Project co-financed by the European Regional Development Fund

B-Blue

Building the blue biotechnology community in the Mediterranean

WP3 - Studying

DELIVERABLE 3.2.2

BBt research challenges and market oriented evaluation of most promising value chains

July 2021

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Project co-financed by the European Regional Development Fund

Document information	
Project Acronym:	B-Blue
Project Title:	Building the blue biotechnology community in the Mediterranean
Grant Agreement no.	7032
Programme	Interreg MED 2014-2020
Project Start Date:	01/09/2020
Project duration	22 months
Related work package	WP3
Lead partner for this document	HCMR
Due date	February 2021
Submission date	July 2021
Dissemination level	Internal

Revision history

Date	Author/ Reviewer	Version/Notes
01/02/2021	A. Giannakourou, A. Venetsanopoulou , G. Triantaphyllidis	Definition of the structure of the report
01/03/2021	A. Venetsanopoulou , G. Triantaphyllidis	Questionnaires sent to PPs
01/05/2021	G. Triantaphyllidis , I. Kotzamanis, E. Roussos	First version of the Waste valorisation value chain
01/06/2021	A. Venetsanopoulou, A. Giannakourou, C. Efstratiou	First version of the Algae + IMTA value chains
30/06/2021	A. Giannakourou, A. Venetsanopoulou, G. Triantaphyllidis, I. Kotzamanis , C. Efstratiou, E. Roussos	Comments and last version of the report

List of Abbreviations and Acronyms

Acronym	
Asociación Nacional de Fabricantes de Conservas de Pescados (Asociación Nacional de Fabricantes de Conservas de Pescados)	ANFACO
Arrantzatzuarekiko Zientzi eta Teknoloji Ikerketa (Scientific and Technological Centre in Spain)	AZTI
BBt	Blue Biotechnology
BBH	Blue Biotechnology HUB
BPs	Best Practices
Centre National de la Recherche Scientifique (France)	CNRS
Common Fisheries Policy	CFP
Croatia	HR
Ecole Nationale Supérieure de Chimie de Montpellier	ENSCM
European Commission	EC
European Union	EU
European Market Observatory for fisheries and aquaculture	EUMOFA
The Food and Agriculture Organization of the United Nations	FAO
Fish by-products	FBP
Fish protein concentrate	FPC
France	FR
General Fisheries Commission for the Mediterranean	GFCM
Greece	GR
Horizon 2020	H2020
The Hellenic Centre for Marine Research	HCMR
High value added biomolecules	HVAB
Institute des Biomolécules Max Mousseron	IBMM
Institute Charles Gerhardt of Montpellier	ICGM
Italy	IT
Landing Obligation	LO
Minimum Conservation Reference Size	MCRS
Montenegro	ME
Portugal	PT
PPs	Project Partners
Recirculating aquaculture systems	RAS
Rest Raw Materials	RRMs
Slovenia	SL
Spain	SP
The EC Scientific, Technical and Economic Committee for Fisheries	STECF
Unwanted catches	UWC
Waste Water	WW

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About B-Blue project

10 partners with proved experience in the Blue Bioeconomy field from 8 Med countries and more than 300 Med stakeholders from universities, research centres, public authorities, business support organizations and Med multilateral organizations, working together for 22 months to create the Blue Biotechnologies (BBt) community in the Mediterranean. The exploitation of marine bio-resources through biotechnological solutions is a field with massive potential for innovation and economic growth. This field is a relatively young discipline, so opportunities and key enabling factors need coordination. B-Blue project aims at gathering the key actors of the Med BBt sector and increase their innovation capacity and their coordination in order to unlock the innovation potential in the field through joint transnational initiatives, involving also organizations from the Southern Shore of the Mediterranean. The transnational coordination framework, the project aims to create, is based on an inclusive quintuple-helix approach always including the socio-environmental perspective in the decisional process and building on a common knowledge ground selected on the basis of its potential of addressing the SGDs at Med level. B-Blue project works towards the implementation of a transnational coordination mechanism for the BBt community through the mutual interconnection of the digital BBt community platform and a MED network of territorial based-collaborative space on selected BBt value chains (BBt HUBs).

1. About WP3 – Deliverable 3.2.2

Blue Biotechnology (BBt) is a field with massive potential for innovation and economic growth, but it is a relatively young discipline, so opportunities and key enabling factors need coordination. Despite the promising prospect, BBt's development in the MED region faces specific bottlenecks such as clear the identification of the different value chains and high fragmentation of business innovation initiative: BBt value chains move from and are linked to many different sectors and research and innovation are often developed as isolated initiatives without a coordination which could ease the access to the market. WP3 tackles all these issues collecting, analysing and systematizing knowledge so that it can be exploited during the project activities and in additional/future contexts as basis for innovation and business.

It allowed in D3.2.1 the definition of BPs of already implemented, ready to the market and pilot actions of innovative solutions in the BBt sector. Furthermore it provided an accessible and concise overview of evidence-based BPs for innovation in the BBt sector, which exist worldwide and can be followed in MED area to accelerate the transition to resource-efficient and sustainable economies D.3.2.2 aims to bring out the innovation potential in the BBt field and define the value chains that are better thought-out and with high market potential. It focuses on the description of BBt research challenges and market oriented evaluation of most promising value chains in order to create a project knowledge package in the MED BBt sector to be used to exchange knowledge among the PPs and the BBt communities (BBHs). Thus, knowledge contents will be tested in WP4 considering their potential to support the achievement of Med SDGs and connection to RIS3 and aiming to develop policy recommendations and strategic plans to identify joint initiatives, common approaches and transnational projects for the growth of the Med BBt.

2. The concept of value chain in Blue Biotechnology

A value chain is defined as a system of independent business operations in which the outcome of one activity affects the cost or profitability of another[3] A value chain consists of a range of activities required to bring a product from its inception to its end consumer, through a series of steps involving physical transformation and input of various producer services, and disposal after use[4]. In the context of blue biotechnology, a value chain would be a set of actors and activities that are involved in bringing an agricultural product from production to final consumption, with value addition at each stage[5].

Blue biotechnology covers a complex network of activities linked to research and product development. The various sectors can be structured differently depending on the BBt

[3] Porter M.E., 1985. The Competitive Advantage: Creating and Sustaining Superior Performance. NY: Free Press

[4] Kaplinsky R. and Morris M., 2000. Handbook for Value Chain Research, IDRC.

[5] FAO, 2018. The global status of seaweed production, trade and utilization. Globefish Research Program, Vol. 124. Rome, Italy.

value chain. A full value chain from the marine habitat to the biotechnology product includes all aspects from collection of the marine organisms or preservation in culture collections, the extraction, purification, structure elucidation and characterization of natural products, optimisation of production conditions, patent/publish results in order to safe intellectual property rights for possible industrial application and scale up to a pilot scale for biotechnological production of bioactive natural products. For the analysis of each value chain, it is crucial to examine the nature of each link and the degree of synergy between them.

The starting point of all activities or input to the process of extracting value from aquatic bio-resources is the collection/culture and harvesting of available biomass. Aquatic biomass is composed of many forms, including e.g. whole fish or parts, micro and macro-algae, sponge, fungi, marine invertebrates, microbiomes that may derive from near shore/offshore, aquaculture activities, integrated multi-trophic cultures (IMTA), discards from fisheries or aquaculture products. This biomass is the main source for the production of high value products, principally, as food and nutritional supplements, animal feed, bioactive compounds, fine chemicals/enzymes, biofuel/biogas and used in commercial applications for the development of nutri-cosme-pharmaceuticals, in agriculture, energy and environmental conservation and remediation.

All the above constitute different components, economic subsectors with different associated business models and in diverse technological stages of development. However they are all interdependent and should be considered as complementary field of activities within the long BBt value chain/chains.

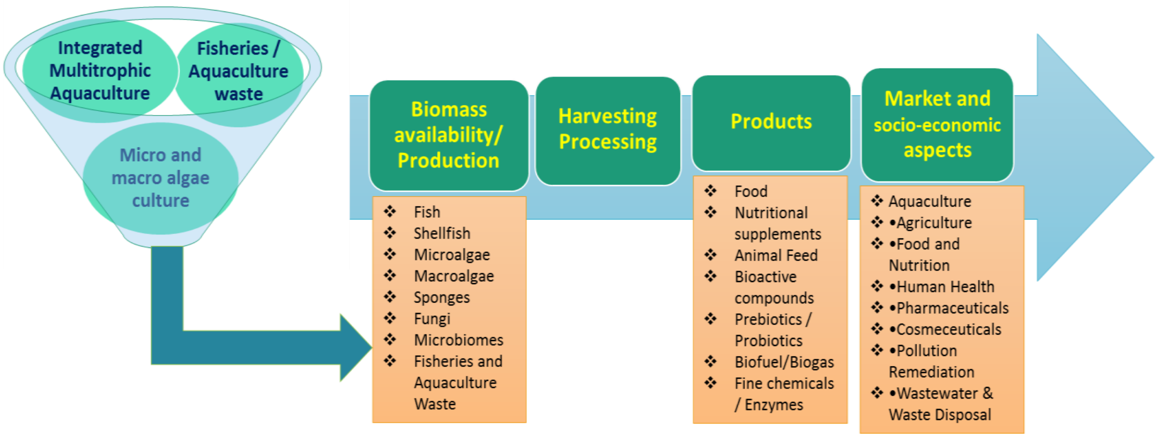


Fig. 1: The different segments of Blue Biotechnology value chain/s

The information collected in D.3.2.1 through the BPs identification and the sectors of interest support the four value chains as initially described.

1. algae market (micro and macro-algae production for high-value compounds)
2. aquaculture/fisheries discard valorisation in added value sectors,
3. sustainable aquaculture and integrated multi-trophic aquaculture (IMTA)

Finally a cross sectoral subject of interest is marine environment conservation/restoration and the use of ICT tools.

From the selected BPs, mainly considering the technological field with practices in deployment phase (TRL 7-9), >50% refer to the algae market value chain, 16% to sustainable aquaculture and IMTA. Aquaculture/fisheries discard valorization and collection/exploitation of natural resources corresponds to 16% and 12% respectively of the innovative technological applications described, whereas ICT tools refer only to 4% of the BPs.

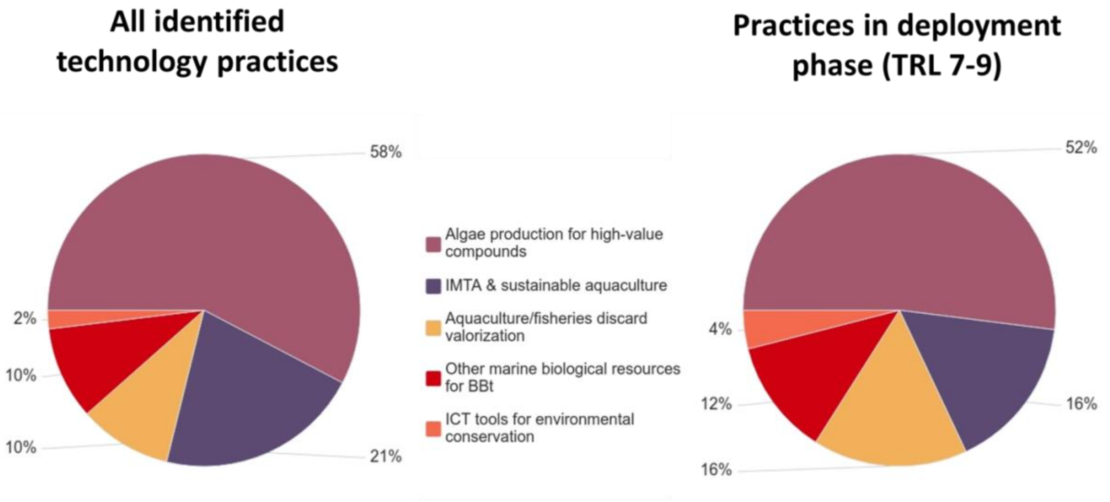


Fig. 2: BPs identified in the technology sector and practices in a technological readiness level TRL>7, as collected in D3.2.1.

3. Algae market value chain analysis

Taking into account the strategic activities needed for the creation of algae enhanced products or algae derived products, the value chain has two major links i) biomass production and ii) biomass processing. After this point the chain is divided into two paths. The first one leads directly to final products without any further processing (e.g. dried micro-macro algae, seaweed for sushi) and the other includes one more link which comprises advanced procedures for the production of high added value products.

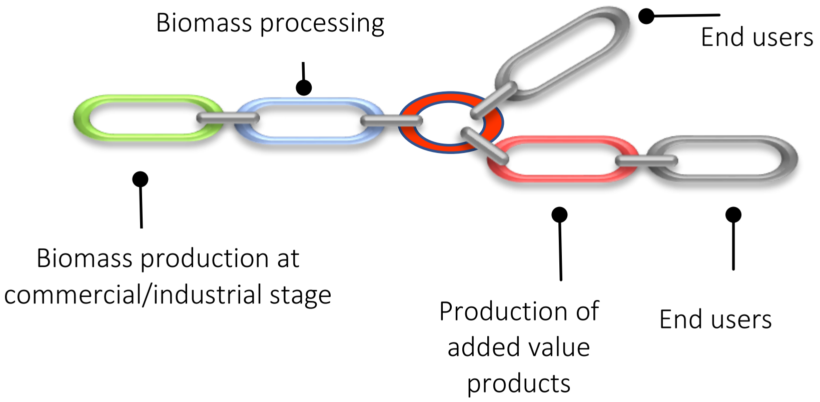


Fig. 3: Links of the Algae market value chain

3.1 Biomass production at an industrial/commercial stage

The first step for the algae market value chain is to examine the production of the biomass at an industrial/commercial stage. Microalgae and macroalgae are included under the term of algae, and in order to succeed large scale cultivation, the species selection and the choice of suitable cultivation systems are the most crucial factors.

