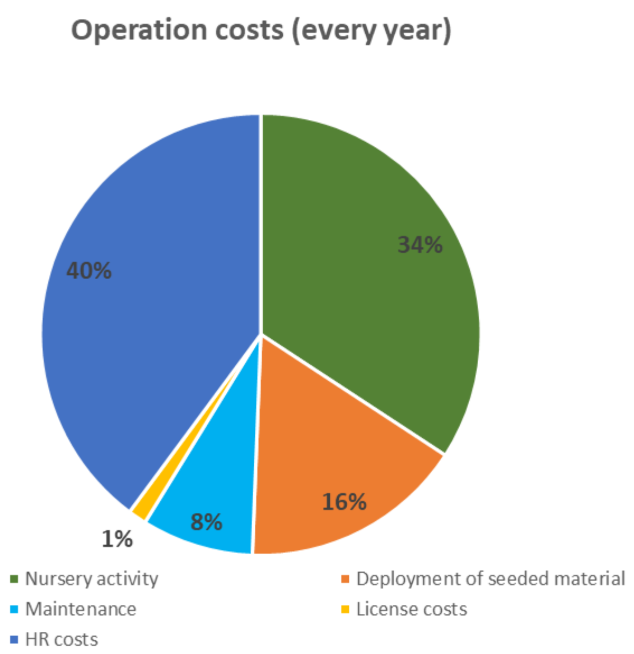
Investment in this system breaks down as follows:

- First investment: focuses on infrastructure and equipment, encompassing items such as seaweed growing lines, oyster baskets, and related materials and services, amounting to 245,400 euros.
- Licensing: this aspect demands time, causing a delay in the return on investment. A period of three years is required before the first seaweed crops, which might be perceived as a drawback for potential investors.
- Operating costs and maintenance

From 1 to 5 people are involved in the IMTA lab with a time distribution of 80% dedicated to seaweeds and 20% to oysters, for a total cost of about €138,000 each year.

These are the main money outflows for the production:





Approximately 70% of the system's expenses, amounting to €232,000, are allocated for the first year. These costs primarily cover one-time expenses like the life cycle assessment and the fabrication of mooring. The remaining 30% of the expenses will be dedicated to ongoing activities such as monitoring, nursery activities, and line deployments.

Prospective revenues

Forecast sales are mainly based on production sales and depend on market segments.

- **Oysters:**

The average price of a native oyster is £0.5 (€0.58) per shell, contributing £0.05 (€0.06) million to the total Scottish shellfish value of £10.4 (€12) million.

Each native oyster typically costs £0.5 (which is approximately €0.58) per shell. The contribution of these oysters amounts to £0.05 million (around €0.06 million) within the overall Scottish shellfish value, which stands at £10.4 million (approximately €12 million) (Scottish Shellfish Farm Production Survey 2022 (www.gov.scot)).

However, sales prices depend on product quality, oyster species and maturation. The export price depends strongly on the destination (transport costs) (EUMOFA, 2022).

- **Seaweeds:**

In Scotland, the primary market segment for seaweeds is human food and bioactive products.

The average turnover on human foods markets for companies involved in production is estimated at £210,000 (€242,000) per year with average profits reported around £34,000 (€39,000) every year representing 9 companies (Source: Marine Scotland, 2022).

Regarding Bioactive markets, the average turnover is estimated at £87,000 (€100,000) per year with profits estimated around £15,000 (€17,200) per year representing 7 companies (Source: Marine Scotland, 2022).

Regarding commercial value based on fresh wet biomass, the research organization leading the Astral Lab currently values sales at approximately 2.18 to 2.3 euros per kilogram.

4.1.2 The Business Model Canvas

The Business Model Canvas

IMTA LAB / OPEN WATER SYSTEM
SEAWEED AND OYSTER

SCOTLAND

Key Partners

- **Upstream partners :**

Funds provider; public/private

Government

Marine operator (if rental boat)

Juveniles oyster suppliers & producers / Seaweed nursery

Professional organizations: AlgaeUK Network, Association for Scottish Shellfish Growers (ASSG), Native Oyster Restoration Network (NORA)

- **Downstream partners**:

Research organization for collaborations related to seaweed compounds as well as seaweed/shellfish health based in the UK and Europe

Processors

Transport society

Key Activities

IMTA production system
Production process : Seeding / nursery or hatchery, harvesting, cultivation
Grading (for oysters)
Monitoring
Installation and maintenance
R&D
Processing
Sales and marketing

Key Resources

Site location and licenses

Supply of infrastructures and equipment

Supply of juveniles and seeds

Qualified / Skilled human resources

Marketing

Feed

Value Propositions

Product developed through a sustainable IMTA system

Production of **kelp** *(Saccharina latissimi / Alaria esculenta)* :

- Improved accessibility of biomass by extending the optimum harvesting period from two months to four months
- Stimulated growth (adding nutrients from shellfish)
- Chemical, bioactive properties

Hypothesis of product format : (dried products (mainly); fresh frozen, flakes, salted)

Production of **oysters** (*Ostrea edulis*):

- Provide an potential additional income to the seaweed culture
- high value shellfish
- Native shellfish from the country/area
- Bioactive properties (zinc, selenium, omega3 fatty acid…)

Hypothesis of product format : fresh, smoked

Potential ecosystemic services (bioremediation…)

Customer Relationship *

Direct feedback from distributors

Direct feedback from customers if direct sales

Potential IMTA branding

Reputation of the products

Channels *

Outsourcing
Store or internet based

Oyster food market :
Retail / fishmongers / wholesalers / restaurants /direct sales

Seaweed market:
Wholesalers, industry processors

Customer Segments *

Oysters :
Domestic market :
Food / table market : mainly fresh products
Rewilding/spat market : for local producers

Shells for soil improvement in agriculture, civil engineering and biomaterials

Export market :
EU market : food industry / fresh products

Seaweeds : wide range of potential segments
Food market (optimum of 25 tons/year) – Food processors
Bioactive market for cosmetics, nutraceuticals and pharmaceuticals
Agriculture : seaweed fertilizer
seaweed product developers (that struggle to achieve adequate supply from natural populations)
Biomaterials
Biofuel

Crops : Seaweed growers

Domestic and EU market

Cost Structure *

Infrastructure :
Site installation (seabed mooring, cushion buoys, site marks, etc.) €34500
Equipment (sewed lines/ oysters baskets, etc.) / cost of material and services : €245400
Boat (purchasing price €230 000/rental costs - 290 to 1500€ day rate)

Licensing : significant investment (€11 000)

Site Maintenance (€11 000/year)
Human resources (1 to 5 persons) (80% seaweeds / 20% oysters) : cost of time €138 000/year

Revenue Streams *

Public & private funding

Sales of products :
Seaweeds : Food market : sale value €2.18-2,3 per kg of fresh wet biomass
Oysters : Food market : first sale value of €0.69 per shell
Rewilding market (e.g. €0.12 per 25 gram oyster)

Funding mechanism for potential Ecosystem services (premium price…)

******Prospective*

4.1.3 Synthesis

INTERNAL FACTORS

STRENGTHS
Technical • Increasing growth rates through nutrient income from the action of filter shellfish to seaweeds • Complete utilisation of the space: strong practical synergies • Pooling of some equipment: seaweed buoyancy using oysters • Low-cost cultivation infrastructure for oyster production (one equipment for 2 species) • Increasing accessibility: extension of the harvesting period from two months to four months (seaweed) and improve the accessibility of biomass throughout the year • Mainly local markets: reducing transport costs • Develop a reliable low-cost direct seeding method • Carbon retention by seaweeds **Environmental** • Oyster: filtration of particulate organic matter from the surrounding environment: efficient circulation system • Astral LCA highlights the potential of low-trophic species to improve the recycling of organic matter and nutrients "Key aspect of the bioremediation potential of IMTA is the balance between nutrient input and removal" **Economic** • Additional income (more species for the producer) • 100% public fundings • Once capital costs are established, fixed cost are modest for seaweeds
WEAKNESSES/CHALLENGES
Technical • Open water system: dependency to water quality and to surroundings environmental incomes / climate • No organic certification for seaweeds due to the addition of artificial nutrients (inorganic nitrogen) during the nursery stage • Expensive technical equipment required (boat, mooring, oyster lines) • Lack of qualified human resources • At this small scale: no strong ecological synergies by cultivating different trophic groups • Spat availabilities in Scotland **Economic** • Profitability of IMTA approach not yet confirmed • High capital costs at the beginning

EXTERNAL FACTORS

	Opportunities	Threats
Political	● Support of The Scottish government (IMTA) ● The Scottish aquaculture sector is technologically advanced as a driver of productivity ● Advantages of carbon retention by seaweed: to be promoted	● Conflicts for space, especially with the tourism sector in Scotland ● Lands access: lease seabed to The State Scotland and the Crown ● Links between schools, training program and jobs in aquaculture ● Cost and time and complexity to get planning permission, leases, and licences ● Regional differences in the licensing process due to local interpretation ● Divergent views on aquaculture development between planners, licensers and the government
Economic	● Expensive market of seaweed in the food industry. A growing demand: 7-10% per annum (Marine Scotland, 2022) ● Large seaweed market potential: rapid development on snacks, meals, condiments and skin-care products…	● Long return on invest: about 3 years for the first crop ● Regarding the IMTA misreading: there is not a strong demand for IMTA products in particular ● Seaweed aquaculture is currently too expensive to reach large scale markets ● High level of capital funds requested: Costs of premises, equipment and locations (Marine Scotland, 2022) ● Seaweed is not currently considered as economically viable: The start-up investment cost, the cost of seeded lines in Scotland); the relatively low value of species that can currently be cultivated at sea; the labour intensive process (Marine Scotland, 2022) ● Small market of oysters in Scotland and strong competition with France, Ireland and Netherlands ● Seaweeds: competition with France, Spain on sea vegetables and Portugal on bioactives products (Marine Scotland, 2022)
Social	● Consumer's quest for sustainability: Consumer awareness and interest in sustainable sources of healthy food, particularly plant based. (Marine Scotland, 2022) ● Seaweeds: New market opportunities for revenue diversification (nutraceutical) ● Growing interest in protecting, regenerating and restoring native oysters species in European waters	● IMTA misreading: Low public awareness as IMTA is still not well known by the public and the consumers ● For seaweeds: high value food markets are poorly defined ● Scottish society attach a high importance to minimising environmental damage from aquaculture (Whitmarsh et al, 2006)

	Opportunities	Threats
Technical	● Innovations and R&D projects in aquaculture to reduce risks and to develop products: ● Open water system: reducing the land use ● Need for more professional training	● The availability of skilled staff ● Growing demand for technological skills (digital technologies) ● Development of new technologies – adaptation needed by producers ● Lack of technical data on environmental effects of IMTA ● Lack of knowledge within the public and producer community regarding the IMTA model benefits, the seaweeds market ● Complexity of IMTA production system and technical challenges ● Lack of commercial experience in IMTA ● Spat availabilities ● Quality and consistency of supply because of seasonality (seaweeds) ● Low processing facilities for Scottish producers (for seaweeds): preprocessing facilities
Environmental		● Impact of climate change on sea temperature ● Disease propagation and pest in open water / pollution ● Seaweeds fragility: wave action wears on the seaweed fronds causing a 'whipping effect' (loss of large parts of the frond lengths) ● Sea lice: biosecurity process required
Legal	● Existing Organic certification: the ASC-MSC Seaweed (Algae) Standard ● Environmental certification: ASC MSC seaweed standard for 'environmentally sustainable and socially responsible seaweed production'	● Authorisations and permits delivery process / rates ● The Seaweed Cultivation Policy Statement (SCPS): designated shellfish waters where waters and product quality are monitored and protected for harvesting products for human consumption. ● European standards and the soil association standards do not allow use of organic nitrogen anywhere in a process to certify ● The time taken to receive a marine licence for cultivation

4.2 IMTA Brazil - case study

Land based and recirculation system - Shrimps, fish, seaweeds and oysters (Brazil)

This pilot production system is located in extreme southeastern Brazil, in a humid subtropical climate with hot, humid summers (maximum temperatures of 40°C) and cool to very mild winters.

This is a land based IMTA system established under a greenhouse, using recirculation and producing various species: Marine shrimps, Tilapia, seaweeds (*Ulva* and *Marine asparagus*) and oysters.

The system is using a super-intensive production in biofloc systems which is a sustainable and biosecure alternative to intensive culture systems. Biofloc is composed of uneaten feed, faeces, secretions, and their associated algal, bacterial, and microplankton communities.

4.2.1 Business model presentation

Value proposition

This pilot site is producing different species in the same system, allowing production to be diversified:

- The key species: Marine white shrimp *(Litopenaeus vannamei)*
- Two extractive species: Tilapia (*Oreochromis niloticus*) and oyster (*Crassostrea gasar*)
- Seaweed: sea lettuce (*Ulva fasciata*) and *Marine asparagus* (*Salicornia neii)*

This system allows several benefits, including circularity. Different trophic level species are using various resources and compounds produced within the IMTA system. It reduces the generation of effluents since most compounds are reused. The Marine shrimps have been chosen for their ability to absorb and use bioflocs and are releasing nutrients and organic materials into the recirculation system. This capability in using bioflocs is resulting in improved growth rates and reduced feed consumption (external inputs). It is also a highly adaptable species to various environmental conditions allowing versatile combinations with different fish species at varying salinity levels.

This IMTA system is allowing several benefits for the production:

- Tilapia and oysters are feeding with bioflocs reducing the inputs of external feed by 50% (economic benefits)
- The use of bioflocs is improving growth rate of shrimps by feeding them with a high protein diet (Wasielesky et a*l.*, 2006) and reduce the rate of external feed inputs (nutrient inputs)
- Seaweeds are using bioflocs increasing their growth and remove the toxic compounds in the water supply (ammonia and nitrites) allowing recirculation (Carvalho et al., 2023)
- Use of a single water supply for several systems by recirculation and bioremediation

These products are all marketable and can add economic benefits for the producer by selling them fresh or processed, increasing the marketable value:

- Tilapia could be sold fresh (whole fish or fillet), frozen (whole piece or fillet) or processed (ie breaded)
- Shrimps are mainly sold fresh or frozen
- Native mangrove oyster could be sold fresh, dried, frozen or as spat

In this system, seaweeds are used as a biofilter as a powerful system of ammonium and nitrogen detoxification. But sea lettuce is rich in nutrients with medicinal and health-promoting effect. From a nutritional point of view, the main properties of sea lettuce are their richness in polysaccharides, protein and amino acids, fatty acids, minerals, and vitamins. Therefore, their nutritional value makes them valuable food supplements. Furthermore, seaweeds can be used as input in processed food. Finally, *Marine asparagus* have high nutritional value and can be consumed as fresh vegetables or for animal diets.

Prospective market customers, relationships and channels

- **Tilapia (*Oreochromis niloticus*)**

Brazil is one of the most important producers of Tilapia in the world, facilitated by low feed costs, since the country is producing large quantities of soya, for example. Brazil also has a strong domestic demand for fish and especially Tilapia which is the most consumed freshwater product in the country (Lopes and de Freitas, 2023).

The main market for Tilapia is thus the domestic market, for the country's consumption.

For about 99% of this local market, the production is used by the food industry and Tilapia are mainly marketed fresh, as whole fish gutted and head-on. Another part of the sales is frozen Tilapia processed in fillets (Barroso *et al*, 2019).

The main channel used for this market is B2B:

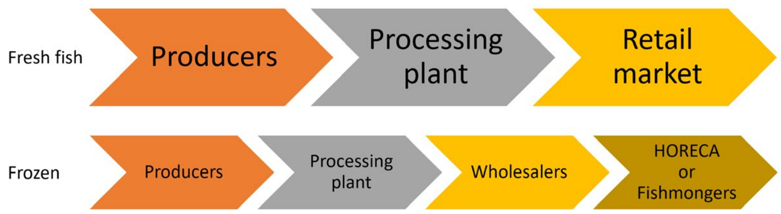


Figure 17: Distribution channel for Tilapia (Creation PMBA)

A niche market can be exploited on a local scale including direct sales to local producers of fish juveniles or for direct consumers to use Tilapia as bait fish or ornamental fish.

An export market is possible, mainly to the USA which represents 81% of Brazilian fish exports (Barroso et al, 2019) with an increasing tendency.

Prioritised packaging for this market is frozen (whole pieces of fish or fillets) for 70 to 80% and fresh fillets for 20 to 30%.

There is also a "*prospect of reopening the European market for Brazilian fish which was closed in 2018 and could contribute to an increase in exports of fish farming products*" (Santos, 2023).

- **Shrimps *(Litopenaeus vannamei)***

Just as Tilapia, the local and regional demand for shrimps is high and the tendency is increasing. Supplying the domestic market is thus a target for more than 90% of the production.

Shrimps are mainly sought-after fresh, without any processing reducing additional cost for the producer, for the food industry.

A direct B2C channel can also be used by the producer for two types of sales: shrimps can be sold alive to direct consumers or larvae can be sold to local aquaculture producers.

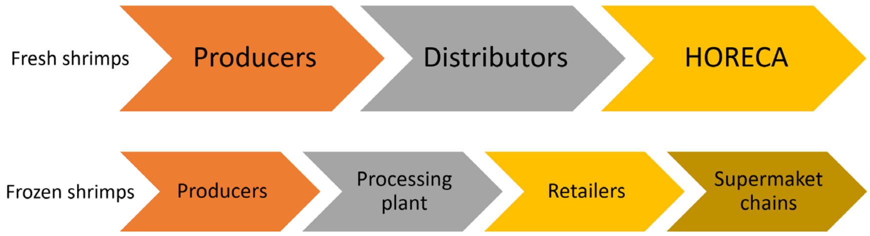


Figure 18: Distribution channel for Shrimps (Creation PMBA)

Frozen shrimps can also be sold to supermarket chains by retailers, inducing a processing plant to process the fresh product into a frozen one.

The export market to Europe or even USA decreased over decades but there is a potential tendency to restart to growth and a new market is in the process of rising in the Middle East and especially in the United Arab Emirate (Seixas and Troutt, 2003).

- **Seaweeds**

The local use of seaweed in the country remains quite low and the food market for seaweed is restricted.

However, seaweeds can be used for growing local alternative markets:

- as a resource for the manufacture of phycocolloids (agar and carrageenan) and in cosmetics
- Brazil being a major agricultural producer, the use of seaweeds in agriculture as a fertiliser represents a major potential.

For this domestic market, raw biomass is mainly used.

Another perspective would be to export Brazilian production to nearby countries (Chile and Argentina) for phycocolloids or in Europe for cosmetics. The quantities required for these markets are significant, since processors use large quantities of fresh biomass to extract the necessary components.

The economic interest in algae lies in their composition in components with a high market value which can be used in a wide range of applications including cosmetics, agriculture, pharmaceuticals. Seaweeds can be used as a feed input due to the high composition in nutrients and vitamins and has shown a good social acceptability (Carvalho et al., 2023).

- **Oysters (*Crassostrea gasar*)**

Oysters are a high-value product for human consumption and the main market for Brazilian oysters is the domestic food market.

Indeed, the export market for those products is highly limited as there is a non-recognition of the value of Brazilian oysters abroad.

Domestic market is thus to prioritize, and the demand is real in the food industry.

As products are mainly consumed alive, the process is reduced to a minimum.

Figure 19: Distribution channel for Oysters (Creation: PMBA)

Key activities

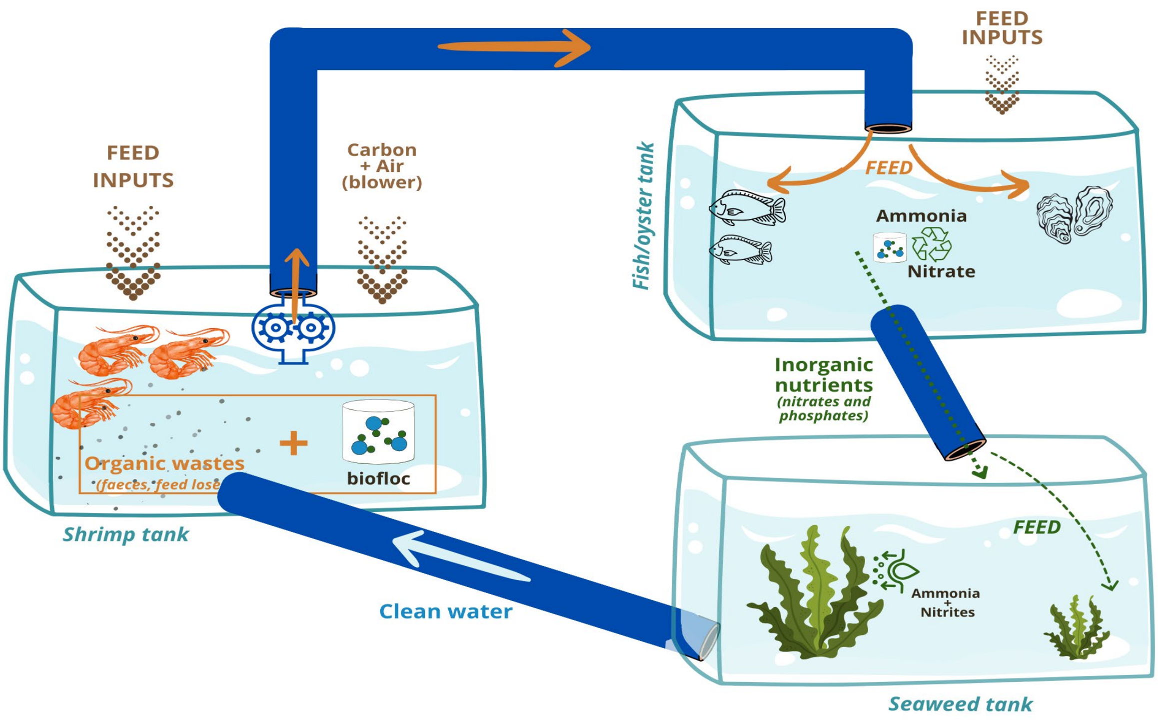


Figure 20: Tilapia, shrimps, seaweeds IMTA system (Creation: PMBA)

Shrimps are farmed in a tank at a high-density rate (X25 compared to a regular system) with a high concentration of water in nutrients (phosphates and nitrates) and organic matter: bioflocs. To control those high organic matter concentrations, Tilapias are farmed in separated tanks, as are oysters. They are used as filter feeders, filtering out bioflocs and using it as food, reusing the organic material in the production system. The nutrient from the effluent water (from shrimps) is used as food material for fish (organic matters), reducing the external feed inputs. Bioflocs and bacterias present in it are used as supplementary feed for shrimps and fish and are also the primary food source for oysters and indirect source of nutrients for the plant species.

Water from tilapia is flowing to another tank with seaweeds which are absorbing dissolved nutrients by reusing nitrates and phosphates accumulated in the system. Those species can handle the organic load and are taking advantage of the transformation of nitrogenous compounds produced by bacteria present in bioflocs. Toxic compounds (ammonia and nitrites) are assimilated by their leaves and roots, removed and transformed into usable plant biomass.

The water from the main tank, used for the shrimp production, is pumped into the fish tank. With gravity, the effluent from fish production is going to the seaweed and oysters benches. The water then flows back by gravity to the main tank containing shrimps.

The production site is currently organised in sets of three tanks: one for shrimps (20 m^2), one for fish and oyster and the last one for seaweeds. There are 6 sets in the site, and they are settled within greenhouses to maintain a controlled environment temperature.

The experimental production activities are divided into pre-production, production and postproduction activities.

The recirculation system is almost a completely closed system: produced waste is transformed into non-toxic products by the system and environmental conditions are fully controlled. Water is thus recycled and reused for every production cycle, allowing a minimal land use and water supply by decreasing water exchange near to zero.

In addition to IMTA, the production process also involves the use of the biofloc technology which are macroaggregates of bacteria, protozoa, algae and particulate organic matter (food and feces).

The biofloc provides a substrate for microbial nitrification of toxic ammonia into nitrate, in the same production tank. Treatments are no longer necessary, nor is changing the water, improving economic and environmental sustainability.

The main pre-production activity is hatchery. Juvenile forms of shrimp, fish, and oysters are easily obtained in Brazil with local producers, while plants such as macroalgae are sourced from the natural environment and brought to the site to increase their biomass prior to cultivation.

Main production activities for this system are:

- Daily monitoring water quality parameters because those tropical species are highly dependent on temperature
- Feeding the fish and shrimp tanks (twice a day)
- Weekly growth assessment for fish and shrimps
- Pruning seaweed to remove excess biomass and create more biomass production (can be done every month)
- Size monitoring and grading
- Harvesting and cleaning

The species have different growth periods influencing the harvesting process. Fish are the slowest to reach minimum commercial size, so are taken as a reference for the harvesting of the other species. Shrimps have faster growth so can be harvested twice while producing one fish harvest. Oysters have slower growth rates so are kept during the whole cultivation period.

Once fish reach their final size, every tank for every species can be harvested and the water is reused for the next production process.

Post-production activities are R & D to target the market, for product development and to reach the ideal conditions of growth to increase the profitability of the production site. Process oyster into bulk and shrimps and sales are also main activities.

The system produces each year three cycles of shrimp production, two cycles for oysters and 3 cycles for seaweeds. The production volumes of each species can vary between cultivation cycles, but the average volumes are :

- Shrimps: 1.2 ton/year (5 kg/m^2)
- Tilapia: 1.6 ton/year (15 kg/m^3)
- *Ulva*: 0.36 ton/year (1.0 kg/m^3 of halophytes, and 1.2 kg/m^3 of macroalgae)

Key resources

The system is highly dependent on the site location and availability of resources (water supply) and on environmental parameters such as temperature as the species' production is affected by temperature variations. Indeed, the first key resource needed is a suitable area to implement the farm, with a close water supply and weather conditions suited to the species selected. In this case, the use of tropical species requires high temperature areas.

To set up an aquaculture system in Brazil, there are a number of compulsory regulatory steps to follow (see figure 21).

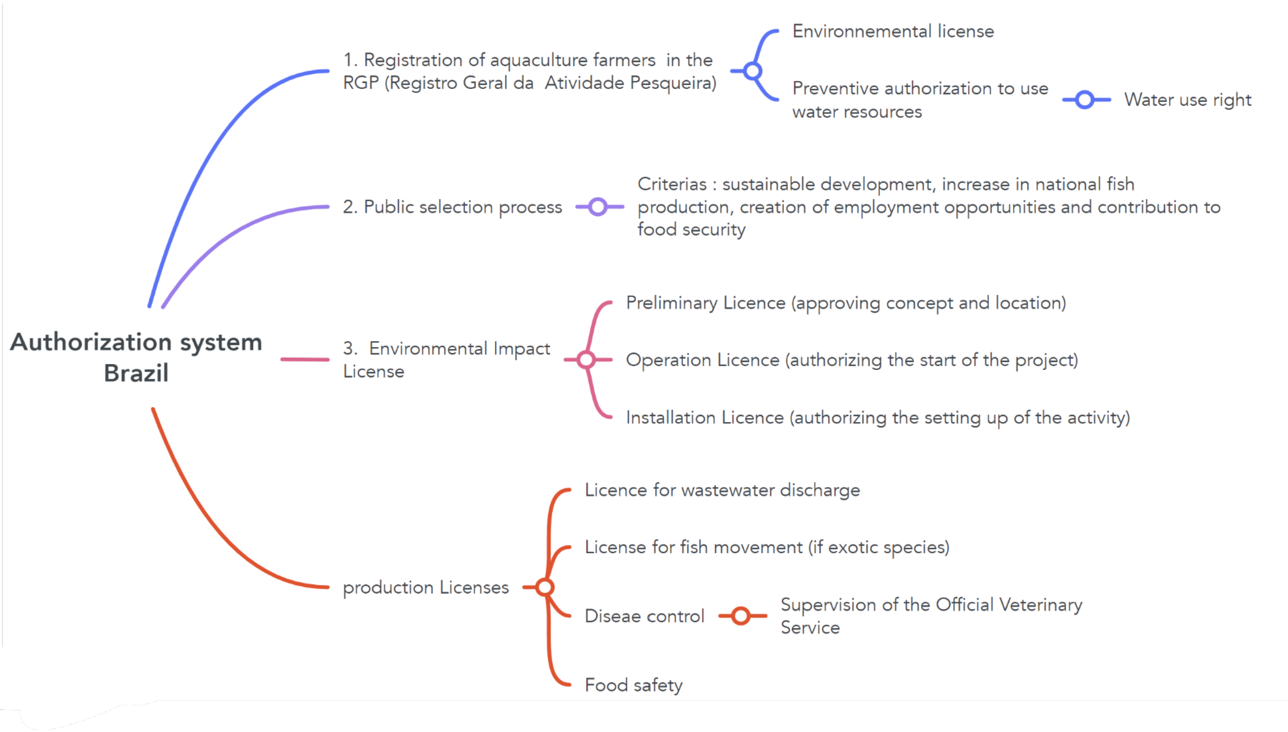


Figure 21: Reglementary pathway - Brazil land based IMTA system (creation: PMBA)

The second key resource is also about implementation and is focusing on authorisations and permits. In Brazil, licences are required by environmental agencies at various levels of government and involve a series of requirements: focusing on environmental criteria or analyses of historical heritage.

Production obviously requires specific equipment depending on the chosen species and the parameters required, and depending on the activities that will take place on the production site. In this system, the whole installation including greenhouse, tanks, pumps, pipelines and monitoring kits are needed.

To start the cultivation activity, main inputs are essential:

- juveniles and larvae of each species which are going to be hatched in the production site and then implanted
- feed inputs for fish and probiotics
- Bioflocs

To run activities, qualified human resources are needed, with a higher labour intensity during the harvesting periods. Brazilian aquaculture is in competition with the artisanal fishing sector, inducing a depreciation of prices when it's high fishing periods. It is highlighting the need for the producer to develop a strategic planning for cultivation and harvesting periods and the high dependency of production to qualified / skilled human resources and market differentiation (R&D and marketing)

Key partners

In Brazil, several financings are possible for setting up an aquaculture business and several funds are available for the rural sector, including aquaculture (see figure 22).

Programs have been created by the government to promote the productivity and competitiveness of the agricultural sector, like the MODERFROTA program to finance the acquisition of tractors and agricultural equipment. PRODECOOP and PROCAP-AGRO are other programs promoting the modernization of production systems.

The Brazilian Development Bank (Banco Nacional de Desenvolvimento Econômico e Social - BNDES) is a main investor or credit provider in Brazil. Rates are variable and depending on the project (buying equipment, investment project…) and the funds can be borrowed indirectly (via financial agent) or directly by producers (Priscila et al. 2022). For aquaculture, the relevant fund is the BNDES Rural Credit.

Private firms like Ocean 14 Capital, a UK private investment fund working in sustainable aquaculture and fisheries, or Aqua Spark, a global investment fund investing in sustainable aquaculture businesses.

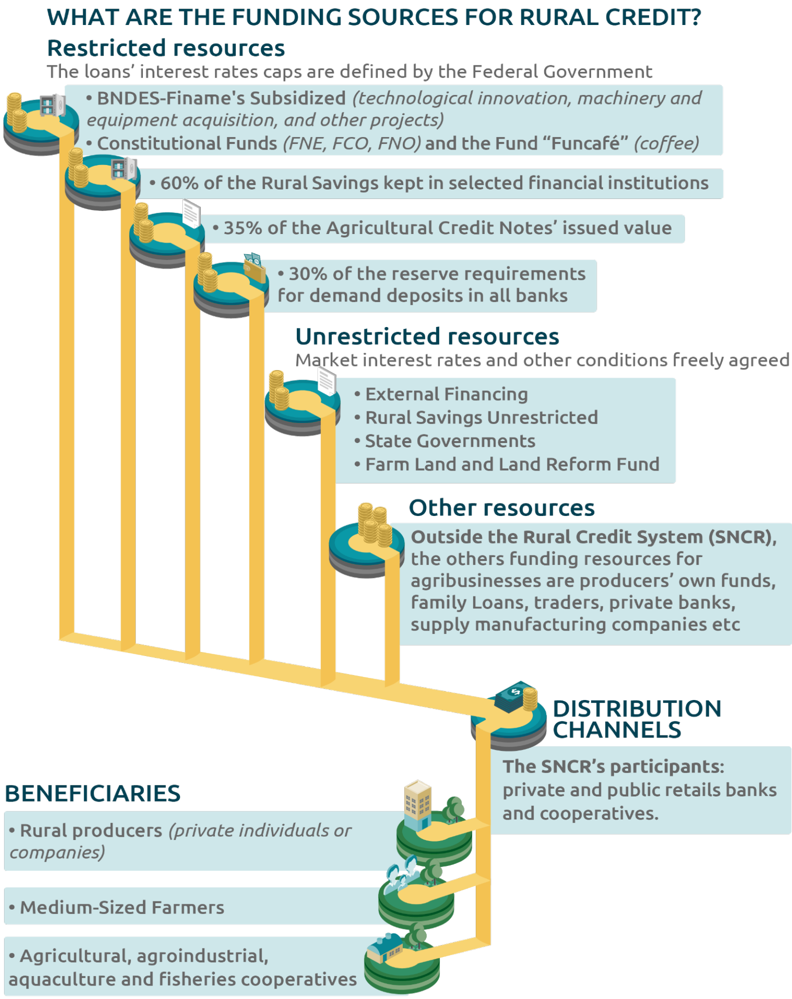


Figure 22: Funding sources in Brazil (Source Banco central do Brasil)

The installation process makes the producer dependent on suppliers:

- To run the production, upstream partners are needed by the producer including juveniles and seeds suppliers. In this system, larvae for shrimp and juveniles for fish come from specialised laboratories and oysters from local producers.
- equipment suppliers to build the system and ensure maintenance.

In post-production, downstream partners are mainly actors involved in processing and selling including transport companies, processors and distributors.

Cost structure (pilot scale)

In this theoretical production system, investment costs are main costs as the farm is demanding high technical equipment for different species, each having specific needs.
Investments are thus highly impacted by the land acquisition, project development and licensing process. Tools for main activities (materials for the construction of aeration and recirculation systems, greenhouses, generators, and equipment for air injection into the system, water intake pumps, and system recirculation pumps / nourishment) is also a major investment part.

For an average of 1 hectare of productivity for this system, the first investment costs represented an initial investment of €320,000 and are divided as followed:

- Construction: 55% to 68%
- Acquisition of the geomembrane: 30%
- Aeration and water pumping system 15 to 25%
- Licence (can reach 5% of the total investment)

Production costs are mainly impacted by purchase of juveniles and food inputs (feed and probiotics). As this IMTA system is highly specialised, management and skilled resources are key costs. Human resources can be divided (in work time) for shrimps (49%), Tilapia (49%) and *Ulva* (2%). Biofloc particles are also used and consumed directly by species: shrimp, tilapia and oysters. This input is making a more efficient use of the nutrients contained within the feed and subsequently lowering the feed costs.

Prospective revenue

The main sources of income would be sales of the most valuable products, namely shrimp and oysters. These two products do not require processing by the producer and can be sold directly at high prices. In September 2023, prices of shrimps reached 3.69€/kg and oysters can be sold even at 2.20€ a dozen. To be profitable (with its own processing plant) for a monoculture oyster farm in Brazil, the production needed is around 150,000 dozen per year (Suplicy, 2021).

Tilapia is a low-valued product, but the relatively high production of the system coupled with low processing costs can be profitable. Prices for Tilapia are depending on the distribution: from 1.7€/kg to 1.8€/kg for wholesalers (source: CEPEA) to 5€/kg for the whole fish in retail.
For every product, the more the product is processed, the higher the selling price will be. For Tilapia, frozen fillets can be the double prices of fresh whole fish.