The global production of algae amounts to 32.7 million tons (Mt) of fresh weight annually. According to FAO approx. 99% of all algae come from Asia, of which 58% come from China[6], with the European contribution representing only 0.88% of the global algae production. According to the EU Blue Economy report of 2019[7], the EU algae sector employs over 17,000 people (direct and indirect activities), with an annual turnover of

[6] FAO, 2016. FAO yearbook of Fishery and Aquaculture Statistics 2016, Rome, Italy, pp.104
[7] EU Blue Economy Report. 2019. Publications Office of the European Union. Luxembourg

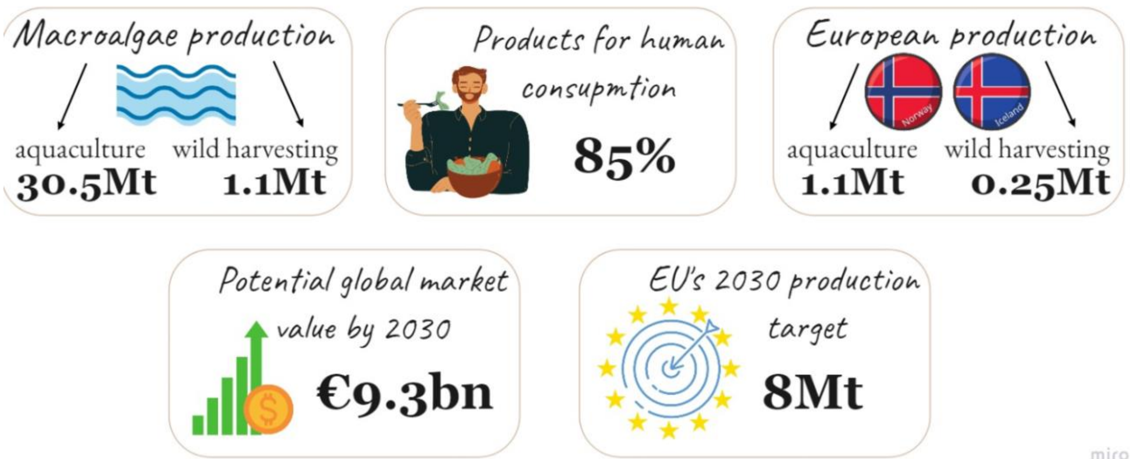
€1.5 billion for direct activities, with indirect activities such as research adding an additional €240 million[8].

3.1.1 Macroalgae

Globally, macroalgae production is more than a 6 billion USD industry of which 85% comprises food products for human consumption. Seaweed derived extracts-carrageenan-alginates-agar make up 40% of the hydrocolloid world's market (FAO 2018). Seaweed aquaculture predominantly is practiced in China and Indonesia is contributing 87% of the global supply, where food production and carrageenan extraction are two large industries. Global production of seaweed based on aquaculture registers up to 30.5Mt while the global wild harvesting of macroalgae reaches 1.1Mt.

Europe production is currently small-scale but several drivers point towards a potential expansion. When we examine the corresponding production in Europe, the harvesting of macroalgae wild stock is the predominant production system with a total harvesting biomass of 0.25Mt (EU, Norway and Iceland), representing 22.7% of the global harvested biomass. Additionally, macroalgae production based on aquaculture in the EU and Norway reaches ≈ 1Kt.

The European market is small, nevertheless large cultivation projects are progressing. Europe is perfectly suited to scale-up seaweed industry to €9.3bn potential market value by 2030 (of which 30% supplied by seaweed grown in Europe) To deliver this potential, the European seaweed industry must accelerate and significantly grow its production capacity from 0.25Mt to >8Mt of fresh weight seaweed produced in 2030[9].



Taking into account the number of companies based in Europe and actively involved in the seaweed market, France, Ireland and Spain are the top 3 countries (Fig.4). Norway is

[8] EU, 2019. Blue Bioeconomy Forum- Roadmap for the Blue Bioeconomy https://ec.europa.eu/maritimeaffairs/index_en

[9] Seaweed for Europe, the Hidden Champion of the Ocean, 2021. SUN Institute - Environment and Sustainability

the frontrunner in biomass production with ≈016Mt and France follows with 0.045Mt. Taking into consideration the variety of species produced, Spain is the first country with at least 17 different species, followed by France and Ireland with 15 species. Among the B-Blue MED countries only France, Spain and Portugal produce macroalgae.

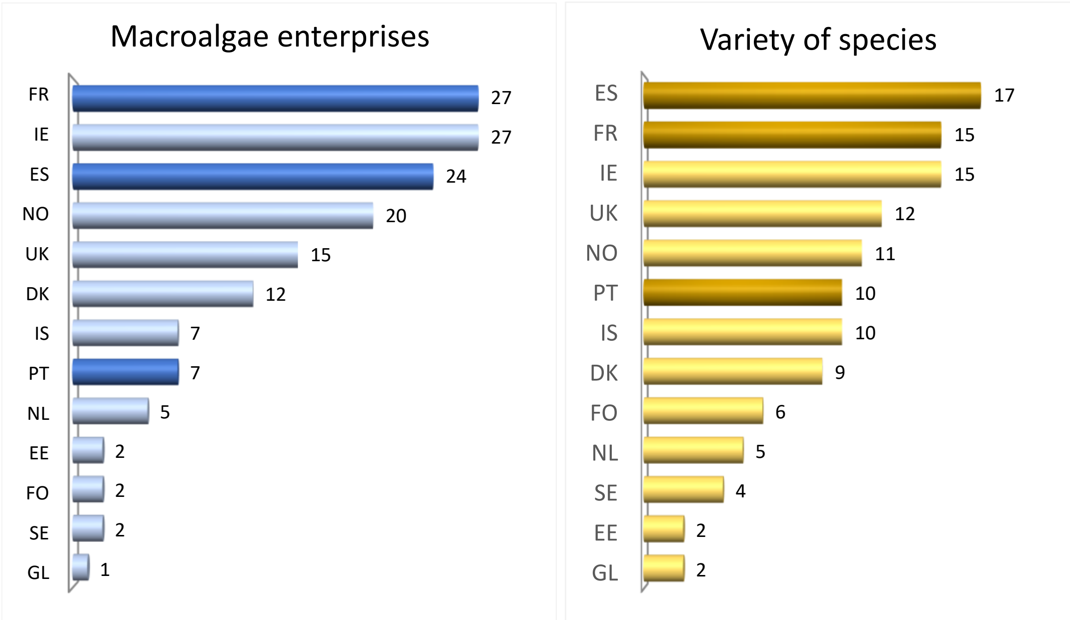


Fig. 4: A.) Number of companies involved in the production of macroalgae. B.) Variety of macroalgae species produced in each country

Seaweed production in Europe (both harvesting from wild stocks and aquaculture) is primarily concentrated in the Atlantic region with few units cultivating species that are native in the Mediterranean Sea e.g., *Ulva* sp., *Gracilaria* sp. (Araujo *et al.* 2021)[10]. Macroalgae are cultivated in land-based tanks or ponds or in sea-based (coastal and offshore) structures such as long-lines or rafts (Buschman *et al.,* 2017)[11]. They can be cultivated as a monoculture or integrated multi-trophic aquaculture (IMTA), which is being promoted as a strategy to mitigate the potential negative impacts of marine aquaculture (Ellis *et al.,* 2019[12]; Nardelli et *al.,* 2019)[13]

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[10] R.Araújo, F. Vázquez Calderón, J. Sánchez López, I. Costa Azevedo, A. Bruhn, S. Fluch, M.Garcia Tasende, F. Ghaderiardakani, T. Ilmjärv, M. Laurans, M. Mac Monagail, S. Mangini, C. Peteiro, C. Rebours, T. Stefansson, J. Ullmann. (2021) Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy. *Frontiers in Marine science* Vol. 7 doi: 10.3389/fmars.2020.626389

[11] Buschmann, A. H., Camus, C., Infante, J., Neori, A., Israel, Á, Hernández González, M. C., et al. (2017). Seaweed production: overview of the global state of exploitation, farming and emerging research activity. *Eur. J. Phycol.* 52, 391–406. doi: 10.1080/09670262.2017.1365175

[12] Ellis, J., Tiller, R. , 2019. Conceptualizing future scenarios of integrated multi-trophic aquaculture (IMTA) in theNorwegian salmon industry. *Marine Policy,* Vol. 14, pp. 198-29

The species commercially harvested in Europe are primarily *Laminaria hyperborea* and *Ascophyllum nodosum* (Mac Monagail *et al.,* 2017)[14] while *Saccharina latissima, Alaria esculenta, Laminaria* sp., *Palmaria palmata,* και *Ulva* sp. are the species mainly cultivated (Barbier *et al.,* 2019). Macroalgae production at a commercial scale is recorded only in France, Spain and Portugal however, in Greece and Italy macroalgae are cultivated at a pilot scale as part of several research programs (aquaculture in open tanks and small aquariums)

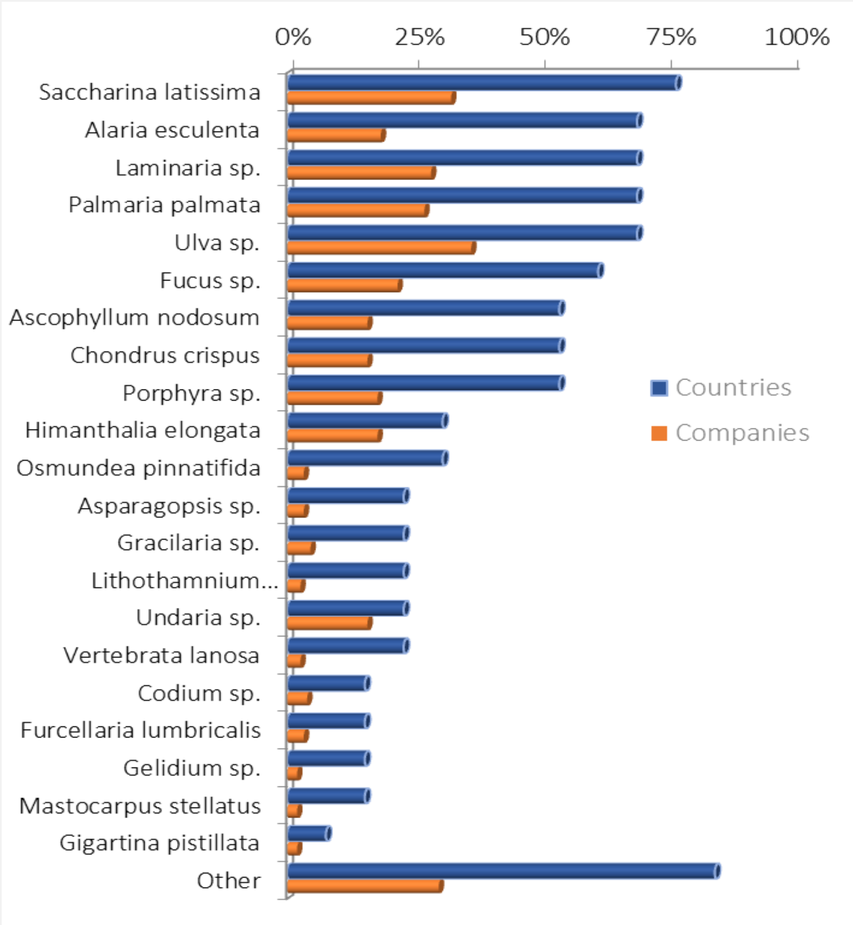


Fig. 5: The common macroalgae species produced in Europe. In blue the percentage of countries active in macroalgae harvest/cultivation (13 in total) that produces each species; in orange the percentage of companies (out of a total of 151 in all countries) producing each species.

3.1.2 Microalgae

There is an important gap of data about microalgae global biomass production, but there is no doubt that it is much less than macroalgae production. According to official data the

[13] Nardelli, A.E., Chiozzini, V.G., Braga, E.S. and Chow, F., 2019. Integrated multi-trophic farming system between the green seaweed Ulva lactuca, mussel, and fish: a production and bioremediation solution. *J. Appl. Phycology,* Vol. 31, pp. 847–856

[14] Mac Monagail, M., Cornish, L., Morrisson, L., Araújo, R., and Critchley, A. T. (2017). Sustainable harvesting of wild seaweed resources. *Eur. J. Phycol*. 52, 371–390. doi: 10.1080/09670262.2017.1365273

number of enterprises based in Europe and actively involved in microalgae production is presented separately from Spirulina producers. For the needs of this report microalgae will also include *Arthrospira platensis* (commonly known as Spirulina).

France is the leading country in microalgae production in Europe with 142 registered Spirulina enterprises, whereas Portugal is the country with the higher variety of species produced (Fig.6). The dominant microalgae species produced in Europe are *Chlorella* sp., *Haematococcus pluvialis, Nannochloropsis* sp. and *Tetraselmis* sp.

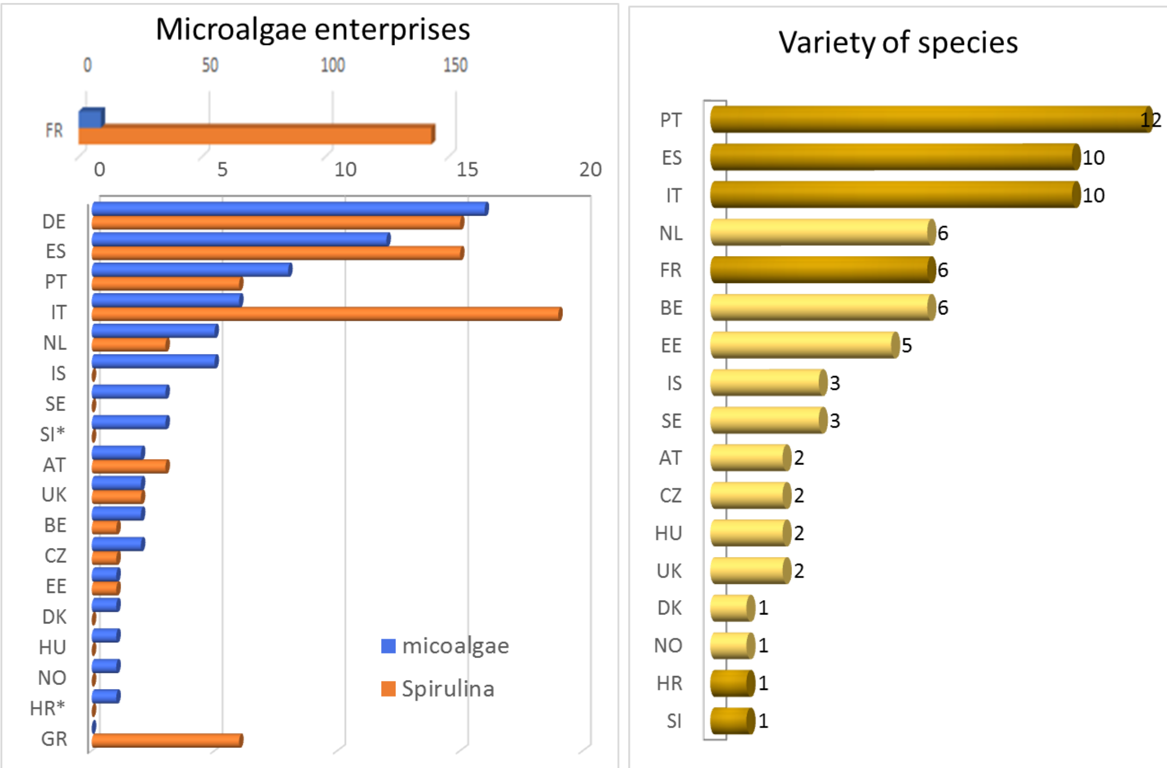


Fig. 6: A) Number of companies active in microalgae production. B) Variety of microalgae species produced in each country.

*Source: European Marine Observation and Data Network (EMODnet) Human Activities Portal, algae industry directory, https://www.emodnet-humanactivities.eu/view-data.php. *information collected from B-BLUE partners contribution*

The official data have no records about microalgae cultivation in Greece, Slovenia and Croatia. However, Greece has a great experience in microalgae cultivation of the species *Isochrysis* sp, *Chlorela* sp, *Tetraselmis* sp, *Nannochloropsis* sp, *Rhodomonas* sp, *Dunaliella* sp at industrial scale, as part of the daily routine of several hatcheries which support larvae feeding in fish farms. Croatia has an enterprise in microalgae cultivation (hatchery) and Slovenia records 3 enterprises producing small quantities of microalgae.

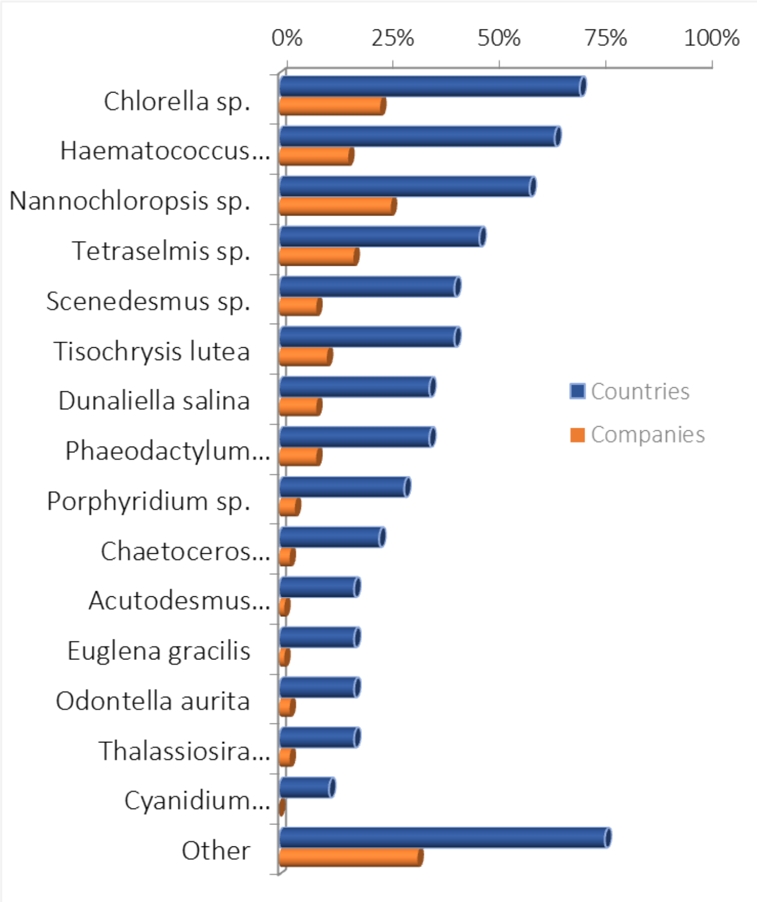


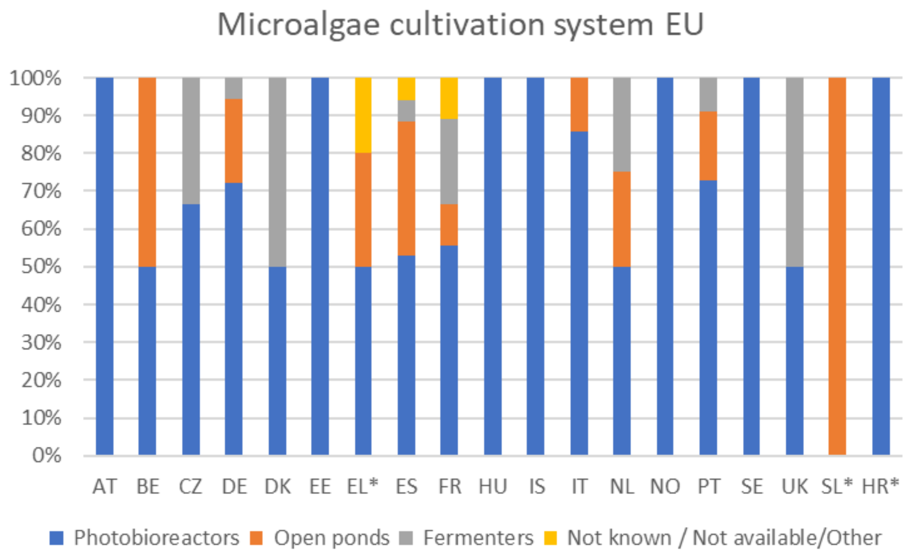
Fig. 7: The common microalgae species produced in Europe. In blue the percentage of countries (17 in total) active in microalgae cultivation that produces each species. In orange, the percentage of companies (out of a total of 218 in all countries) producing each species.
**Spirulina* is not included.

Microalgae are widely cultivated using different production systems or a combination of them. Photo-bioreactors, commonly used for microalgae production in Europe (71%), are generally capital intensive allowing a stricter control of the environmental factors and biomass quality as well as an increase in the photosynthetic efficiency and productivity (Narala *et al.,* 2016[15]; Acién *et al.,* 2017)[16]. Open ponds demand lower investment however have a high risk of contamination, lower control of the environmental

[15] Narala, R. R., Garg, S., Sharma, K. K., Thomas-Hall, S. R., Deme, M., Li, Y. , 2016. Comparison of microalgae cultivation in photobioreactor, open raceway pond and a two-stage hybrid system. *Front. Energy Res*. 4:29. doi: 10.3389/ fenrg. 2016.00029

[16] Acién, F. G., Molina, E., Reis, A., Torzillo, G., Zittelli, G. C., Sepúlveda, C. (2017). Photobioreactors for the production of microalgae. *In* Microalgae- Based Biofuels and Bioproducts, (Eds) C. Gonzalez-Fernandez and R. Muñoz (Amsterdam: Elsevier Ltd) p. 1–44. doi: 10.1016/b978-0-08-101023-5.00001-7

conditions and greater land and water requirements (Mayers *et al.*, 2016[17];Costa *et al.*, 2019[18]*).* Finally, fermenters refer only to heterotrophic algae. Fig.8 presents the preferable microalgae cultivation system by country with the corresponding percentage.



**information collected from partners contribution*

Fig. 8: Microalgae cultivation systems in the EU countries

Despite the difficulties in microalgae biomass up-scaling, microalgae are still of high interest due to their multiple applications in a wide range of fully developed commercial sectors or/and due to their potential in new markets. Large-scale cultivation will decisively contribute to the development of a sustainable industry for biomass production as well as generating cost-effective high-value products.

.2 Algae biomass production in the B-BLUE countries

For some countries and years, due to deficient reporting EU databases lack references to macroalgae production. Furthermore, statistics (EU, FAO) contain very few references to the microalgae species production and in the case of Europe the production reported is almost absent. Another important gap identified is the lack of a standardized conversion metrics to transform produced biomass based on wet weight to processed dry weight biomass. This conversion is not always obvious; relationship between wet and dry biomass is variable depending on species, season, age of the individual and drying method. Due to these aspects there are often discrepancies between reported data that

[17] Mayers, J. J., Nilsson, A. E., Svensson, E., Albers, E. (2016). Integrating microalgae production with industrial outputs reducing process inputs and quantifying the benefits. *Indust. Biotechnol.* 12:4.

[18] Costa, J. A. V., Freitas, B. C. B., Santos, T. D., Mitchell, B. G., Morais, M. G. (2019). Open pond system for microalgae culture. *In* Biomass, Biofuels and Biochemicals, Biofuels from Algae, (Eds) A. Pandey, J.-S. Chang, C. R., Soccol, D.-J. Lee, and Y. Chist, Amsterdam: Elsevier, p. 199–223.

should be considered when the countries report yearly their algae production biomass in futures studies.

Table 1: Algae Aquaculture Production Quantity by Country (2015-2019) - The production volume is expressed in tonnes live weight of the product

	2015	2016	2017	2018	2019
Greece	14,8	9,6	15,2	129,9	142,3
Spain	0,1	0,2	1,3	1,1	5,2
France	61,0	0.0	0.0	142,7	179,8
Croatia	0.0	0.0	0.0	0.0	0.0
Italy	0.0	0.0	0.0	0.0	0.0
Portugal	3,5	8,0	33,5	64,9	0,8
Slovenia	0.0	0.0	0.0	0.0	0.0
Montenegro	0.0	0.0	0.0	0.0	0.0

Source: Eurostat, Production from aquaculture

The following Table 2 displays the composition of algae production in B-BLUE countries. The whole production in Greece concerns the species Spirulina, while in France the 58.3% consists of Brown seaweeds.

Table 2: Algae production value in B-BLUE countries (2019) – in tonnes, by species

2019	Brown seaweed	Red seaweed	Green seaweed	Chlorella vulgaris	Algae nei
Greece	:	:	:	:	142,.3
Spain	0	0	5,23	:	:
France	104,93	:	6,21	4,77	63,93
Croatia	:	:	:	:	:
Italy	:	:	:	:	:
Portugal	:	:	:	:	0,78
Slovenia	:	:	:	:	:
Montenegro	:	:	:	:	:

Table 3: Algae Aquaculture Production Value by Country (2015-2019) – in Euro

	2015	2016	2017	2018	2019
Greece	561.615	382.225	1.614.460	1.308.936	1.366.435
Spain	694	126.174	165.689	8.619	23.556
France	263.215	0	0	1.340.280	1.554.432
Croatia	0	0	0	0.0	0
Italy		0	0	0.0	0
Portugal	152.763	202.869	901.893	522.759	141.341
Slovenia	0	0	0	0	0
Montenegro	0	0	0	0	0

Prices are reported as average price per unit (tonnes) in the national currency and converted to Euro. The economic value of the production in Euro is calculated by multiplying the mean price with the quantity produced.