4.2.2 The Business Model Canvas

The Business Model Canvas

IMTA LAB / RECIRCULATION LAND-BASED
SHRIMPS / FISH / SEAWEED / OYSTERS

BRAZIL

Key Partners

- **Funders:**

Credit provider (BNDES)
Government (public programs)
Private firms : Ocean 14 Capital / Aqua Spark

- **Upstream partners** : local and national

Juveniles suppliers : shrimp and fish from specialized laboratories / oysters from local producers
Equipment suppliers (local or national) : agriculture company / specialized suppliers
Scientific partners : university and scientific networks

- **Downstream partners :**

Transport company
Processor
Agents/distributors
Communication agency

Key Activities

IMTA production
Hatchery
Water quality and size monitoring
Feeding for fish and shrimps (input twice a day)
Growth assessment (fish and shrimps) (weekly)
Harvesting
Processing and sales / marketing
R&D and product development

Key Resources

Suitable area of implementation: availability of water supply and suitable environmental criteria
Structure and equipment: greenhouse with sets of tanks, technical equipement
Authorizations and permits
Food inputs
Juveniles
Human resources
R&D to increase productivity / product development

Value Propositions

Various species produced in the same area : Performance

Production of **Marine white shrimp** :
- Increasing growth with bioflocs
- Allow no water renewal

Production of ***Tilapia*** *:*
- *Reduce* feed inputs (50%)
- Highly consumed and easily sold in many forms

Production of **Seaweeds** (*Ulva* and *Marine asparagus*) :
- Absorb dissolved nutrients (nitrates and phosphates) increasing growth rates
- Removing toxic compounds (ammonia)
- Producing saleable plant biomass
- Marketable components (polysaccharides, nutrients, vitamines)
- High nutritional value

Production of **oysters** (Native oyster)
- Control the biofloc concentration (filter) reducing food input

Customer Relationship *

Feedback from distributors

Sale on site / direct feedback from consumers : direct loyalty

Year-round availability of products

Engaged staff

IMTA branding

Channels *

Tilapia : BtoB approach
Processors and retail markets
Wholesalers for restaurant and fishmongers

Shrimp : BtoC (direct sale to consumer)
BtoB : distributors/retailers

Oysters : BtoB : Processor and distributors

Customer Segments *

Tilapia :

Domestic market (99%) :
Food industry (99%) : Mainly fresh whole fish and frozen fillets for restaurants and fishmongers

Niche markets : baitfish, ornemental, juveniles production

Export market : USA
Potential futur markets : Europe
Frozen : 85% / Fresh : 25%

Shrimp :

Domestic market (+90%)
Food industry : supermarket chains, restaurant, hotels -- Mainly fresh products

Export market : USA /Europe / Middle East
Mainly fresh

Seaweed : Raw material (mainly)
domestic market (low)
Food industry and ingredient for feed (mainly)
Possible use in agriculture
Export market (low)
Cosmetics, food industry and nutraceutics : Europe/Latin countries

Oysters :
domestic market (mainly) for food industry

Cost Structure *

Initial investment :for 1 hectare of productive area, requires an initial investment of about 320 000 euros.
Land and area implementation : License (5% of the total investment)
Construction : 55% to 68%
Acquisition of the geomembrane: 30%
Aeration and water pumping system 15 to 25%

Production costs : Juveniles / Feed inputs / Monitoring and water quality assessment
Human resources: Shrimps (49%), Tilapia (49%) and Ulva (2%)

Revenue Streams *

Sales of products :

Oysters : between 1.10€/dozen and 2.20€/dozen

Tilapia : Wholesales : between 1.75€/kg and 1.80€/kg
Retail : average of 5€/kg

Shrimp : Local : 3.69€/kg (September 2023) / Export : between 11 and 20€/kg
Frozen (USA) : between 8€ to 24€/kg

******Prospective*

4.2.3 Synthesis

INTERNAL FACTORS

STRENGTHS
Technical • Production of 4 species in the same system • Avoid the water change (stable quality) by the presence of AOB and NOB • Use of bioflocs: increase growth rate for seaweeds, oysters and shrimps • Circularity: using species using resources and compounds produced within the system • Minimal use of space by pooling equipment and increasing production densities: reducing occupancy and site size • Greenhouse: provide protection against predators and pathogens introduction • Adaptability of shrimps to different conditions (temperature, food, light) • Recirculation: controlled environmental criteria • Recirculation is reducing the use of treatment: Bioflocs enables the conversion of toxic ammonia to nitrate, improving the water quality and providing microbial nutrients improving the overall productivity **Environmental** • Closed system and limited water exchange: reduce the impact on surrounding environment • Re-use of compounds in the system itself: reducing effluents • Use of bioflocs (bacteria) to reduce toxic components • Astral LCA confirms that the IMTA system with shrimps, tilapias and seaweeds has lower environmental impacts per kg of biomass produced than the monoculture system with shrimps **Economic** • Thanks to IMTA system: improved productivity with lower amount of feed required, lower material and energy needed for feed production and transportation (Astral LCA) • Production of large sized shrimps to overcome competition with artisanal fishing • Production of shrimps during periods when fishing is restricted or has lower production • Recirculation of water reducing the water supply by using it several times
WEAKNESSES/CHALLENGES
• Power outages and equipment failures causing oxygen deficiency leading to mass mortality: dependency to equipment • Biosecurity: presence of vibriosis in shrimp and presence of Streptococcus in fish • Lack of trained human resources to operate and understand the system: system complexity • High temperature needs to be maintained high: increasing costs and location reliability • High cost of setting up the infrastructure (including greenhouses, tanks, pumps, filtration system and electricity: used for aeration to maintain the dissolved oxygen concentration in water especially for shrimps' production)

EXTERNAL FACTORS

	Opportunities	Threats
Political	● The Brazilian government is actively involved in the development of aquaculture	● Several licences are required by environmental agencies: long and expensive process (from 6 month to 2 years) ● Competition with artisanal fishing: abundant shrimp supply through fishing reduces the price of cultivated shrimp ● Frequent local changes in government agencies prevent achieving continuous and sufficient investment and to adopt mid-term or long-term strategies ● Dumping measures imposed by US government on shrimp imports from Brazil ● Regulatory uncertainties leading to difficulties to obtain permits and access to credit. ● Environmental laws are unclear and complicated ● Difficult access to public fund for the aquaculture sector ● Lack of standardisation of environmental licensing procedures ● Limited preparation of environmental agencies to review projects
Economic	● Aquaculture is one of the fastest-growing industrial activities in Brazil (gross revenue in 2019 USD 1 billion (€935 million) (Wagner ; 2021) ● Brazil is the fourth largest producer of Tilapia in the world ● High consumption of fish compared to the quantity produced locally, which remains insufficient: market opportunity ● Reopening the European market for Brazilian fish – closed since 2018: new market for exportation (Santos, E. (2023)	● Most small farms in Brazil: produce volatile income and unregulated work ● Return on invest / higher risks in investments: can take few years ● IMTA increase the production costs in Brazil, regarding to monoculture: more resources and time to be implemented ● Lack of commercial/market experience through IMTA farming ● Regarding the IMTA misreading: there is not a strong local demand for IMTA products ● Local deficiency of cold chain impacting freshness of products (crucial for the sales value) ● Tilapia is not a high-value or a high consumed species in foreign countries

	Opportunities	Threats
Social	● Develop coastal areas and communities through employment, environment preservation ● Access to new emerging market in Islamic countries: search for fish with Halal certification (Santos, E. (2023) ● Increase of Brazilian consumers interest to sea food	● IMTA misreading: Low public awareness as IMTA is still not well known by the general public and the consumers ● Activists pressure to farm native species, avoid ecologically sensitive areas, and protect the water quality of waters (Valenti et al., 2021) ● Non-recognition of the value of Brazilian Oyster abroad
Technical	● Innovations in aquaculture to reduce risks & development of products: R&D ● Solid scientific community and strong capacity in aquaculture sector ● Use of bioflocs: particularity to Brazil ● In Southeast Brazil, IMTA models have better results than co-culture systems, in terms of profitability and survival ● Large supply of grains for feed production (for fish) ● Large extension of land and plenty of water supply for pond aquaculture in tropical areas ● Continuous quality control to deliver a premium quality tilapia	● Lack of available skilled human resources: interdisciplinary skills needed (biological, technical, management, marketing, health management) ● Lack of technical data on environmental effects of IMTA ● Lack of knowledge within producers community regarding the IMTA model benefits ● Complexity of production system and technical challenges ● Loss of production due to energy problem in Brazil
Environmental	● Country rich in natural resources water, lands) ● Land-based recirculation system: reducing impacts on the surrounding environment	● Complex and lengthy licensing application process ● Constraints for exportation: internal demand, logistics, bureaucracy, international and national regulations
Legal		● Price of environmental license in Brazil

4.3 IMTA Ireland - case study

Offshore - Salmonids, seaweeds, molluscs, urchin (Ireland)

This Lab pilot scale production system is located in West Ireland, in an area with a temperate oceanic climate and water temperature ranges from 5 to 18°C. It is an open-water system located in a sheltered and shallow bay that is not subject to strong swell conditions. The site is settled in a relatively enclosed area.

This IMTA pilot scale system is producing a number of species at various trophic levels, each having a complementary role. This method creates synergistic interactions between these species to bioremediate the generated waste products. and recreate a food chain to reduce external feed additions and environmental impacts.

4.3.1 Business model presentation

Value proposition

This pilot scale production site is producing a combination of species at different trophic levels, in the same location and using quite the same equipment allowing pooling of resources, as well as labour. It is a circular production using the same equipment for multiple purposes.

Produced species are:

- Fish: Atlantic salmon (*Salmo salar*)
- Seaweeds: Atlantic wakame and sugar kelp
- Molluscs: King scallop and Native oyster/flat oyster
- Sea urchins: purple urchin *(Paracentrotus lividus)*

This IMTA system is using seaweeds and filter feeders (oysters and sea urchins) to assimilate and extract dissolved nutrients and suspended particulate organic matter generated by the higher trophic species (fish). This nutrient-rich waste will enhance the growth of the lower trophic species (bivalves, molluscs and seaweed) allowing for nutrient recycling.

Benefits of this experimental production system are the capacity to remove carbon using seaweeds and the use of seaweed to offset the inputs from the fish based between November and the end of March.

Moreover, this multitrophic system enhances environmental protection due to bioremediation. Fish wastes are valued by growing seaweeds downstream of nutrient flows and several other species will benefit from this nutrient input by using it as feed (in a dissolved or particulate form).

This lab is firstly based on knowledge and know-how transfer business model. Indeed, it enables farmers to become more profitable and sustainable by helping them grow and secure supply of high-quality products using efficient mixed cultivation systems and approaches.

The species cultivated within this system have a higher value due to the production method used: a more sustainable aquaculture with less environmental impact. By recognising a focus on sustainability and reduced environmental impact in product marketing, manufacturers can increase the perceived value of their products.
Salmon is a high value-added product with high market prices, especially for the Irish one, which has a strong reputation for its salmon production, which is 100% organic. It can be sold fresh or processed: smoked, canned.
For oysters, the brand image of the Irish production is seen as a “premium and pure product” inducing high market prices (EUMOFA, 2022). It can be sold mainly fresh but also processed: smoked or canned for example.
The potential value proposition of seaweeds is huge. Thanks to their organoleptic, biochemical, nutritional characteristics and properties, they can provide raw material for wide application. They can be sold as whole, for valuable components or by-products. They offer a large range of possibilities as end products such as fresh, freshly, frozen, dried (mainly), flakes, salted, cubes.
Sea urchins have a high market value and are highly sought-after in Asia, where wild stocks are dwindling.

Prospective market customers, relationships and channels

Within this theoretical business model, markets can be different according to the products:

- **Salmon**

Part of the production can be valorised and sold on the local/national/international markets for the food industry. Indeed, Ireland is still reliant on imported Norwegian salmon even if the tendency is decreasing. In 2021, more than 165 000 tons were imported from Norway. In Ireland, there was a 5% increase in salmon consumption in 2021, so a domestic consumption of salmon exists locally (EUFOMA, 2022).
More than 20% of the local production is sold for the local consumption (Dennis et al, 2022).

The export food industry market is the dominant market for Irish salmon production. in 2021, an average of 9 700 tons has been exported (Dennis et al, 2022) with an upward trend in recent decades (EUFOMA, 2022).

Main Irish export destinations are EU member States: mainly France, Poland, Germany and Belgium. Transport costs are advantageous for producers.

Due to the proximity of those countries, transport costs are advantageous for producers.

For those markets, the most popular products are whole fish (head-on-gutted), or processed fillets or steaks (frozen).

Smoked salmon is also highly valued in the export market and favoured by the luxury sector.

In the European market, most of the sales are made by retailers, mainly fresh (for more than 70% of sales).

- **Oysters**

Irish oyster production is mainly exported. Indeed, more than 60% of the local production is exported and 78% of those exported products are sold on the French market.

This production is almost exclusively sold fresh (99%) as oysters are consumed alive in France (EUMOFA, 2022). Basically, Irish products are sold in bulk to French wholesale markets.

Those exportation rates are showing a low local consumption of oysters in Ireland (average of 38%), which is concentrated in the HORECA sector.

New markets are likely to emerge for Irish oysters with an increasing tendency in Southeast Asia (China and Hong Kong mainly) where oysters are seen as a luxury product. The Netherlands are also increasing their oyster's importation.

To set in these new emerging markets who are looking for a high-valued oyster, to achieve a luxury offer sought, there is a need for marketing investment to valorise the Irish brand image (packaging and branding).

- **Seaweeds:**

Domestic and export markets are both valid for this Lab pilot scale production site. Part of the production will be used as a feed input for the system itself so only a remaining percentage can be sold.

The export market is more valuable and Irish seaweeds are currently mostly exported to be used in the food industry and inputs for the animal feed, pharmaceutical or cosmetics.

Main importers are European countries, and the seaweed food market is growing as well as the consumption in Europe, mainly in coastal areas: France, UK, Denmark (BIM, 2021). In addition to the rapid rise of Asian restaurants in Europe using seaweeds in their processes daily, it is also sold to be used in cosmetics.

Raw material and dried seaweeds are mainly used in the export market and the process will depend on the final consumer/buyer. Cosmetics needed mainly high amounts of raw material for molecules extraction and the food industry is mainly using dried seaweeds.
For export, the production is sold to a wholesaler.

In Ireland, there is a rising demand on the domestic market.
The most important domestic market in Ireland is agriculture and horticultural seaweed-based products. Seaweeds are used as a biostimulant for plant growth and can also be used as plant supplements, fertilisers and feeds for animals. In Ireland, "*agricultural products account for nearly 100% of the raw material used and 70% of the value generated*" (Walsh and Watson, 2012). Given the trend towards organic farming, the use of these natural fertilisers will continue to grow and the market will expand. For this market, producers can directly sell the production in bulk of raw material (B2B). Seaweeds are mainly sold in bulk in raw material or lightly processed. The production is often sold for further processing for the local market or abroad.
For the local Irish food market, seaweeds are sold directly to supermarkets or specialised shops for human consumption. Producer is using B2B (bulk market) or B2C directly to consumers (packaged) to sell fresh products (mainly).
This market has an increasing tendency, but local consumption remains low and the market is liable to several criteria leading to high price fluctuation: weather, high stock availability, growth period, seeds availability (Walsh and Watson, 2012).

- **Urchins**

There is currently a very low urchin consumption in Ireland so the production could preferably be export oriented.
There are two main markets for sea urchins:

- the main one is Asia, with Japan consuming more than 80/90% of the total current supply
- the European market and especially the Mediterranean countries: France, Italy and Spain

For both, a major logistical effort is required as urchins are sensitive to changes in temperature and to pressure (to maintain the integrity of the shell). Logistic costs are thus high as the production is transport air freight and road being used to ship the sea urchins.
The European market is demanding lower transport costs regarding the localization of both countries and there is a high demand for good product, low distribution costs (Guðmundur, S. et al. 2017). Currently, imports for the French market are mainly handled by Spain and Ireland.

Key activities

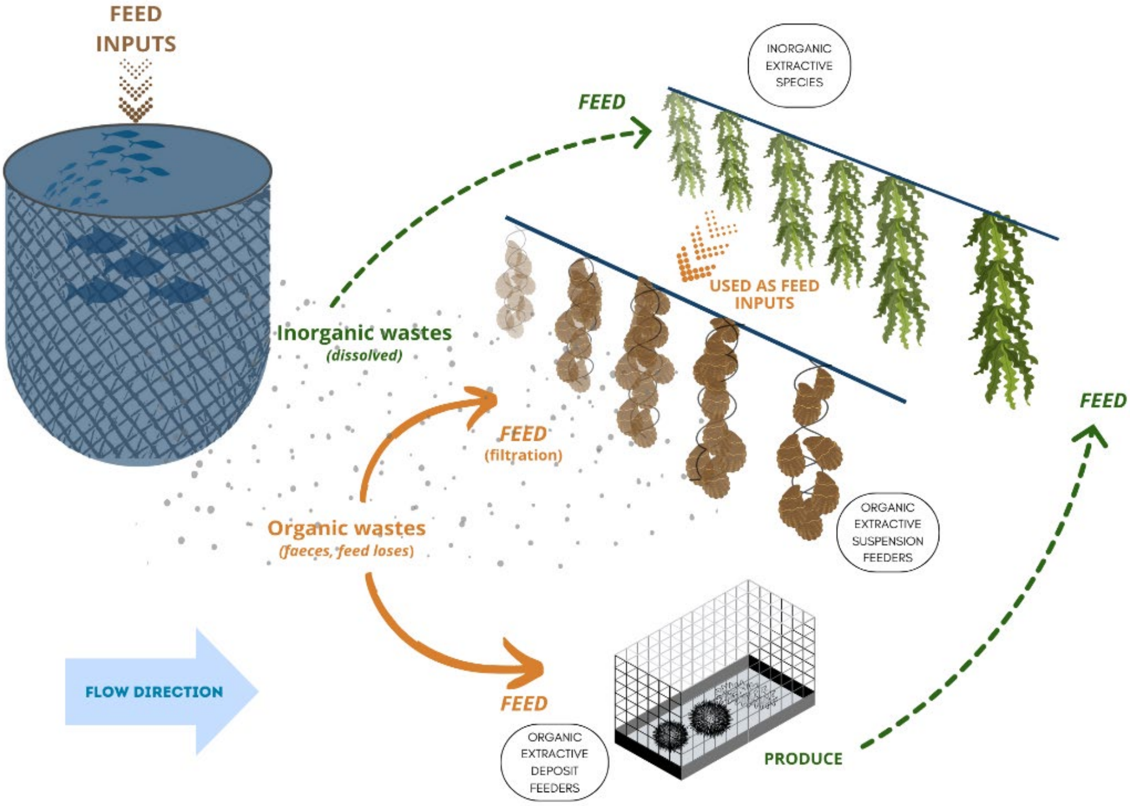


Figure 23: Description of the theoretical system (Source: MI / Creation: PMBA)

Salmon are farmed in pens and fed by an external input of commercially manufactured salmon feed (EWOS Harmony Nature pellet). As a result, fish release two types of waste into the surrounding waters: organic particles (food leftovers and faeces) and dissolved inorganic waste (excretions and dissolved faeces).

Filter feeders (organic extractive feeders like native oysters) filter out suspended particulate organic waste generated by the higher trophic species (salmon) and use it as food. Organic extractive deposit feeder or benthic scavenger (sea cucumber) are also using organic wastes by removing particles present in suspension or in the upper surface of sediments (faeces, feed wastes).

Inorganic extractive species (seaweeds) extract and absorb dissolved nutrients (minerals and carbon) present in the waste from fish and from organic extractive deposit feeders.

The inorganic extractives species (seaweeds) that have used the dissolved waste will then be used as a food source for organic extractive species such as the spiny urchin.

To increase the potential for nutrient uptake by lower species, equipment is set downstream of the nutrient plume.

This IMTA pilot scale site is producing:

- Atlantic salmon (*Salmo salar*)
- Atlantic wakame (*Alaria esculenta*)
- Sugar kelp (*Saccharina latissima*)
- King scallop (*Pecten maximus*)
- Native oyster/flat oyster (*Ostrea edulis*)
- Purple urchin

Atlantic wakame (*Alaria*) and Saccharina are the two species of seaweed that have proven the most successful and the most marketable easy to handle (grow kicker, and faster).

The farm is organised in six circular pen grids of 50m circumference for fish farming with associated longlines (110 metres each so a total of 7810 m) and structures. Longlines are established to grow seaweeds. Containment structures for shellfish (lantern nets, baskets and barrels) are also used.

Key activities are:

- Pre-production: hatchery

Seaweeds are seeded on longlines and smolts are prepared to transfer into fish pen grids

- Production:

-Feeding is done daily for salmons (by hand and with mechanical feeders)

-Harvesting with different harvesting periods depending on the species:

Species	**Cultivation Period**	**Harvest Period**
Seaweed	Approx. 7 months	May/June
Salmon	Approx. 18 months (commercial)	Continuous
Oyster	3 – 4 years	September to April
Urchin	12 months	Continuous

-Monitoring parameters like water quality, temperature, oxygen, salinity and turbidity. Done on a regular basis with daily/weekly/monthly observation of the species and environmental factors.

- Post-production: cleaning, sales and R&D

Process activity is also required to ensure the logistics of sales, marketing and packaging.

Key resources

This IMTA system is highly dependent on the site location, water quality and on environmental parameters such as temperature. Indeed, the first key resource needed is a suitable area to implement the production site. The implementation is also reliant on several authorisations and permits; there are a number of compulsory regulatory steps to follow (see figure 24).

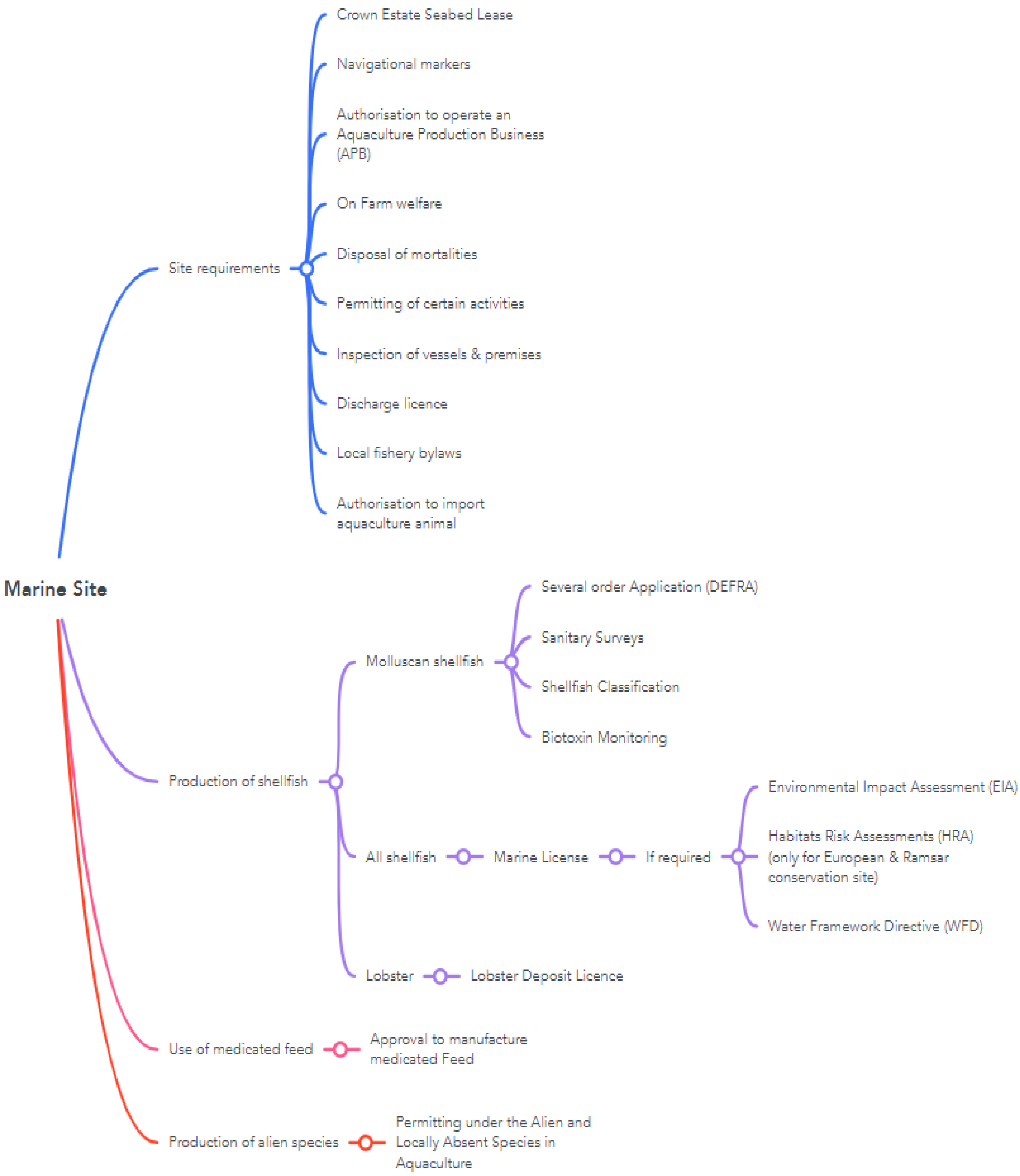


Figure 24: Reglementary pathway for aquaculture in Ireland (Source DEFRA/ creation PMBA)

The second key resource is the supply of infrastructure and equipment that will not only withstand the climatic challenges but also enable the simultaneous production of species with different trophic levels. Appropriate technical equipment is therefore required, depending on the chosen species and the parameters required, and depending on the activities that will take place on the production site.

To start the cultivation activity, main inputs are essential:

- supply of juveniles of each species
- feed inputs for fish

To run activities, skilled or qualified human resources are needed, with a higher labour intensity during the harvesting periods. As it is a technical site and activities, the availability of competent staff is a key to run the production site. For this pilot scale site, two farmers are needed, 1 manager, 2 research scientists, administrative support is also required, and this research site allows for training to occur which can lead to the presence of apprentices on an ad hoc basis.
Marketing and R&D is another key resource, needed to target the right market for every produced species, to evaluate markets and commercialise products (product development).

Key partners

Every production site is dependent on fundings for the installation. At this research site, most of the funding is coming from public funds, in this instance the EU and Irish Government are thus key partners.

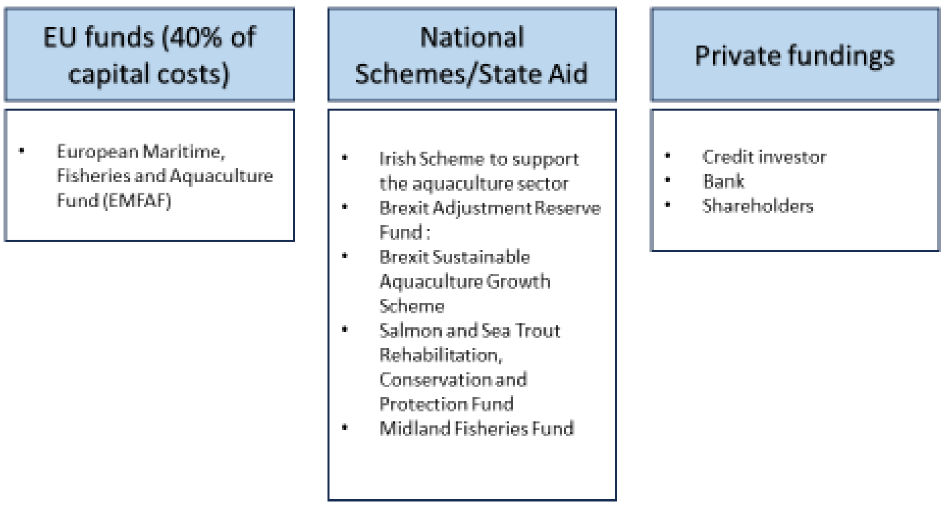


Figure 25: Possible fundings in Ireland for aquaculture producers (Sources: BIM, EU funds / Creation PMBA)

Ireland has a quite complex licensing system and is reliant on national legislative instruments and EU regulations (see Appendix 1: Governance of aquaculture in Ireland and the players involved). Many stakeholders are involved in the governance of aquaculture. In this context, governmental and national institutions are relevant stakeholders.

Key partners are also linked to professional organisations and associations and involvement in link-minded scientific projects (R&D aspects especially for the product development, the choices of species in the system, etc.).

As the pilot scale production system needs juveniles, a key upstream partner is juveniles' suppliers as this is currently a barrier in Ireland. Indeed, the availability of native oyster seed is problematic and non-existent for sea urchins.

Depending on markets, produce is mostly purchased by wholesalers or specialised agents, they are key intermediaries for production sales. In addition, processors, with whom the producer may have a direct link, are key partners for the company.

Cost structure (pilot scale)

In this multiple species system, investment costs are the main costs as the farm is reliant on technical equipment. For this site, main technical materials needed for the settlement are, fish pens, anchors, buoys, long-lines (cultivation and feed) and baskets. These expenses are not frequently recurring but do represent a large initial investment.

Investments are thus highly impacted by the site location and availability, project development and licensing process.

In this case, investment costs are estimated at more than €0.6 million in three years.

Annual production costs for this site are about €230,000 and to illustrate, as one of the key activities for this site is monitoring, the estimated costs for this activity is about €5,000 each year.

As this IMTA system is highly specialised, management and skilled resources are key costs. Indeed, one of the costliest activities for this Lab site is human resources, split as follows: fish (70% of the time), molluscs (20% of the labour time) and seaweeds (10%).

Prospective revenue

As mentioned before, the lab is firstly based on knowledge and know-how transfer business model with no commercial ambition. It's fully public funded.

Within a theoretical business model, the main source of income would come from sales of the production:

The current price for Atlantic Salmon is depending on the process; the more the product is processed, the higher the selling price will be. For salmon, fillets are sold for an average 12.5€/kg, whereas a whole fish is sold 6 to 8€/kg (wholesale prices). COVID had a huge impact on the value of this product and the limited supply is also acting on the market value.

Depending on the end consumers, seaweeds prices can have different values. Raw materials have relatively low prices (wholesale is about 2€/kg of fresh wet biomass/ export average price €20/kg) and dried and processed seaweed can reach 55 to 100€/kg in the retail market.

For oysters, the French export market "*is generating the highest export earnings but prices are tending to be higher in the Asian market"*: the Irish Oyster is seen as a high-valued product for a luxury offer sought in the Asian market (EUMOFA, 2022). Export prices vary from 5.80 euro/kg (EUMOFA, 2021) to 11.50 euro/kg in the Asian market.

Prices of urchins gonads are highly dependent on the quality of eggs, the colour and texture and difference can be significant.
As an example, in October 2023, prices on the Tokyo market:

RED LARGE (300g)	113€/tray
RED MEDIUM (150g)	48€/tray
WHITE LARGE (300g)	430€/tray

The same species in the Osaka market will be 340 €/tray for wholesale prices.

Prices of sea urchins on the French market can be advantageous as well. As an example, 2018 prices in the Rungis market, the main supplier for the HORECA sector reached €100 per kilo of gonad. Retail prices for consumers range from €130 to €170 per kilo of gonad (FranceAgriMer, 2018).
Private and public funds could be also requested to develop the farm (see figure 25).

4.3.2 The Business Model Canvas

The Business Model Canvas

IMTA LAB / OPEN WATER SYSTEM
SALMONIDS, MOLLUSKS, BIVALVES, SEAWEED

IRELAND

Key Partners

- **Funding :**

Irish government / publics funds
Private shareholders or investors

- **Upstream partners :**

Institutions and associations:
European Aquaculture Society
Irish Farmers Association – Aquaculture Section
Atlantic Technical University
University of Galway
BIM

Scientific partners: Universities

R&D expertise

Juveniles' suppliers

- **Downstream partners :**

Processor
Wholesaler or agent

Key Activities

IMTA production

Hatchery

Production process

Logistics

Communication

Human resources / management

R&D (research on ongoing funding)

Key Resources

Site location and licenses

Supply of infrastructures and equipment

Supply of juveniles

Qualified / Skilled human resources

Marketing

Feed

Value Propositions

Production of a combination of species

Fish : **Atlantic salmon** (*Salmo salar*)
- high-value species
- Quality image from the Irish production (premium market)
- Fresh or processed products

Seaweeds : Atlantic wakame and sugar kelp
- High nutritional product
- Wide range of applications

Mollusks : King scallop and native oyster
- Premium and pure product
- High market prices
- Fresh or processed products

Sea urchins : purple urchin
- high market value and highly sought-after in Asia

Environmental services:
- bioremediation of wastes and nutrient recycling by seaweeds and filter feeders
- Removing carbon from the site

Customer Relationship *

Marketing and branding: promotion of the Irish brand image

Reputation of products

Range of products available for the customer

Channels *

Outsourcing

Seaweeds :
Domestic market for the food industry : BtoB or BtoC
Domestic market for cosmetic industry : BtoB

Export market : BtoB

Oysters :
Export markets : BtoB (retailer or wholesalers)

Customer Segments *

Salmon :
Domestic market (24% of the local production)
Exports : EU market (France 40%, Poland 20%, Germany 14%, and Belgium, 10%)
→ Fresh products / frozen / smoked

Oysters :
Export : 62% of the Irish production
France (79%) : bulk wholesalers (live products : 99%)
New markets : South Asian country (luxury product) and Netherlands
Domestic market : 38% of the total production

Seaweeds :
Export : EU market : food industry and ingredient for cosmetics (mainly dried)
Domestic market :
Agriculture (mainly) : bulk raw material
Human consumption : restaurants, artisan food producers (fresh products or dried, macerated)
Cosmetics (wet product mainly)
Potential new markets : Oil extraction, biofuel/-ethanol production

Urchins : *100% export*
Main market : Japan fresh product mainly)
European market : France and Mediterranean countries
Fresh mainly
Processed : canned or dried

Cost Structure *

Investment costs: €0.6 M over the past three years (infrastructure and equipment)
Licenses (Aquaculture License - €635 ; Foreshore License - €968.90)

Monitoring activity (annual monitoring costs €5,000.00)

Human resources (costly) : fish (70% of the time) / mollusks (20%) / seaweeds (10 %)
Production costs: Annual costs - €230,000

R&D(Costliest)

Revenue Streams *

Private and public funds / Sales of products (seafish.org)

Salmon : Fresh (6 to 8€/kg) or processed (filets) (more than 12€/kg)
Seaweeds : Retail market (processed) : 55 to 100€/kg
Wholesale : average of 2€/kg of fresh wet biomass
Export : average price €20/kg.
Oysters : Food market (first sale value of 0.70€ per shell) / Table market (1,15€ per 75 gram oyster)
Rewilding market (e.g. 0.1€ per 25 gram oyster)
Export price : FR : 5.80 euro/kg (EUFOMA , 2021) / Asia : (processed product sold to wholesaler) : 11,50 euro/kg

Sea urchins : France(wholesale price): from 10 to 20€/kg (whole piece) / 100€/kg of gonads (retail market) : 130 to 170€/kg of gonads
Gonads (Asia) : highly dependent on the quality of roe : prices vary from 48€ to 430€/kg of gonads

***Prospective*

4.3.3 Synthesis

INTERNAL FACTORS

STRENGTHS
• Equipment can be shared for different species: pooling equipment • Use seaweed to offset the inputs from the fish based between November and the end of March • Increase growth rates with the IMTA system • According to Astral LCA, the IMTA system is a better aquaculture system considering the reduction in overall feed needed per unit of biomass production, and waste extraction from fed species by low trophic species • Reduced wastes released so decreasing environmental impacts of the production: Astral LCA confirms circularity benefits: Bioremediation of wastes and nutrient recycling by seaweeds and filter feeders • Carbon removed from the site through seaweeds • Production of different species: diversification of incomes for the producer • High-value product for niche and luxury markets (salmon / urchins) • Use of farmed seaweeds as a food input: saving costs
WEAKNESSES/CHALLENGES
• Natural hazards (i.e. storms, accidental pollution...) • Complex production system as it uses differing systems for the different species on one site • Operational challenge to synchronise the harvesting of different crops and manage resources • Technical equipment: need skilled human resources • Reliability on good environmental parameters of the site location • All farmed salmon related pathogens (mainly AGD and Sea lice) • Predators: otters, seals, & HABS • Microplastics • The production of IMTA species increases the costs due to the requirements for infrastructure

EXTERNAL FACTORS

	Opportunities	Threats
Political	● Public funding from the government ● National funding authorities expressed their will to help the ● aquaculture diversification and are planning to open calls for funding or direct funds to help producers in their development ● Government's measures: income support, job retention schemes, bounce back loans and income tax deferral (Patience, Motova and Cooper, 2021)	● Ireland's aquaculture licensing system: complex and fragmented regulatory environment, with several national legislative instruments and EU regulations: a barrier for a sustainable development of the sector ● Intense local opposition and blockage of licensing and environmental assessment programmes (Carr, 2019)
Economic	● New markets opportunities for revenue diversification ● Sea urchins' consumption booms in Asian markets ● Salmon greatest value market ● Opportunity for job creation in rural areas	● Long return on invest / higher risks in aquaculture investments ● Increasing transport costs (COVID, higher fuels costs…). ● Due to the lack of familiarity of IMTA there is not a strong demand for IMTA products ● Logistics of marketing new products ● Product value: bivalves and molluscs have less value than finfish so how to encourage producers to go to these markets ● The mussel sector in Ireland is decreasing ● Over the period 2019 to 2021, the cost of feed and stock input doubled in proportion to other costs and also in proportion to 2019 costs: +86% for the feed cost (2019/2021) ● Energy cost: +35% from 2019 to 2021 ● Price fluctuation of seaweed market: due to seaweed liability to weather, growth period… ● Dependency on intermediaries to access markets (EU, UK)

	Opportunities	Threats
Social	• Consumer's quest for sustainability and for produced species have a higher low carbon protein • Irish brand image as a good quality producer: Ireland is one of the world's high value salmon producers mainly the production is certified organic (EUMOFA, 2022) • Rise of vegetarianism and veganism in UK and Europe: higher demand for seaweeds products and growing recognition of seafood as a healthy diet • Few conflicts of use for offshore farms: good acceptance by the Irish population (Hynes et al., 2018) • Aquaculture: valued by the public as a provider of opportunities (economic and employment)(Hynes et al., 2018) • Misreading of the sea urchin in many countries, particularly Ireland: needs to valorise the product • Social perception: higher value for a premium product	• Opposition of environmental groups to development of aquaculture project • Low public awareness: IMTA is still not well known by the general public and the consumers
Technical	• Innovations in aquaculture to reduce risks: R&D and BlueBioeconomy • Adding value to seaweed Irish production by developing processing methods (link University/industry and agencies) • The choice of species combination: Astral LCA highlights a necessary guidance to select the best species to achieve better environmental performance at the same time maximising resource use	• Available qualified and skilled human resources • Growing demand for technological skills (digital technologies) • Lack of technical data on environmental effects of IMTA • Complexity of IMTA production system and technical challenges • Lack of control over interactions between the multiple trophic levels • Space conflicts with other producers or users in the sea • No urchin seeds availability in Ireland • Lack of seaweed processing in the area: decreasing the add-value of the product • Dependency on foreign country for seed and juveniles' supplies • Low availability of raw material to produce local fish feed

	Opportunities	Threats
Environmental	● Sheltered areas suitable for aquaculture ● “Accredited Quality and Environmental Standards” DAFM (2022). ● Carbon sequestration potential of seaweeds	● Open water system vulnerability ● Emerging pollutants ● Impacts of climate change: increasing weather events (storm), water temperature (direct physical effects and biological and ecological impacts) ● Biofouling ● Eutrophication risks on offshore production site ● Diseases of oyster seeds in Ireland: lack of seeds (Coyle et al., 2023) ● Sea-lice for salmon ● Limited knowledge on the aquaculture carbon footprint DAFM (2022).
Legal	● The EU wishes to “provide coordinated messaging on the sustainable, low carbon nature of Irish aquaculture production, supported by independent certification and open dialogue” DAFM (2022).	● Complex and lengthy licensing application process ● Authorisations and permits delivery process / rates ● Roadblocks to financing because of licensing issues

4.4 IMTA South Africa - case study

Land-based partially recirculating system - Sea urchin and *Ulva* (South Africa)

This pilot production site is located on the Southwest coast of South Africa, in the Western Cape Province. The climate in this area is temperate, characterised by warm and dry summers and cold and wet winters.