Table 4: Algae aquaculture production value in B-BLUE countries (2019) – in Euro by species

2019	Brown seaweed	Red seaweed	Green seaweed	Chlorella vulgaris	Algae nei
Greece	:	:	:	:	1.366.438
Spain	0.0	0.0	23.556	:	:
France	403.343	:	59.983	27.343	1.063.763
Croatia	:	:	:	:	:
Italy	:	:	:	:	:
Portugal	:	:	:	:	141.341
Slovenia	:	:	:	:	:
Montenegro	:	:	:	:	:

Source: Eurostat, Production from aquaculture

Mechanical harvesting is undertaken by boats and is mainly practiced in France (Brittany), Spain (Galicia and Asturias) and to a lesser degree in the Basque country (France). Manual harvesting of seaweed and gathering of storm cast seaweed are important in France, Spain and Portugal. Harvesters either gather the cast or cut seaweed at low tide. Diving is another way to harvest seaweed manually and is practiced mostly in Portugal (Eumofa, 2018)[19]

Table 5: Macroalgae production value by harvesting in B-BLUE countries (2019) – in tonnes

	2015	2016	2017	2018	2019
Greece	0	0	0	0	0
Spain	4.074	4.795	4.086	4.044	3.492
France	19.111	55.042	39.073	40.759	51.300
Croatia	0	0	0	0	0
Italy	0	0	0	0	0
Portugal	71	0	0	0	0
Slovenia	0	0	0	0	0

Source: Eurostat, Fisheries Production, Catches of fish, crustaceans, molluscs and other aquatic organisms.

[19] EUMOFA, European Market Observatory for Fisheries and Aquaculture Products, Blue Bioeconomy, Situation report and perspectives, 2018, p. 65

There are two players in macro algae harvesting among the B-Blue countries, France and Spain. France is the major producer with 51.300 tonnes in 2019. The production trend is upward in the recent years although earlier there was a peak in 2016. The production in Spain is much lower at 3.492 tonnes in 2019 while the official statistics record no production in the other countries.

Table 6: Macroalgae production by Harvesting - Quantity by Country & Species (2019) in tonnes

Species	Spain	France
Brown seaweeds	315	51.142
Red seaweeds	242	158
Green seaweeds	0	:
Gelidium spp (Gelidium seaweeds)	232	:
Phaeophyceae (Brown seaweeds)	105	:
Rhodophyceae (Red seaweeds)	2	0
Algae (Seaweeds nei)	2.595	0
TOTAL Macroalgae	**3492**	**51300**

Source: Eurostat, Fisheries Production, Catches of fish, crustaceans, molluscs and other aquatic organisms.

3.3 Biomass Processing

Biomass up-scaling is the first challenge while harvesting for further processing, is the next crucial step. Both steps remain the major obstacles for industrial scale development and contribute ≈1/3 of the final biomass cost (Benedetti M. *et al.,* 2018)[20]. Biomass processing, mainly includes harvesting methods, dewatering, drying, sorting, cleaning and preserving of biomass. For the current report it also includes several methods for the detection and isolation of bioactive compounds (Fig.9) Harvesting procedures are commonly taking place within the production units while the detection and isolation of bioactive compounds demand a high level of R&D teams, essential equipment and laboratory infrastructures.

Algae biomass composition consists of carbohydrates, proteins, lipids and other bioactive compounds such as pigments, vitamins, etc (Fig 10). Seaweeds are the most abundant source of polysaccharides, including alginates, agar and carrageenans (Gomez D'Ayala *et al.,* 2008[21]; Laurienzo, 2010[22]), while microalgae appear as a promising sustainable alternative protein source.

[20] M. Benedetti, V. Vecchi, S.Barera and L. Dall'Osto (2018). Biomass from microalgae: the potential of domestication towards sustainable biofactories. *Microb Cell Fact* 17:173 https://doi.org/10.1186/s12934-018-1019-3.

[21] G. Gomes D'Ayala, A. De Rosa, P. Laurenzo, M Malinkoniko (2007). Development of a new calcium sulphate-based composite, using alginate and chemically modified chitosan for bone regeneration. J. Biomed. Materials Res. Part A 81(4):811-20

[22] P. Laurenzo (2010). Marine polysaccharides in pharmaceutical applications: an overview. Mar Drugs 2;8(9):2435-65 doi: 10.3390/md8092435

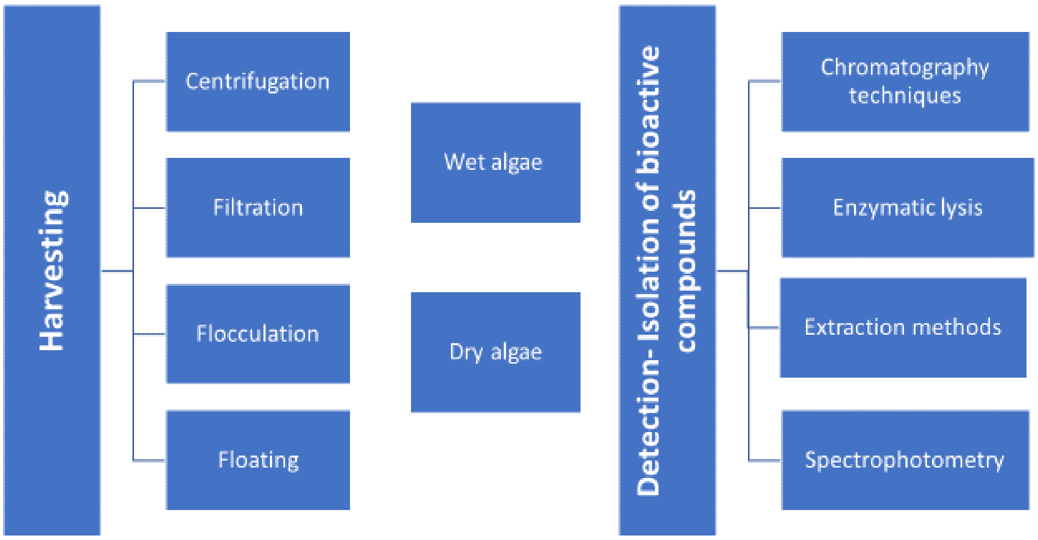


Fig. 9: Biomass processing in the Algae value chain

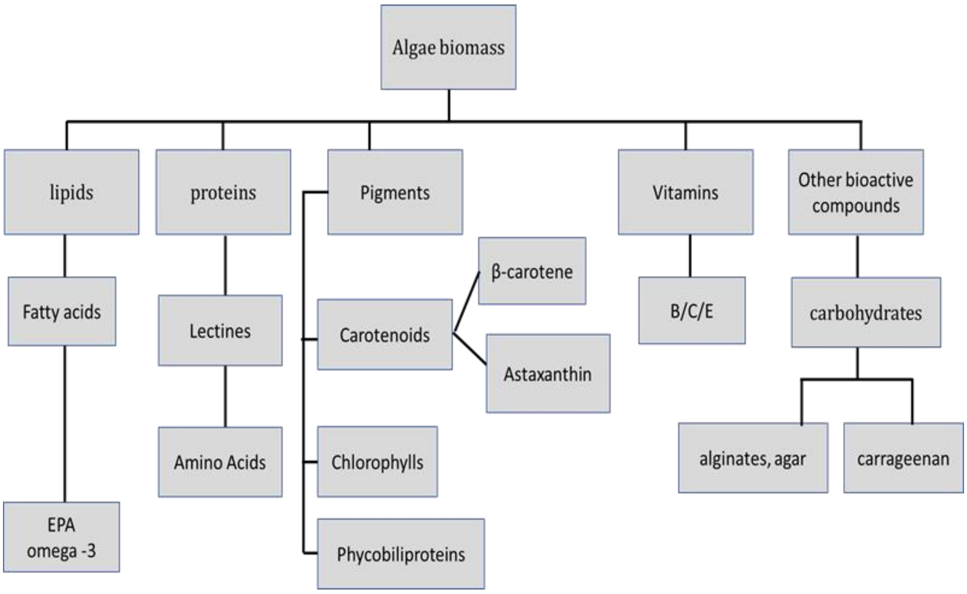


Fig. 10: Algae added value end products

3.4 Marketing and trade of algae biomass

Three types of seaweed are usually sold on the international market a) directly consumed as food seaweed products, b) dried seaweed as raw material for further processing and c) the hydrocolloids agar/alginate and carrageenan used widely in many countries for food and non- food usage.

The reported imports and exports for the MED B-Blue countries are presented in Fig 11 (international trade data from International Trade Centre -ITC).

The market demand for seaweed has been increasing over the recent years because of the increasing demand from the algae extracts (agars, alginate & carrageenan) industry. The two countries with remarkable external trade of algae are France and Spain followed by Portugal and Italy. The other countries' external trade is of small importance. The total seaweed imports in France faces a strong upward trend during the last 4 years from 11.969 tonnes in 2017 to 70.609 tonnes in 2020. A series of several challenges such as stock reduction, increasing processing production and labour costs and environmental constraints of the seaweed harvest in protected areas, the share of local algae in the processing EU industry has been mostly declining. These factors have negatively impacted the European processing industries local supply, which has conducted to an increase of imports of seaweed unfit for human consumption.

In Europe one of the most important expanding reasons of the algae market is the consumer view for algae as the natural "superfood". The demand for "all-natural ingredients" has been on the rise, owing to the safety concerns associated with synthetic ingredients; hence, the demand for algae products is expected to grow considerably in the coming years. Consumers perceive the impact of natural food additives on health as positive, thereby increasing their demand in food products. The external trade of micro and macro algae in the B-BLUE countries incorporates this growing importance in some countries.

According to Harmonized System (HS) Codes which is a standardized method of classifying traded products by the World Customs Organization for the monitoring of international trade, there are two codes (at 6 digit level) in which all the species of algae are included. The data was extracted from International Trade Centre database. 1) Product code 121221: Seaweeds and other algae, fresh, chilled, frozen or dried, whether or not ground, fit for human consumption, 2) Product code 121229: Seaweeds and other algae, fresh, chilled, frozen or dried, whether or not ground, unfit for human consumption.

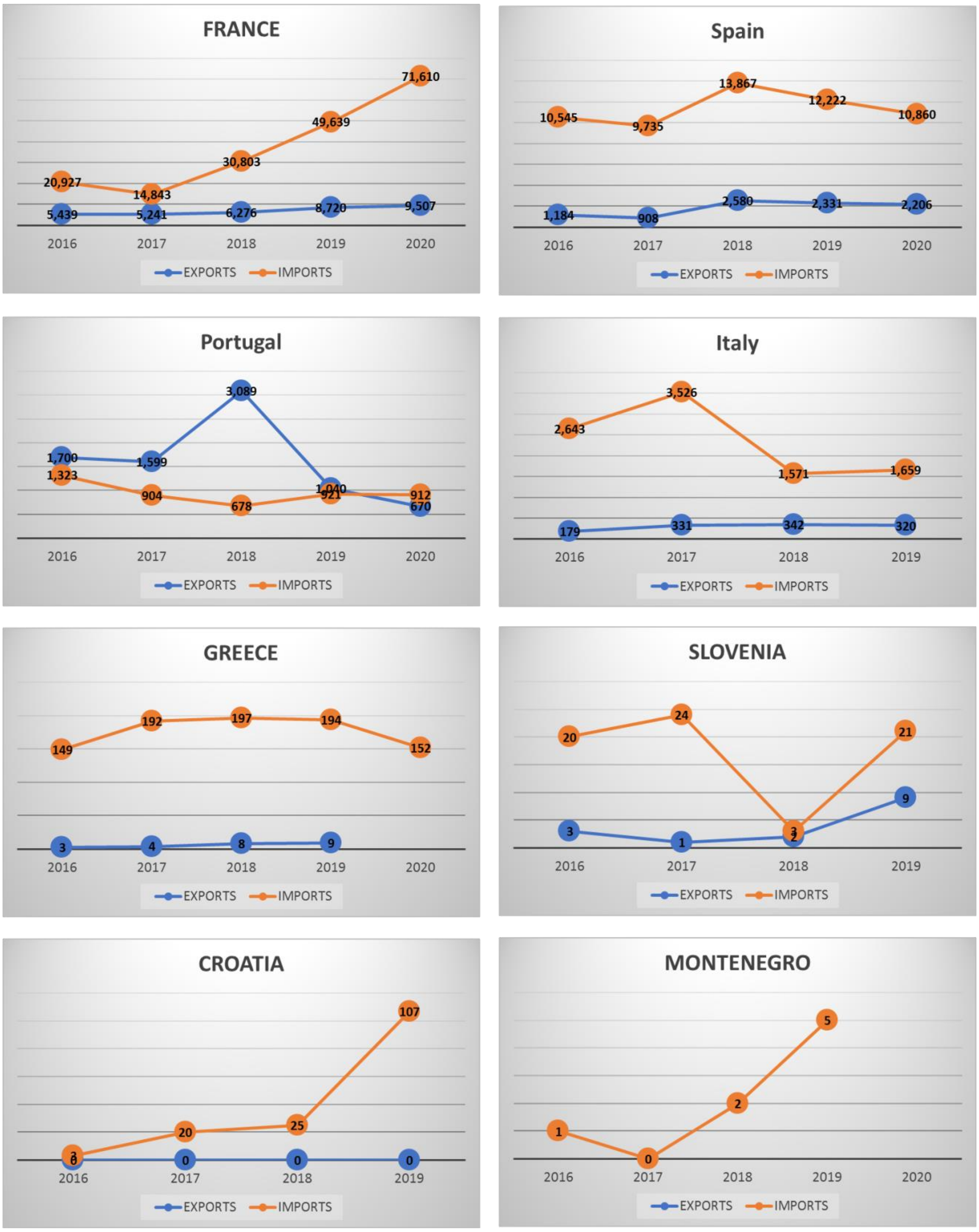


Fig. 11: Algae Imports and exports for the MED B-Blue countries

Source: International Trade Centre database

Table 7: Algae fit for human consumption exports in tonnes

Exporters	2016	2017	2018	2019	2020
France	991	717	622	540	901
Spain	238	153	142	344	961
Portugal	35	84	186	109	171
Italy	21	21	14	25	
Greece	1	1	2	3	0
Slovenia	3	0	0	1	
Croatia	0	0	0	0	