This experimental system is land-based and is using an IMTA aquaculture system to produce two marine species: the sea urchin (*Tripneustes gratilla*) and seaweed (the sea lettuce, *Ulva lacinulata*).

4.4.1 Business model presentation

Value proposition

The IMTA Lab is producing the tropical sea urchin *Tripneustes gratilla,* a species with high- market value and high-potential for aquaculture, which is sought-after in Asian countries for their roe (gonads). This species has high growth rates (Cyrus, Bolton and Macey, 2015) and is one of the top traded species in Asian countries, especially Japan, which consumes more than 80% of the world's total production of sea urchin gonads. This sea urchin species produces high quality gonads with high market acceptance (Cyrus et al, 2014).

The IMTA Lab is also growing *Ulva lacinulata*, which is used for two main purposes: as a biofilter allowing the effluent water of sea urchins to be bioremediated (removal of ammonia) to enable a high level of water recirculation, and as a feed component. The use of natural material (*Ulva*) as a feed for sea urchins increases the value and quality of the product (urchin gonad) produced (Cyrus et al., 2014, 2015).

The diet used for sea urchins is critical for enhancing the colour and the texture of the gonads, directly impacting the commercial value of those products (Cyrus et al., 2014). Indeed, fresh *Ulva* contains high concentrations of beta-carotene and the use of fresh *Ulva* as a direct feed input for sea urchins is acting "as a natural source of carotenoid pigments" (Cyrus et al, 2014). The conversion of these pigments to gonad pigments will have a direct impact on the colour of sea urchin gonads, giving them a yellow-orange colour, a sign of high-quality roe for this species.

The use of *Ulva* as a component of formulated feed (15 – 20% dry weight inclusion) has also been demonstrated to support and even improve the somatic growth of sea urchins (Cyrus et al., 2015) by improving consumption and protein, as well as energy and digestibility of the formulated feed.

The *Ulva* production capacity in the IMTA is 1,5 to 2 tons per month and the aim is to harvest about 500 kg fresh seaweed per week as feed. This production capacity is determined by the optimal stocking density, which needs to be kept between 1,5 to 2 tons for 150 m3 raceway to ensure optimal growth and functionality of the paddle-raceway system.

Ulva is also known to have nutritional and health benefits regarding its nutrient and bioactive compounds, making it “an ideal candidate for functional foods and nutraceuticals” (Cyrus et al., 2015).

The sea urchin production using IMTA has high potential to compete with the existing international industry that is dominated by wild-collected sea urchins (more than 90%), which has resulted in overexploitation of wild sea urchin populations in various countries. Indeed, consistent supply of good quality wild-collected sea urchin products can only be guaranteed approximately 60% of the time, whereas with full life-cycle grow-out of sea urchins in IMTA, the quality of sea urchin gonads can be guaranteed over 90% of the time.

The market for sea urchin gonads in Asian countries, especially in Japan, as well as in Europe and the Americas, is currently increasing and the IMTA system will be able to provide a consistent supply with a more consistent quality from the full life-cycle grow-out of the sea urchins. However, the IMTA is not currently supplying markets, but a pilot commercial scale test system is in operation.

The production method is much more sustainable, and customers are attracted by this notion of sustainability, increasing their consideration for this product.

The urchin marketable product (the gonad, known in Japan as ‘uni’) can be sold fresh, frozen or canned.

Prospective market customers, relationships & channels

The lab is targeting different markets.

Tripneustes is a sought-after product in certain cultures and sea urchins are mainly processed for their roe (gonads) which are eaten, for example, in sushi and as sashimi (Wilen and Reynolds, 2000).

It is an emerging species globally that has high market value and is in high demand in certain countries, particularly in Asia. Asian markets represent the main part of urchin’s consumers, and T. *gratilla* is one of the top traded species in countries such as Japan (80% of the roe market), followed by China, Korea, Europe and the USA.

Sea urchin production will be marketed in these international markets (99% of the production) for the food industry, with a small percentage of product distributed to local markets.

The Japanese market is looking for high quality roe and mainly fresh products (Wilen and Reynolds, 2000).

In Europe, sea urchins are also consumed mostly in France, Italy, and Spain. France is the world's second-largest consumer, the favourite species is the purple sea urchin (*Paracentrotus lividus*) and the consumption trend is increasing (Guðmundur et al., 2017).

Imports for the French market are mainly handled by Spain and Ireland (Castilla Gavillan, 2018) and sold in the main market, Rungis, where most French restaurants and wholesalers are supplied.

The remaining 1% of the sea urchin's production could be supplied as larvae (or spat) to emerging producers in the country (local market). This market is a direct domestic market and producers can deal directly with each other; there is no need for intermediaries.

In South Africa, the full extent of the market is unknown. However, according to Nestle Foods (2016), sea urchin is presently among the top ten trending food products and appears to be gaining momentum. Local consumption in South Africa will most likely be concentrated on a niche market; gonads could also be supplied to specialised restaurants in the region. The local South African tourism industry is also projected to grow by an additional 25% over the next couple of years, which in turn will create increased demand for high value seafood products, such as sea urchin, from international visitors.

The theoretical production site (IMTA Lab South Africa) is focusing on a B2B approach, by working only with professional customers using seafood international agents exporting to Asian markets, based on the same model as the South African abalone industry. Those intermediaries will give them customers feedback.

They rely on the added value of the sold products and the rarity of producers for such high-quality products. The use of IMTA gives the company a sustainable image and sales will be based on the consistent supply (year-round production) of high-quality products.

Ulva production is fully used for the IMTA production system as feed for urchins and for bioremediation of urchin effluent to enable partial recirculation. In South Africa, *Ulva* is mainly used in abalone aquaculture production as feed and to enable partial recirculation (Amosu et al., 2013).

There is a long-standing seaweed industry in South Africa. For *Ulva*, the specific industry is not fully structured but could represent an interesting market opportunity if sufficient quantities are produced. *Ulva* has a wide range of applications. Used as an input in formulated feed (Cyrus et al. 2014), it has shown "antibacterial and immuno-stimulatory properties" (Bolton et al, 2016). Regarding the high amount of minerals and vitamins in this seaweed, *Ulva* can also provide a wide range of health benefits when used in human food (Bolton et al., 2016).

Ulva can be used as food but can also have applications in biosecurity, food preservation and industry (Bolton et al., 2016).

Key activities

The lab is focusing on the production of two species: tropical sea urchin (*Tripneustes gratilla*: white-spined or collector urchin) and *Ulva* seaweed *Ulva lacinulata*: (sea lettuce).

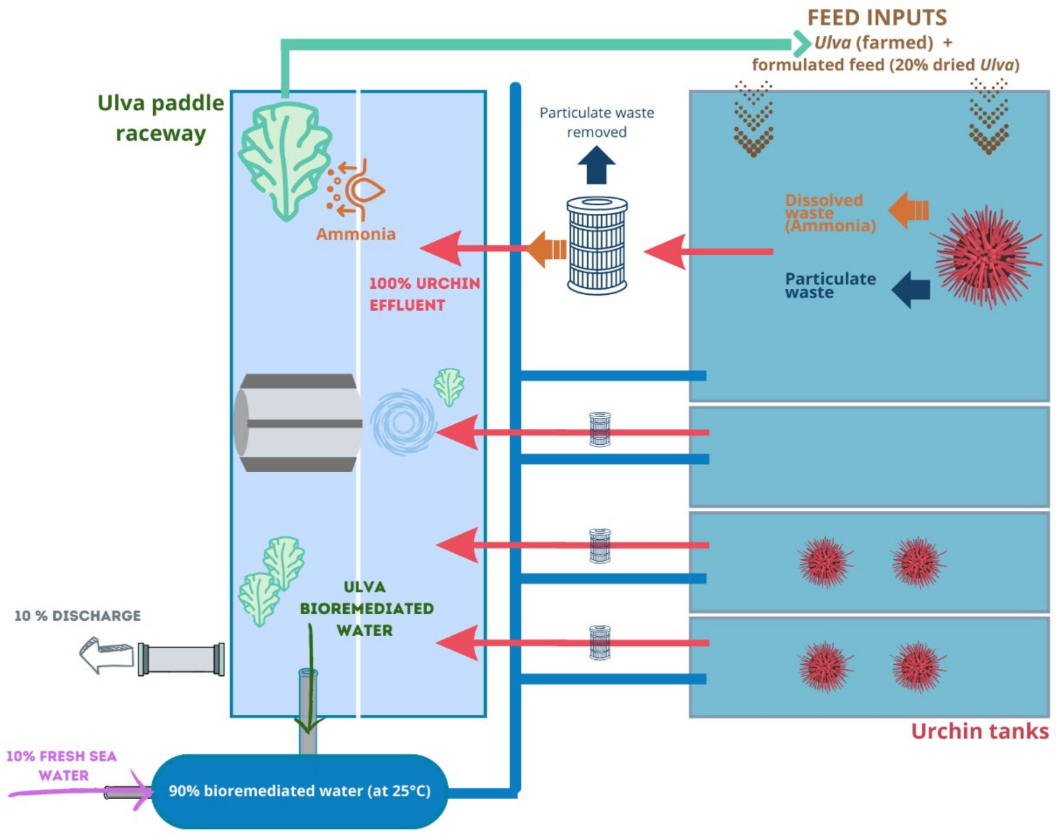


Figure 26: Sea urchin and Ulva IMTA system farming (Source: IMTA Lab, creation PMBA)

The species are cultivated in an integrated system and the *Ulva* is used to bioremediate the sea urchin effluent water to enable partial (90%) recirculation of seawater.
Sea urchins are grown in baskets suspended in tanks and fed with a combination diet of fresh *Ulva* (co-produced in the system using nutrients from the urchin waste) and formulated feed that incorporates 20% dried *Ulva*.

Urchins are producing waste (particulates and dissolved waste), which is present in the effluent water. This effluent water from the sea urchin tanks is discharged into a D-shaped *Ulva* paddle-raceway, after it has passed through a drum filter to remove fine particles/ particulate organic matter (POM), constantly in motion. The bioremediated seawater then enters the sump (gravity fed). The fresh seawater entering the IMTA (10% replacement), as well as the seawater in the sump, is constantly recirculated through a heat pump that heats/maintains the water at 24-25°C. Constant circulation of the water in the *Ulva* raceway is important to ensure good oxygenation, access to light, mixing of effluents and nutrients and flow rate over the *Ulva* plants for maximum absorption of dissolved waste.

In the paddle raceway, *Ulva* is used as a biofilter for bioremediation allowing the removal of dissolved ammonia in the effluent water of sea urchins. This water supply, cleaned of its toxic components and bioremediate, is mixed with 10% of fresh seawater in a sump adjacent to the *Ulva* paddle raceway before being returned to the sea urchin raceway tanks. Additionally, the *Ulva* produced in the system is used as a feed for the sea urchins so is harvested daily.

This system is organised on a 1500m2 production with 42 tanks at a stocking density of 6.36 kg/m^3 of urchin per basket (optimal density). The production of sea urchins is 3.75 tons of urchin per month in the system described above, which equates to a total of approximately 0.75 tons of gonads per month. For the IMTA Lab, the aim is to produce sea urchins using full life cycle grow-out allowing a better control of gonad quality and year-round production. This input contributes to the model's competitiveness versus the wild harvested urchins.

IMTA is also providing a recirculation capacity and even full recirculation possibility for a short amount of time (3 to 4 days) if necessary, in the event of a harmful algal bloom (HAB) event, while suitable environmental and system monitoring (water quality, HAB monitoring) takes place. The recirculation capacity thus allows better control of water temperature, significantly reduces pumping costs and can provide partial protection against Harmful Algal Blooms (HABs).

The input of *Ulva* in the production process reduces the reliance on transformed food material (fishmeal-based feeds) and will reduce the nutrient load in the water released back to the sea. This process will reduce risks and impacts on surrounding ecosystems. The IMTA aspect increases the sustainability of aquaculture by utilising waste from the animals as nutrients for the seaweeds, which are fed back to the animals. The system thus has two circularity aspects: re-use of 90% of seawater enabled by seaweed bioremediation, and reuse of major nutrients by feeding effluent grown seaweeds back to the animals. Both have financial benefits.

The farm is producing their own juveniles (hatchery based at the farm). When the juvenile urchins reach a size of 15 mm (diameter) they are transferred to the farm to be fed with a mix of farmed *Ulva* and formulated feed (containing 20% dried *Ulva*) and stocked into baskets in tanks. The tanks are held under a tunnel to maintain the temperature of the water to 25°C, an optimal environment for those sea urchins.

Producers control all the production processes for *Ulva* and sea urchins:

- Hatchery preparation and broodstock conditioning
- Grow-out in baskets (sea urchins take approximately 9-12 months to reach a marketable size) and grading

- Daily monitoring: water quality and temperature, animal health, feeding, and optimal functionality of the system
- Maintenance and daily cleaning tasks

Post-production processes include harvesting (monthly or bi-monthly harvesting for sea urchins) and processing for export.

Processing urchins is usually done by a processor and not on the farm. Animals are transported using refrigerated trucks to the processing plant and urchins are chilled. As the marketing part of the product is roe, processors crack and scoop gonads out of the shell of urchins. Roes are then transferred into baskets which will be soaked in a potassium-iced saltwater solution.

Depending on the quality and the end consumers/market, the soaked roes will be graded and stocked in trays or cups (Wilen and Reynolds, 2000).

As mentioned before, the urchins are mainly sold fresh (high quality) and the lowest quality is processed: frozen, dried, canned or steamed.

Globally, for the Japanese market, most of the urchins are sold during auctions at the Tokyo Central Wholesale Market and main supplies are sold fresh. Another market segment of roes is sold directly in wholesale markets such as Osaka, mainly fresh as well. Usually, fresh whole urchins are then processed (gonad extraction) to be sold to the wholesale market and supermarket chains.

Buyers can be supermarket chains for fresh products while frozen roe and processed (salted) are bought by processors specialising in canned products.

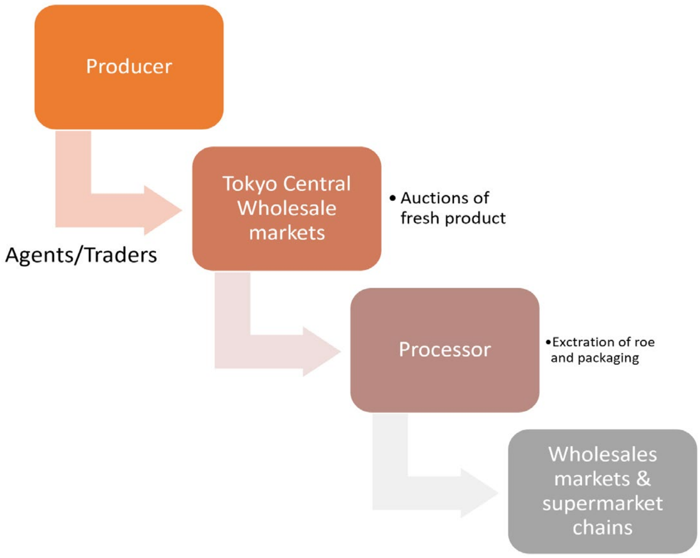


Figure 27: The common Japanese supply chain (creation PMBA)

The particularity of the species and the markets requires extensive product development; R&D is a key activity for this production.

Key resources

To set up an aquaculture system in South Africa, there are a number of compulsory regulatory steps to follow to get the right permits and authorisations (see figure 28).

Figure 28: Pathway to implement an aquaculture system in South Africa (Source: DFFE (Krala, 2015)/ Creation PMBA)

To undertake any commercial marine aquaculture activity in South Africa, each applicant must first obtain a “right to engage in marine aquaculture” from the Department of Forestry, Fisheries and the Environment (DFFE), in accordance with section 18 of the Marine Living Resources Act, 1998 (Act No. 18 of 1998) (MLRA).
This Act provides for the granting of a “right” to engage in marine aquaculture, whereas the permission to run the activity is granted by an annual permit. A “*right to engage in marine aquaculture*” is valid for 15 years, whereas marine aquaculture permits are renewable and valid for a period of 12 months. Depending on the nature of the aquaculture set-up (offshore or onshore) and the type of species to be cultured and managed, several licenses and permits may be needed (see figure 28). These may include a lease to the right to sea or land space, water usage and waste management licenses and permits to import or transport live animals (Krala, 2015).

Sea urchins are reliant on water quality and water temperature. The production site, a land-based infrastructure, must be close to good incoming water quality and in good climatic conditions as *T. gratilla* is a subtropical/tropical species optimally grown at 25°C. For those reasons, electricity is also a major resource required for those species. However, electricity supply is not sufficiently reliable in South Africa and farmers need to consider generating electricity themselves. This has a major initial cost implication in terms of infrastructure.
The access to feed material is also a key resource. In this system, there are two different food inputs: *Ulva* produced in the IMTA and formulated feed (incorporating 20% dried *Ulva*).
To ensure the whole production process, several governmental authorisations are needed such as an aquaculture right to farm the species and environmental authorisation (depending on the scale, environmental assessments need to be conducted with an environmental authority). Permits are also required for collecting and keeping broodstock on-site, for a hatchery and grow-out space, and for processing and transport.
Skilled human resources are also key resources as main activities are by hand (manual technologies).
Main human resources are used for the sea urchin production (80%) and 20% are used for the *Ulva* production and harvesting. For this theoretical production site, an estimated 20 people are needed to run the system, including one senior manager, two production managers (for hatchery and grow-out), about 10 technicians/labourers, two administrative employees, 1 engineer, students and 3 or 4 people for the hatchery team. The species and the market's specificities require extensive product development for processing and packaging, so R&D is a key resource as well. At least 1 research scientist (R&D person on farm) needs to work on urchins and *Ulva* to further improve production technologies, including processing technologies to meet market demands etc.

Key partners

Several key partners are needed for optimisation and an economy of scale, reduction of risks and uncertainty and for the acquisition of specific resources.

Government institutions are key partners to develop aquaculture as the necessary steps and licences are numerous and demanding in South Africa.

Access to finance for aquaculture in South Africa is also a major challenge. Several funding sources are possible for the aquaculture sector: public and private funding are needed to invest (land, infrastructure/technical equipment, human resources) and to run the production site (see figure 29 and Appendix 2: Potential sources of funding for aquaculture in South Africa).

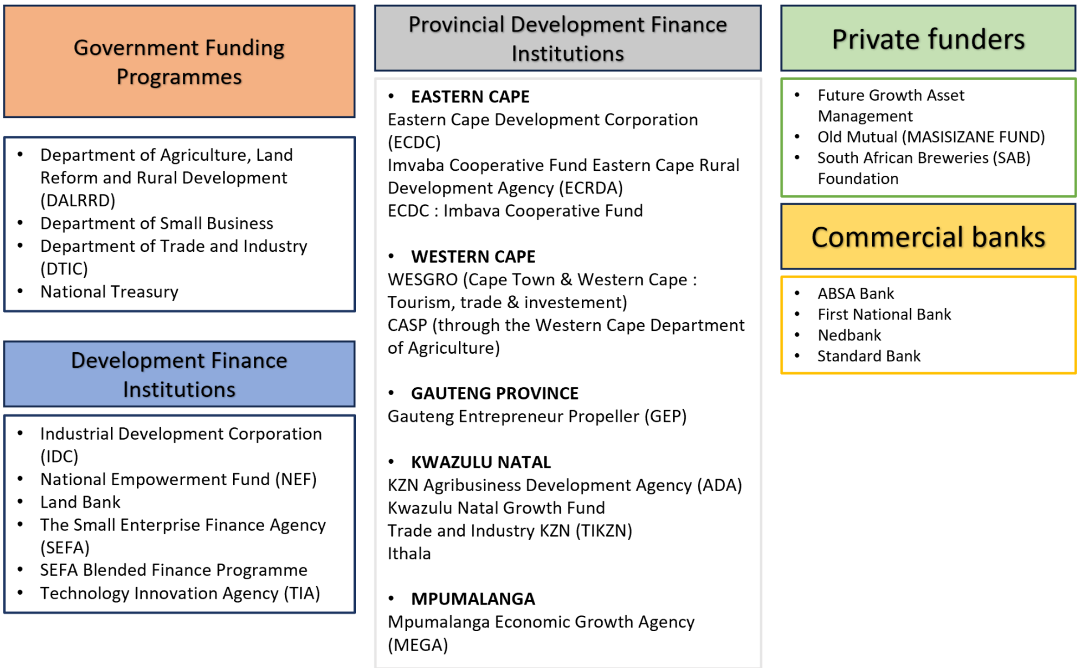


Figure 29: Possible fundings for the aquaculture sector ((Source: DFFE, 2021), creation PMBA))

Scientific partnerships and involvement of researchers in aquaculture projects are key to continue developing optimal growing conditions and profitability.

This IMTA system is based on the use of *Ulva* as a natural input in sea urchin feed, but this input does not represent 100% of the feed input. Indeed, this system remains dependent on formulated feed as a complementary input so strong partnerships with local feed manufacturers are needed.

Using a B2B approach, international specialised agents are also key downstream partners to ensure a high representation of the products and efficient feedback. Processors are needed for processing gonads and *Ulva* for potential future markets; they represent another key downstream partner.

Cost structure (pilot scale)

The use of *Ulva* as a complementary feed for sea urchins is providing the farm a significant economic advantage by decreasing the feed costs and enhancing the value of the product. In addition, growing *Ulva* for bioremediation is also an economic advantage for the farm by reducing the pumping costs of the system as less fresh seawater needs to be pumped to supply tanks.

Human resources and production costs are the main cost structures (60% for human resources). The production process is highly dependent on electricity and water supplies (30% of the production costs). The investment costs are mainly needed for infrastructure and equipment at €72,000 for 42 tanks. Given the newness of the production and market, R&D costs are also significant (average of €162,000 each year).

Sea urchins are easily affected by variations in parameters like moisture (in transport), temperature, and salinity. Processing and transport methods must therefore be adapted to preserve the appearance and quality of roes to sell high-value products.

For long distance transport, the preferred method of transport is air freight, which guarantees gonad quality for up to 40 hours in ideal conditions for the food industry. In this case, urchins are chilled. For a longer distance and time, road or sea transport can be used using a system in which urchins are immersed in a chilled and aerated seawater (James and Evensen, 2018). Packaging and transport costs for sea urchins are therefore high.

Prospective revenue

Predictive revenues are mainly influenced by sales of the products (sea urchins) and production costs, but product quality and current market prices will impact selling prices.

Prices of urchin gonads are highly dependent on the quality of gonads, which is impacted by the colour, texture and taste/flavour. Differences in these factors can have a significant effect on the market value and on the company's revenue (Cyrus et al., 2014). As an example, in October 2023, prices of fresh urchin gonad on the Tokyo market:

RED LARGE (300g)	113€/tray
RED MEDIUM (150g)	48€/tray
WHITE LARGE (300g)	430€/tray

The same species in the Osaka market will be 340 €/tray for wholesale prices. Prices of sea urchins on the French market can be advantageous as well. As an example, 2018 prices in the Rungis market, the main supplier for the HORECA sector reached €100 per kilo of gonad. Retail prices for consumers range from €130 to €170 per kilo of gonad (France AgriMer, 2018).

4.4.2 The Business Model Canvas

The Business Model Canvas

IMTA LAB / LAND-BASED PARTIALLY RECIRCULATING AQUACULTURE SYSTEM

SEA URCHINS AND ULVA

SOUTH AFRICA

Key Partners

- **Investors:**

Private / public funds

- **Upstream partners :**

Local feed manufacturers (two feed companies)
International partners specializing in echinoculture (AquaVitae)
Government : The South African Department of Forestry, Fisheries and the Environment (DFFE)
HEI's (UCT), AfriMAQUA network, LIMAQUA (international joint laboratory), All-Atlantic Ocean Research Alliance, Aquaculture Association of Southern Africa.
Local equipment suppliers
Juvenile suppliers from hatchery (sister company)
R&D academics: University of Cape Town and the Department of Forestry, Fisheries and the Environment

- **Downstream partners :**

International agents acting as supplier to the Asian market

Key Activities

IMTA production
Hatchery and reproduction process
Production process: *feeding, cleaning, grading, collection*
Daily assessment (*monitoring, system maintenance, water quality monitoring)*
Processing and transport
R&D : marketing, product development & optimization
Broodstock conditioning / gonad assessment

Key Resources

Lands: < 10 ha
Feed: formulated feeds
Permits/authorization : right to engage and permit for aquaculture activity
Infrastructure (i.e. optimal basket designs, lighting, laboratory, sediment tanks)
Electricity and water supply
Skilled human resources
R&D

Value Propositions

Production of **sea urchin** (*Tripneustes gratilla) :*

- Year round production (only 10% of the world industry)
- High valued low-trophic species (one of the top traded species globally)
- High growth rates
- High quality gonads with high market acceptance
- Full life-cycle grow-out in IMTA : gonads quality guaranteed over 90% of the time
- Quality guaranteed for 90% (full life cycle grow-out)

Fresh, frozen or canned products

Production of ***Ulva*** *(Ulva lacinulata)* :

- Food input for sea urchins
- Bio-filter for bioremediation
- Marketable
- Natural feeding stimulant
- Nutritional and health benefits
- Source of nutrients
- Increasing the urchins growth rate

Recirculation capacity :

- controlled environment and system monitoring
- mitigation of HABs

Customer Relationship *

Feedback from the agents distributing the products on the international markets (mostly Asian).

Sales based on the quality and availability by insuring consistent supply of high-quality product and year round products.

Channels *

Outsourcing distribution network

BtoB for the Asian market :
Seafood agents exporting to Asian market (mainly Japan)

BtoC with local producers

Customer Segments *

Sea urchins :

Export :
International customers (99%) : mainly Asian markets (Japan for 80% of the roe market)

Europe (France, Italy, Spain)
Local niche market (restaurant)

Food industry for roe consumption

Mainly fresh products
Processed (<10%) : Frozen/dried/canned

Domestic market (1%):
Local producers in South Africa for spat: niche market

Cost Structure *

Infrastructure costs : Tanks and raceway : 15 000 euros
Equipment (tanks, baskets, pumps for urchins) : 72 000€ of investment (Depreciation costs (3 years) : 25 000 euros)
Production costs :
Human resources (60%) : about 20 persons (80% for sea urchins production and 20% for Ulva)
Water and electricity supplies (30%)
Feed : (30%)
Maintenance and processing for export
R&D : 162 000 euros/year

Revenue Streams *

Funds and Sales of goods
Sea **urchins** for roe (main market)
Average price : (Wholesale) from 10 to 20€/kg (whole piece)
Japan prices : Wholesale : 340€/tray and retail from 48€ to 430€/tray of gonads
France market : 14€/kg for whole urchins
Wholesale: 100€/kg of gonads
Retail : 130/170€/kg of gonads

*****Prospective*

4.4.3 Synthesis

INTERNAL FACTORS

STRENGTHS
Technical • Consistency of the production of sea urchins: year-round production (only 10% of the industry) • Quality of gonads guaranteed for 90% of urchins produced from full life cycle grow-out • Optimised growth and gonad development/quality • Strong scientific partnerships of the company • Land-based tank system: mitigate disease spread and HAB risk reduction • Production of two species in the same system: diversification • Recirculation system: controlled environment, reduced pumping cost and advantage in case of Harmful Algal Blooms • Increased growth rate of animals by using *Ulva* in formulated feed (Cyrus et al. 2015) • Land-based system resistance and controlled interaction system **Environmental** • Land-based system reducing wastes and environmental impact on surrounding environment • ASTRAL LCA confirms that *Ulva*, plays a role as a biofilter, efficiently harnessing, and utilising waste nutrients, primarily nitrogen and phosphorus, from the sea urchin production. It assimilates approximately 84% of the dissolved nitrogen released by the sea urchins **Economic** • Support from local government institutions • Saving feed costs: use of *Ulva* as a feed input (50% at least) • Saving production costs and dependency: recirculation is decreasing water pumping costs and electricity requirements • New high-valued low-trophic aquaculture species from South Africa and emerging species with high market value and with high demand in Asia (Japan 80%) • Marketing advantage of the IMTA: by using a sustainable production system and natural feed (consumers perception) • The use of natural material (*Ulva*) as a supplementary food for sea urchins is increasing the value and quality of the production: direct impact on the colour and texture of gonads (ASTRAL LCA) Compared to the monoculture production of sea urchin, the IMTA system used 53% less energy (ASTRAL LCA)

WEAKNESSES/CHALLENGES
Technical • Ability to produce enough *Ulva* in a cost-effective manner in the required space • Dependency on water supply (sea), electricity (pumping system), and feed(s) • R&D: Sea urchin is a new species under development in South Africa so extensive market development and research still needs to be conducted • Funding for R&D • Skilled human resources • Sensitiveness of sea urchins to environmental conditions, especially during early life stages: require intensive monitoring and special attention during the production process • Sea urchins are very sensitive during early life stages. However, consistent water quality, particularly temperature, is also vital during the final stages of production when the animals are mature (mature gonads) as a sudden increase or decrease in water temperature will cause animals to spawn, which will adversely affect gonad quality and can cause a large loss of revenue and potentially loss of animals • Consistent production of microalgal feeds is a challenge during early life stages (for urchins' larvae) **Economic** • Space – some producers may have space limitation and a difficulty in producing *Ulva* on site • Cost of electricity high to run heat pumps, unless one can produce the species in a warmer climate (subtropics/tropics) • Difficulty of getting products to market and establishing a relationship (market entry) • Obtaining certification

EXTERNAL FACTORS

	Opportunities	Threats
Political	● Private lands ● South African government prioritising aquaculture in its National Development Plan to 2030. ● The Government supports investments in the development of aquaculture with aid.	● Minimal research on aquaculture socio-economic dimensions and minimal technical data to communicate to communities (Morake, 2015) ● Access to public and private land and water bodies for aquaculture purposes: Access to land in coastal areas can be difficult/ costly
Economic	● Private funding: relative autonomy of the production site ● New market opportunities for revenue diversification ● Decline of Japanese urchin stocks: marketers are seeking new alternative sources of raw urchin ● Sea urchins (roe): emerging market and high selling prices ● South African producer community has a good understanding of the IMTA model benefits	● Long return on investment: an average of 4 years for a small/family farm / higher for a larger farm ● Increasing transport costs (COVID, higher fuels costs…) ● External Funding dependency ● Consumer habits: urchins are not a food source for local people ● Regarding the IMTA misreading: there is not a strong demand for IMTA products ● Weak knowledge of the sea urchin markets ● No large global market for Ulva (Cyrus, Bolton and Macey, 2015), although this may improve rapidly with current initiatives ● Dependency to export and transport (urchin market)
Social	● Increasing the coastal areas and communities: provide employment, environment preservation ● Local partners dynamic: professional organisations, research partnerships, local dynamic ● Consumer's quest for sustainability ● Sea urchins' consumption booms in Asian markets ● Social positive perception on natural feed inputs ● Social perception: higher value for a premium product (+ 10% for a better product)	● IMTA misreading: Low public awareness as IMTA is still not well known by the general public and the consumers

	Opportunities	Threats
Technical	• Innovations & R&D projects in aquaculture to reduce risks: • Growing interest in aquaculture and corresponding increase in development of new technologies to support sustainable aquaculture • No dependency on processors: raw products already have a high market value and are sought-after (urchins).	• Need of skilled human resources and difficulty to recruit • Growing demand for technological skills (digital technologies) • Development of new technologies – adaptation needed by producers • Complexity of production system and technical challenges • Reliability of electrical infrastructure in South Africa
Environmental	• Market demand for eco-certified seafood in sustainable aquaculture system • Circularity and waste management	• Dependency of sea urchins on a specific temperature regime: *Tripneustes* need to be cultivated in a tropical environment, so there are limited areas in South Africa where this can be done • Increasing demand for sea urchins: pressure on wild harvesting is growing (represent 90% of the industry globally)
Legal		• Authorisations and permits delivery process / rates • Weak feedback and/or support from sector representatives and associations on IMTA • No single policy or managerial practice • Lack of availability of fundings, including for R&D

5 Catalogue of business models value chains for each use case

5.1 Kelp value chain (Norwegian monoculture farm)

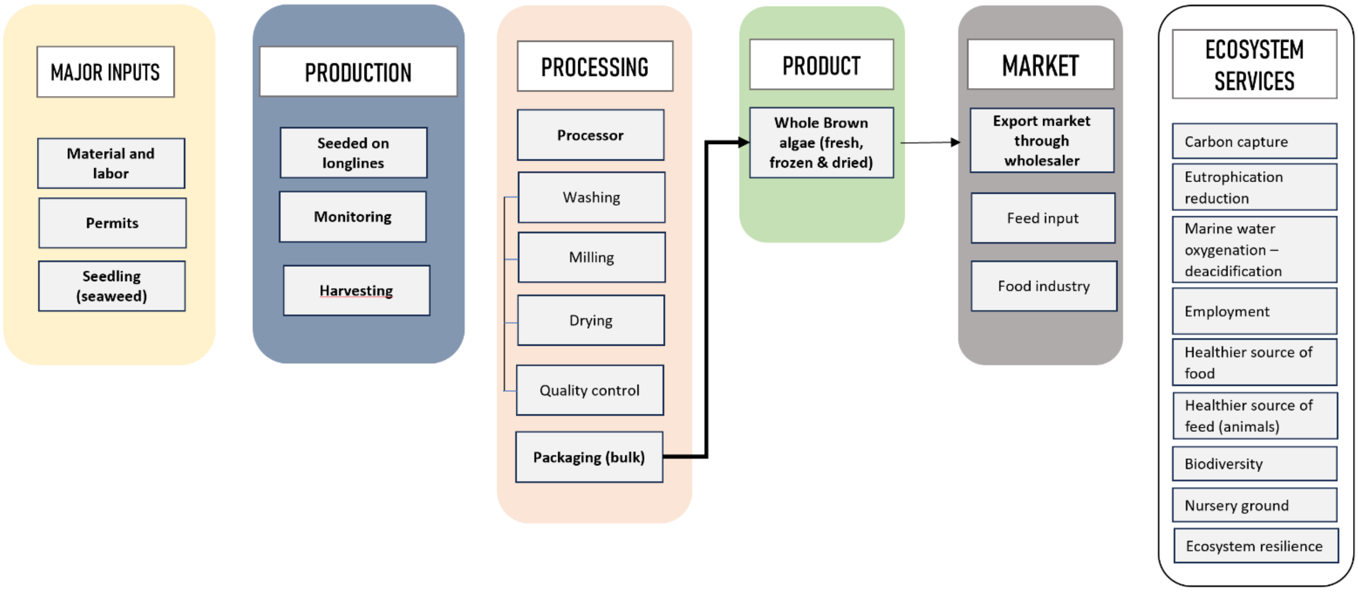


Figure 30: Kelp value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation TQC)