Table 8: Algae unfit for human consumption exports in tonnes

Exporters	2016	2017	2018	2019	2020
France	4.448	4.524	5.654	8.180	8.606
Spain	946	755	2.438	1.987	1.245
Portugal	1.665	1.515	2.903	931	499
Italy	158	310	328	295	
Slovenia	0	1	2	8	
Greece	2	3	6	6	62

Table 9: Algae fit for human consumption imports in tonnes

Importers	2016	2017	2018	2019	2020
France	3.489	2.874	3.035	1.870	1.001
Italy	581	578	479	496	
Spain	593	540	559	321	694
Portugal	78	104	110	54	52
Greece	14	11	19	11	4
Croatia	2	5	3	4	
Slovenia	3	3	3	2	
Montenegro	1	0	1	1	

Table 10: Algae unfit for human consumption imports in tonnes

Importers	2016	2017	2018	2019	2020
France	17.438	11.969	27.768	47.769	70.609
Spain	9.952	9.195	13.308	11.901	10.166
Italy	2.062	2.948	1.092	1.163	
Portugal	1.245	800	568	867	860
Greece	135	181	178	183	148
Croatia	1	15	22	103	
Slovenia	17	21	0	19	
Montenegro	0	0	1	4	

Source: International Trade Centre

3.5 A source of Biomass for Biotechnological Applications

Due to the algae high nutritional value and the wide range of applications in almost every industrial sector, it is of great importance to advance the process of industrialization of algae products. The growing trend towards using natural ingredients isolated from micro-macroalgae in a wide range of products, such as food & beverages, pharmaceuticals, cosmetics, nutraceuticals for humans and animal nutrition, biodiesel production, makes imperative to accelerate technologies which aim at delivering added value algae-based products (Rotter *et al.,* 2021)[23]. Among these technologies several techniques, such as modification, formulation and encapsulation are included, aiming at the enclosing of the isolated biomolecules or algae extracts into, the final products for the creation of innovative value-add products.

- ✓ In biological formulation development, the main objective is to find the conditions that offer the greatest level of stabilization to support the highest proportion of native bioactive compound, to be delivered.
- ✓ Modification includes all the techniques are required for the modulation of the micro or macro biomolecules (in fact part of their chemical structure) in order to modify the physico-chemical properties of them (e.g. improvement of the solubility of lipophilic compounds).
- ✓ Encapsulation of bioactive compounds is another crucial procedure targeting at the insertion of the isolated biomolecules within materials. It is a sophisticated method which is using nano or microparticles in order to enclose the desired compound it the final product and contributes to the protection of the functional properties of bioactive compounds, (improves the bioavailability the chemical and thermal stability, decreases the instability etc) during the life cycle of the final product. Encapsulation technology has been extensively researched and applied in diverse areas, such as the pharmaceutical, medical, food, cosmetics, chemical, and agricultural industries (Augustin M.A. & Hemar Y., 2009[24], Champagne C.P. & Fustier P., 2007[25]). There are several examples of products consisting of algae or their extractions in various applications of several industrial sectors such as food industry, animal feed, nutraceuticals, cosmetics, pharmaceuticals, energy, agriculture, chemical industries.

[23] Rotter, A., Barbier, M., Bertoni, F., Bones, A., Cancela, L., Carlsson, J., Carvalho, M., Ceglowska, M., Chirivella-Martorell, J., Dalay, M., Cueto, M., Dailianis, T., Deniz, I., Diaz-Marrero, A., Drakulovic, D., Dubnika, A., Edwards, C., Einarsson, H., Erdogan, A., ... Vasquez, M. (2021). The essentials of marine biotechnology. *Frontiers in Marine Science*, 8(8), https://doi.org/10.3389/fmars.2021.629629

[24] Augustin M.A., Hemar Y. (2009). Nano- and micro-structured assemblies for encapsulation of food ingredients. *Chem. Soc. Rev.* 38, 902–912.

[25] Champagne C.P. & Fustier P. (2007). Microencapsulation for the improved delivery of bioactive compounds into foods. *Curr. Opin. Biotechnol*., 18, 184–190.

3.5.1 Food, feed nutritional supplements

Microalgae biomass

Concerning the rules of safe production and consumption, the cyanobacteria *Spirulina* sp., along with the green algae *Chlorella* sp. and *C. reinhardtii* are internationally recognized as "generally regarded as safe" or GRAS, a certification legislated under the United States Food and Drug Administration (FDA, 2019)[26]. Other certified GRAS species include the green algae *Haematococcus* sp. and *Dunaliella* sp. (FDA, 2019).

Chlorella **and Spirulina (*Arthrospira platensis*)** are the dominant microalgae species, mostly commercialized as a nutritional supplement or representing a source of natural food colorants (Soletto et al., 2005)[27]. They are mainly marketed as **tablets**, **capsules**, **dry powder** and **liquid**. ***Dunaliella*** is also marketing, as powder, for human consumption as an ingredient of dietary supplements and functional foods.

Approximate prices (US$) for Spirulina and Chlorella tablets are **100 -120 $/kg tablets.**

The largest current application of microalgae in the feed sector is in aquaculture. ***Isochrysis sp, Chlorela sp, Tetraselmis sp, Nannochloropsis sp, Rhodomonas sp, Dunaliella sp. Pavlova sp,*** due to their high content in fatty acids are commonly used as live feed for shellfish or fish larvae in hatcheries. In addition, ***Chlorella*** *and* ***Spirulina*** are used as ingredients in the feed for many types of animal such as cats, dogs, horses, poultry etc (Spolaore *et al.* 2006)[28] which positively affect the survival, physiology, development, growth, disease resistance (Nath *et al.,* 2012)[29] and fertility of animals (Kaparaku, 2018[30]). **Approximately 30% of world microalgae production (including 50% of Spirulina production) is sold as feed supplement.**

Haematococcus pluvialis, (freshwater algae) is a source for astaxanthin pigment. The algae can accumulate astaxanthin up to 3% dry weight (Pulz, 2004)[31]. The largest astaxanthin consumer is the fish feed industry e.g. salmon (Olaizola, 2003)[32]. But a new market for astaxanthin has also expanded in human nutraceuticals.

Current production costs of **microalgal-derived astaxanthin are still higher than those of synthetic (EUR 1540/kg** and EUR 880/kg, respectively).[33]

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[26] FDA (2019). Available online at: https://www.fda.gov/food/food-ingredients-packaging/generally-recognized-safe-gras (accessed October, 2019).

[27] Soletto D., Binaghi L., Carvalho J.C.M., Converti L., (2005). Batch and fed-batch cultivations of Spirulina platensis using ammonium sulphate and urea as nitrogen sources. *Aquaculture*, 243 (1-4): 217-224.

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Fig. 12: Products with microalgae for food industry (human consumption and animal feed)

Mass production of certain protein-rich micro-algae is considered as a possibility to close the predicted so called "protein gap" (Milledge, 2011)[34]. Comprehensive analyses and nutritional studies have demonstrated that these algal proteins are of high quality and comparable to conventional vegetable proteins. However, due to high production costs as well as technical difficulties to incorporate the algal material into palatable food preparations, the propagation of algal protein is still in its infancy[35]. Although microalgae and their extracts are used for food in certain niche applications, the large-scale production of algae to solve the world's food crisis and shortage of protein has not been practiced nowadays, likely due to the high cost of production.

Macroalgae biomass

The Edible seaweeds due to their content of various bioactive compounds with potential health benefits, set new challenges in food industry and inaugurate new product lines in food processing. Many edible macroalgae have high nutritional value and the environmentally friendly cultivation and harvesting methods make them appealing as raw material for food and feed (MacArtain *et al*. 2007[36]; Barbier *et al.* 2019[37]; Cherry *et al.* 2019[38]). Seaweeds and especially Brown and Red algae are particularly important for their cell-wall polysaccharides, (alginates, agars, carrageenans) which are used extensively in the food-processing industry due to their unique thickening and gelling properties.

[34] Milledge J., (2011). Commercial Application of Microalgae Other Than as Biofuels: A Brief Review. Reviews in Environmental Science and Bio/Technology 10(1):31-41.

[35] Amorim M.L., Soares J., dos Reis Coimbra J.S., de Oliveira Leite M., Teixeira Albino L. F., Martins M.A. (2021). Microalgae proteins: production, separation, isolation, quantification, and application in food and feed. Critical Reviews in Food Science and Nutrition, https://doi.org/10.1080/10408398.2020.1768046.

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[37] Barbier M, Charrier B, Araujo R, Holdt S, Jacquemin B, Rebours C (2019) PEGASUS – PHYCOMORPH European guidelines for a sustainable aquaculture of seaweeds, COST action

[38] Cherry P, Yadav S, Strain C, Allsopp P, McSorley E, Ross R, Stanton C (2019) Prebiotics from seaweeds: an ocean of opportunity? Marine Dugs 17(6):327

These types of polysaccharide are generally very abundant, in and represent an average of 30–70% of dry weight of the thallus and as algae extracts are used in yogurts, jellies, ice creams, pie fillings, puddings, processed cheese, beer fining application, salad dressings.

Porphyra sp, commonly known as nori, is the most widely consumed seaweed on earth, belongs to the red algae and can be bought in supermarkets as dried, very thin sheets used to prepare sushi. ***Undaria pinnatifida***, widely known as Wakame, it is used as an ingredient in noodles, soups and salads for human consumption but it is also a functional ingredient which along with ***Himanthalia elongate***, have mostly been reported as ingredients in meat and meat-derived products (Alfonso *et al* 2019[39]). In addittion Silva-Neto *et al.* (2012[40]) suggested that kelp meal works as an excellent additive in pelleted feeds for penaeid shrimps and thus improved feed utilization efficiency in this slow feeding species. Valente *et al* (2006[41]) recommended that macroalgae such as *Gracilaria* and *Ulva* can be incorporated in sea bass feeds without affecting the performance of fish.

New sources for protein are investigated and protein extracted from farmed seaweed is considered an alternative. Seaweed protein product (SPP) can be used as a protein ingredient for fish feed, as several macroalgae species have a dry matter crude protein content of approximately 50%, which is higher than other terrestrial plants and a well-balanced amino acid profile (Emblemsvåg *et al.,* 2020)[42]. However the rapid decay of harvested seaweed creates a requirement for a rapid and large capacity to process the biomass to preserve quality. After harvest, the seaweed must be immediately treated onboard of a ship with sufficient scale and treatment capabilities, to take advantage of the economies of scale benefits and the costs of processing equipment (Stevant *et al.* 2017)[43]. Additionally preferably would be the extraction of seaweed protein and at the same maximize the extraction of value-added ingredients to increase probability.

Fig. 13: Products containing macroalgae for food industry (human consumption and animal feed)

[39] N, C., Anfonso., M. D. Catarino , A. M. S. Silva , S. M. Cardoso (2019). Brown macroalgae as valuable food ingredients. *Antioxidants* , Vol. 8; doi:10.3390/antiox8090365

[40] Silva-Neto J.F., Nunes A.J.P., Sabry-Neto H., Sa M.V.C. (2012). Spirulina meal has acted as a strong feeding attractant for *Litopenaeus vennamei* at a very low dietary inclusion level, *Aquaculture Research*, 43:430-437.

[41] Valente, L. M. P.; Gouveia, A.; Rema, P.; Matos, J.; Gomes, E. F.; Pinto, I. S., (2006). Evaluation of three seaweeds Gracilaria bursa-pastoris, Ulva rigida and Gracilaria cornea as dietary ingredients in European sea bass (Dicentrarchus labrax) juveniles. *Aquaculture*, 252 (1): 85–91.

[42] Emblemsvåg J., Pereira Kvadsheim N., Halfdanarson J., Koesling M., Nystrand B.T., Sunde J., Rebours C., (2020). Strategic considerations for establishing a large-scale seaweed industry based on fish feed application: a Norwegian case study. J. of Applied Phycology, 32:4159-4169.

[43] Stévant P., Marfaing H., Rustad T., Sandbakken I., Fleurence J., Chapman A. (2017) Nutritional value of the kelps Alaria esculenta and Saccharina latissima and effects of short-term storage on biomass quality. . of Applied Phycology 29:2417–2426.

3.5.2 Pharmaceuticals, Cosmetics

A large number of papers, reviews, and books demonstrate that algae cells are an inexhaustible source of biologically active compounds suitable for use in pharmacology and cosmetology. These bioactive molecules are nothing more than the primary and secondary metabolites, produced from all kind of algae. However, as a general rule the microalgae are the main source of primary metabolites such us lipids, proteins, amino acids and pigments while macroalgae are mainly producers of polysaccharides, vitamins, sterols and pigments (Kornprobst, 2014)[44]. For purely pharmacological applications the isolation and purification of these compounds is needed though procedures which are complex and expensive. On the other hand, extracts from micro and macroalgae which contain more than one active compound are widely used in the cosmetic industry, which is of considerable importance from an economic point of view. Most algae effects in cosmetics are described in patents without considerable explanation about the type of bio compounds or the mechanisms responsible for each cosmetic performance. Algae bioactive metabolites with antioxidant, anticancer, antimutagenic, antibacterial antifungal etc properties, make algae an interest field for further exploitation. Therefore, the use of such compounds seems to be a promising and innovative approach to the development of healthier, functional, and sustainable products.