5.2 Mussel and kelp value chain *(Irish co-culture farm)*

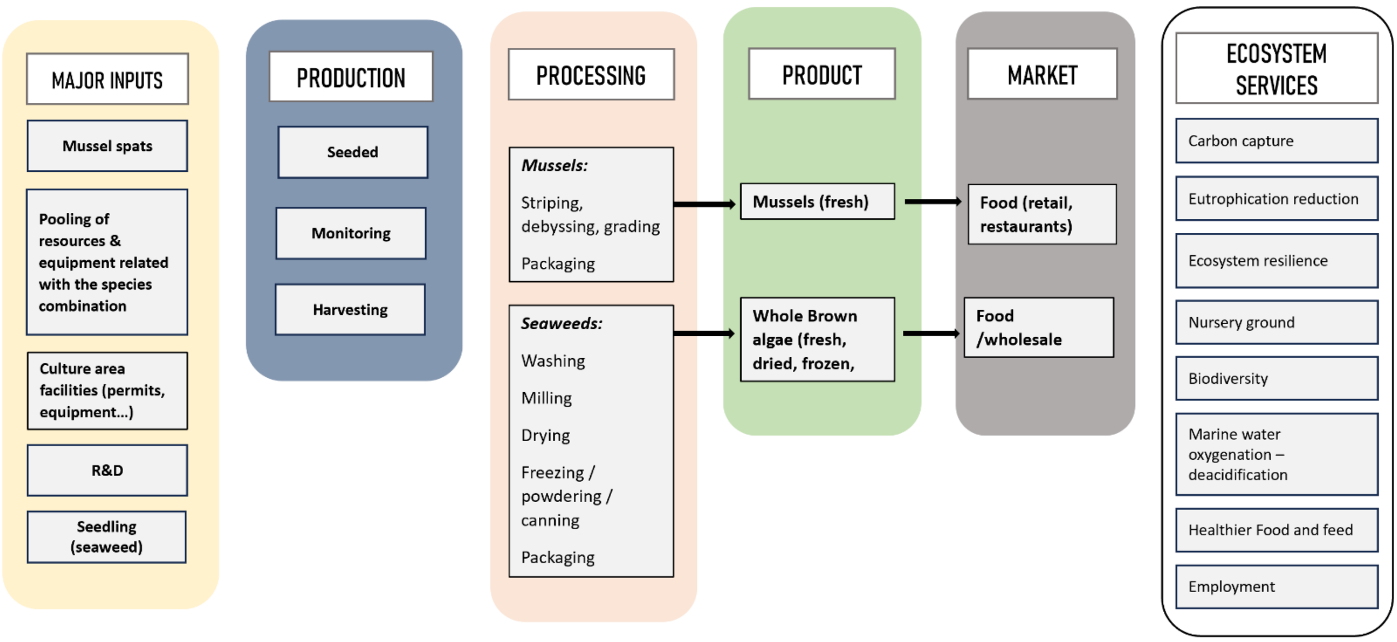


Figure 31: Mussel and kelp value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation TQC)

5.3 Winkle and oyster value chain (French IMTA commercial farm)

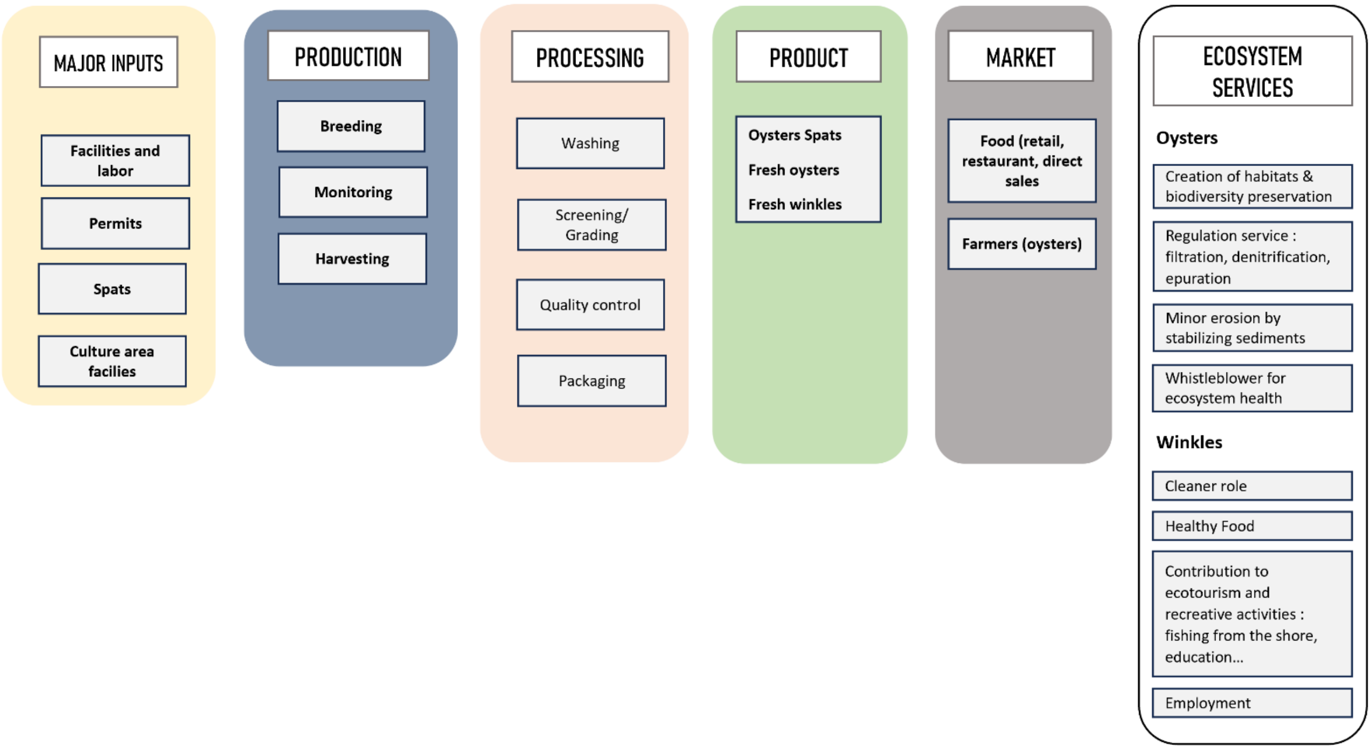


Figure 32: Winkle and oyster value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation TQC)

5.4 Abalone and Ulva value chain (South African IMTA commercial farm)

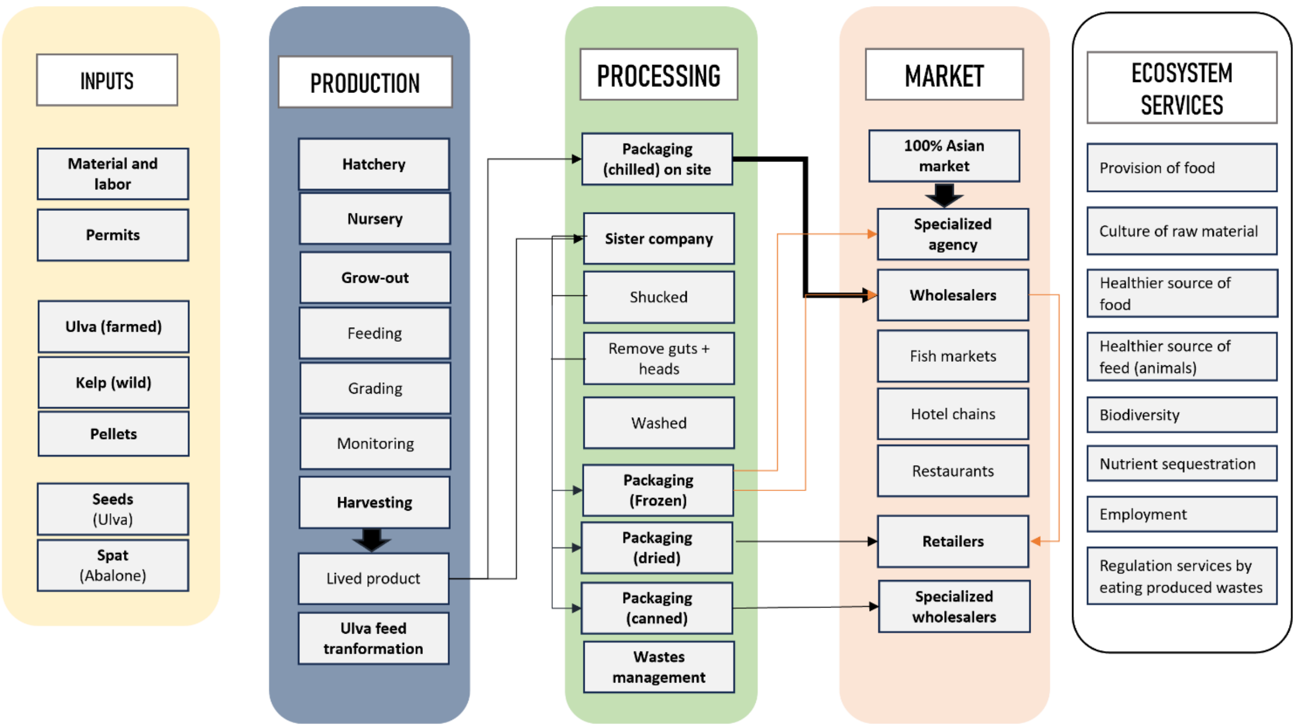


Figure 33: Abalone & Ulva value chains (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation PMBA)

5.5 Shrimps, fish, seaweeds and oysters value chains (Brazilian IMTA pilot farm)

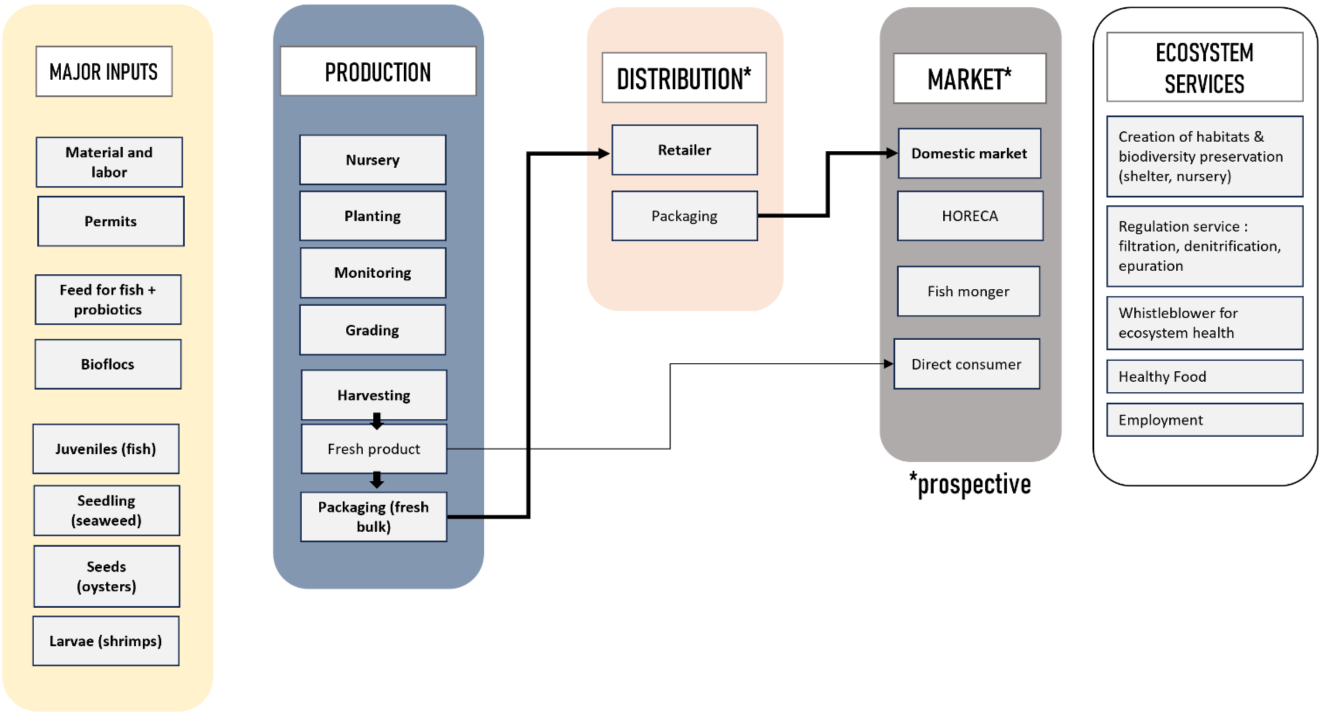


Figure 34: Oyster value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation PMBA)

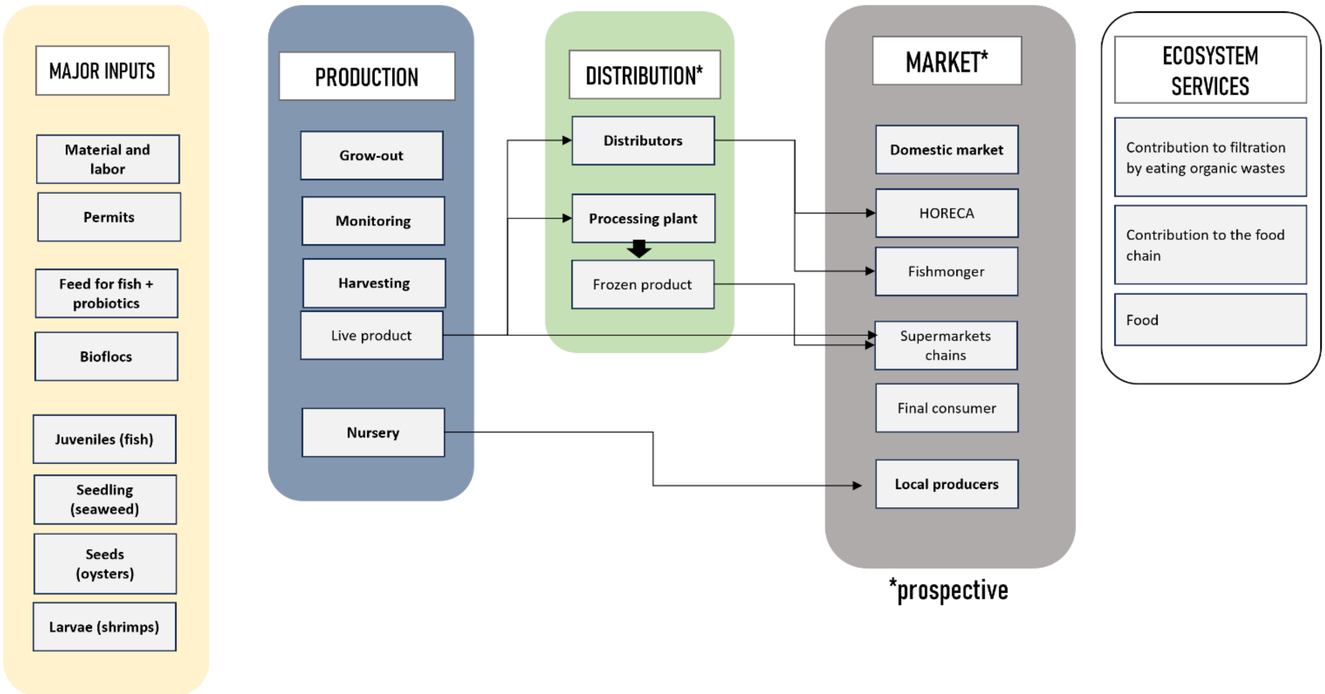


Figure 35: Shrimp value chain for this system (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation PMBA)

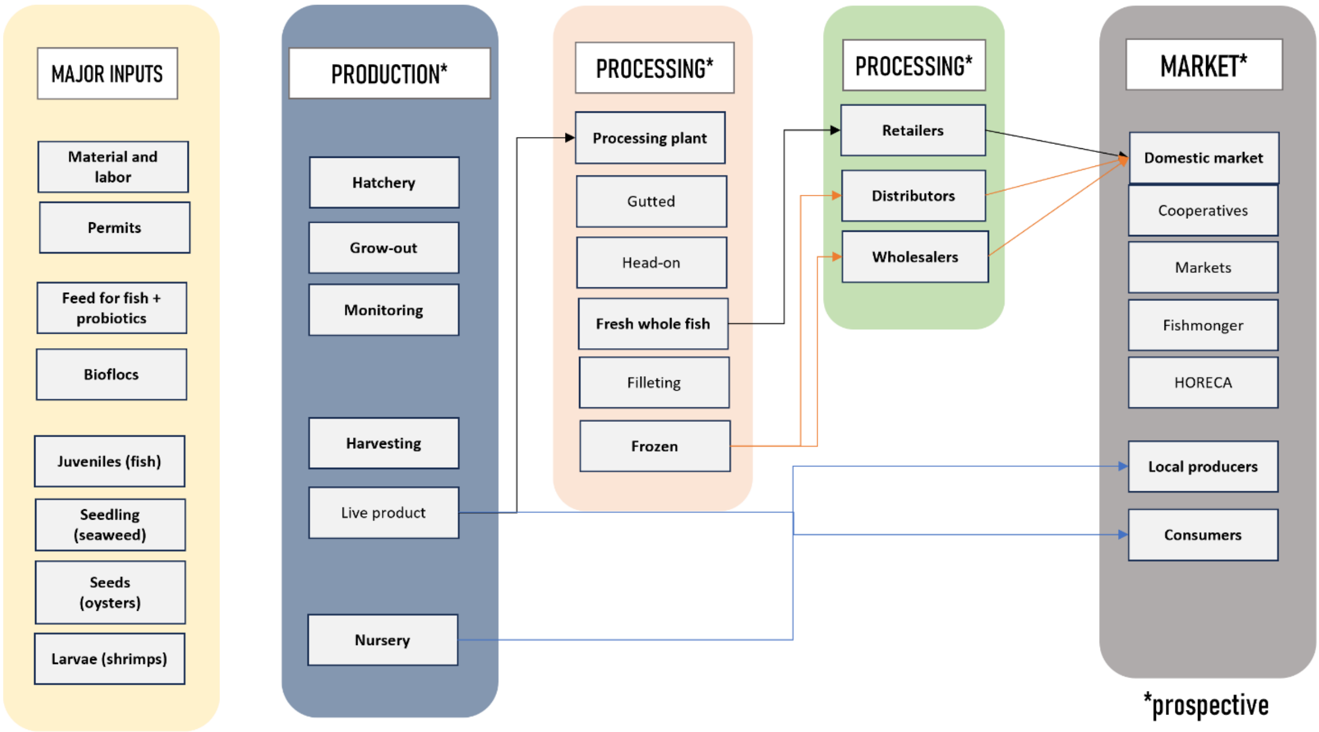


Figure 36: Tilapia value chain for this system (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation PMBA)

5.6 Salmonids, seaweeds, molluscs, and urchin value chains (Irish IMTA pilot farm)

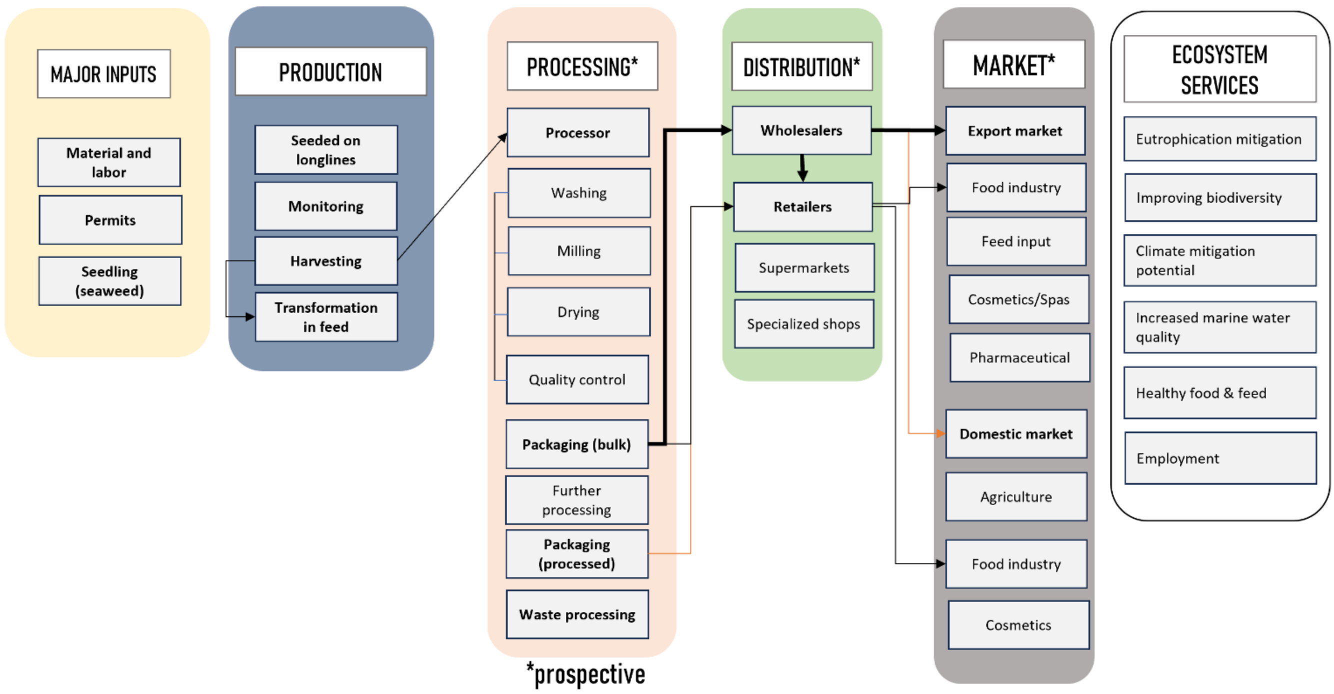


Figure 37: Seaweed value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023 / Creation PMBA)

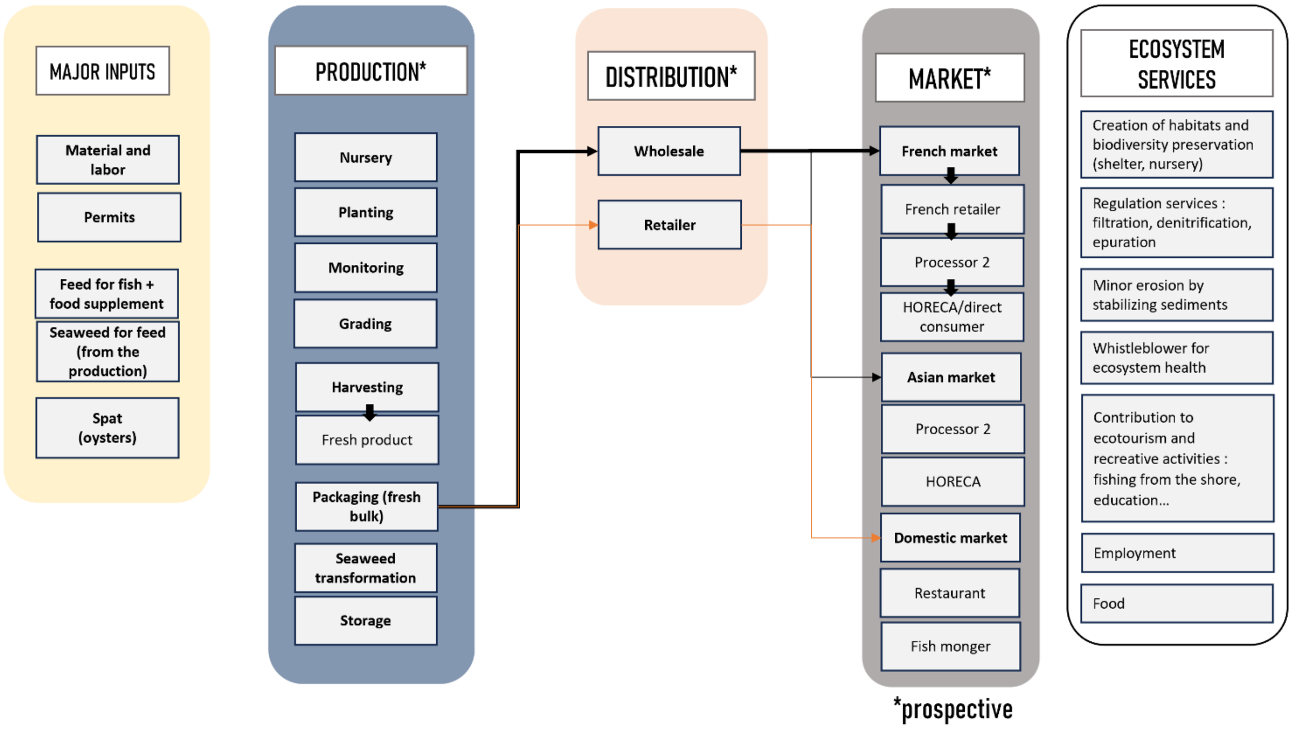


Figure 38: Oysters value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023 / Creation PMBA)

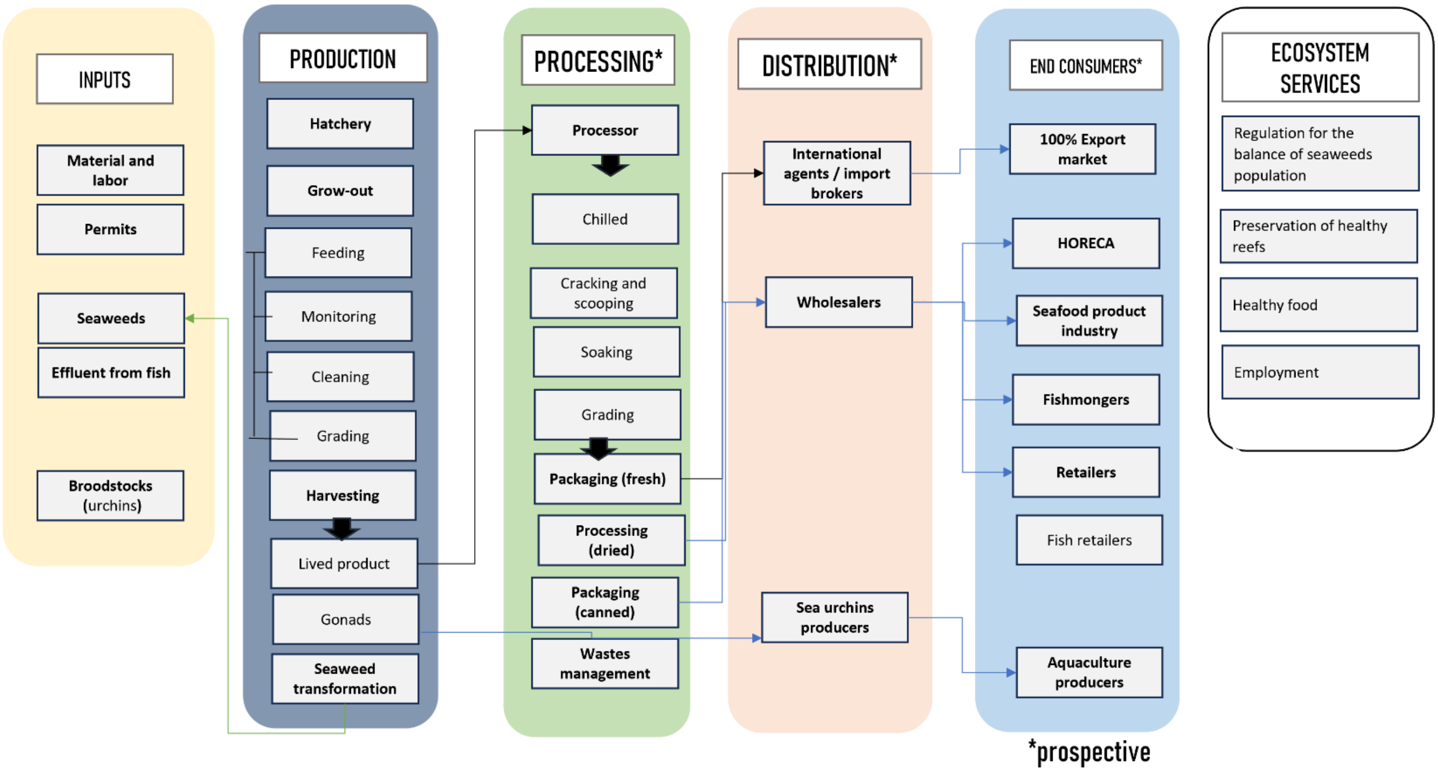


Figure 39: Urchins value chains (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023 / Creation PMBA)

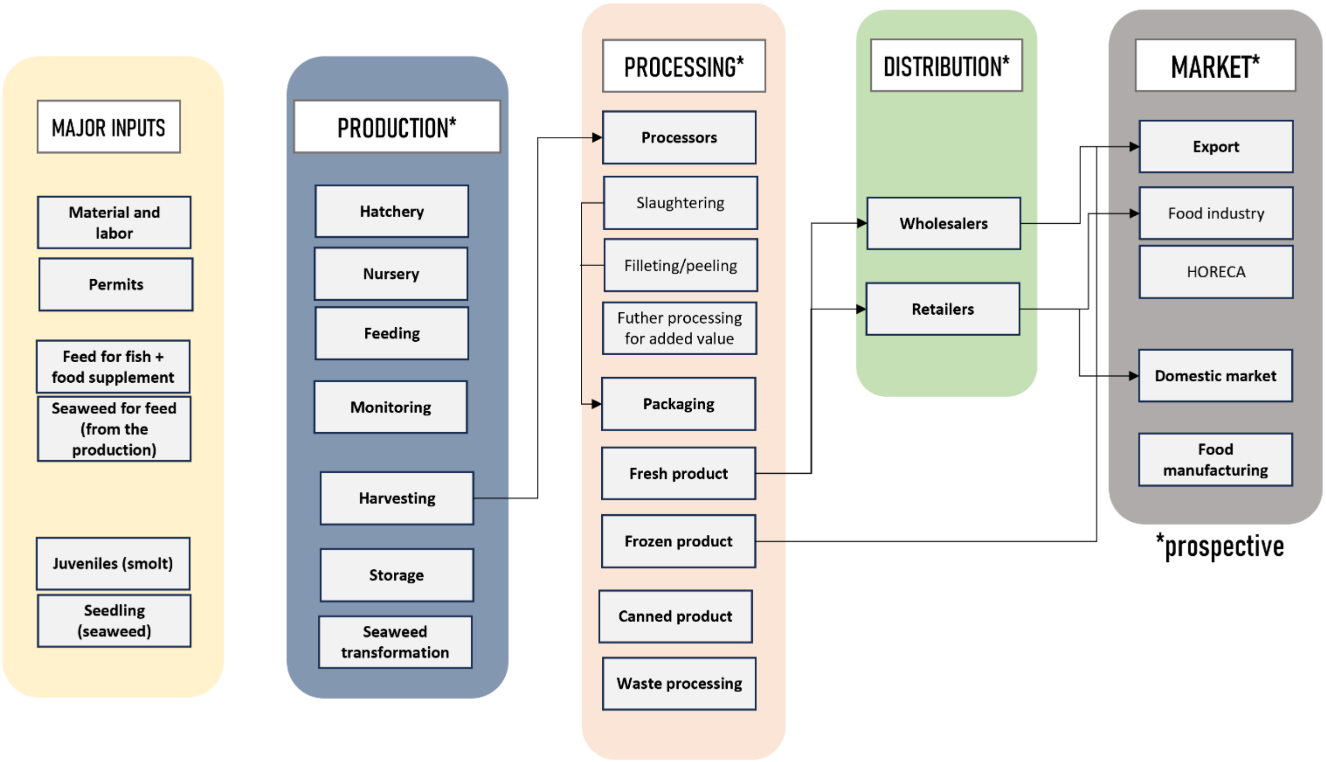


Figure 40: Salmon value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023 / Creation PMBA)

5.7 Urchin and Ulva value chain (South African IMTA pilot farm)

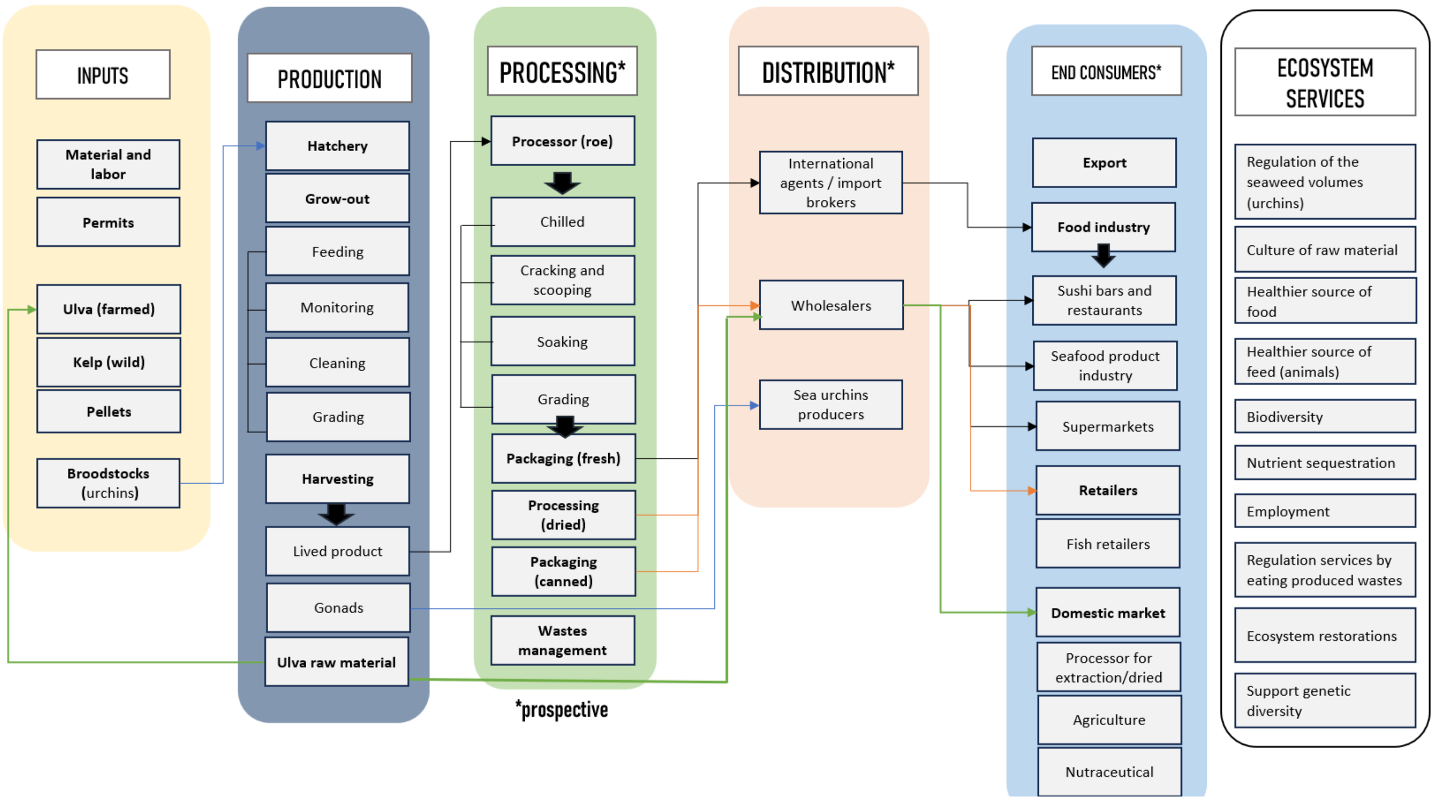


Figure 41: Value chain for the South African IMTA Lab (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation PMBA)

5.8 Seaweed and Oysters value chain (Scottish IMTA pilot farm)

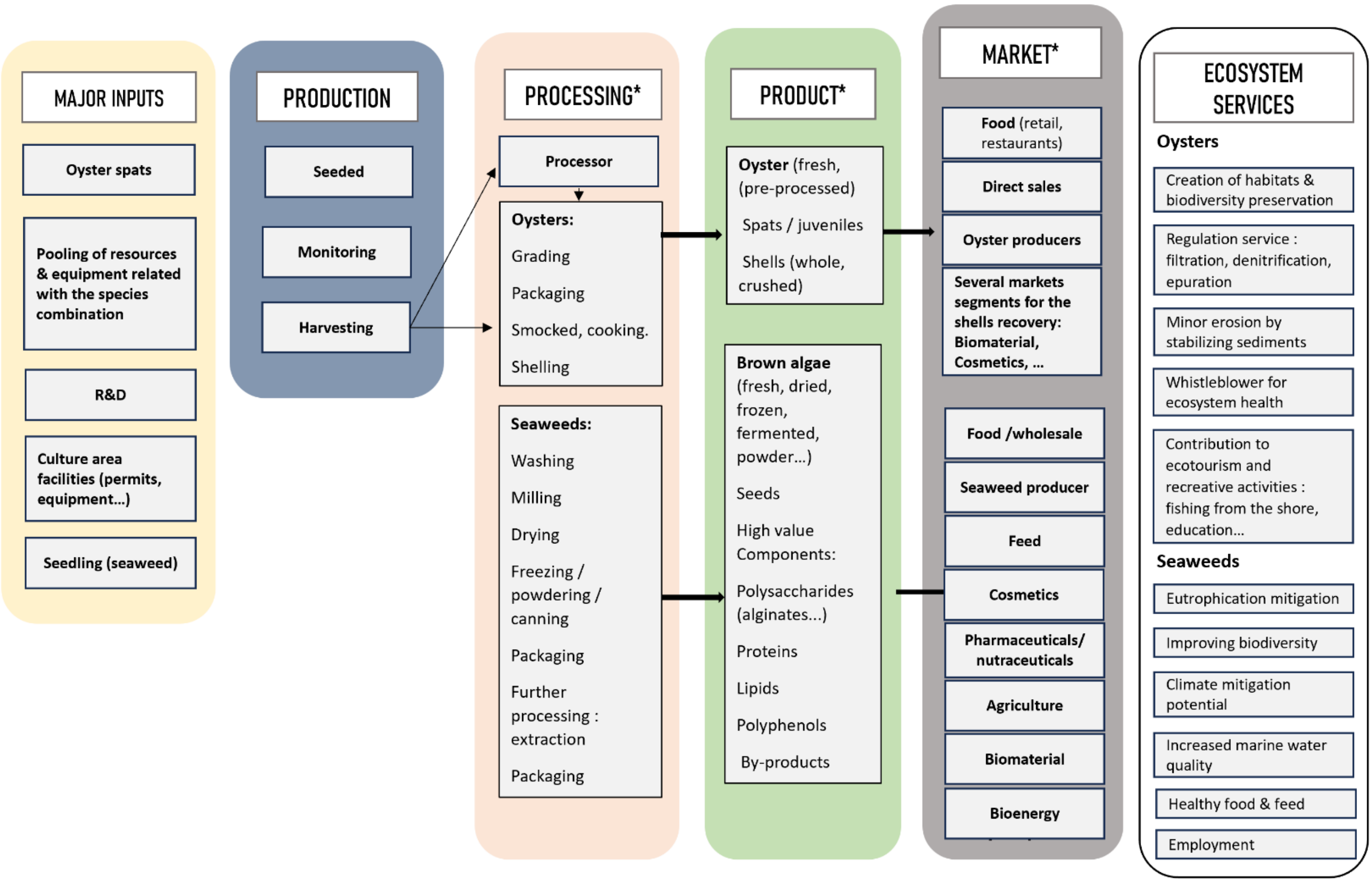


Figure 42: Oysters and brown seaweeds IMTA value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation TQC)

Conclusion

The work carried out in this deliverable clearly shows the plurality of aquaculture business models, both in traditional and IMTA systems. It allows a precise description of each economic operation, but also to project prospective scenarios for IMTA systems that are not at commercial scale.