Pigments

Phycoerythrin, chlorophyll, fucoxanthin, β-carotene, xanthophyll phycoerythrin and phycocyanin are the pigments mainly derived from algae and are commonly used in pharmacology and cosmetology due to their powerful antioxidant, anti-inflammatory moisturizing and regenerating properties. It has been reported that fucoxanthin induces apoptosis in osteoclast-like cells and could be useful for the prevention of osteoporosis and rheumatoid arthritis (Das *et al.,* 2010)[45]. In addition, has been suggested that the application of algal carotenoids in modern pharmacology can lead to the development of cancer or cardiovascular diseases treatment (Gammone *et al.* 2015)[46]. Spirulina and Porphyridium are two common microalgae, which are commercially exploited for production of phycobiliproteins with potential in food as natural dyes, cosmetic products and diagnostic tools in biomedical research as fluorescent markers The price of phycobiliproteins vary from US$ 3 to US$ 1500/ mg (Sharma & Sharma, 2017)[47]

Polysaccharides

Polysaccharides constitute the most widespread group of compounds found in algae and demonstrating pharmaceutical properties (Kornprobst, 2014), due to their anti-

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[44] Kornprobst J.M. (2014). Encyclopedia of Marine Natural Products, 2nd Edition, Wiley-VCH Verlag GmbH & Co. KGaA.

[45] Das, S.K., Ren, R., Hashimoto, T., and Kanazawa, K. (2010) Fucoxanthin induces apoptosis in osteoclast-like cells differentiated from RAW264.7 cells. *J. Agric. Food Chem.,* 58, 6090–6095.

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[47] Sharma N and sharma P. (2017). Industrial and Biotechnological Applications of Algae: A Review. J. of Advances in Plant Biology, ISSN NO: 2638-4469, DOI : 10.14302/issn.2638-4469.japb-17-1534.

inflammation activity (Raposo *et al.* 2015)[48] and the anticancer activity of fucoidan extracts. It it is important to mention that according to several experiments, fucoidan extracts lead to an induction of apoptosis in different kind of tumor cells (Boo *et al.* 2013[49], Yamasaki *et al.* 2012[50], Zhang *et al.* 2013[51]). Furthermore, alginates are considered as biomolecules with pharmacological potential (Draget and Taylor 2011[52], Lee and Mooney 2012[53]). The sulfated polysaccharides in the walls of microalgae cells are active as antioxidants (Assunção *et al.* 2017[54]) and may be used in the development of medicines and cosmetics.

Fatty acids and Proteins

Polyunsaturated fatty acids (PUFAs) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) play crucial roles in human health. They cannot be synthesized by higher eukaryotes and are thus high-value compounds of algae. Besides their widely use as nutraceuticals and their positive effects in enhancing immune system (Sanchez-Machado *et al.* 2002)[55] their anti-allergic activity has also been reported (Chen *et al.,* 2015)[56]. Presently, **the production costs associated with microalgal derived EPA/DHA reach US$ 40/kg EPA + DHA**, but technological advancements could possibly lower this to ~US$ 10/kg EPA + DHA, which is competitive if compared to fish oil (~US$ 8/kg EPA + DHA) (Fabris *et al.* and references there in, 2020).

The protein content of marine algae is up to 70% of the dry weight, depending on the season and the species (Abreu *et al.* 2014)[57]. Marine algae proteins and their applications in pharmacology and cosmetic industry, relates to their bioactive peptides and specifically to the biological function of the latest, including antioxidant, anticancer, anti-atherosclerotic, and immune-modulatory effects (Fan *et al.* 2014[58], Riccio & Lauritano. 2020[59])

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[48] Raposo MDJ, De Morais AM, De Morais RM (2015) Marine polysaccharides from algae with potential biomedical applications. *Mar Drugs* 13(5):2967–3028

[49] Boo HJ, Hong JY, Kim SC (2013) The anticancer effect of fucoidan in PC-3 prostate cancer cells. Mar Drugs 11(8):2982–2999.

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[51] Zhang Z, Teruya K, Yoshida T et al (2013) Fucoidan extract enhances the anti-cancer activity of chemotherapeutic agents in MDA-MB-231 and MCF-7 breast cancer cells. Mar Drugs 11 (1):81–98

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[58] Fan X, Bai L, Zhu L, Yang L, Zhang X (2014) Marine algae-derived bioactive peptides for human nutrition and health. J Agric Food Chem 62:9211–9222.

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Fig. 14: Cosmetics and Pharmaceutical products contain bioactive compounds derive from algae

3.5.3 Bioenergy and Biofertilizers

Carbohydrates, lipids and proteins that can be transformed to various forms of biofuel are the major biochemical components of algae biomass. The algae derived energy (micro and macroalgae) conversion into different solid, liquid and gaseous biofuels is mentioned as Bioenergy. Exploitation of algae for bioenergy applications is widely accepted as a great opportunity for sustainable management of natural resources, although there remain substantial technical, economical and sustainability barriers to commercial deployment of algae-based technologies. The high required biomass volumes, the high cost of cultivating and harvesting algal biomass and the substantial decline in petroleum prices since August 2014 are some of the obstacles to be overcome. The main problem for commercial algae-based biofuels production remains the high cultivating cost. Cultivating cost varies significantly and can range between $0.54/kg (open ponds) and $10.2/kg (photobioreactors).

A cost which can be considered as cost-effective biofuel production from algal biomass is $0.54/kg ($491/tonne), which is a cost target of the U.S. Department of Energy's for the year 2022 (IEA, 2017)[60].

Microalgae have been recognized as potentially good sources for biofuel production because of their rapid biomass production and their high oil content (Brennan & Owende, 2010)[61]. The most common algae used in biodiesel production, are aquatic green algae. The key for an effective biofuel production is the maximization of lipid production which in general terms can be succeeded through experimental cultivation enhancing lipid production in the cell and/or genetic modification (genetic engineering) for the creation of more suitable strains (ElFar *et al,* 2021[62]). A microalgae-based biogas

[60] State of Technology Review – Algae Bioenergy Published by IEA Bioenergy: Task 39: January 2017.

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industry is far from commercialization, although significant steps are being taken in the wastewater treatment sector to demonstrate facilities of a significant scale (IEA, 2017).

Macroalgae present during the last decade a noteworthy interest for biogas. However, most of the studies refer to lab scale cultivation, as up-scaling of algae biomass production is the main issue still needed to be solved to unfold macroalgae potential for uses as biofuel (Narala *et al.,* 2016)[63]. Taking into account than in Europe seaweed biomass production is still very dependent on the harvesting of wild stocks and wild stocks continue to decline, new technological improvements in the biomass cultivation systems are essential for promoting an economic viability of algal biofuels production. In addition, due to the lack of natural source of nutrients in the Mediterranean Sea, co-production through an integrated multi-trophic aquaculture (IMTA).

Despite the extensive scientific literature on liquid biofuel production and the notable progress in the last decade in upgrading technologies and better understanding of algae production, the sector is not developed at the EU level. In Denmark, a biogas facility digests cast seaweeds and the residues of seaweed processing industries, as a "**green**" biofuel industry in order to increase the environmental sustainability and ensure access to, sustainable and modern energy -SDG's 7 (IEA, 2015)[64].

Biofertilisers enhance agricultural production by promoting the adequate supply of nutrients to the host plants. Biofertilizers are environmentally friendly products and could be a great alternative against synthetic fertilizers which have a significant impact on environmental degradation (Kawalekar 2013)[65]. The biofertilizer and biopesticide properties of microalgae, which contain high levels of micronutrients and macronutrients, have been found to enhance soil organic matter accrual, water use efficiencies, rooting, higher crop yields and quality, and tolerance to pests, drought and salts (Chatterjee *et al.,* 2017)[66]. Microalgae -cyanobacteria have been successfully used as biofertilizer in rice cultivation in India and extracts of macroalgae , *Ascophyllum nodosum,* has also traditionally used as a soil biofertilizer and conditioning agent (Fan *et al.,* 2011)[67]. In addition, the biological compounds of macroalgae except of being crops growth accelerators (Stirk *et al*. 2020)[68], play also a protective role to the plants through their bacteriostatic action. On the contrary phytohormone treatments can improve microalgae

[63] Narala R. R., Garg S., Sharma K. K., Thomas-Hall S. R., Deme M., Li Y. (2016). Comparison of microalgae cultivation in photobioreactor, open raceway pond and a two-stage hybrid system. *Front. Energy Res*. 4:29. doi: 10.3389/fenrg. 2016.00029.

[64] International Energy Agency Bioenergy, 2015. Task 37. Solrød Biogas – Towards a Circular Economy. http://www.iea-biogas.net/case-studies.html.

[65] Kawalekar, J.S. (2013). Role of Biofertilizers and Biopesticides for Sustainable Agriculture. *Journal of Bio Innovation*, 2, 73-78.

[66] A. Chatterjee, S. Singh, C. Agrawal, S. Yadav, R. Rai, L.C. Rai (2017). Role of algae as a biofertiliser. *In*: Algal Green Chemistry, Chapter 10, 189-197. http://dx.doi.org/10.1016/B978-0-444-63784-0.00010-2

[67] Fan X., Bai L, Zhu L., Yang L., Zhang X. (2014) Marine algae-derived bioactive peptides for human nutrition and health. *J.Agric Food Chem* 62: 9211–9222.

[68] Stirk W.A., StirkKannan A., Rengasamy K.R.R.., Kulkarni M., Van Staden J. (2020). Plant Biostimulants from Seaweed: An Overview, *In: The Chemical Biology of Plant Biostimulants, Publisher: Wiley.*

cultivation practices, increasing lipid content and productivity for biofuel production (Stirk *et al.,* 2020)[69].

One kg of algae containing 7%N and 0.8%P used as a fertilizer has the potential to reduce the CO2 emissions from conventional inorganic fertilizers by 0.23 kg CO2EQV /kgAlgae (Wood and Cowie, 2004)[70]. It is worthy to mention a case in Spain, when Spanish coasts faced problem with invasive macroalgae species (entered into, through the Suez Canal) they decided to use them as bio-fertilizers in order to control their proliferation in a sustainable and environmentally friendly way. By this way they managed to convert a considerable threat such as the increasing of invasive species biomass, into a great source of extracts and compounds with industrial interest (Pereira *et al*., 2021)[71].

As biological products and organic cultivations gain ground against conventional cultivations and in order to achieve effective protection of the environment it is essential to improve the plant productivity using natural alternatives which should be safe to maintain ecological integrity (Nagy and Pinter, 2014)[72]. The economic benefits of algal application may not always come from increases in production but from savings in fertility expenses and benefits to ecosystem services.

There are currently a few companies marketing microalgae or microalgal based products, primarily *Chlorella vulgaris*, in agriculture (Nickols, 2020)[73]

- ✓ Heliae– PhycoTerra or PhycoTerra Organic– liquid suspended 10% solids product of pasteurized *Chlorella vulgaris.*
- ✓ AlgEternal – ElixEarth Soil Amendment Concentrate – Liquid concentrate of living Chlorella vulgaris and Scenedesmus acuminatus - 10-15 million cells per milliliter (mL) and ~60% water.
- ✓ Ferticell –Calcium 880, Microelements 1-0-0 and Nutri-Plus 2.5-0-0,– All products contain microalgal extracts mixed with other elements such as potassium sulfate, calcium carbonate, amino acids
- ✓ TrueAlgae– P Liquid Fertilizer– liquid product derived from *Chlorella vulgaris*
- ✓ AgriAlgae –Pasteurized Chlorella

3.5.4 Wastewater treatment

Microalgal species can treat municipal, industrial, agro-industrial, and livestock wastewaters (Abdel-Raouf et al., 2012)[74]. Organic and chemical contaminants can be

[69] Stirk W.A. & Van Staden J., (2020). Potential of phytohormones as a strategy to improve microalgae productivity for biotechnological applications. Biotechnology Advances, vol. 44 https://doi.org/10.1016/j.biotechadv.2020.107612.
[70] Wood S.W. &Cowie A. (2004). A Review of Greenhouse Gas Emission Factors for Fertiliser Production. r IEA Bioenergy Task 38.
[71] A.G. Pereira, M. Fraga-Corral, P. Garcia-Oliveira, C. Lourenço-Lopes, M. Carpena, M. A. Prieto, J.Simal-Gandara (2021). The Use of Invasive Algae Species as a Source of Secondary Metabolites and Biological Activities: Spain as Case-Study. *Mar Drugs.* 2021 Apr; 19(4): 178.
[72] Nagy P.T, Pinter (2014). Effects of Foliar Biofertilizer Sprays on Nutrient Uptake, Yield, and Quality Parameters of Blaufrankish (Vitis vinifera L.) Grapes. *Communications in Soil Science and Plant Analysis* 46(sup1):219-227
[73] Nickols K. (2020). MYLAND COMPANY LLC

removed, along with heavy metals and pathogens, during a wastewater remediation process at the same time with the production of biomass aimed for biofuels (Muñoz and Guieysse 2006)[75].