A limitation of this work lies in the need to extrapolate data for prospective scenarios, in order to scale up from an experimental system to a commercial one. Indeed, not all economic data are available, and factors and impacts may vary from the pilot to the commercial scale.

Other limitations were identified when collecting data:

- Most of the interviewees were reluctant to provide their economic data, especially for reasons of confidentiality and because some data were not available.
- IMTA commercial development is quite recent in the countries involved in the ASTRAL project. Most IMTA projects are at an experimental stage and do not have enough economic data to share.

This study is linked to the ASTRAL deliverable 6.2, which shows the established benefits of IMTA by country, as well as the costs and benefits.

The intention of this deliverable is to support the development of the aquaculture sector in the Atlantic area by:

- highlighting the economic functioning of IMTA production and the economic advantages or disadvantages for each type of system, depending on the location and the species produced
- providing the various stakeholders an overview of different types of IMTA production, both for existing and experimental sites.
- providing producers and entrepreneurs de roadmaps, key steps and milestones that they need in order to get into the IMTA systems.

Highlight of main drivers

On the IMTA commercial sites, that already have a sales strategy, few major trends are emerging:

Table 5: Key ideas for IMTA commercial business models

Type of channels	Mainly B2B
Main markets	Food market mainly addressed Sales of raw products Basic supply / minimal processing Other potential market less explored

Risks	Technology risks: mainly still lab scale / limited at scale trials On commercial cases: R&D essential to pursue the development of the farm Market risks Variability of price No label for IMTA products
Emerging factors	Booming market for biobased, healthy and sustainable food
CAPEX / OPEX intensity	High CAPEX Medium OPEX: IMTA systems tend to reduce the production and HR costs but it is not generalised: depends on several factors (size, species produced, aquaculture system chosen…) + rising production costs + low processing

Through their similarities or, on the contrary, their specificities, these business models' analyses highlight main drivers for IMTA. These are key elements that can be exploited by different stakeholders.

***An economic interest*:** from a global perspective, the IMTA systems studied bring additional economic dynamism to the coastal areas in which they are set up, enabling job creation as well as local economic growth. Moreover, it has been shown that net present value for IMTA systems is higher, which could be linked to the diversification of revenues brought about by the pooled production of several species.

A change in consumer habits: an increase in the overall consumption of aquatic products is noted and significant changes were identified in consumer habits, especially in developed countries.
The consumption of aquaculture and fisheries products is increasing but there is also a growing interest for alternative protein sources, biobased products which have been produced with limited environmental impact and using a sustainable method. Consumers' awareness regarding the origin of products is thus evolving and, depending on their localisation and financial resources, they could be willing to pay a higher value for a premium product (+ 10% for a better product).
These developments are also affecting sales channels, which are increasingly turning to alternatives methods: click and collect, baskets or home delivery. Producers need to adapt to these new distribution channels.

***New market on the rise**:* There is considerable scientific evidence for multiple nutritional and health benefits from the consumption of seaweeds which, along with their relative ease of production, make them ideal candidates for functional foods and nutraceuticals.

In addition, the potential for use of seaweeds as an aquafeed component is enormous, and there seems to be little doubt that seaweeds as *Ulva* will increasingly be grown in IMTA systems for aquafeed, and for human consumption in the future, an asset given the rise of veganism and vegetarianism.
The large-scale production of *Ulva* as a component of feed for aquaculture animals awaits broader acceptance in the industry and technological advances in offshore *Ulva* production, but the literature indicates a considerable future role for *Ulva* in feeding humanity (Cyrus, Bolton and Macey, 2015). From a global perspective, algae are products of the future that can be used in a wide range of applications. The only requirement is that a large amount of biomass is needed, so a large-scale production and industries capable of extracting, processing, and using this biomass with a higher market value. However, increasing global production level means decreasing market prices for the food industry: to avoid it, the sector needs to open to new market (biofuel, cosmetics…) where the value of products remains high.

High-quality products**:** IMTA products are high quality products, produced under controlled and sustainable systems. The traceability of those products increases their quality and value. This represents a competitive advantage for producers, which must be valued and could be certified. Labelling or certification of IMTA products, currently non-existent, may have disadvantages (quality criteria, label costs, etc.) but could also be an opportunity for the valorisation of IMTA products and a criterion for increasing market value.

R&D and skilled human resources are key: all case studies have a large part of their activity oriented towards research and development. This is a key element of IMTA systems, which is new and requires constant adaptation. Another issue is the need of expertise and skilled human resources on those sites. Growing several species at the same time with different trophic levels, despite the potential economic and ecological benefits, requires technical equipment and operating methods that can be complex and need more expertise. Having a skilled workforce for a difficult manual work is an issue raised by every use case analysed.

Political and financial support needed: IMTA systems require considerable installation investment. Operational expenses and research and development costs are also important and mandatory. The existence of these systems is therefore highly dependent on the presence of funds; private or public. In addition to the necessary funding, administrative support is required. These limits have been identified by all case studies, regardless of the country, as a major obstacle to the development of business models.

This highlights the importance of adapted policies, which are also simplified, facilitating, and developed in consultation with all stakeholders involved.

Develop a market vision and a commercial strategy: so far, all of these IMTA case studies have an already well-developed technical functioning, but the exploration of potential markets is limited, as is the understanding of the needs of various customers (e.g. nutraceutical). It is important for producers to develop a marketing strategy that considers emerging markets and diversifies customer segments (currently, most of them only have one segment). For the sustainability and profitability of IMTA businesses, it is necessary to increase producers' marketing and commercial development skills.

Branding: in order to increase the market value of IMTA products, it is also necessary to develop the visibility of this mode of production with consumers and buyers. Sustainable production by IMTA must be promoted as a brand image and producers could develop the marketing and branding of their products to increase value in the final market allowing a diversification of products compared to competition. As an example, Ireland is currently underrepresented on new markets (like the Asian market). Building an Irish brand will capitalise on the positive international perception of Ireland as a green food producer and increase penetration of premium niche markets. Product development on packaging/branding is thus a real issue for producers, just as improving the local supply chain content with competitiveness and investment to produce high valued product and promote differentiation.

Increasing the visibility of IMTA will also have a direct impact on increasing social acceptance.

Ecosystem services to explore in IMTA business models as a new benefit

Balancing economic growth with environmental responsibility is a key challenge for the aquaculture industry. Ecosystem services refer to the benefits that people derive directly or indirectly from ecosystems (Clark et al. 2021). They offer value to be explored through the IMTA approach by increasing societal acceptance. It can be a new way or an opportunity to develop new and resilient business models and to impact farmers' incomes. Putting a monetary value on ecosystem services is a challenge, but reducing environmental and economic risks in the long term should also make it easier to obtain funding from private and public sources.

Four types of services can be identified according to their direct of indirect use value, according to Clark et al. (2021):

- **Provision of services** as goods from the natural ecosystem (e.g. aquaculture products)
- **Regulatory services** that moderate or regulate natural phenomena (e.g. bioremediation)
- **Cultural services** that promote the cultural progress of the individual and of society as a whole (e.g. leisure)
- **Support services,** which serve as the basis for the other three types of ecosystem service and make them possible (e.g. carbon storage)

There are several methods for measuring the economic value of ecosystem services (based on costs, market price...). The World Bank proposes several potential leading payment mechanisms:

Table 6: Potential leading payment mechanisms (Source World Bank 2023)

Potential leading payment mechanisms	**Definition**
Charging aware consumers price premiums	Consumers pay the costs via price premiums on final products. This would require consumer awareness (eco-labelling…).
Trading credits for ecosystem services	Tradeable credits for ecosystem services can be traded business-to-business like carbon sequester system
Providing subsidies for achieving positive impacts	Subsidies can be provided to the farmers (e.g. governments can subsidize the use of methane-reduction supplements)
Paying ecosystem services producers through taxes	Producers of lower-trophic species can be paid for the ecosystem services provided through general taxes collected
Sharing the costs of production among beneficiaries	The costs of producing lower-trophic species are partially paid for by other businesses of the ecosystem services provided.

Monetising the ecosystem services generated by the IMTA system is a complex exercise. Several parameters need to be collected to efficiently assign a value to them, and it faces many obstacles, such as:

- Lack of knowledge about the impact of climate change on species and production sites, which can vary depending on location
- Lack of data on large-scale and/or commercial IMTA farms (large-scale production could have unintended negative effects (i.e. Nutrient levels or proximity to wild ecosystems)
- The need for a collective territorial approach bringing together public/private, local/regional/national stakeholders and authorities convinced by IMTA and the economic valuation of ecosystem services (determination of the right spatial resolution...)
- or the choice of a method to assess this economic value of ecosystem services

In any case, this valuation of ecosystem services opens up promising perspectives for the sector and policy makers to support the development of IMTA systems.

Bibliography

Agrocampus Ouest. INTEGRATE project. (2019). Rapport d'action n°3 : Diagnostic du secteur de l'AMTI sur l'Arc Atlantique. WP6 – Définir un cadre pour le développement de l'AMTI sur l'Arc Atlantique

Aquavitae project (2021). AquaVitae_D7_2_Value_chain_analysis

Barroso, R.M., Muñoz, A.E.P. and Cai, J. 2019. Social and economic performance of tilapia farming in Brazil. FAO Fisheries and Aquaculture Circular No. 1181. Rome, FAO. Licence: CC BY-NC-SA 3.0 IGO.

BIM and Ireland's Seafood Development Agency (2021) *Review of the Irish seaweed aquaculture sector and strategy for its development to 2030.* Available at: https://bim.ie/wp-content/uploads/2023/05/BIM-IMAS-Strategy.pdf.

Bolton JJ, Cyrus MD, Brand MJ, Joubert M, Macey BM (2016). Why grow *Ulva*? Its potential in the future of seaweed aquaculture. Perspectives in Phycology 3: 113-120.

Carr, L. M. (2019). Seeking stakeholder consensus within Ireland's conflicted salmon aquaculture space. M*arine Policy*, *99*, 201–212. https://doi.org/10.1016/j.marpol.2018.10.022

Carvalho, A., Costa, L., Holanda, M., Poersch, L., & Turan, G. (2023). Influence of Total Suspended Solids on the Growth of the Sea Lettuce *Ulva* lactuca Integrated with the Pacific White Shrimp Litopenaeus vannamei in a Biofloc System. *Fishes*, *8*, 163. https://doi.org/10.3390/fishes8030163

CASTILLA GAVILAN, M. (2018). *Diversification of oyster farming by sea urchin Paracentrotus lividus culture: A study of the socio-technical modalities in a model aquaculture farm*. Université de Nantes.

Coyle, N. M., O'Toole, C., Thomas, J. C. L., Ryder, D., Feil, E. J., Geary, M., Bean, T. P., Joseph, A. W., Waine, A., Cheslett, D., & Verner-Jeffreys, D. W. (2023). Vibrio aestuarianus clade A and clade B isolates are associated with Pacific oyster (Magallana gigas) disease outbreaks across Ireland. *Microbial Genomics*, *9*(8), mgen001078. https://doi.org/10.1099/mgen.0.001078

Cyrus MD-, Bolton JJ, De Wet L, Macey BM (2014). The development of a formulated feed containing *Ulva* (Chlorophyta) to promote rapid growth and enhanced production of high quality roe in the sea urchin *Tripneustes gratilla* (Linnaeus). Aquaculture Research 45: 159-176

Cyrus MD-, Bolton JJ, Macey BM (2015). The advantages of *Ulva* (Chlorophyta) as an additive in sea urchin formulated feeds, effects on palatability, consumption and digestibility. Aquaculture Nutrition 21: 578-591.

Cyrus MD-, Bolton JJ, Macey BM (2015). The role of the green seaweed *Ulva* as a dietary supplement for full life-cycle grow-out of *Tripneustes gratilla* (Linnaeus). Aquaculture. 446: 187-197.

DAFM (2022). Draft National Strategic Plan for Sustainable Aquaculture Development 2030. 114 pp + appendices

Dennis, J., Jackson, E., Perry, S. and Rihan, D., 2022. Annual Aquaculture Report 2022: A Snapshot of Ireland's Aquaculture Sector. Bord Iascaigh Mhara (BIM).

DFFE. (2021). *A directory of development finance and grant funding organizations for Aquaculture Operations in South Africa.* The Department of Forestry, Fisheries and the Environment.
Estate Scotland.

EUMOFA. (2022). Case study Mussels in the EU. Price structure in the supply chain. Focus on Spain, France, Italy and Ireland. https://www.eumofa.eu/

EUMOFA. (2022). Case study Oysters in the EU. Price structure in the supply chain. Focus on France, Ireland and the Netherlands. https://www.eumofa.eu/

European Commission. (2023). EU funding opportunities available for aquaculture. Background paper. Produced under the EU Aquaculture Assistance Mechanism which is part of a Service Contract jointly managed by DG MARE and the European Climate, Infrastructure and Environment Executive Agency (CINEA). https://cinea.ec.europa.eu/

European Commission. Directorate General for Maritime Affairs and Fisheries. & EUMOFA. (2022). *The EU fish market: 2022 edition.* Publications Office. https://data.europa.eu/doi/10.2771/716731

European Commission. Directorate General for Maritime Affairs and Fisheries. and EUMOFA. (2022) *Oysters in the EU: price structure in the supply chain : focus on France, Ireland and the Netherlands : case study.* LU: Publications Office. Available at: https://data.europa.eu/doi/10.2771/802589

FAO. (2022). The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO. https://doi.org/10.4060/cc0461en

Guðmundur, S., Holly, K., Hannon, C., & James, P. (2017). *Markets for Sea Urchins: A Review of Global Supply and Markets*.

Hughes, C., & King, J. W. (2023). Habitat suitability modelling for an integrated multi-trophic aquaculture (IMTA) system along Europe's Atlantic coast. *Ecological Modelling*, *484*, 110459. https://doi.org/10.1016/j.ecolmodel.2023.110459

Hynes, S., Skoland, K., Ravagnan, E., Gjerstad, B., & Krøvel, A. V. (2018). Public attitudes toward aquaculture: An Irish and Norwegian comparative study. *Marine Policy*, *96*, 1–8. https://doi.org/10.1016/j.marpol.2018.07.011

James, P., & Evensen, T. (2018). *Sea Urchin transportation systems for land, sea and air*. Nofima.

Knowler, D., Chopin, T., Martínez-Espiñeira, R., Neori, A., Nobre, A., Noce, A., & Reid, G. (2020). The economics of Integrated Multi-Trophic Aquaculture: Where are we now and where do we need to go? *Reviews in Aquaculture*, *12*(3), 1579–1594. https://doi.org/10.1111/raq.12399

Krala, M. V. (2015). *Guide to the authorisation requirements for aquaculture in South Africa*.

Lena Førde, Marte Skarbø. Norwegian University of Science and Technology. (2022). Sustainable business model innovation: A multiple case study of three Norwegian firms in the aquaculture industry. Master's thesis in International Business and Marketing.

Lopes, I. G., & de Freitas, T. M. (2023). Fish consumption in Brazil: State of the art and effects of the COVID-19 pandemic. *Aquaculture*, *574*, 739615. https://doi.org/10.1016/j.aquaculture.2023.739615

Morake, K. S. H. (2015). An investigation of public awareness and perception of marine aquaculture in south african coastal communities : a pilot study in the hermanus community. https://api.semanticscholar.org/CorpusID:202735084

Munro, L. (2022). Scottish Shellfish Farm Production Survey 2021. *Marine Scotland Science*.

Mzibra, A., Aasfar, A., Douira, A., Kadmiri, I. M., & Bamouh, A. (2022). Utilisation des polysaccharides des algues marines comme biostimulants en horticulture. *Revue Marocaine des Sciences Agronomiques et Vétérinaires*, *10*(2), 229–233.

O. Amosu, A., V. Robertson-Andersson, D., W. Maneveldt, G., J. Anderson, R., & J. Bolton, J. (2013). South African seaweed aquaculture: A sustainable development example for other African coastal countries. *African Journal of Agricultural Research*, *Vol. 8*(43).

Osterwalder, Alexander & Pigneur, Yves. (2010). Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers.

Philippe Ahier (2018). Développer l'aquaculture multi trophique intégrée sur l'Arc Atlantique français : une étude sur l'acceptabilité sociale. Sciences du Vivant [q-bio]. ffdumas-01949434f

Priscila, S., Sant´Anna, A., Machado,L., (2022). Intropidi B. and Vogt, P.. Credit for Investments in Brazilian Agriculture and the Role of the Brazilian Development Bank. Rio de Janeiro: Climate Policy Initiative.

Sander van den Burg, Trond Selnes, Liliana Alves, Else Giesbers, Ana Daniel. (2020). Prospects for upgrading by the European kelp sector. Journal of Applied Phycology (2021) 33:557–566

Santos, E. (2023) 'Brazilian fish exports hit record', *Embrapa*.

SAOS. (2021). *Alternative markets for farmed Scottish shellfish and associated requirements*. Crown

Scottish Government (2022). Understanding the potential scale for seaweed-based industries in Scotland Final report https://www.gov.scot

Seaweed for Europe (2021) Hidden champion of the ocean Seaweeds as a growth engine for a sustainable European future. www.seaweedeurope.com

Seaweed for Europe (2021). Investor memo: The case for seaweed investment in Europe. with the support of the SUN Institute Environment & Sustainability www.seaweedeurope.com

Seixas, C., & Troutt, E. (2003). Evolution of a local Brazilian shrimp market. *Ecological Economics*, *46*(3), 399–417. https://doi.org/10.1016/S0921-8009(03)00082-X

Suplicy, F. (2021). *Economic analysis of five oyster farms in Southern Brazil*. https://doi.org/10.52945/rac.v34i3.1093

World Bank. Pro Blue. (2023). Global seaweed New and emerging market report. https://www.worldbank.org/

Tord Hauge Nilsen. Norwegian University of Science and Technology (2018). Analysis of the kelp farming industry in Norway with regard to conceptual design of vessels for harvesting and deployment operations. Department of Marine Technology

Troya, M. D. C., Ansong, J. O., & O'Hagan, A. M. (2023). Transitioning from blue growth to the sustainable blue economy: A review of Ireland's new marine governance in the aquaculture sector. *Frontiers in Marine Science*, *10*. https://www.frontiersin.org/articles/10.3389/fmars.2023.1075803

Valenti, W. C., Barros, H. P., Moraes-Valenti, P., Bueno, G. W., & Cavalli, R. O. (2021). Aquaculture in Brazil: Past, present and future. *Aquaculture Reports*, *19*, 100611. https://doi.org/10.1016/j.aqrep.2021.100611

Van Osch, S. *et al.* (2017) 'Estimating the Irish public's willingness to pay for more sustainable salmon produced by integrated multi-trophic aquaculture', *Marine Policy*, 84, pp. 220–227. Available at: https://doi.org/10.1016/j.marpol.2017.07.005.

Walsh, M., & Watson, L. (2012). *A Market Analysis towards the Further Development of Seaweed Aquaculture in Ireland*. Irish Sea Fisheries Board (BIM).

Wasielesky, W., Atwood, H., Stokes, A., & Browdy, C. (2006). Effect of natural production in a zero exchange suspended microbial floc based super-intensive culture system for white shrimp Litopenaeus vannamei. *Aquaculture*, *258*, 396–403. https://doi.org/10.1016/j.aquaculture.2006.04.030

Whitmarsh, David & Wattage, Premachandra. (2006). Public attitudes towards the environmental impact of salmon aquaculture in Scotland. European Environment. 16. 108

Wilen, J., & Reynolds, J. (2000). The Sea Urchin Fishery: Harvesting, Processing and the Market. *Marine Resource Economics*, *15*. https://doi.org/10.1086/mre.15.2.42629295

Appendix 1: Governance of aquaculture in Ireland and the players involved

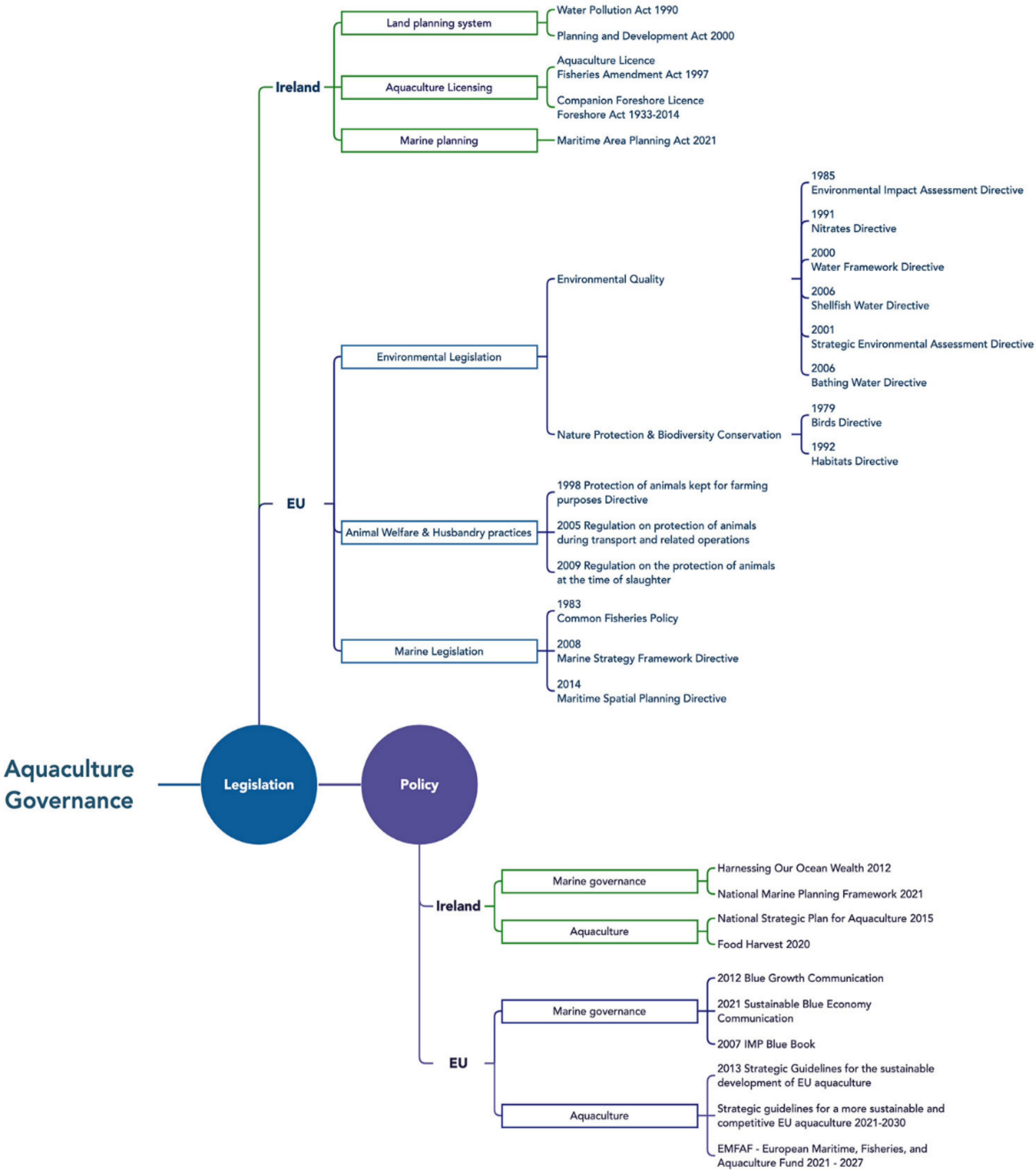


Figure 43: Review of Ireland's aquaculture governance (Source: Troya, M. D. C., Ansong, J. O., & O'Hagan, A. M. 2023)

Appendix 2: Potential sources of funding for aquaculture in South Africa

Government Funding Programmes

Department of Agriculture, Land Reform and Rural Development (DALRRD) :

- Financial Institutions South Africa (MAgriBEE)
- Comprehensive Agriculture Support Programme (CASP)
- Micro Agriculture AFISA)

Department of Small Business

- Black Business Supplier Developement Programm (BBSDP)
- Cooperative Incentive scheme (CIS)
- Secondary Marketing Cooperative Incentive Scheme (SMCIS)
- Enterprise Incubation Programme (EIP)
- Shared Economic Infrastrcuture Facility (SEIF)
- Start Up Enterprise Developement Program (SEDp)

Department of Trade and Industry (DTIC)

- Agriculture Development and Enhancement Program (ADEP)
- Agro-Processing Support Scheme (APSS)
- Black Industrialist Scheme (BIS)
- Cluster development Program (CDP)
- Critical Infrastructure Programme (CIP)
- Export Market and Investment Assistance (EMIA)
- Incubation support Programme

National Treasury

- Jobs fund

Development Finance Institutions

- Industrial Development Corporation (IDC)
- National Empowerment Fund (NEF)
- Land Bank
- The Small Enterprise Finance Agency (SEFA)
- SEFA Blended Finance Programme
- Technology Innovation Agency (TIA)

Provincial Development Finance Institutions

- **EASTERN CAPE**

Eastern Cape Development Corporation (ECDC)
Imvaba Cooperative Fund Eastern Cape Rural Development Agency (ECRDA)
ECDC : Imbava Cooperative Fund

- **WESTERN CAPE**

WESGRO (Cape Town & Western Cape : Tourism, trade & investment)
CASP (through the Western Cape Department of Agriculture)

- **GAUTENG PROVINCE**

Gauteng Entrepreneur Propeller (GEP)

- **KWAZULU NATAL**

KZN Agribusiness Development Agency (ADA)
Kwazulu Natal Growth Fund
Trade and Industry KZN (TIKZN)
Ithala

- **MPUMALANGA**

Mpumalanga Economic Growth Agency (MEGA)

Private funders

- Future Growth Asset Management
- Old Mutual (MASISIZANE FUND)
- South African Breweries (SAB) Foundation

Commercial banks

- ABSA Bank
- First National Bank
- Nedbank
- Standard Bank

Figure 44: Possible fundings for the aquaculture sector (Source: DFFE, 2021) (Creation PMBA)

Appendix 3: IMTA case study compendium

ASTRAL

***A**ll Atlantic Ocean **S**ustainable, Profi**T**able and **R**esilient **A**quacu**L**ture*

GA no **863034**

Research and Innovation Action (RIA)

Start date: 1st September 2020. End date: 30th September 2024

D6.3 - Business models

IMTA case study compendium

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 863034

Content

Table of figures

Introduction

Integrated multi-trophic aquaculture (IMTA) is a sustainable type of farming where multiple aquatic species from different trophic levels are farmed together. The IMTA principle is based on the cocultivation in the same site of higher trophic level species with extractive species. Those extractive species will use and assimilate the wastes (organic and inorganic) produced by the fed species; one species' waste becomes another's food input (Hughes and King, 2023).

IMTA can be a solution to reduce the ecological impacts on the surrounding environment but can also increase the social acceptance of aquaculture by presenting a more sustainable system. The economic benefits could also be highlighted, with income diversification for the producer, greater market value for IMTA products and possible faster production cycles (Knowler et al., 2020).

To support the development of IMTA, one of the objectives of the ASTRAL project is precisely to address IMTA value chains from the socio-economic and profitability point of view; these aspects are crucial to promote and deploy the IMTA approach widely.

This deliverable aims at demonstrating the economic benefits and constraints of integrated multitrophic productions, defining the processes used and identifying market requirements and opportunities. This deliverable is intended to be a tool for existing or future producers and also as a decision-making tool by providing an overview of best practices, relevant economic frames, value chains and external impacts of IMTA farms.

To do so, a business model analysis was run for existing monoculture, coculture and IMTA farms. This summary version focusses only on IMTA systems: commercial ones and prospective ones through the labs. Those IMTA labs are still at an experimental stage: each site manages a production on an experimental scale, with no post-production facilities, neither market channels nor defined target, they are not at a commercial scale.

Methodology

1 Deliverable 6.2: cost-benefit and socio-economic assessment

This deliverable is based on previous work: an in-depth description of the socio-economic aspects of aquaculture and IMTA, as well as the existing challenges and includes a preliminary cost-benefit assessment (ASTRAL deliverable 6.2). 39 interviews with producers (IMTA, co-culture and monoculture) were conducted to collect economic and qualitative data in the 10 countries included in the ASTRAL project, from January to August 2022.

2 Definition of case studies

Eight case studies have been identified for this deliverable, located in different countries within the Atlantic Area. Within those eight use cases, four are existing commercial farms and four prospective IMTA systems which correspond to the ASTRAL IMTA labs. As mentioned before, those pilot sites produce different species but have not yet reached the commercial stage and are not selling their products.

Table 7: Presentation of the eight use cases

Aquaculture model	Species	Location
Monoculture farm (X1)	Kelp	Norway
Co-culture farm (X1)	Kelp and mussels	Ireland
Existing IMTA commercial farm (X2)	Oysters and winkles	France
	Abalone and *Ulva*	South Africa
Pilot sites (ASTRAL - IMTA labs) (X4)	Fish (Atlantic salmon) Seaweeds Oysters Sea urchin	Ireland
	Native oysters and seaweeds	Scotland
	Sea urchins and seaweeds	South Africa
	Tilapia Shrimp Seaweeds Oysters	Brazil

This compendium focusses on IMTA systems and their business models (commercial models and Astral IMTA Labs).

3 Intrinsic and external factors of the business models

For the description of these business models, we have used the Business Model Canvas (BMC) approach. This concept is using a visual approach to identify the core elements needed to create value: Value proposition, customer segments, channels, customer relationships, revenues streams, key activities, key resources, key partners and cost structure.

Three different types of data were used: guided interviews with the responsible of each site (producers and/or researchers), bibliographic review and all the complementary work done within the ASTRAL project through other deliverables.

For the prospective business models, deeper interviews were made with the IMTA Labs (Scotland, Ireland, South Africa and Brazil). Those interviews were used as key inputs to thoroughly understand the production phase of the systems and therefore allow us to generate hypotheses for the commercial aspects of the BMC. Notably, the ASTRAL labs are not at a commercial scale (the production is not sold) hence a prospective work was required for the commercial aspects.

In order to complete the case studies, an analysis of all internal and external factors impacting each model was required. A crossed analysis of two different methods was used: a SWOT (Strengths / Challenges) and a PESTEL (Opportunities / Threats from a political, economic, social, technical, environmental, and legal point of view).

Environmental performances of IMTA systems are considered with key inputs from the life-cycle assessment deliverable of ASTRAL.

1 IMTA Commercial farms

1.1 Commercial IMTA farm – French farm

OFFSHORE - OYSTERS AND WINKLES (FRANCE)

Located in the northwest of Brittany, the company is focused on spats and high value half-breed oysters (*Crassostrea gigas)* and winkles *(Littorina littorea)* in an IMTA offshore farm.