Various types of wastewaters have varying nutrient loads and different types of biochemical composition, which affect the efficiency of their treatment process significantly. Mostly, monocultures of microalgae are used in wastewater treatment (WWT), but microalgae–bacteria consortia have received significant attention recently (Rani S. *et al.* 2021)[76]. Many microalgae species have been adapted to grow efficiently in wastewater. This way, the cost of production may be decreased due to the simultaneous use of wastewater and cultivation of specific nutrient-rich microalgae. As an alternative to conventional tertiary treatment, both nitrogen and phosphorus can be removed by rapidly growing cultures of algae. This way, nitrogen and phosphorus can directly be taken up by microalgae, resulting in valuable algal biomass. The biomass can further be utilized as biofuel, feedstock or agricultural fertilizer. Composting the algal biomass with green waste (leaves, grass, etc.) for 6 months will be sufficient to remove the pathogens found in wastewater. Therefore, phycoremediation is a sustainable biorefinery approach (Michelon et al., 2020)[77].

Wastewater, with high levels of CO2, is an exceptional growth medium, facilitating algae production with high growth rates, no need for nutrient input, reduced harvesting costs and elevated lipid content. Microalgae-mediated CO2 bio-mitigation can be more economic, cost-effective, and eco-friendly, when it is incorporated into a wastewater treatment infrastructure (Collotta et al., 2018)[78]. A number of studies have reported successful cultivation of several species of microalgae such as *Chlorella*, *Scenedesmus*, *Phormidium, Botryococcus, Chlamydomonas*, and *Arthrospira* for wastewater treatment and the efficacy of this method is promising.

Furthermore, combining the wastewater nutrient removal with capturing CO2 from flue gas may provide an environmentally and economically useful system to reduce greenhouse gas emission. Numerous studies have demonstrated that wastewater grown algae has higher photosynthetic efficiencies and productivities when CO2 is added to the culture (Kuo *et al.,* 2016[79]; Chaudhary et al., 2018)[80]. An increase in pH due to photosynthetic

[74] Abdel-Raouf, N.; Al-Homaidan, A. A.; Ibraheem, I. B. M., (2012). Agricultural importance of algae. *African. J. Biotech*., 11 (54): 11648-11658.

[75] Muñoz R. & Guieysse B., (2006). Algal-bacterial processes for the treatment of hazardous contaminants: a review. *Water Res.* 40(15):2799-815. doi: 10.1016/j.watres.2006.06.011.

[76] Rani S., Gunjyal N., Ojha C. S. P., Asce F., Prasad Singh R. (2021), Review of Challenges for Algae-Based Wastewater Treatment: Strain Selection, Wastewater Characteristics, Abiotic, and Biotic Factors. *J. of Hazardous, Toxic, Radioactive Waste*, 25 (2).

[77] W. Michelon, A.Viancelli G. Fongaro, L. M. de Andrade, H. Treichel, C. J. de Andrade (2020). Phycoremediation: A Sustainable Biorefinery Approach. Microbial Rejuvenation of Polluted Environment pp. 101-140.

[78] Collotta M., Champagne P., Mabee W., Tomasoni G. (2018). Wastewater and waste CO2 for sustainable biofuels from microalgae. Algal Research 29:12-21.

[79] C.-M. Kuo, J.-F. Jian, T.-H. Lin, Y.-B. Chang, X.-H. Wan, J.-T. Lai, J.-S. Chang, C.-S. Lin (2016). Simultaneous microalgal biomass production and CO 2 fixation by cultivating Chlorella sp. GD with aquaculture wastewater and boiler flue gas. *Bioresour Technol.* 221:241-250. doi: 10.1016/j.biortech.2016.09.014.

[80] R. Chaudhary, Y.W Tong, A.K. Digshit (2020). Kinetic study of nutrients removal from municipal wastewater by Chlorella vulgaris in photobioreactor supplied with CO2-enriched air. *Environmental Technology* 41(5).

activity in any cultivation system can inhibit the optimum growth of microalgae. Addition of CO2 to wastewater treatment HRAP systems makes a balance in the acidity of media and thus neutralizes the effect of increasing pH. The major disadvantages are the increased land requirements of the algal plants, in cases of open pond systems and the increased cost in capital, in cases of photobioreactor systems.

3.5.5 Bio-materials

The sources that can be used for bioplastic production are plant-based raw materials, natural polymers-carbohydrates, proteins, etc and other small molecules-sugar, disaccharides, and fatty acids (Cinar et al. 2020[81]; Thylen *et al,* 2014[82]). Microalgae can be a potentially biomass source for bioplastic production since it does not compete with food sources, has the ability to grow on waste resources, and can achieve high lipid accumulation (Hempel *et al.* 2011[83]; Rahman and Miller 2017)[84]. Microalgae polymers are 100% vegetable and 100% biodegradable. By breaking down into very small pieces, it does not release any toxic compound for its environment. Bioplastic production from microalgae can be sustainable and contributes to the circular economy as well as the bioeconomy (Mohan et al., 2019[85]). Bioplastics can be used in food packaging, pharmaceuticals and cosmetics, as biodegradable material made from algae that could replace regular crude oil-based plastic packaging.

Chlorella and *Spirulina* species are the most commonly used in the production of both biopolymers and plastic blends. In addition, there has been some research conducted using other microalgae species such as *Phaeodactylum tricornutum*, *Nannocloropsis gaditana*, *Calothrix scytonemicola*, *Scenedesmus almeriensis*, *Neochloris oleoabundans* (Cinar et al., 2020 and references there in). Long chain organic polymers of seaweeds make them an ideal substitute for many material and fabric requirements.

Algopack, a Brittany based company and affiliated researchers have devised and perfected production of a wide range of algal bioplastics products capable of replacing almost all the demands currently met with fossil plastic, which is especially important for single-use items A Dutch seaweed farming company estimate that 0.15% dry weight of their seaweed harvest could be recovered plastic and civil engineers report encouraging results in using plastic granules as a sand substitute in concrete Loliware a seaweed-based straw company that received some attention amid the 2018 wave of activism

[81] S.O. Cinar, Z.K. Chong, M.A. Kucuker, N. Wieczorek , U. Cengiz, K. Kuchta (2020). Bioplastic Production from Microalgae: A Review. *Int. J. Environ. Res. Public Health* 2020, 17, 3842; doi:10.3390/ijerph17113842.

[82] Thielen, M. (2014). Bioplastics: Plants and Crops Raw Materials Products; Fachagentur Nachwachsende Rohstoffe eV(FNR) Agency for Renewable Resources: Gülzow, Germany.

[83] Hempel, F.; Bozarth, A.S.; Lindenkamp, N.; Klingl, A.; Zauner, S.; Linne, U.; Steinbüchel, A.; Maier, U.G. (2011). Microalgae as bioreactors for bioplastic production. Microb. Cell Factories 2011, 10, 81

[84] Rahman, A.; Miller, C.D. Microalgae as a Source of Bioplastics. In Algal Green Chemistry: Recent Progress in Biotechnology/Edited by Rajesh Prasad Rastogi, Datta Madamwar, Ashok Pandey; Rastogi, R.P., Madamwar, D., Pandey, A., Eds.; Elsevier: Amsterdam, The Netherlands, 2017; pp. 121–138. ISBN 9780444637840.

[85] Mohan, S.V.; Hemalatha, M.; Chakraborty, D.; Chatterjee, S.; Ranadheer, P.; Kona, R. (2019). Algal biorefinery models with self-sustainable closed loop approach: Trends and prospective for blue-bioeconomy. *Bioresour. Technol*. 295

against single-use plastic straws. It produced a hyper-compostable straw that is not only degradable on both land and water but also, theoretically, even edible. Algix creates an algae-blended ethylene-vinyl acetate material it calls Bloom (bouncy and flexible foam) used in the soles of shoes. It replaces the incumbent material traditionally made from petroleum. Algae-based packaging innovations looking to make a dent in the single-use plastic market include Ooho, an edible and biodegradable water sachet and Indonesian start-up Evoware, which makes seaweed-based cups, wraps and bags. AlgiKnit is producing fibers from seaweed to curb the toxicity of textile production.

Various sulphur containing polysaccharides provide structural stability to most of the algae. As a potential feedstock, cellulose-containing algae can be owned for production of paper; a mixture of algae was taken from municipal waste water treatment plant (Ververis *et al.*, 2004[86]) used it as 10% of pulp mix, resulting in appreciable increase in mechanical paper strength with 45% lower material cost due to decrease in brightness.

3.6 A sustainable Algae Industry - Moving forward

Algae biomass is currently used by the food industry and for human nutritional products; some seaweed can be eaten as a vegetable, Spirulina and Chlorella as dietary supplements used as dried whole, while others are processed for the chemical industry as raw material for the extraction of hydrocolloids (alginate, carrageenan and agar-agar).

Taking into account a classic biomass value pyramid applied to algae biomass (Fig. 13) the current global seaweed industry primarily produces seaweed as food for human consumption and some higher-value/lower-volume products. Macroalgae have by far the largest production volumes worldwide, although lower-value/higher-volume products such as seaweed-based biomaterials, bioenergy and fertilisers are not yet produced on a significant scale. The prospects of cultivated seaweed biomass to contribute to more sustainable futures can largely depend on the bottom lines of seaweed production.

Cultivated seaweed biomass sold for food can indeed be profitable, even comfortably profitable in the MED context. The biomass could possibly also be produced for lower-value/higher quantity products and the market for such products may develop into generating higher returns for producers. Given the urgent need to phase out fossil-based energy, materials and fertilisers, seaweed biomass may well be among the key bio-resources for the next decades.

Seaweed, as described in the previous paragraphs, can be used for many applications. The final products depend on the processes used. **Today, cultivated European seaweed is insufficient in volume, too expensive and produced by a fragmented supply chain, concentrated in the Atlantic area.**

[86] Ververis Ch., Georgiou K., Christodoulakis N.S., Santas P., Santas R. (2004). Fiber dimensions, lignin and cellulose content of various plant material and their suitability for paper production*Industrial Crops and Products* 19(3):245 - 254

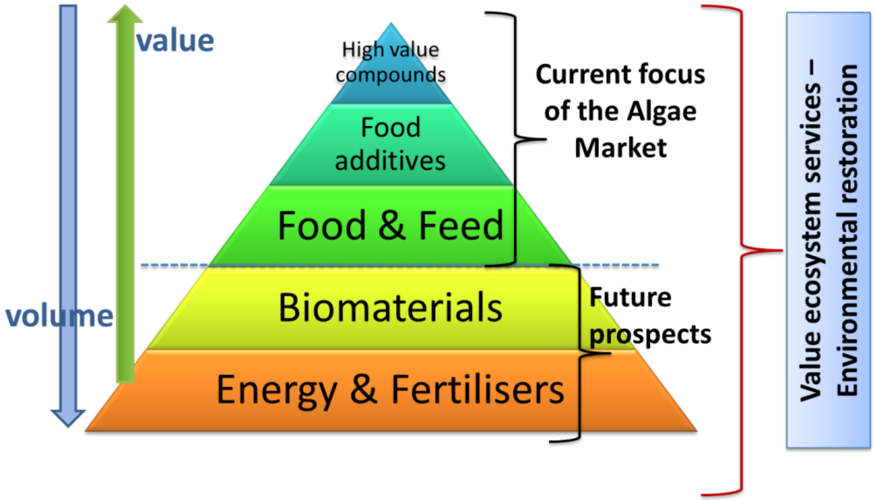


Fig. 15: Pyramid for the algae value chain (*modified from Thomas 2020)*[87]

The nascent MED sector comes with the need to rethink its role in the organization and innovation in the seaweed value chain. So far only a few companies have managed to secure a license for large-scale operations and leverage sufficient funding to expand. The demand for "all-natural ingredients" has been on the rise, owing to the safety concerns associated with synthetic ingredients; hence, the demand for seaweed protein-based products is expected to grow considerably in the coming years. The Asia Pacific market is estimated to account for the largest share in 2020. This is primarily attributed to factors such as large-scale production and domestic consumption of edible seaweeds in the region, which is fueled by the processed food industry. In addition, the expansion of the seaweed protein market in Asian countries such as Japan, China, Indonesia, South Korea, and the Philippines is attributed to factors such as availability of raw materials, favorable climatic conditions for the production of seaweeds, and availability of cheap labor.

On the other hand, microalgae based high-value molecules (such as astaxanthin, omega-3 fatty acids, β-carotene) have smaller production volumes but larger market potential. For example, the production volumes of poly-unsaturated fatty acids (DHA/EPA) from micro-algae are only 240 tons/year, but the market value of this production (mostly extracted from ocean fish) is estimated to be higher than $300 Million/year.

At present, the low volumes and high production costs of microalgae encourage exclusively the production of high-value supplements and nutraceuticals for human consumption. The microalgae-based molecules have specific advantages with respect to their synthetic and traditional alternatives that make their use commercially viable for the food sector compared to the corresponding alternatives, despite the higher production costs. However, the bulk production of microalgae carbohydrates and proteins for the food and feed sector is not yet expected to grow in the near future, because it would require higher production volumes and consequently the boosting of the cost effective scale-up

[87] L. Hasselström, J.B. Thomas, J. Nordström, G. Cervin, G. M. Nylund, H. Pavia & F. G. Thomas (2020). Socioeconomic prospects of a seaweed bioeconomy in Sweden. *Scientific Reports*, Nature Research, 10: 1610 | https://doi.org/10.1038/s41598-020-58389-6

with dramatic reduction of production costs. According to World Bank predictions (2021) it is difficult to compete with the soy protein (0.45€/kg), palm oil (0.73€/kg) and fishmeal (1.5€/kg) and for these reasons, the actual contribution of microalgae-based food and feed products to European food security is rather limited.