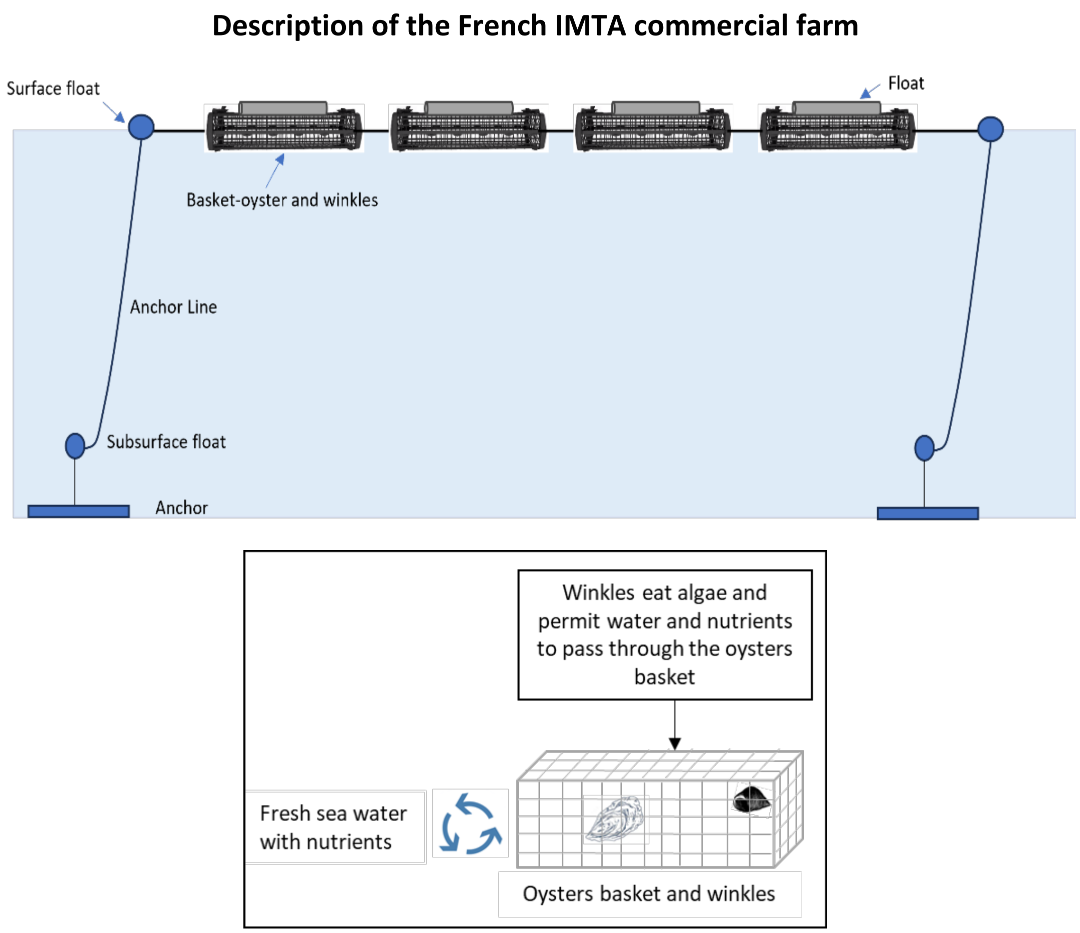


Figure 45: Winkles-Oysters IMTA farm example in France in an offshore area (Source: producer; creation: TQC)

1.1.1 The Business Model Canvas

The Business Model Canvas

IMTA FARM – OFFSHORE

WINKLES / OYSTERS

FRANCE

Key Partners

- **Investors**

Private and Public funders

- **Upstream partners :**

R&D and professional organizations : Institut Agro Rennes Angers, Member of Cluster Pôle Mer Bretagne Atlantique, Comité régional Conchylicole Bretagne Nord
SYSSAAF
Scientific network
Winkles hatcheries (Ireland)

- **Downstream partners :**

Distributors and gastronomic restaurants

Key Activities

R&D

Production process: all the value chain (from hatchery to commercialization)

Grading

Sales & marketing

Management

Key Resources

Juveniles from hatcheries

Technical process from research institutions

Scientific knowledge

Offshore oysters' production area
Skilled human resources: 7 people (6 permanent staff)

Value Propositions

IMTA Offshore production of **oysters** (200 tons) :

- High nutritional potential
- a marked iodized tasty and meatier oyster
- Increased growth rate by 15%
- Increased survival rate
- Offshore products : higher quality

Spat/**semi-rearing (18 month) oysters** (foreshore)

IMTA Offshore production of **winkles** (8 tons):

- Jumbo size products
- Use fouling as feed
- Increase the water and nutrient circulation in bags
- Reduce bacterial load by eating dead oysters
- No antibiotic or artificial feeding
- Offshore products : higher quality

Winkles sold in bag of 100g

Customer Relationship

Customers contact them directly for their high-quality products.

Distribution based on the company's reputation.

Several species to offer to the buying consumer.

Channels

BtoB model: directly to restaurants, oyster farmers or distributor

BtoC model: directly consumers

Customer Segments

Oysters (fresh products):
Mainly European market (80%)
(Italy/Switzerland/Ireland)

National market

Customers :
Oyster farmers for spat and semi-rearing (oysters of 12 month)

Offshore IMTA oysters :
Wholesalers and Oysters farmers for non-purified oysters of 3 or 4 years
Gastronomic Restaurants and end consumers (food industry)

Winkles (fresh products):
Consumers
Oyster farmers
Distributor (Poiscaille)

Cost Structure

Cost production: structural costs (buildings, oyster farming equipment, boats) and mainly human resources (60%)

R&D costs

Cost of a farm and of a second-hand barge: €150,000

Revenue Streams

Sales of products (fresh oysters and winkles) : Winkles prices: around 30€/kg
Oysters prices: 3 times the price of a classic oyster

Public & private fundings
Turnover: €360,000 . Desired €420,000 turnover by 2022. €520,000 in 2023.
Winkles: 10% of turnover

1.1.2 Synthesis

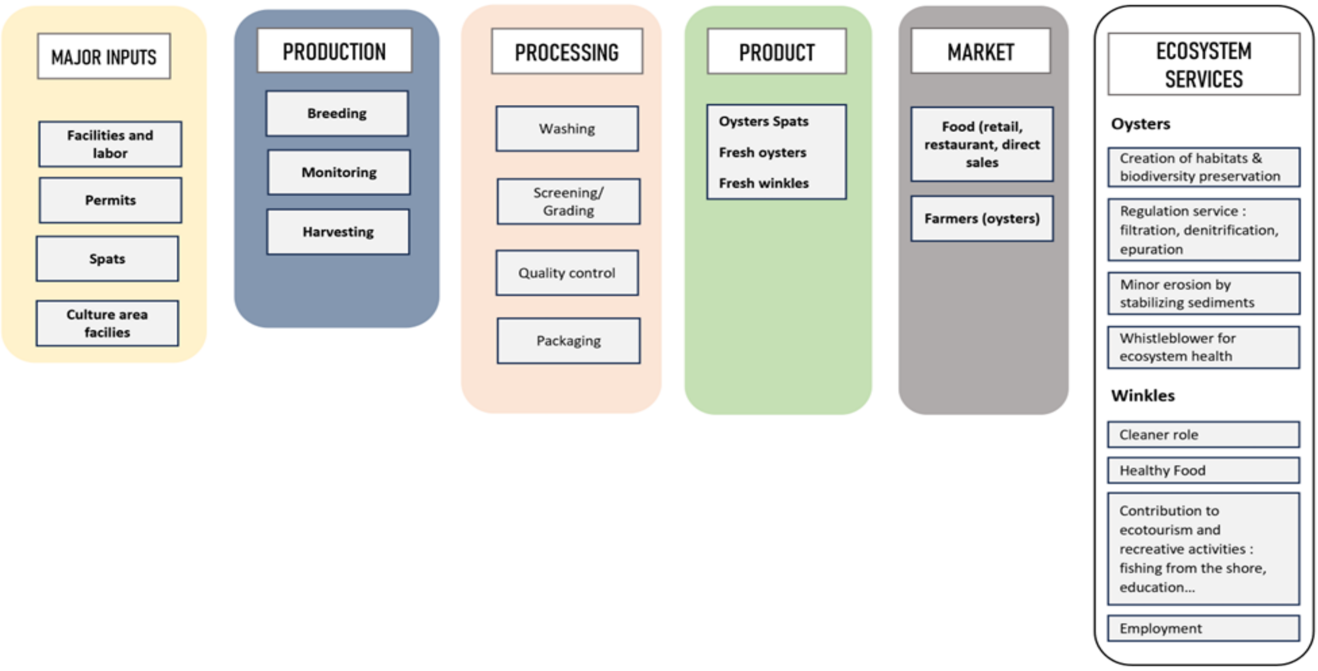


Figure 46: Winkle and oyster value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation TQC)

Internal factors

STRENGTHS

- Growing winkles combined with oysters requires less R&D because the combination of species is quite easy and the profitability is quickly reached
- A strong internal R&D and close partnerships with research organisations (shared knowledge)
- The control of the production process and oysters' life cycle
- IMTA reinforced their business model, especially as this type of farming should enable them to fight against oyster mortality.
- Capacity to adapt the harvest and sorting process with the mix species
- Offshore system reducing the pollution risk from coastal areas (agriculture effluents discharged into the sea…) and optimising farming.
- An assertive entrepreneurial & business approach
- The value proposition: producing high-quality oysters and winkles in offshore farm (unique case).
- Several sales segments to make sure that they can sell all products.
- A competitive advantage on competitors: winkles are a high-value species, but not many farms invest in R&D to produce them at large scale + an open sea oyster production = rare + high quality and distinctive taste.
- The use of an IMTA system is also positive for their image and their dynamism

WEAKNESSES/CHALLENGES

- Reliability on robust equipment because of an open sea system
- The need to develop and to finance regular R&D projects on the IMTA system (strong effort: funding watch, set up applications, administrative costs…)

External factors

	Opportunities	Threats
Political	• Support from supranational organisations and policy makers to develop the booming aquaculture industry (Ahier, 2018)	• Complex and long regulatory process for setting up aquaculture farms (minimum 12 months)
Economic	• The support of investors who share this same sustainable vision • A growing market for French high-quality winkles (doris.ffessm.fr) • Local production of seafood products is only covering a quarter of the overall consumption • Development of rural/coastal areas by providing employment and stimulating economic activities.	• Need to buy winkles spat (from Ireland) and risk of price fluctuation • Lack of knowledge about IMTA in France and doubts about their profitability. • Public distrust of the environmental risks caused by aquaculture farms
Social	• Producing oysters in the open sea gives consumers a good image of natural farming, with no artificial feed or pollutants => respect of the environment • Good French stakeholders' perception of IMTA as a means of limiting environmental impacts (Ahier, 2018)	• Lack of visibility and understanding of IMTA. • Aquaculture in France is facing a lack of attractiveness (difficult working conditions, low social acceptance)
Technical	• Development of R&D in aquaculture • Raising of offshore wind energy zones in France: an opportunity for the offshore aquaculture site	• Strong resistance of the equipment on open sea environment to resist to swells, storms • Difficulty to recruit with adequate skills, to attract or to maintain because of tight labour
Environmental	• Better water quality offshore because there's less land-based pollution risks (fertilisers, pesticides, etc.). • Seafood products are a source of protein intake	• Adequacy between the open sea production site and a sufficient and continuous nutritional input: difficulty to guarantee (dependence = a risk) • The risks of natural (turbidity, waves, winds, swell), diseases, or accidental (oil) hazards and the impact of the climate change
Legal		• Necessary sanitary authorisations to be able to sell their own products resulting from their innovation. • Complexity to encourage IMTA farm: multiplicity of authorisations (per species) • Maritime safety policies in the implementation of offshore production site

1.2 Commercial IMTA farm – South African farm

LAND BASED AND SEMI-CLOSED SYSTEM - ABALONE AND *ULVA* (SOUTH AFRICA)

Located on the Buffeljags site in South Africa, this company produces abalones (*Haliotis midae)* and *Ulva* in a land-based and semi-closed system.

Description of the South African IMTA commercial farm

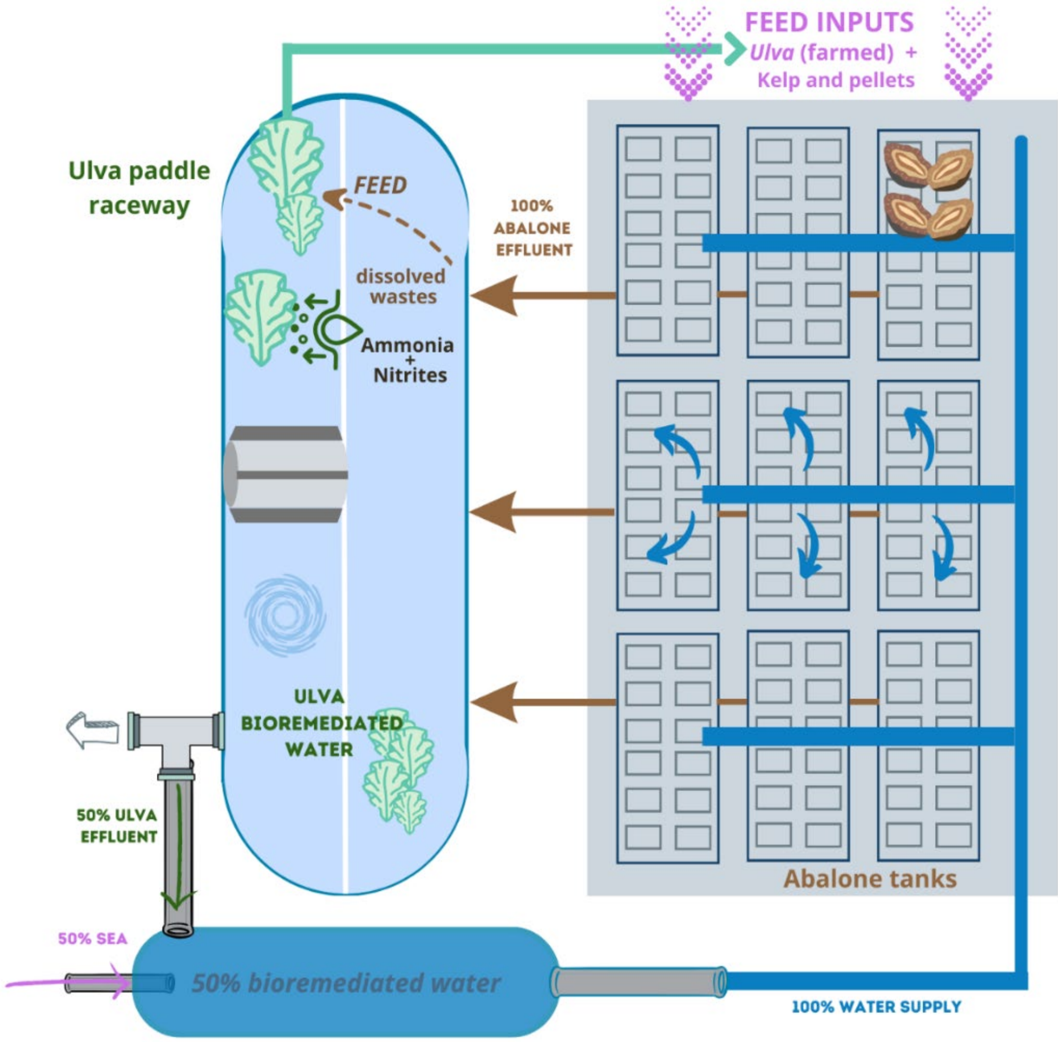


Figure 47: Abalone-Ulva IMTA farm example in South Africa (Source: producer, creation: PMBA)

1.2.1 The Business Model Canvas

The Business Model Canvas

IMTA FARM – LAND BASED AND SEMI CLOSED SYSTEM

ABALONE / ULVA

SOUTH AFRICA

Key Partners

- **Investors :**

Private / shareholders
Public funders (7%)

- **Upstream partners :**

Feed manufacturer
Representative bodies and professional organizations (The Abalone Association of South Africa)
R&D academics (university in Australia, New Zealand and Sweden, University of Cape Town) and like-minded research projects
Governmental organization (i.e. Ministry of Environment, Forestry and Fisheries, Department of Trade and Industry)

- **Downstream partners :**

Sister company of the group :
100 % processing for canned and dried products)
100 % : sales and marketing
30% feed pellet production

Wholesalers
Intermediate in the retail sector

Key Activities

IMTA production

Production process: all the value chain (hatchery, parameters monitoring, and processing)

Monitoring and maintenance

Logistics ; packaging and transport (for live products)

Management / human resources

R&D

Key Resources

Private land and suitable localization

Feed for abalone

Qualified human resources

Electricity (for recirculation system and aeration)

Wind turbines

Access to processing/live packing for exports

Species & producer reputation: second most valuable abalone species in the world

R&D support and scientific knowledge

Value Propositions

IMTA production system

Production of **Abalone** (*Haliotis midae*)

- High quality product (second most valuable abalone species / fed 75% or more on natural feed)
- Partially fed on natural food
- Significantly increased growth rate
- Fresh products, canned, frozen and dried

Production of ***Ulva spp***

- Environmental and quality benefits (enhance the growth, health, product quality and sustainability / Improved water quality of the water returning to sea / reducing the pressure on the kelp resources / reduce disease propagation)
- High nutritional and environmental potential

Customer Relationship

Frequent customer visits (international travels) and fitting the supply by identifying their specific needs

Attending fairs: i.e.food expo's (China, Hong Kong, Singapore and Taiwan)

Distribution based on the producer/country reputation (consistent supply and quality)

Channels

BtoB (indirect distribution channels) :

50 % : specialized agency located in Ireland (specialized in shellfish in Asian markets)
50 % : wholesalers in Hong Kong and Taiwan

Customer Segments

Abalone :

Export market

International customers (mainly Asian customers) (100% of the abalone production) :
Wholesales in Hong Kong, Taiwan and China
Retailers in Singapore and Malaysia

Fresh products (80% of the production):
wholesalers to restaurants
wholesalers specialized in fish markets or in hotel chain.
Canned products (10%) : sold mostly to wholesalers and then to retail chains

Remaining 10% exported for specialized wholesale houses : 1 – 2% dried abalone and +-8 % frozen

Cost Structure

Human resources (30%)
R&D costs (3.5% of the total cost)
Production costs : Feed / raw material (32%) / Environmental assessment/sustainability
Structural costs : (infrastructures, fluids, technical facilities) (24%) / Wages (27%)
Processing and packaging for transport
Subcontract costs (for dried and canned products)
Transport cost (airfreight or ship)

Revenue Streams

Public grants (5 to 7% of the investment) : Aquaculture Development Enhancement Program for 30% of the capital investment and CASIDRA (agricultural fund in the Western Cape)

Private fundings (>90% of the investment)
Shareholders (direct transfers)

Sales of products (abalone) : COD (on delivery for fresh) and COC (on command) for canned)
Average per kilogram : Live - $ 30 €/kg ; canned - 450€/box ; Dried - 330€kg

1.2.2 Synthesis

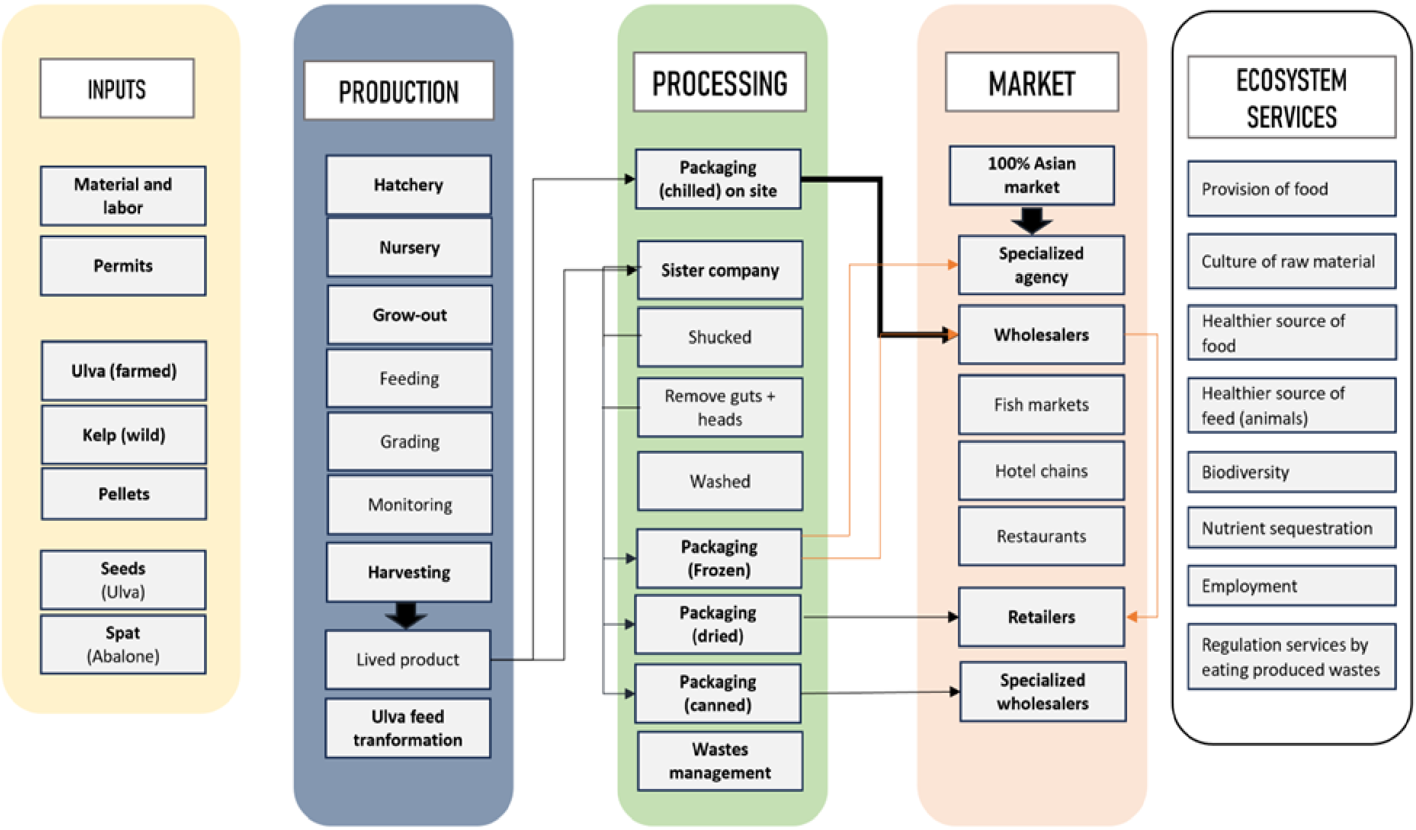


Figure 48: Abalone and Ulva value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation PMBA)

Internal factors

STRENGTHS

Technical

- Electricity production with wind turbines: optimisation of production costs + stabilise the voltage
- Significantly increasing species growth rate (Cyrus et al., 2015)
- Strong partnerships with research organisations (shared knowledge) and R&D stakeholders
- Improvement of farm efficiency by the circularity process
- More than 50% of natural feed using *Ulva*

Environmental

- Traceability: 100 % control of the production process
- IMTA cluster system: reduces the probability of experiencing losses due to HABs by over 90% and mitigate diseases
- Reducing environmental impacts (improves the quality of water returning to sea)
- Biosecurity: it's a major threat for abalone and IMTA is reducing parasite loads

Economic

- High-value and quality products (sought-after by the Asian markets)
- High reputation: second most valuable abalone species
- Strong private shareholders and direct transactions: no pressure on cash flow
- Production of *Ulva* as a feed material: decreasing feed costs
- Production and use of *Ulva* as biofilter: water recirculation decreasing water supplies
- Marketing advantage by using IMTA: by using a greener production system and natural feed
- Market and wholesaler faith
- Private lands: autonomy of the farm
- Diversification: the farm is developing new species like sea urchins

WEAKNESSES/CHALLENGES

Technical

- R&D: Continued research to manage the IMTA system to go onto 100% recirculation reducing the risk of losing stock due to Harmful Algal Blooms.
- Skilled human resources

Economic

- Marketing to face competitors: Australian, Chilean, and Californian species are also high-quality products, so putting efforts in marketing and brand image is key to keep the status (country and species reputation)
- Valorisation with a certification of the product to increase the market differentiation, traceability, easiest profit margins and profitability
- High investment costs (infrastructure)

External factors

	Opportunities	Threats
Political	• Strong group dynamic in SA within producers • South African government prioritising aquaculture in its National Development Plan to 2030: support investment in the development of aquaculture with aid	• Kelp resource management: political resource; (take it away from current concession holders to give it to community fishers) • Minimal research on aquaculture socio-economic dimensions and minimal technical data to communicate to communities (Morake, 2015) • Restricted access to public and private land and water bodies for aquaculture purposes
Economic	• Private fundings • New market opportunities for revenue diversification • Asian market is looking for eco-labels, especially in the high-end market: increasing the value of IMTA products	• Long return on investment: 4 years for a small/family farm / higher for a larger farm • Increasing transport costs (COVID, higher fuels costs…). • External funding dependency
Social	• Local benefit: Increasing the coastal areas and communities: job creation, environment preservation, economic benefits • Partner dynamic: professional organisations, research partnerships, local dynamic •	• Low general awareness of South African communities on aquaculture • IMTA misreading • Criticism of marine aquaculture due to the negative perception of the environmental impacts and a lack of knowledge and data on the socio-economic impact (Morake, 2015)
Technical	• Innovations in aquaculture to reduce risks and to develop markets: R&D	• Skilled human resources • Growing demand for technological skills (digital technologies) • Slow adaptation of producers to new technologies and slow integration of new technology due to the costs • Lack of technical data on environmental effects of IMTA • Lack of knowledge within the public and producer community regarding the IMTA model benefits • Degradation of electrical infrastructure in South Africa

External factors

	Opportunities	Threats
Environmental	● Market demand for eco-certified seafood in sustainable aquaculture system ● Circularity and waste management ● Social perception on natural feed inputs ● Reduced pressure on wild stock populations of abalone and kelp	● Impact of climate change on seawater supply and temperature ● Biosecurity and disease spread
Legal	● Labelling products and branding	● Administrative slowness ● Authorisations and permits delivery processes Weak feedback and/or support from sector representatives and associations on IMTA

2 ASTRAL IMTA Labs: Prospective business models analyses of pilot sites

2.1IMTA Scotland - case study

OFFSHORE IMTA - SEAWEED AND OYSTERS (SCOTLAND)

Located along the western coast of Scotland, this system integrates seaweeds and oysters within an open-water, low-trophic aquaculture site. It operates a submerged tensioned grid system which provides the infrastructure to develop and validate a wide range of cultivation approaches seeking to efficiently combine the cultivation of seaweeds (*Saccharina latissima* and *Alaria esculenta*) and European flat oysters (*Ostrea edulis*).

Description of the IMTA Lab in Scotland

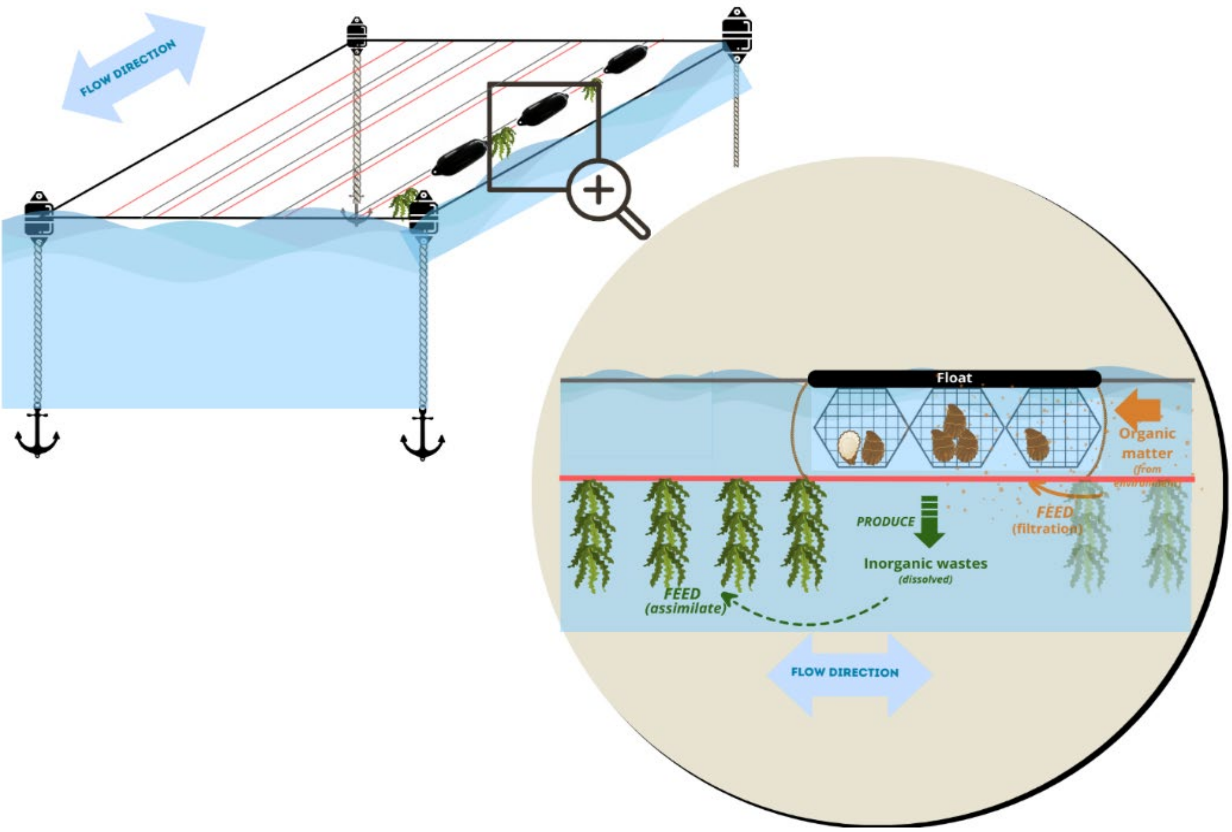


Figure 49: The IMTA Lab system organisation in Scotland (Source: SAMS, creation: PMBA)

2.1.1 The Business Model Canvas

The Business Model Canvas

IMTA LAB / OPEN WATER SYSTEM
SEAWEED AND OYSTER

SCOTLAND

Key Partners

- **Upstream partners :**

Funds provider; public/private

Government

Marine operator (if rental boat)

Juveniles oyster suppliers & producers / Seaweed nursery

Professional organizations: AlgaeUK Network, Association for Scottish Shellfish Growers (ASSG), Native Oyster Restoration Network (NORA)

- **Downstream partners**:

Research organization for collaborations related to seaweed compounds as well as seaweed/shellfish health based in the UK and Europe

Processors

Transport society

Key Activities

IMTA production system
Production process : Seeding / nursery or hatchery, harvesting, cultivation
Grading (for oysters)
Monitoring
Installation and maintenance
R&D
Processing
Sales and marketing

Key Resources

Site location and licenses

Supply of infrastructures and equipment

Supply of juveniles and seeds

Qualified / Skilled human resources

Marketing

Feed

Value Propositions

Product developed through a sustainable IMTA system

Production of **kelp** *(Saccharina latissimi / Alaria esculenta)* :
- Improved accessibility of biomass by extending the optimum harvesting period from two months to four months
- Stimulated growth (adding nutrients from shellfish)
- Chemical, bioactive properties

Hypothesis of product format : (dried products (mainly); fresh frozen, flakes, salted)

Production of **oysters** (*Ostrea edulis*):
- Provide an potential additional income to the seaweed culture
- high value shellfish
- Native shellfish from the country/area
- Bioactive properties (zinc, selenium, omega3 fatty acid…)

Hypothesis of product format : fresh, smoked

Potential ecosystemic services (bioremediation…)

Customer Relationship *

Direct feedback from distributors

Direct feedback from customers if direct sales

Potential IMTA branding

Reputation of the products

Channels *

Outsourcing
Store or internet based

Oyster food market :
Retail / fishmongers / wholesalers / restaurants /direct sales

Seaweed market:
Wholesalers, industry processors

Customer Segments *

Oysters :
Domestic market :
Food / table market : mainly fresh products
Rewilding/spat market : for local producers

Shells for soil improvement in agriculture, civil engineering and biomaterials

Export market :
EU market : food industry / fresh products

Seaweeds : wide range of potential segments
Food market (optimum of 25 tons/year) – Food processors
Bioactive market for cosmetics, nutraceuticals and pharmaceuticals
Agriculture : seaweed fertilizer
seaweed product developers (that struggle to achieve adequate supply from natural populations)
Biomaterials
Biofuel

Crops : Seaweed growers

Domestic and EU market

Cost Structure *

Infrastructure :
Site installation (seabed mooring, cushion buoys, site marks, etc.) €34500
Equipment (sewed lines/ oysters baskets, etc.) / cost of material and services : €245400
Boat (purchasing price €230 000/rental costs - 290 to 1500€ day rate)

Licensing : significant investment (€11 000)

Site Maintenance (€11 000/year)
Human resources (1 to 5 persons) (80% seaweeds / 20% oysters) : cost of time €138 000/year

Revenue Streams *

Public & private funding

Sales of products :
Seaweeds : Food market : sale value €2.18-2,3 per kg of fresh wet biomass
Oysters : Food market : first sale value of €0.69 per shell
Rewilding market (e.g. €0.12 per 25 gram oyster)

Funding mechanism for potential Ecosystem services (premium price…)

**Prospective*

2.1.2 Synthesis

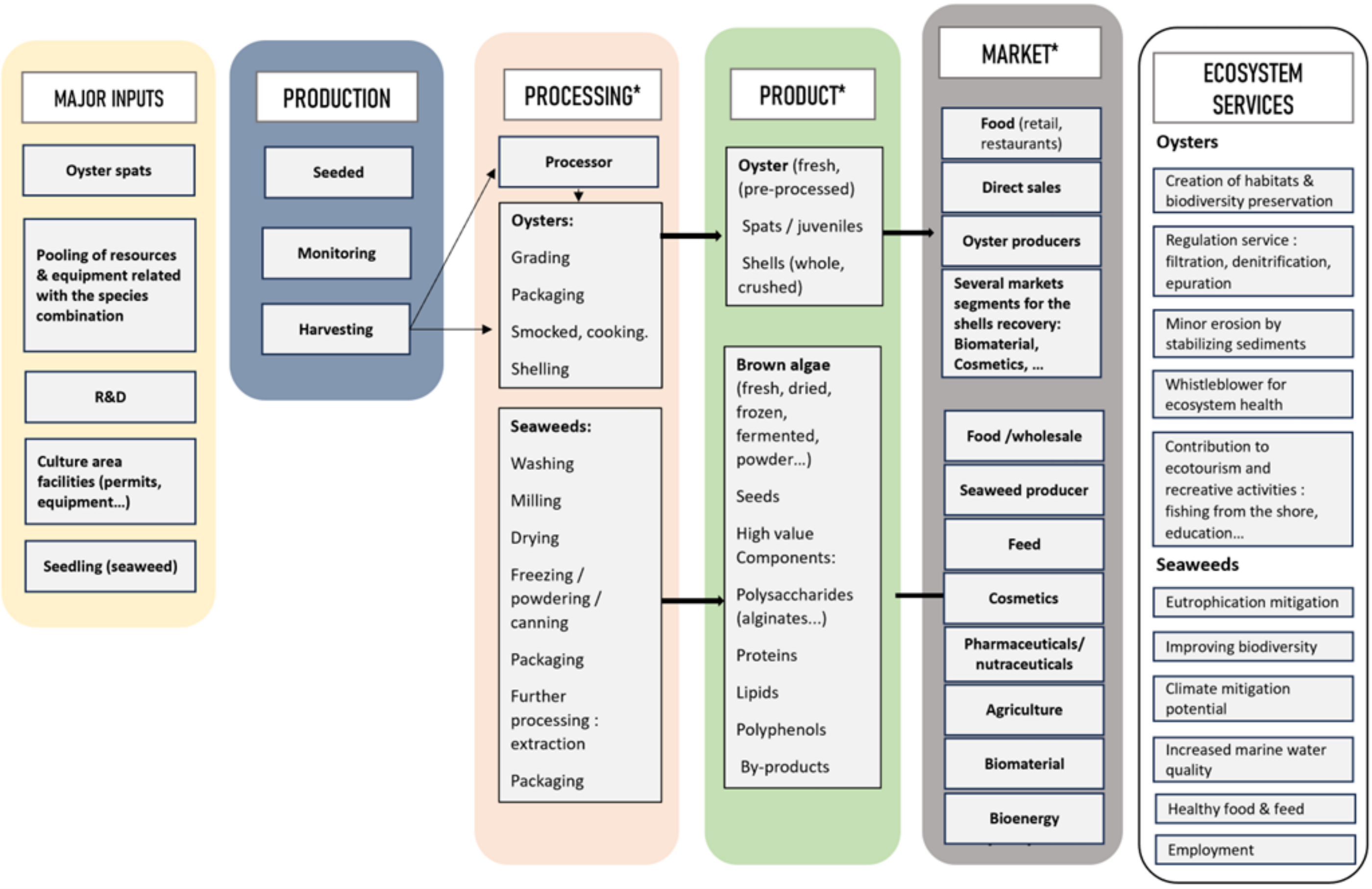


Figure 50: Oysters and brown seaweeds IMTA value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation TQC)

Internal factors

STRENGTHS
Technical • Increasing growth rates through nutrient income from the action of filter shellfish to seaweeds • Complete utilisation of the space: strong practical synergies • Pooling of some equipment: seaweed buoyancy using oysters • Low-cost cultivation infrastructure for oyster production (one equipment for 2 species) • Increasing accessibility: extension of the harvesting period from two months to four months (seaweed) and improve the accessibility of biomass throughout the year • Mainly local markets: reducing transport costs • Develop a reliable low-cost direct seeding method • Carbon retention by seaweeds **Environmental** • Oyster: filtration of particulate organic matter from the surrounding environment: efficient circulation system • Astral LCA highlights the potential of low-trophic species to improve the recycling of organic matter and nutrients “Key aspect of the bioremediation potential of IMTA is the balance between nutrient input and removal” **Economic** • Additional income (more species for the producer) • 100% public fundings • Once capital costs are established, fixed cost are modest for seaweeds
WEAKNESSES/CHALLENGES
Technical • Open water system: dependency to water quality and to surroundings environmental incomes / climate • No organic certification for seaweeds due to the addition of artificial nutrients (inorganic nitrogen) during the nursery stage • Expensive technical equipment required (boat, mooring, oyster lines) • Lack of qualified human resources • At this small scale: no strong ecological synergies by cultivating different trophic groups • Spat availabilities in Scotland **Economic** • Profitability of IMTA approach not yet confirmed • High capital costs at the beginning

External factors

	Opportunities	Threats
Political	● Support of The Scottish government (IMTA) ● The Scottish aquaculture sector is technologically advanced as a driver of productivity ● Advantages of carbon retention by seaweed: to be promoted	● Conflicts for space, especially with the tourism sector in Scotland ● Lands access: lease seabed to The State Scotland and the Crown ● Links between schools, training program and jobs in aquaculture ● Cost and time and complexity to get planning permission, leases, and licences ● Regional differences in the licensing process due to local interpretation ● Divergent views on aquaculture development between planners, licensers and the government
Economic	● Expensive market of seaweed in the food industry. A growing demand: 7-10% per annum (Marine Scotland, 2022) ● Large seaweed market potential: rapid development on snacks, meals, condiments and skin-care products…	● Long return on invest: about 3 years for the first crop ● Regarding the IMTA misreading: there is not a strong demand for IMTA products in particular ● Seaweed aquaculture is currently too expensive to reach large scale markets ● High level of capital funds requested: Costs of premises, equipment and locations (Marine Scotland, 2022) ● Seaweed is not currently considered as economically viable: The start-up investment cost, the cost of seeded lines in Scotland); the relatively low value of species that can currently be cultivated at sea; the labour-intensive process (Marine Scotland, 2022) ● Small market of oysters in Scotland and strong competition with France, Ireland and Netherlands ● Seaweeds: competition with France, Spain on sea vegetables and Portugal on bioactive products (Marine Scotland, 2022)
Social	● Consumer's quest for sustainability: Consumer awareness and interest in sustainable sources of healthy food, particularly plant based. (Marine Scotland, 2022) ● Seaweeds: New market opportunities for revenue diversification (nutraceutical) ● Growing interest in protecting, regenerating and restoring native oysters species in European waters	● IMTA misreading: Low public awareness as IMTA is still not well known by the public and the consumers ● For seaweeds: high value food markets are poorly defined ● Scottish society attach a high importance to minimising environmental damage from aquaculture (Whitmarsh et al, 2006)

External factors

	Opportunities	Threats
Technical	• Innovations and R&D projects in aquaculture to reduce risks and to develop products: • Open water system: reducing the land use • Need for more professional training	• The availability of skilled staff • Growing demand for technological skills (digital technologies) • Development of new technologies – adaptation needed by producers • Lack of technical data on environmental effects of IMTA • Lack of knowledge within the public and producer community regarding the IMTA model benefits, the seaweeds market • Complexity of IMTA production system and technical challenges • Lack of commercial experience in IMTA • Spat availabilities • Quality and consistency of supply because of seasonality (seaweeds) • Low processing facilities for Scottish producers (for seaweeds): preprocessing facilities
Environmental		• Impact of climate change on sea temperature • Disease propagation and pest in open water / pollution • Seaweeds fragility: wave action wears on the seaweed fronds causing a 'whipping effect' (loss of large parts of the frond lengths) • Sea lice: biosecurity process required
Legal	• Existing Organic certification: the ASC-MSC Seaweed (Algae) Standard • Environmental certification: ASC MSC seaweed standard for 'environmentally sustainable and socially responsible seaweed production'	• Authorisations and permits delivery process / rates • The Seaweed Cultivation Policy Statement (SCPS): designated shellfish waters where waters and product quality are monitored and protected for harvesting products for human consumption. • European standards and the soil association standards do not allow use of organic nitrogen anywhere in a process to certify • The time taken to receive a marine licence for cultivation

2.2 IMTA Brazil - case study

LAND BASED AND RECIRCULATION SYSTEM - SHRIMPS, FISH, SEAWEEDS AND OYSTERS (BRAZIL)

This pilot production system is located in extreme southeastern Brazil, in a humid subtropical climate. This is a land-based IMTA system established under a greenhouse, using recirculation and bioflocs, producing various species: Marine shrimps *(Litopenaeus vannamei)*, Tilapia (*Oreochromis niloticus*), seaweeds (*Ulva* and *Marine asparagus*) and oysters (*Crassostrea gasar*).

Description of the IMTA Lab in Brazil

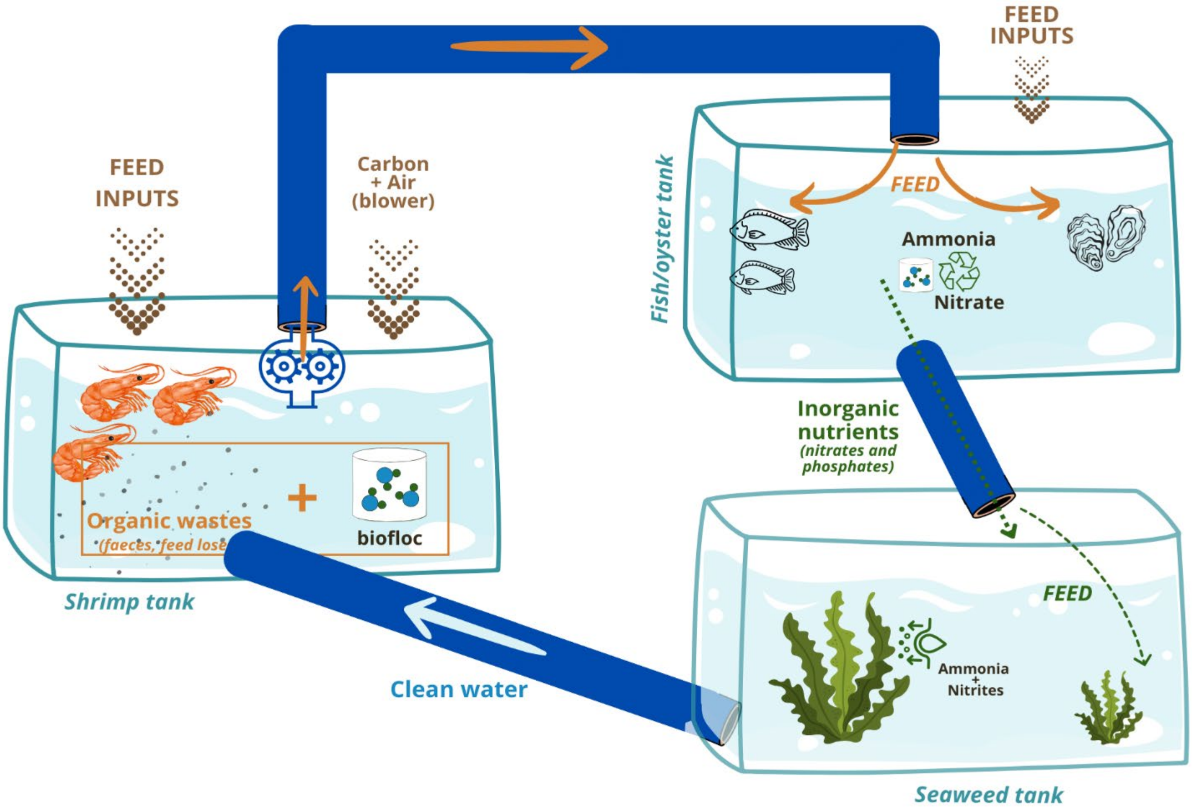


Figure 51: Tilapia, shrimps, seaweeds IMTA system (Creation : PMBA)

2.2.1 The Business Model Canvas

The Business Model Canvas

IMTA LAB / RECIRCULATION LAND-BASED
SHRIMPS / FISH / SEAWEED / OYSTERS

BRAZIL

Key Partners

- **Funders:**

Credit provider (BNDES)
Government (public programs)
Private firms : Ocean 14 Capital / Aqua Spark

- **Upstream partners** : local and national

Juveniles suppliers : shrimp and fish from specialized laboratories / oysters from local producers
Equipment suppliers (local or national) : agriculture company / specialized suppliers
Scientific partners : university and scientific networks

- **Downstream partners :**

Transport company
Processor
Agents/distributors
Communication agency

Key Activities

IMTA production
Hatchery
Water quality and size monitoring
Feeding for fish and shrimps (input twice a day)
Growth assessment (fish and shrimps) (weekly)
Harvesting
Processing and sales / marketing
R&D and product development

Key Resources

Suitable area of implementation: availability of water supply and suitable environmental criteria
Structure and equipment: greenhouse with sets of tanks, technical equipement
Authorizations and permits
Food inputs
Juveniles
Human resources
R&D to increase productivity / product development

Value Propositions

Various species produced in the same area : Performance

Production of **Marine white shrimp** :
- Increasing growth with biofloc
- Allow no water renewal

Production of ***Tilapia*** :
- *R*educe feed inputs (50%)
- Highly consumed and easily sold in many forms

Production of **Seaweeds** (*Ulva* and *Marine asparagus*) :
- Absorb dissolved nutrients (nitrates and phosphates) increasing growth rates
- Removing toxic compounds (ammonia)
- Producing saleable plant biomass
- Marketable components (polysaccharides, nutrients, vitamines)
- High nutritional value

Production of **oysters** (Native oyster)
- Control the biofloc concentration (filter) reducing food input

Customer Relationship *

Feedback from distributors

Sale on site / direct feedback from consumers : direct loyalty

Year-round availability of products

Engaged staff

IMTA branding

Channels *

Tilapia : BtoB approach
Processors and retail markets
Wholesalers for restaurant and fishmongers

Shrimp : BtoC (direct sale to consumer)
BtoB : distributors/retailers

Oysters : BtoB : Processor and distributors

Customer Segments *

Tilapia :

Domestic market (99%) :
Food industry (99%) : Mainly fresh whole fish and frozen fillets for restaurants and fishmongers

Niche markets : baitfish, ornemental, juveniles production

Export market : USA
Potential futur markets : Europe
Frozen : 85% / Fresh : 25%

Shrimp :

Domestic market (+90%)
Food industry : supermarket chains, restaurant, hotels -- Mainly fresh products

Export market : USA /Europe / Middle East
Mainly fresh

Seaweed : Raw material (mainly)
domestic market (low)
Food industry and ingredient for feed (mainly)
Possible use in agriculture
Export market (low)
Cosmetics, food industry and nutraceutics : Europe/Latin countries

Oysters :
domestic market (mainly) for food industry

Cost Structure *

Initial investment :for 1 hectare of productive area, requires an initial investment of about 320 000 euros.
Land and area implementation : License (5% of the total investment)
Construction : 55% to 68%
Acquisition of the geomembrane: 30%
Aeration and water pumping system 15 to 25%

Production costs : Juveniles / Feed inputs / Monitoring and water quality assessment
Human resources: Shrimps (49%), Tilapia (49%) and Ulva (2%)

Revenue Streams *

Sales of products :
Oysters : between 1.10€/dozen and 2.20€/dozen
Tilapia : Wholesales : between 1.75€/kg and 1.80€/kg
Retail : average of 5€/kg

Shrimp : Local : 3.69€/kg (September 2023) / Export : between 11 and 20€/kg
Frozen (USA) : between 8€ to 24€/kg

**Prospective*

2.2.2 Synthesis

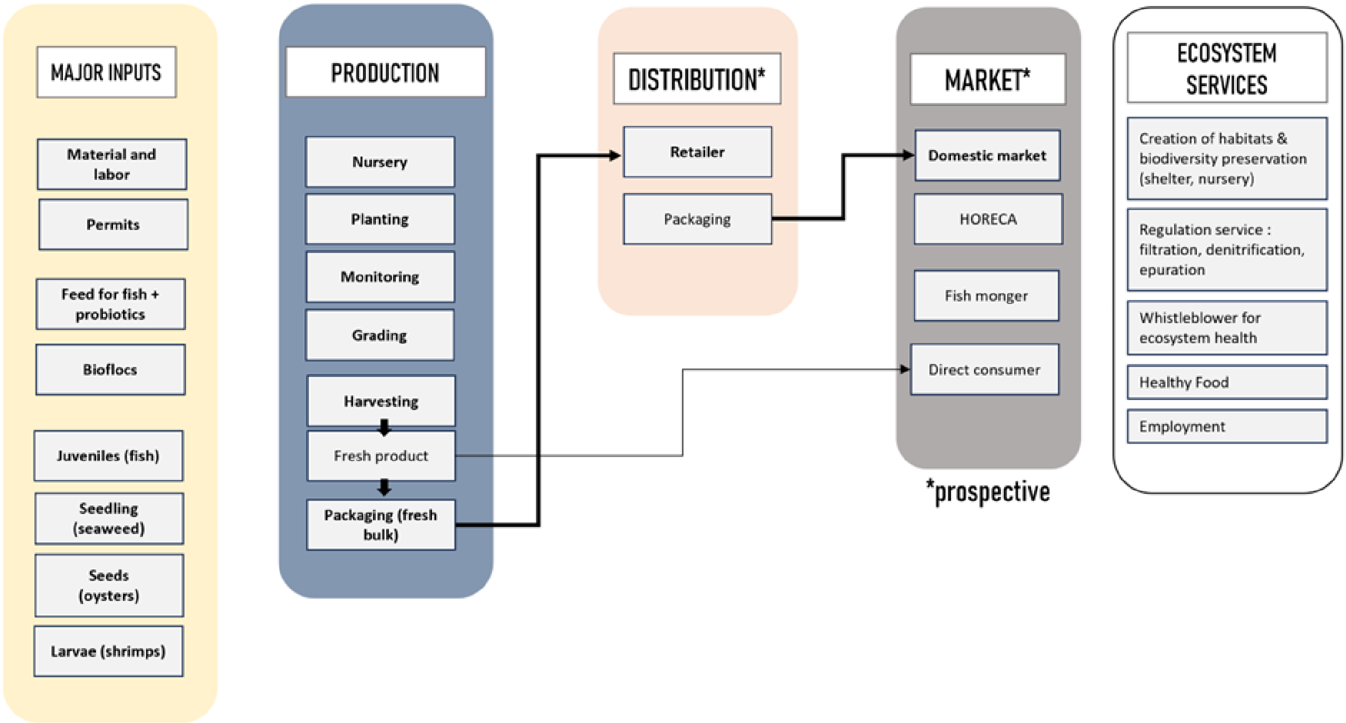


Figure 52: Oyster value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation PMBA)

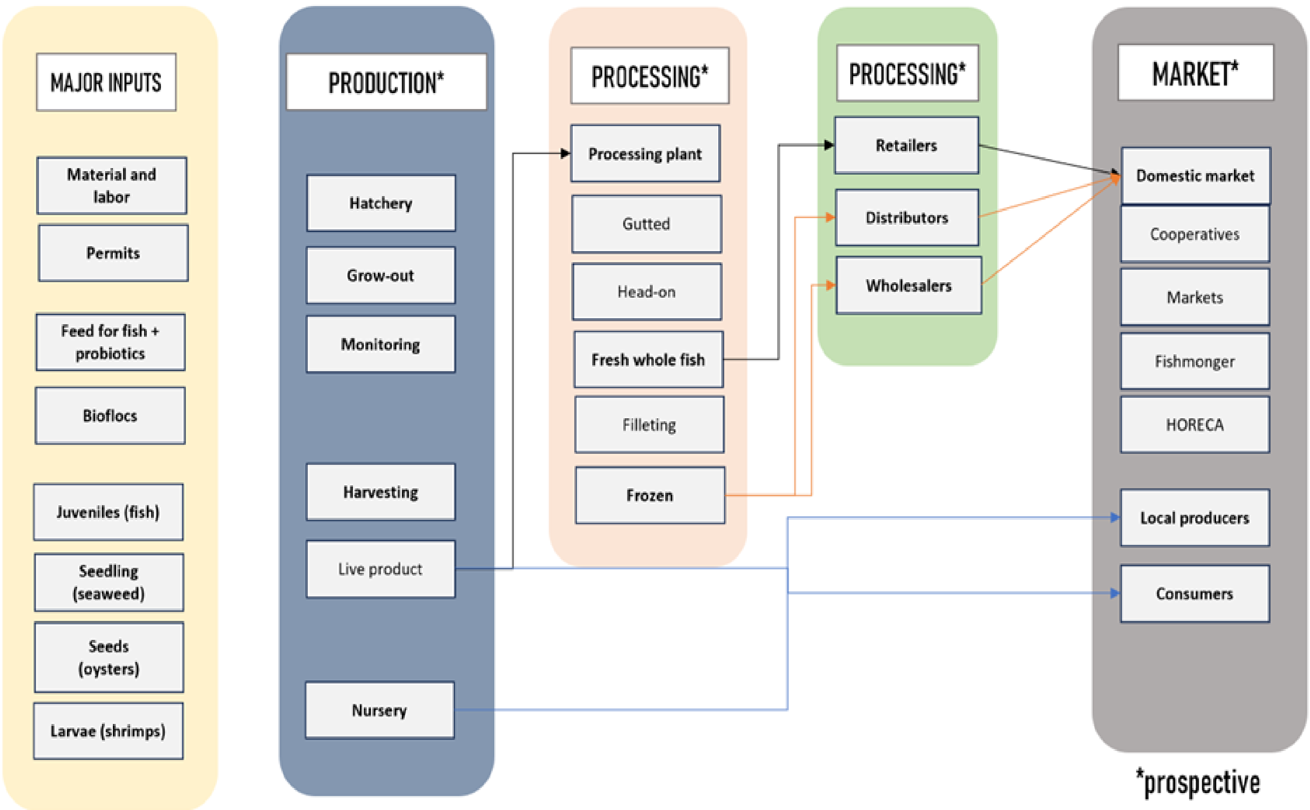


Figure 53: Tilapia value chain for this system (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation PMBA)

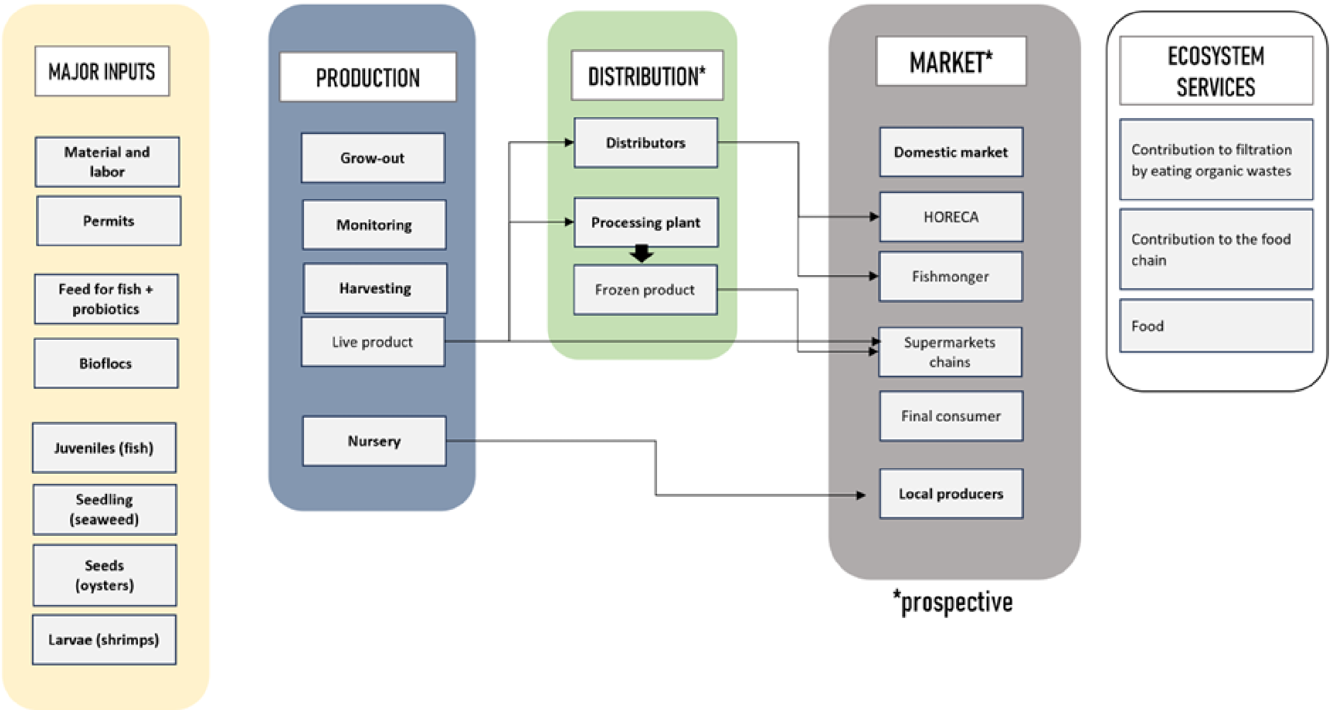


Figure 54: Shrimp value chain for this system (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation PMBA)

Internal factors

STRENGTHS

Technical

- Production of 4 species in the same system
- Avoid the water change (stable quality) by the presence of AOB and NOB
- Use of bioflocs: increase growth rate for seaweeds, oysters and shrimps
- Circularity: using species using resources and compounds produced within the system
- Minimal use of space by pooling equipment and increasing production densities: reducing occupancy and site size
- Greenhouse: provide protection against predators and pathogens introduction
- Adaptability of shrimps to different conditions (temperature, food, light)
- Recirculation: controlled environmental criteria
- Recirculation is reducing the use of treatment: Bioflocs enables the conversion of toxic ammonia to nitrate, improving the water quality and providing microbial nutrients improving the overall productivity

Environmental

- Closed system and limited water exchange: reduce the impact on surrounding environment
- Re-use of compounds in the system itself: reducing effluents
- Use of bioflocs (bacteria) to reduce toxic components
- Astral LCA confirms that the IMTA system with shrimps, tilapias and seaweeds has lower environmental impacts per kg of biomass produced than the monoculture system with shrimps

Economic

- Thanks to IMTA system: improved productivity with lower amount of feed required, lower material and energy needed for feed production and transportation (Astral LCA)
- Production of large sized shrimps to overcome competition with artisanal fishing
- Production of shrimps during periods when fishing is restricted or has lower production
- Recirculation of water reducing the water supply by using it several times

WEAKNESSES/CHALLENGES

- Power outages and equipment failures causing oxygen deficiency leading to mass mortality: dependency to equipment
- Biosecurity: presence of vibriosis in shrimp and presence of Streptococcus in fish
- Lack of trained human resources to operate and understand the system: system complexity
- High temperature needs to be maintained high: increasing costs and location reliability
- High cost of setting up the infrastructure (including greenhouses, tanks, pumps, filtration system and electricity: used for aeration to maintain the dissolved oxygen concentration in water especially for shrimps' production)

External factors

	Opportunities	Threats
Political	● The Brazilian government is actively involved in the development of aquaculture	● Several licences are required by environmental agencies: long and expensive process (from 6 month to 2 years) ● Competition with artisanal fishing: abundant shrimp supply through fishing reduces the price of cultivated shrimp ● Frequent local changes in government agencies prevent achieving continuous and sufficient investment and to adopt mid-term or long-term strategies ● Dumping measures imposed by US government on shrimp imports from Brazil ● Regulatory uncertainties leading to difficulties to obtain permits and access to credit. ● Environmental laws are unclear and complicated ● Difficult access to public fund for the aquaculture sector ● Lack of standardisation of environmental licensing procedures ● Limited preparation of environmental agencies to review projects
Economic	● Aquaculture is one of the fastest-growing industrial activities in Brazil (gross revenue in 2019 USD 1 billion (€935 million) (Wagner ; 2021) ● Brazil is the fourth largest producer of Tilapia in the world ● High consumption of fish compared to the quantity produced locally, which remains insufficient: market opportunity ● Reopening the European market for Brazilian fish – closed since 2018: new market for exportation (Santos, E. (2023)	● Most small farms in Brazil: produce volatile income and unregulated work ● Return on invest / higher risks in investments: can take few years ● IMTA increase the production costs in Brazil, regarding to monoculture: more resources and time to be implemented ● Lack of commercial/market experience through IMTA farming ● Regarding the IMTA misreading: there is not a strong local demand for IMTA products ● Local deficiency of cold chain impacting freshness of products (crucial for the sales value) ● Tilapia is not a high-value or a high consumed species in foreign countries

External factors

	Opportunities	Threats
Social	● Develop coastal areas and communities through employment, environment preservation ● Access to new emerging market in Islamic countries: search for fish with Halal certification (Santos, E. (2023) ● Increase of Brazilian consumers interest to sea food	● IMTA misreading: Low public awareness as IMTA is still not well known by the public and the consumers ● Activists pressure to farm native species, avoid ecologically sensitive areas, and protect the water quality of waters (Valenti et al., 2021) ● Non-recognition of the value of Brazilian Oyster abroad
Technical	● Innovations in aquaculture to reduce risks & development of products: R&D ● Solid scientific community and strong capacity in aquaculture sector ● Use of bioflocs: particularity to Brazil ● In Southeast Brazil, IMTA models have better results than co-culture systems, in terms of profitability and survival ● Large supply of grains for feed production (for fish) ● Large extension of land and plenty of water supply for pond aquaculture in tropical areas ● Continuous quality control to deliver a premium quality tilapia	● Lack of available skilled human resources: interdisciplinary skills needed (biological, technical, management, marketing, health management) ● Lack of technical data on environmental effects of IMTA ● Lack of knowledge within producers' community regarding the IMTA model benefits ● Complexity of production system and technical challenges ● Loss of production due to energy problem in Brazil
Environmental	● Country rich in natural resources water, lands) ● Land-based recirculation system: reducing impacts on the surrounding environment	● Complex and lengthy licensing application process ● Constraints for exportation: internal demand, logistics, bureaucracy, international and national regulations
Legal		● Price of environmental license in Brazil

2.3 IMTA Ireland - case study

OFFSHORE - SALMONIDS, SEAWEEDS, MOLLUSCS, URCHIN (IRELAND)

This Lab pilot scale production system is located in West Ireland. It is an open-water system located in a sheltered and shallow bay that is not subject to strong swell conditions. Produced species are :

- Fish: Atlantic salmon (*Salmo salar*)
- Seaweeds: Atlantic wakame and sugar kelp
- Mollusks: King scallop and Native oyster/flat oyster
- Sea urchins: purple urchin *(Paracentrotus lividus)*

Description of the IMTA Lab in Ireland

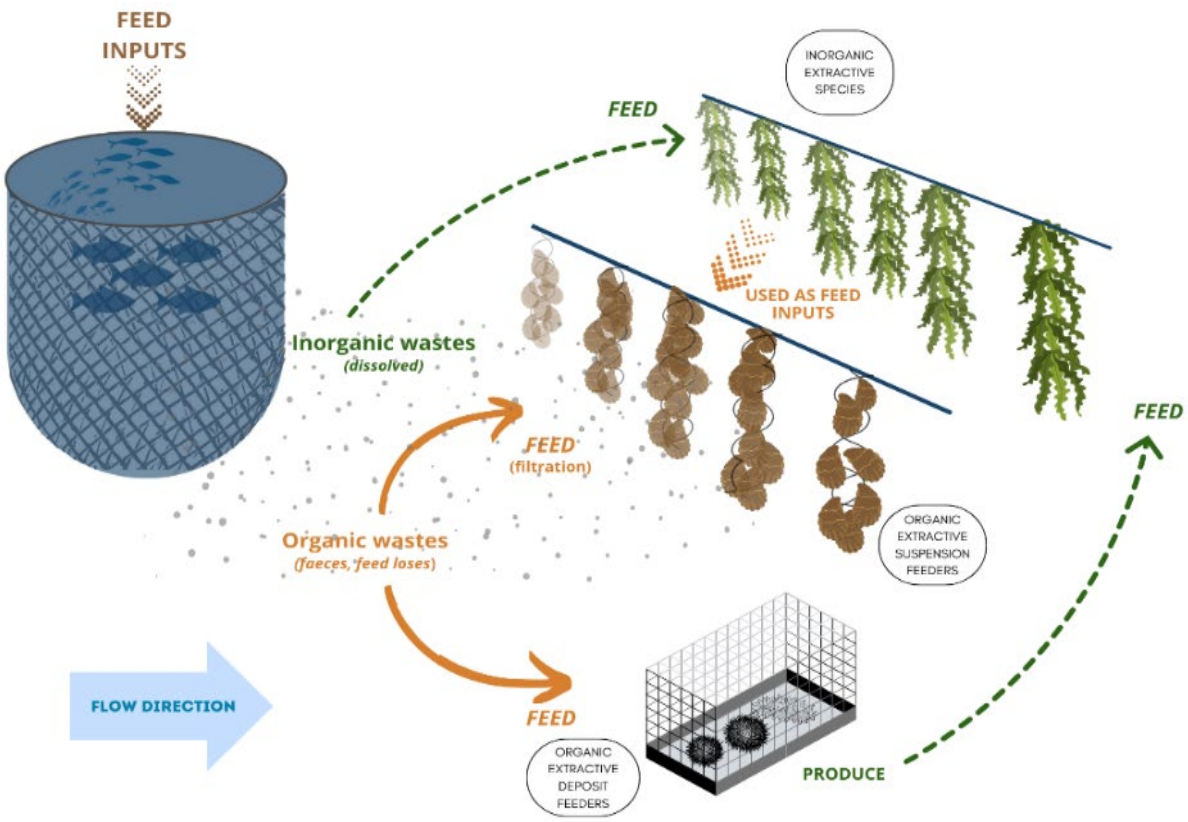


Figure 11: Description of the theoretical system (Source: Marine Institute / Creation: PMBA)

2.3.1 The Business Model Canvas

The Business Model Canvas

IMTA LAB / OPEN WATER SYSTEM
SALMONIDS, MOLLUSKS, BIVALVES, SEAWEED

IRELAND

Key Partners

- **Funding :**

Irish government / publics funds
Private shareholders or investors

- **Upstream partners :**

Institutions and associations:
European Aquaculture Society
Irish Farmers Association – Aquaculture Section
Atlantic Technical University
University of Galway
BIM

Scientific partners: Universities

R&D expertise

Juveniles' suppliers

- **Downstream partners :**

Processor
Wholesaler or agent

Key Activities

IMTA production

Hatchery

Production process

Logistics

Communication

Human resources / management

R&D (research on ongoing funding)

Key Resources

Site location and licenses

Supply of infrastructures and equipment

Supply of juveniles

Qualified / Skilled human resources

Marketing

Feed

Value Propositions

Production of a combination of species

Fish : **Atlantic salmon** (*Salmo salar*)
- high-value species
- Quality image from the Irish production (premium market)
- Fresh or processed products

Seaweeds : Atlantic wakame and sugar kelp
- High nutritional product
- Wide range of applications

Mollusks : King scallop and native oyster
- Premium and pure product
- High market prices
- Fresh or processed products

Sea urchins : purple urchin
- high market value and highly sought-after in Asia

Environmental services:
- bioremediation of wastes and nutrient recycling by seaweeds and filter feeders
- Removing carbon from the site

Customer Relationship *

Marketing and branding: promotion of the Irish brand image

Reputation of products

Range of products available for the customer

Channels *

Outsourcing

Seaweeds :
Domestic market for the food industry : BtoB or BtoC
Domestic market for cosmetic industry : BtoB

Export market : BtoB

Oysters :
Export markets : BtoB (retailer or wholesalers)

Customer Segments *

Salmon :
Domestic market (24% of the local production)
Exports : EU market (France 40%, Poland 20%, Germany 14%, and Belgium, 10%)
→ Fresh products / frozen / smoked

Oysters :
Export : 62% of the Irish production
France (79%) : bulk wholesalers (live products : 99%)
New markets : South Asian country (luxury product) and Netherlands
Domestic market : 38% of the total production

Seaweeds :
Export : EU market : food industry and ingredient for cosmetics (mainly dried)
Domestic market :
Agriculture (mainly) : bulk raw material
Human consumption : restaurants, artisan food producers (fresh products or dried, macerated)
Cosmetics (wet product mainly)
Potential new markets : Oil extraction, biofuel/-ethanol production

Urchins : *100% export*
Main market : Japan fresh product mainly)
European market : France and Mediterranean countries
Fresh mainly
Processed : canned or dried

Cost Structure *

Investment costs: €0.6 M over the past three years (infrastructure and equipment)
Licenses (Aquaculture License - €635 ; Foreshore License - €968.90)

Monitoring activity (annual monitoring costs €5,000.00)

Human resources (costly) : fish (70% of the time) / mollusks (20%) / seaweeds (10 %)
Production costs: Annual costs - €230,000

R&D(Costliest)

Revenue Streams *

Private and public funds / Sales of products (seafish.org)

Salmon : Fresh (6 to 8€/kg) or processed (filets) (more than 12€/kg)
Seaweeds : Retail market (processed) : 55 to 100€/kg
Wholesale : average of 2€/kg of fresh wet biomass
Export : average price €20/kg.
Oysters : Food market (first sale value of 0.70€ per shell) / Table market (1,15€ per 75 gram oyster)
Rewilding market (e.g. 0.1€ per 25 gram oyster)
Export price : FR : 5.80 euro/kg (EUFOMA , 2021) / Asia : (processed product sold to wholesaler) : 11,50 euro/kg

Sea urchins : France(wholesale price): from 10 to 20€/kg (whole piece) / 100€/kg of gonads (retail market) : 130 to 170€/kg of gonads
Gonads (Asia) : highly dependent on the quality of roe : prices vary from 48€ to 430€/kg of gonads

**Prospective*

2.3.2 Synthesis

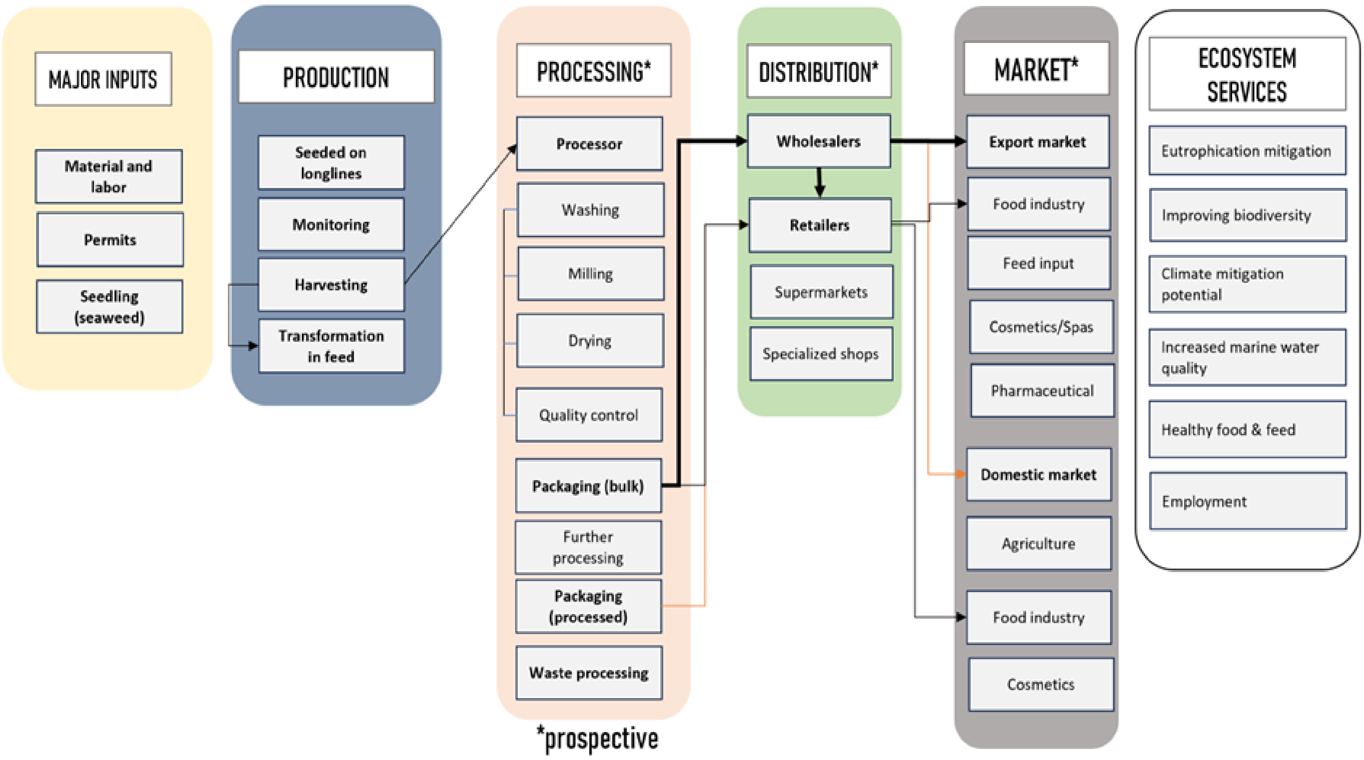


Figure 55: Seaweed value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023 / Creation PMBA)

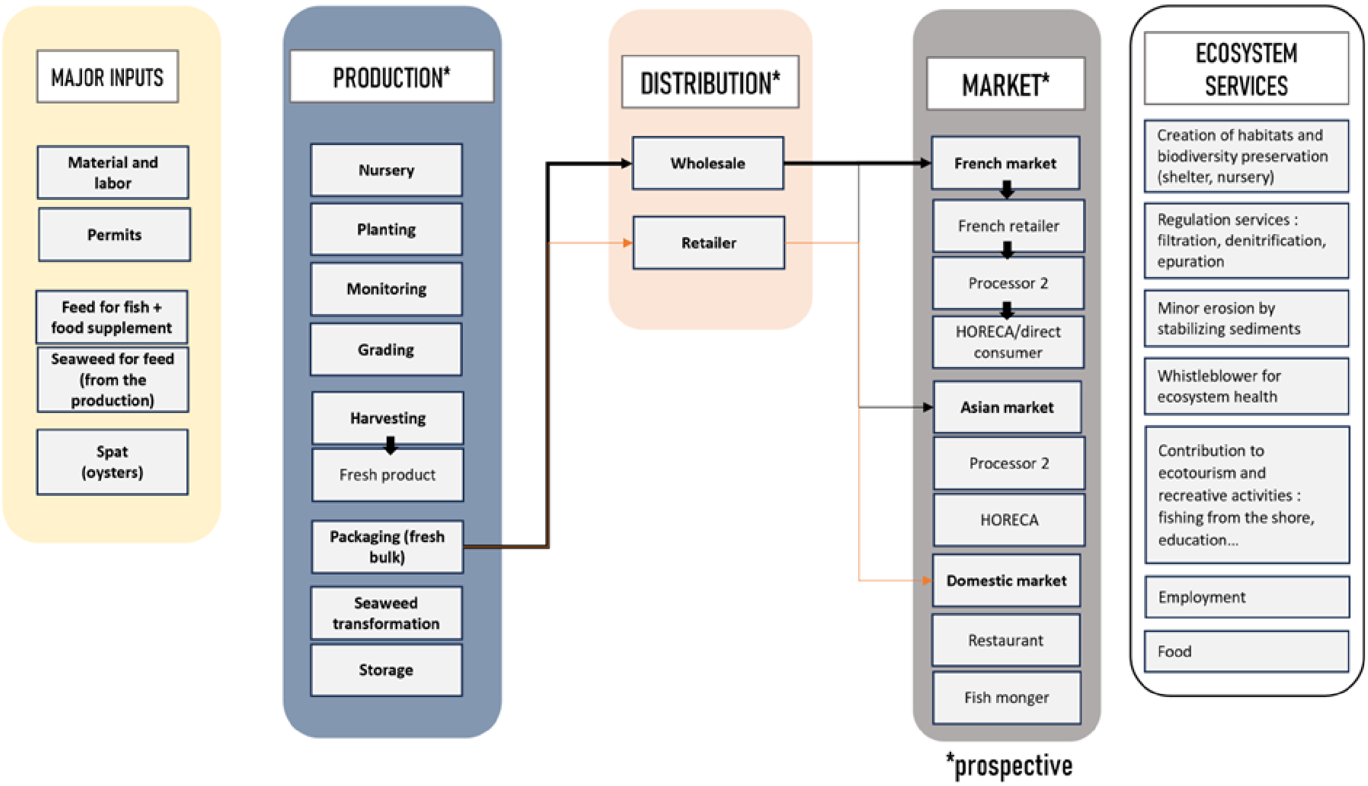


Figure 56: Oysters value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023 / Creation PMBA)

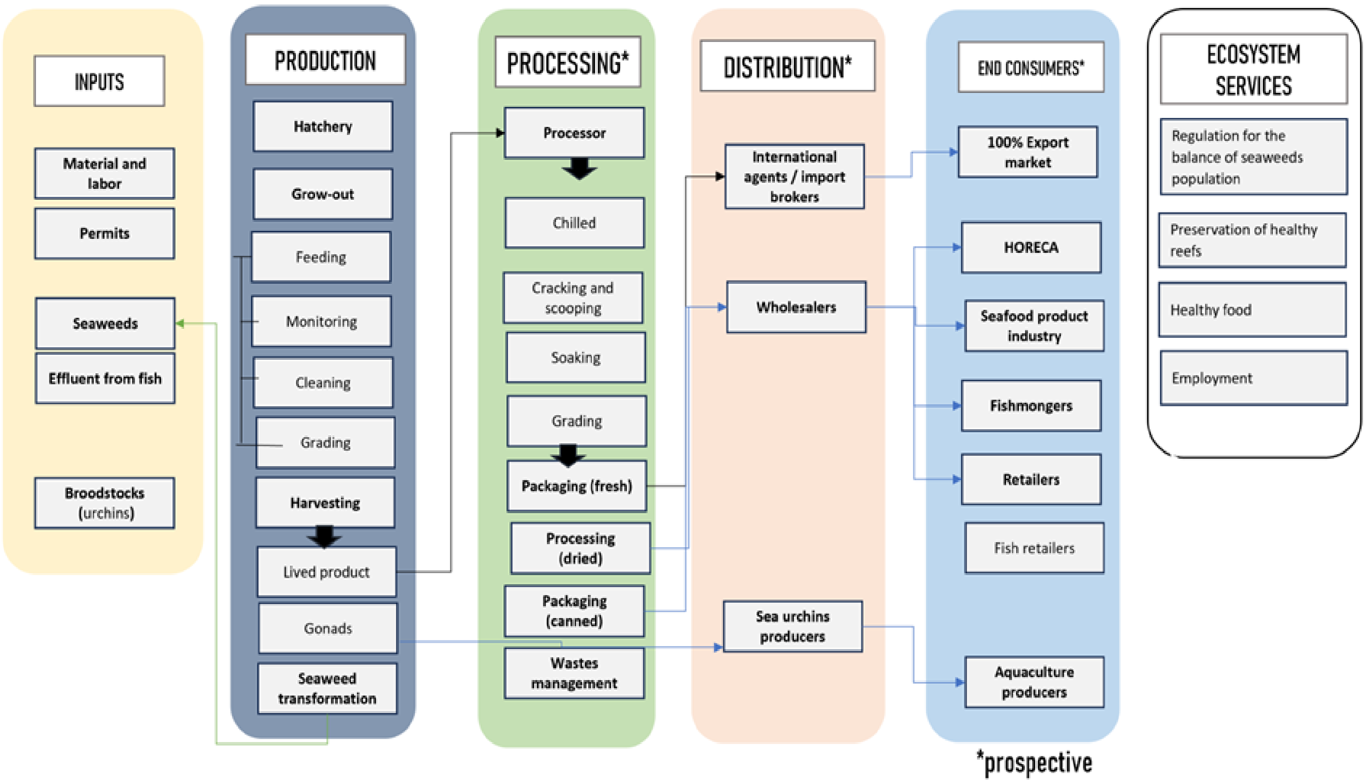


Figure 58: Urchins value chains (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023 / Creation PMBA)

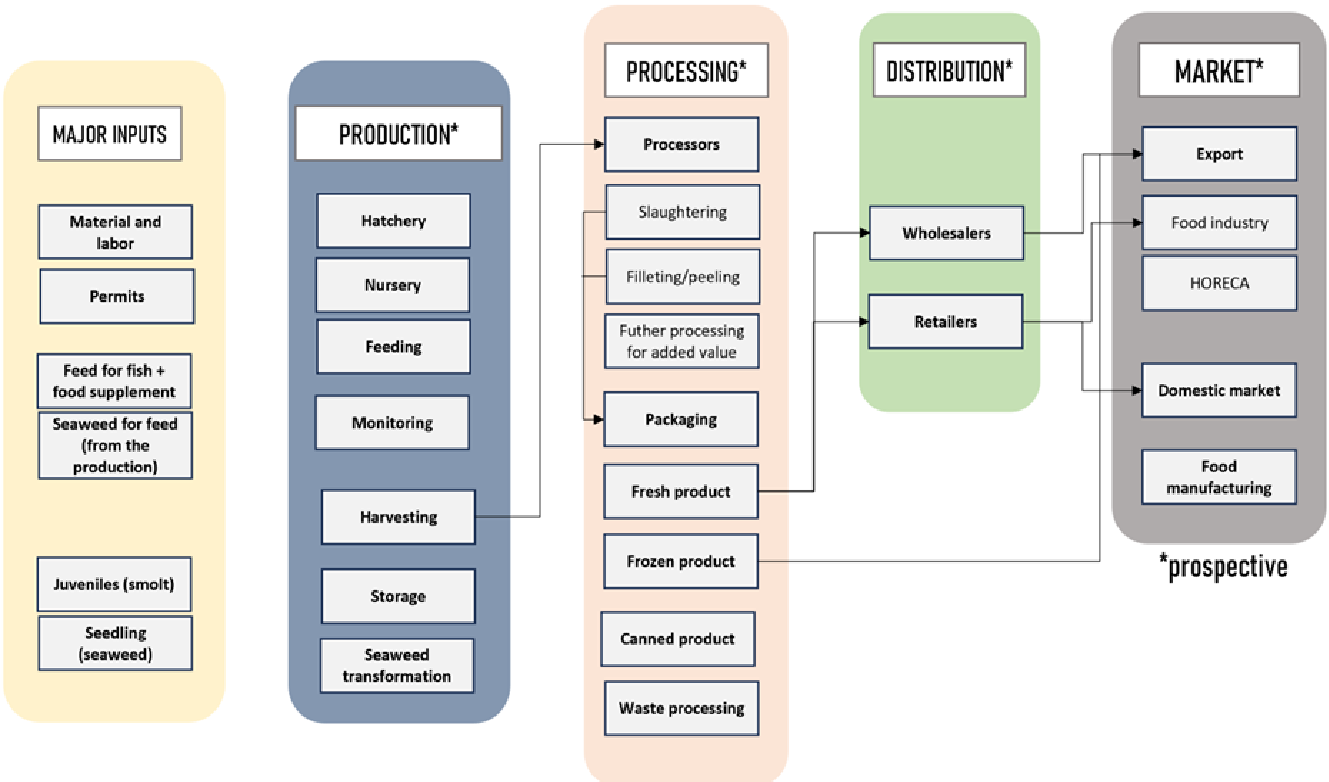


Figure 57: Salmon value chain (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023 / Creation PMBA)

Internal factors

STRENGTHS
• Equipment can be shared for different species: pooling equipment • Use seaweed to offset the inputs from the fish based between November and the end of March • Increase growth rates with the IMTA system • According to Astral LCA, the IMTA system is a better aquaculture system considering the reduction in overall feed needed per unit of biomass production, and waste extraction from fed species by low trophic species • Reduced wastes released so decreasing environmental impacts of the production: Astral LCA confirms circularity benefits: Bioremediation of wastes and nutrient recycling by seaweeds and filter feeders • Carbon removed from the site through seaweeds • Production of different species: diversification of incomes for the producer • High-value product for niche and luxury markets (salmon / urchins) • Use of farmed seaweeds as a food input: saving costs
WEAKNESSES/CHALLENGES
• Natural hazards (i.e. storms, accidental pollution) • Complex production system as it uses differing systems for the different species on one site • Operational challenge to synchronise the harvesting of different crops and manage resources • Technical equipment: need skilled human resources • Reliability on good environmental parameters of the site location • All farmed salmon related pathogens (mainly AGD and Sea lice) • Predators: otters, seals, & HABS • Microplastics • The production of IMTA species increases the costs due to the requirements for infrastructure

External factors

	Opportunities	Threats
Political	● Public funding from the government ● National funding authorities expressed their will to help the ● aquaculture diversification and are planning to open calls for funding or direct funds to help producers in their development ● Government's measures: income support, job retention schemes, bounce back loans and income tax deferral (Patience, Motova and Cooper, 2021)	● Ireland's aquaculture licensing system: complex and fragmented regulatory environment, with several national legislative instruments and EU regulations: a barrier for a sustainable development of the sector ● Intense local opposition and blockage of licensing and environmental assessment programmes (Carr, 2019)
Economic	● New markets opportunities for revenue diversification ● Sea urchins' consumption booms in Asian markets ● Salmon greatest value market ● Opportunity for job creation in rural areas	● Long return on invest / higher risks in aquaculture investments ● Increasing transport costs (COVID, higher fuels costs…). ● Due to the lack of familiarity of IMTA there is not a strong demand for IMTA products ● Logistics of marketing new products ● Product value: bivalves and molluscs have less value than finfish so how to encourage producers to go to these markets ● The mussel sector in Ireland is decreasing ● Over the period 2019 to 2021, the cost of feed and stock input doubled in proportion to other costs and also in proportion to 2019 costs: +86% for the feed cost (2019/2021) ● Energy cost: +35% from 2019 to 2021 ● Price fluctuation of seaweed market: due to seaweed liability to weather, growth period… ● Dependency on intermediaries to access markets (EU, UK)

External factors

	Opportunities	Threats
Social	● Consumer's quest for sustainability and for produced species have a higher low carbon protein ● Irish brand image as a good quality producer: Ireland is one of the world's high value salmon producers mainly the production is certified organic (EUMOFA, 2022) ● Rise of vegetarianism and veganism in UK and Europe: higher demand for seaweeds products and growing recognition of seafood as a healthy diet ● Few conflicts of use for offshore farms: good acceptance by the Irish population (Hynes et al., 2018) ● Aquaculture: valued by the public as a provider of opportunities (economic and employment)(Hynes et al., 2018) ● Misreading of the sea urchin in many countries, particularly Ireland: needs to valorise the product ● Social perception: higher value for a premium product	● Opposition of environmental groups to development of aquaculture project ● Low public awareness: IMTA is still not well known by the general public and the consumers
Technical	● Innovations in aquaculture to reduce risks: R&D and Blue Bioeconomy ● Adding value to seaweed Irish production by developing processing methods (link University/industry and agencies) ● The choice of species combination: Astral LCA highlights a necessary guidance to select the best species to achieve better environmental performance at the same time maximising resource use	● Available qualified and skilled human resources ● Growing demand for technological skills (digital technologies) ● Lack of technical data on environmental effects of IMTA ● Complexity of IMTA production system and technical challenges ● Lack of control over interactions between the multiple trophic levels ● Space conflicts with other producers or users in the sea ● No urchin seeds availability in Ireland ● Lack of seaweed processing in the area: decreasing the add-value of the product ● Dependency on foreign country for seed and juveniles' supplies ● Low availability of raw material to produce local fish feed

External factors

	Opportunities	Threats
Environmental	● Sheltered areas suitable for aquaculture ● "Accredited Quality and Environmental Standards" DAFM (2022). ● Carbon sequestration potential of seaweeds	● Open water system vulnerability ● Emerging pollutants ● Impacts of climate change: increasing weather events (storm), water temperature (direct physical effects and biological and ecological impacts) ● Biofouling ● Eutrophication risks on offshore production site ● Diseases of oyster seeds in Ireland: lack of seeds (Coyle et al., 2023) ● Sea-lice for salmon ● Limited knowledge on the aquaculture carbon footprint DAFM (2022).
Legal	● The EU wishes to "provide coordinated messaging on the sustainable, low carbon nature of Irish aquaculture production, supported by independent certification and open dialogue" DAFM (2022).	● Complex and lengthy licensing application process ● Authorisations and permits delivery process / rates ● Roadblocks to financing because of licensing issues

2.4 IMTA South Africa - case study

LAND-BASED PARTIALLY RECIRCULATING SYSTEM -SEA URCHIN AND *ULVA* (SOUTH AFRICA)

This pilot production site is located on the Southwest coast of South Africa, in the Western Cape Province. This experimental system is land-based and is using an IMTA aquaculture system to produce two marine species: the sea urchin (*Tripneustes gratilla*) and seaweed (the sea lettuce, *Ulva lacinulata*).

Description of the IMTA Lab in South Africa

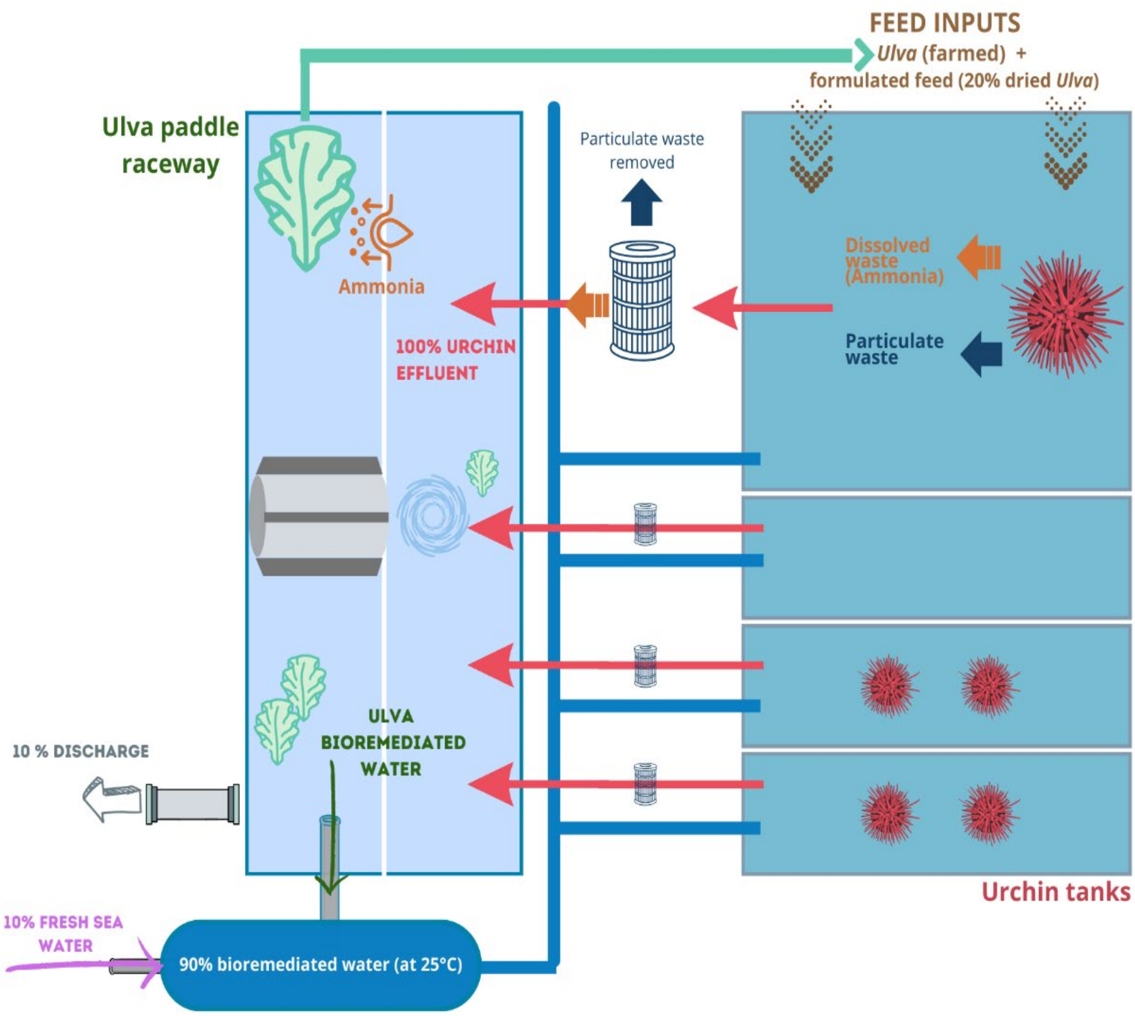


Figure 59: Sea urchin and Ulva IMTA system farming (Source: IMTA Lab, creation PMBA)

2.4.1 The Business Model Canvas

The Business Model Canvas

IMTA LAB / LAND-BASED PARTIALLY RECIRCULATING AQUACULTURE SYSTEM

SEA URCHINS AND ULVA

SOUTH AFRICA

Key Partners

- **Investors:**

Private / public funds

- **Upstream partners :**

Local feed manufacturers (two feed companies)
International partners specializing in echinoculture (AquaVitae)
Government : The South African Department of Forestry, Fisheries and the Environment
(DFFE)
HEI's (UCT), AfriMAQUA network, LIMAQUA
(international joint laboratory), All-Atlantic Ocean Research Alliance, Aquaculture Association of Southern Africa.
Local equipment suppliers
Juvenile suppliers from hatchery (sister company)
R&D academics: University of Cape Town and the Department of Forestry, Fisheries and the Environment

- **Downstream partners :**

International agents acting as supplier to the Asian market

Key Activities

IMTA production
Hatchery and reproduction process
Production process: *feeding, cleaning, grading, collection*
Daily assessment (*monitoring, system maintenance, water quality monitoring)*
Processing and transport
R&D : marketing, product development & optimization
Broodstock conditioning / gonad assessment

Key Resources

Lands: < 10 ha
Feed: formulated feeds
Permits/authorization : right to engage and permit for aquaculture activity
Infrastructure (i.e. optimal basket designs, lighting, laboratory, sediment tanks)
Electricity and water supply
Skilled human resources
R&D

Value Propositions

Production of **sea urchin** (*Tripneustes gratilla) :*

- Year round production (only 10% of the world industry)
- High valued low-trophic species (one of the top traded species globally)
- High growth rates
- High quality gonads with high market acceptance
- Full life-cycle grow-out in IMTA : gonads quality guaranteed over 90% of the time
- Quality guaranteed for 90% (full life cycle grow-out)

Fresh, frozen or canned products

Production of ***Ulva*** (*Ulva lacinulata*) :

- Food input for sea urchins
- Bio-filter for bioremediation
- Marketable
- Natural feeding stimulant
- Nutritional and health benefits
- Source of nutrients
- Increasing the urchins growth rate

Recirculation capacity :

- controlled environment and system monitoring
- mitigation of HABs

Customer Relationship *

Feedback from the agents distributing the products on the international markets (mostly Asian).

Sales based on the quality and availability by insuring consistent supply of high-quality product and year round products.

Channels *

Outsourcing distribution network

BtoB for the Asian market :
Seafood agents exporting to Asian market (mainly Japan)

BtoC with local producers

Customer Segments *

Sea urchins :

Export :
International customers (99%) : mainly Asian markets (Japan for 80% of the roe market)

Europe (France, Italy, Spain)
Local niche market (restaurant)

Food industry for roe consumption

Mainly fresh products
Processed (<10%) : Frozen/dried/canned

Domestic market (1%):
Local producers in South Africa for spat: niche market

Cost Structure *

Infrastructure costs : Tanks and raceway : 15 000 euros
Equipment (tanks, baskets, pumps for urchins) : 72 000€ of investment (Depreciation costs (3 years) : 25 000 euros)
Production costs :
Human resources (60%) : about 20 persons (80% for sea urchins production and 20% for Ulva)
Water and electricity supplies (30%)
Feed : (30%)
Maintenance and processing for export
R&D : 162 000 euros/year

Revenue Streams *

Funds and Sales of goods
S**ea urchins** for roe (main market)
Average price : (Wholesale) from 10 to 20€/kg (whole piece)
Japan prices : Wholesale : 340€/tray and retail from 48€ to 430€/tray of gonads
France market : 14€/kg for whole urchins
Wholesale: 100€/kg of gonads
Retail : 130/170€/kg of gonads

**Prospective*

2.4.2 Synthesis

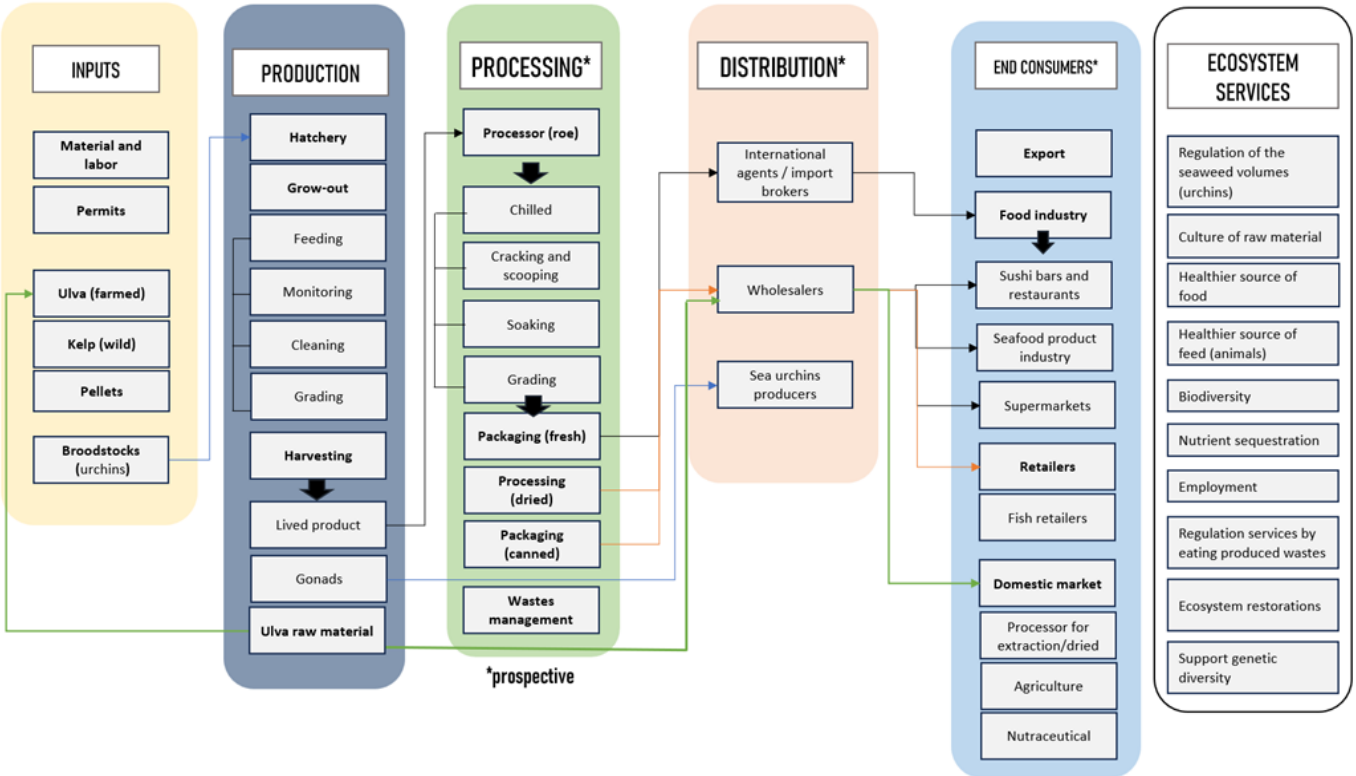


Figure 60: Value chain for the South African IMTA Lab (Adapted from A. Shaji, SAMS, BlueBioClusters, 2023/ Creation PMBA)

Internal factors

STRENGTHS

Technical

- Consistency of the production of sea urchins: year-round production (only 10% of the industry)
- Quality of gonads guaranteed for 90% of urchins produced from full life cycle grow-out
- Optimised growth and gonad development/quality
- Strong scientific partnerships of the company
- Land-based tank system: mitigate disease spread and HAB risk reduction
- Production of two species in the same system: diversification
- Recirculation system: controlled environment, reduced pumping cost and advantage in case of Harmful Algal Blooms
- Increased growth rate of animals by using *Ulva* in formulated feed (Cyrus et al. 2015)
- Land-based system resistance and controlled interaction system

Environmental

- Land-based system reducing wastes and environmental impact on surrounding environment
- ASTRAL LCA confirms that *Ulva*, plays a role as a biofilter, efficiently harnessing, and utilising waste nutrients, primarily nitrogen and phosphorus, from the sea urchin production. It assimilates approximately 84% of the dissolved nitrogen released by the sea urchins

Internal factors

STRENGTHS

Economic

- Support from local government institutions
- Saving feed costs: use of *Ulva* as a feed input (50% at least)
- Saving production costs and dependency: recirculation is decreasing water pumping costs and electricity requirements
- New high-valued low-trophic aquaculture species from South Africa and emerging species with high market value and with high demand in Asia (Japan 80%)
- Marketing advantage of the IMTA: by using a sustainable production system and natural feed (consumers perception)
- The use of natural material (*Ulva*) as a supplementary food for sea urchins is increasing the value and quality of the production: direct impact on the colour and texture of gonads (ASTRAL LCA) Compared to the monoculture production of sea urchin, the IMTA system used 53% less energy (ASTRAL LCA)

WEAKNESSES/CHALLENGES

Technical

- Ability to produce enough *Ulva* in a cost-effective manner in the required space
- Dependency on water supply (sea), electricity (pumping system), and feed(s)
- R&D: Sea urchin is a new species under development in South Africa so extensive market development and research still needs to be conducted
- Funding for R&D
- Skilled human resources
- Sensitiveness of sea urchins to environmental conditions, especially during early life stages: require intensive monitoring and special attention during the production process
- Sea urchins are very sensitive during early life stages. However, consistent water quality, particularly temperature, is also vital during the final stages of production when the animals are mature (mature gonads) as a sudden increase or decrease in water temperature will cause animals to spawn, which will adversely affect gonad quality and can cause a large loss of revenue and potentially loss of animals
- Consistent production of microalgal feeds is a challenge during early life stages (for urchins' larvae)

Economic

- Space – some producers may have space limitation and a difficulty in producing *Ulva* on site
- Cost of electricity high to run heat pumps, unless one can produce the species in a warmer climate (subtropics/tropics)
- Difficulty of getting products to market and establishing a relationship (market entry)
- Obtaining certification

External factors

	Opportunities	Threats
Political	● Private lands ● South African government prioritising aquaculture in its National Development Plan to 2030. ● The Government supports investments in the development of aquaculture with aid.	● Minimal research on aquaculture socio-economic dimensions and minimal technical data to communicate to communities (Morake, 2015) ● Access to public and private land and water bodies for aquaculture purposes: Access to land in coastal areas can be difficult/ costly
Economic	● Private funding: relative autonomy of the production site ● New market opportunities for revenue diversification ● Decline of Japanese urchin stocks: marketers are seeking new alternative sources of raw urchin ● Sea urchins (roe): emerging market and high selling prices ● South African producer community has a good understanding of the IMTA model benefits	● Long return on investment: an average of 4 years for a small/family farm / higher for a larger farm ● Increasing transport costs (COVID, higher fuels costs…) ● External Funding dependency ● Consumer habits: urchins are not a food source for local people ● Regarding the IMTA misreading: there is not a strong demand for IMTA products ● Weak knowledge of the sea urchin markets ● No large global market for Ulva (Cyrus, Bolton and Macey, 2015), although this may improve rapidly with current initiatives ● Dependency to export and transport (urchin market)
Social	● Increasing the coastal areas and communities: provide employment, environment preservation ● Local partners dynamic: professional organisations, research partnerships, local dynamic ● Consumer's quest for sustainability ● Sea urchins' consumption booms in Asian markets ● Social positive perception on natural feed inputs ● Social perception: higher value for a premium product (+ 10% for a better product)	● IMTA misreading: Low public awareness as IMTA is still not well known by the general public and the consumers

External factors

	Opportunities	Threats
Technical	● Innovations & R&D projects in aquaculture to reduce risks: ● Growing interest in aquaculture and corresponding increase in development of new technologies to support sustainable aquaculture ● No dependency on processors: raw products already have a high market value and are sought-after (urchins).	● Need of skilled human resources and difficulty to recruit ● Growing demand for technological skills (digital technologies) ● Development of new technologies – adaptation needed by producers ● Complexity of production system and technical challenges ● Reliability of electrical infrastructure in South Africa
Environmental	● Market demand for eco-certified seafood in sustainable aquaculture system ● Circularity and waste management	● Dependency of sea urchins on a specific temperature regime: *Tripneustes* need to be cultivated in a tropical environment, so there are limited areas in South Africa where this can be done ● Increasing demand for sea urchins: pressure on wild harvesting is growing (represent 90% of the industry globally)
Legal		● Authorisations and permits delivery process / rates ● Weak feedback and/or support from sector representatives and associations on IMTA ● No single policy or managerial practice ● Lack of availability of fundings, including for R&D

Conclusion

Highlight of main drivers

- **Major trends on the IMTA commercial sites studied**

Table 2: Key ideas for IMTA commercial business models

Type of channels	Mainly B2B
Main markets	Food market mainly addressed Sales of raw products Basic supply / minimal processing Other potential market less explored
Risks	Technology risks: mainly still lab scale / limited at scale trials On commercial cases: R&D essential to pursue the development of the farm Market risks Variability of price No label for IMTA products
Emerging factors	Booming market for biobased, healthy and sustainable food
CAPEX / OPEX intensity	High CAPEX Medium OPEX: IMTA systems tend to reduce the production and HR costs but it is not generalised: depends on several factors (size, species produced, aquaculture system chosen…) + rising production costs + low processing

Summary of key drivers

Economic interest

- An additional economic dynamism to the coastal areas in which they IMTA systems are set up, enabling job creation as well as local economic growth.
- A higher net present value (linked to the diversification of revenues brought about by the pooled production of several species).

Change in consumer habits

- An increase in the overall consumption of aquatic products and significant changes identified in consumer habits, especially in developed countries.
- A growing interest for alternative protein sources, biobased products which have been produced with limited environmental impact and using a sustainable method.
- Consumers' awareness regarding the origin of products is thus evolving and they could be willing to pay a higher value for a premium product.
- Emerging of alternative sales channels: click and collect, baskets or home delivery: Producers need to adapt to these new distribution channels.

New markets

- Scientific evidence for multiple nutritional and health benefits from the consumption of seaweeds which make them ideal candidates for functional foods and nutraceuticals.
- Potential for using seaweed as an aquafeed ingredient
- High probability that *Ulva* will increasingly be grown in IMTA systems for aquafeed, and for human consumption in the future : an advantage given the rise of veganism and vegetarianism
- Wide range of applications for seaweeds but need of a large amount of biomass and industries capable of extracting, processing, and using this biomass with a higher market value.
- The sector needs to open to new market (biofuel, cosmetics…) where the value of products remains high.

High-quality products

- IMTA products : high quality products, produced under controlled and sustainable systems.
- The traceability increases their quality and value : competitive advantage for producers, which must be valued and could be certified.
- Labelling or certification of IMTA products, currently non-existent, may have disadvantages (quality criteria, label costs, etc.) but could also be an opportunity for the valorisation of IMTA products and a criterion for increasing market value.

R&D and skilled human resources

- Large part of IMTA systems' activity oriented towards research and development.
- Need of expertise and skilled human resources.
- Growing several species at the same time with different trophic levels, despite the potential economic and ecological benefits, requires technical equipment and operating methods that can be complex and need more expertise.

Political and financial support

- IMTA systems require considerable installation investment.
- Operational expenses and research and development costs are important and mandatory.
- Existence of these systems is highly dependent on the presence of funds; private or public. In addition to the necessary funding, administrative support is required.
- This highlights the importance of adapted policies, which are also simplified, facilitating, and developed in consultation with all stakeholders involved.

Market vision & commercial strategy

- Exploration of potential markets is limited, as is the understanding of the needs of various customers (e.g. nutraceutical).
- It is important for producers to develop a marketing strategy that considers emerging markets and diversifies customer segments.
- For the sustainability and profitability of IMTA businesses, it is necessary to increase producers' marketing and commercial development skills.

- To increase the market value of IMTA products, it is necessary to develop the visibility of this type of production with consumers and buyers : will have a direct impact on the raise of social acceptance.
- Sustainable production by IMTA must be promoted as a brand image and producers could develop the marketing and branding of their products to increase value in the final market allowing a diversification of products compared to competition.

Ecosystem services to explore in IMTA business models as a new benefit

Four types of services thanks to direct or indirect use value:

- **Provisioning services** as goods from natural ecosystems (e.g. aquaculture products)
- **Regulating services** that moderate or regulate natural phenomena (e.g. bioremediation)
- **Cultural services** that enhance cultural advancement for individuals and society (e.g. leisure)
- **Supporting** services that *serve as the foundation for the other three kinds of ecosystem services and make them possible* (e.g. carbon storage)

Several methods exist to measure the economic value of ecosystem services (based on costs, on market price…). The World Bank proposes a range of potential leading payment mechanisms:

Table 8: The World Bank. Pro Blue. (2023)

Potential leading payment mechanisms	Definition
Charging aware consumers price premiums	Consumers pay the costs via price premiums on final products. This would require consumer awareness (eco-labelling…).
Trading credits for ecosystem services	Tradable credits for ecosystem services can be traded business-to-business like carbon sequester system
Providing subsidies for achieving positive impacts	Subsidies can be provided to the farmers (ex: governments can subsidise the use of methane-reduction supplements)
Paying ecosystem services producers through taxes	Producers of lower-trophic species can be paid for the ecosystem services provided through general taxes collected from consumers or businesses.
Sharing the costs of production among beneficiaries	The costs of producing lower-trophic species are partially paid for by other businesses of the ecosystem services provided.

Monetizing ecosystem services generated by IMTA system is complex. Multiple parameters must be gathered to implement efficiently but, this opens promising perspectives for the sector and policy makers to support IMTA systems development.