3.7 CASE STUDIES – Selection of Innovative projects and practices

Algae for Aquaculture and Beauty - ALGAE4A-B

Microalgae diversity is exploited, as a source for state-of-the art high-added-value biomolecules in aquaculture and cosmetics.

♣ Develop and optimize low-input and application-based microalgae culture systems

♣ Develop "-omic" resources for both microalgae and fishes

♣ Develop downstream processing of high added value products from microalgae, with an emphasis on polysaccharides, proteins, enzymes and antioxidants

♣ Develop, formulate and evaluate in vitro a new range of cosmetic and nutraceutical products for aquaculture

FitMar (Spain) produced optimized biomass and *Tetraselmis chuii* extract (10% in 1,3 propanediol) , *Phaeodactylym tricornutum* extract (10% in ethanol) –

APIVITA (Greece) incorporated extracts into a face cream, a serum and an eye cream.

Horizon 2020 - http://www.algae4ab.eu/

ALGAETEC BIOBASE Business Park - A pilot site

ALGATEC is an Eco Business Park designed to welcome entrepreneurial companies and projects in the algae and microalgae sector. Located in Portugal, It is managed by A4F a large biotechnology company, with more than 20 years of accumulated experience in microalgae research & development and microalgae production-up to industrial scale. The Park focuses in the design, build, operation and transfer (DBOT) of commercial-scale microalgae production units, using different technologies and the transfer of knowledge between applied research and industrial production, as well as in new product development and commercialization.

Different species of microalgae, freshwater, saltwater and hypersaline water, autotrophic, heterotrophic and mixotrophic, species are cultivated and with different and the most advanced technological production solutions – tubular and flat-panel photo bioreactors (PBR), open ponds, cascade raceways (CRW) and fermenters – harvesting and processing technologies The production units are supported by investment projects e.g. ARA.FARM , BIOFAT.PT, applying cutting-edge technologies.

Seaweed aquaculture, in the Bizerte Lagoon, Tunisia

Seaweed farming has positive effects in terms of ecosystem services, climate change adaptation, and employment opportunities for local young people and women. Seaweed aquaculture is promoted as an accelerator for a sustainable blue economy in the MED area.

The Bizerte Lagoon is currently facing environmental degradation, suffering from eutrophication, especially due to the sewage from the surrounding towns.

The Selt Marine company first on an industrial scale, comes after years of research to use the lagoons, as the natural reserves of red seaweed diminish in recent years due to overexploitation. Seaweed is grown around cylindrical netting in the lagoon and the plant material (green to dark red in colour) is separated, dried in the sun and taken to a factory to be turned into substances such as agar-agar.

Tunisia's waters and climate favor its farming and as seaweed absorb elements like nitrogen and phosphorous, growing it is also a way of "naturally cleaning the lagoon". The plan is to produce 500 tonnes of wet seaweed, expanding the growing area in the coming years, to 3.500 tonnes yield. Its potential is being studied for products from biodegradable bottles to noodles and even meat-substitute vegetarian nuggets.

ALGA-PLUS - Seaweed Farmers

A company in Rio de Aveiro- Portugal dedicated since 2012 to controlled and sustainable farming of seaweed species from the Atlantic coast, in a land-based system in a perspective of circular and blue bio-economy, by integrating aquaculture with organic certification throughout all process. The production includes the only European commercial-scale hatchery of the species *Porphyra* spp., also known as Atlantic nori.

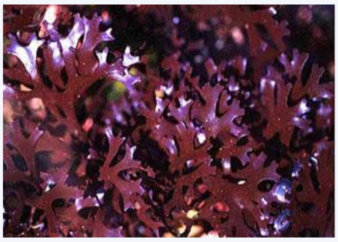
The overall mission is to democratize seaweed applications and consumption of species grown in Portugal, through the optimization of cultivation protocols, to ensure the best quality/price in the global market.

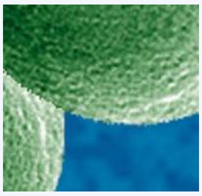
Pioneering Marine Ingredients – PHYTOMER

At the forefront of cosmetic discoveries, PHYTOMER (France) discovers, familiarizes and cultivates new marine algae, and microorganisms to produce completely new natural active ingredients.

ALGORESET : A marine complex by an oligofurcellaran and a blue micro alga. Oligofurcellaran is a marine sugar obtained using an environmentally responsible extraction method. The blue micro alga is grown in photobioreactors and obtained through a 100% green process.

HONDRUS CRISPUS: a red algae, very common on the Atlantic coasts, from Norway to Gibraltar. It is particularly rich in amino acids and polyunsaturated fatty acids. They use its oily extract to moisturize and nourish the skin.





ECO-CHLORELLA extract of green microalga Chlorella Vulgaris is high in peptides and amino acids naturally present in the dermis. Placed in an aqueous medium, the Chlorella Vulgaris is cut by a natural enzyme, without the addition of solvent or a chemical product, to obtain Eco-Chlorella. Extract with exceptional skin firming properties.

ÉTERNELLE MARINE is an extract from the age-old blue micro-alga *Phormidium*. Cultivated in photo-bioreactors, it can develop in conditions very close to its natural environment and keep its protective antioxidant properties intact and its outstanding biomimetic ability to delay skin aging.


Phormidium

MARINE TAURINE is an extract from the JANIA RUBENS red algae. It is used in concentrated doses one thousand times smaller than synthetic taurine, it is still more powerful as it is better assimilated by the skin. It energizes adipocytes, boosts their lipolytic activity and accelerates fat elimination.

ORGANIC WEAVING ALGAE are Laminaria brown algae. PHYTOMER has developed an algae farming program on cords in order to control the use and quality of the resource and to ensure its natural survival.

PALMARIA PALMATA: a red alga along the northern coasts of the Atlantic. It has draining properties and a positive impact on skin microcirculation; it is used it to eliminate built-up toxins and fluids under the eyes.

ALGEN Wastewater Treatment

Algal treatment as one of the technologies for nutrient recycling

New technologies are being developed to take excess waste nutrients produced from anaerobic digestion of food and farm waste to cultivate algal biomass for animal feed and other products of value. Increasing amounts of food and farm waste are processed using anaerobic digestion (AD). AD converts waste to biogas used for energy and a liquid nutrient rich digestate (mainly nitrate and phosphate), most of which is returned to land as a biofertiliser. However, there are strict limits on the amount of digestate which is allowed to be put back on agricultural land. The ability to use these excess nutrients to produce new products presents a circular economy solution. It combines algal and AD technology. Microalgae, mainly photosynthetic microorganisms are cultivated, converting the unwanted nutrients into biomass. The cultivated algal biomass is rich in protein and other useful compounds, and can be used to generate sustainable animal feed products and other useful bio-products.

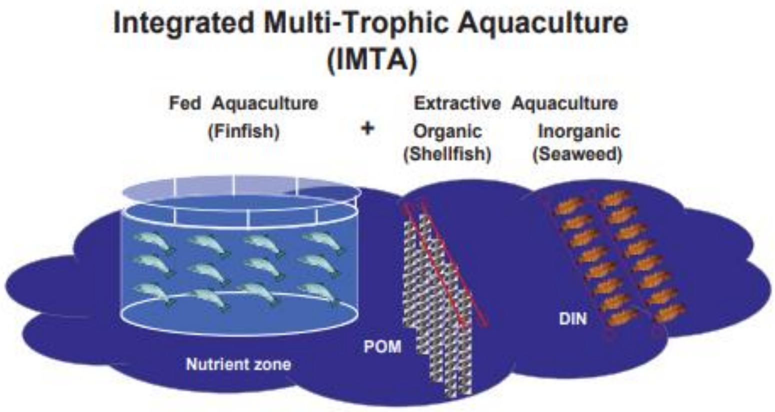
Technologies demonstrated:
400 m2 algal pond system with two inoculation ponds
Anaerobic digestion
WW pre-treatment with nitrogen extraction
Bacillus sp. fermentation

Heterotrophic Algal treatment of WW from the fruit and vegetable industries

A sustainable treatment model of high loaded and salty effluents that combines cost-effective heterotrophic algae cultivation with spray drying of the collected microalgae to obtain a product of commercial interest as raw material for the production of biofertilisers, animal feed, bioplastic, etc. The prototype is powered by renewable energies (solar energy supported by biomass), which will minimise the carbon footprint and operating costs of the process. The final effluent quality will be very high, allowing reuse for equipment cleaning and irrigation purposes.

4. Sustainable Integrated Multi-trophic Aquaculture -IMTA

Integrated Multi-Trophic Aquaculture (IMTA) can be seen as a promising solution for the sustainable development of aquaculture, where multiple trophic level aquatic species are farmed together. Species from different trophic levels are raised in proximity to one another and the co-products (organic and inorganic wastes) of one cultured species are recycled to serve as nutritional inputs (fertilizers and food) for others.



Source: Chopin (2006).

Fig. 16: Conceptual diagram of IMTA (Chopin, 2006), combining fed aquaculture (finfish) with organic extractive aquaculture (shellfish) and inorganic extractive aquaculture (seaweed).

The IMTA value chain is selected because there is a lot of potential to discover ways to develop new, sustainable, profitable value chains and improve aquatic production within the framework of existing, emerging, and potential MED markets. This concept aligns with recommendations made in the Food from the Oceans report (2017)[88], which highlighted the **need to expand low- and multi-trophic marine aquaculture as an ecologically efficient source of increasing food and feed.**

IMTA can reduce the ecological impacts near aquaculture operations, improve social perceptions of aquaculture and provide financial benefits for aquaculture producers, including the increase of circularity and the achievement of zero-waste aquaculture systems. **The concept of IMTA is very much related to the concept of the circular economy** where waste streams from one industry provide the raw materials for another which has gained acceptance across a range of European industries. Furthermore, IMTA can be regarded as a potential mitigation approach, reducing the nutrients and organic matter inputs from finfish aquaculture. Integration of different species in one culture unit can reduce these impacts because the wastes given off from the culture of fish, e.g. uneaten fish food, fish feces and excreted nitrogen (N) and phosphorus (P), can be assimilated by shellfish (organic processors) and seaweed (inorganic processors), thereby reducing the

[88] European Comission (2017). Food from the Oceans - How can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits? Scientific Opinion No. 3/ Brussels 2017.

amount of waste given off from a fish farm and turning it into fodder for another species which is also of commercial value.

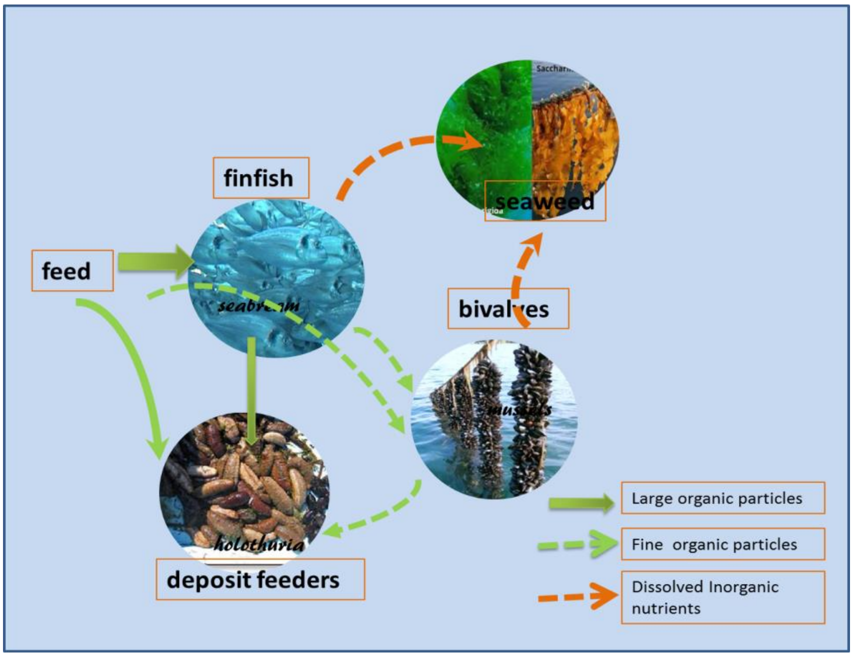


Fig. 17: Species related in an IMTA system

This practice of IMTA can help reduce environmental impacts while also creating other economically viable products at the same time. IIMTA may represent an opportunity to increase the economic and environmental sustainability of the production of all the involved cultures. As stated by the guru of IMTA Chopin "*it is a way to create balanced systems for environment remediation (biomitigation), economic stability (improved output, lower cost, product diversification and risk reduction) as well as social acceptability with better management practices".* [89]

4.1 IMTA systems

In Europe, predominantly Atlantic salmon, sea bass and sea bream have been tested in IMTA, with grey mullet as browsers. The EU mussel, oyster and scallop farming are well-established and the potential for co-culture with seaweed is high, mussels and seaweeds coexisting on the same long-lines. In IMTA, interest is extending to invertebrates besides molluscs and crustacea, including cephalopods, sea urchins, sea cucumbers, polychaetes and sponges.

[89] Chopin T; Buschmann A.H.; Halling C.; Troell M.; Kautsky N.; Neori A.; Kraemer G.P.; Zertuche-Gonzalez J.A.; Yarish C.; Neefus C. (2001). Integrating seaweeds into marine aquaculture systems: a key toward sustainability. *Journal of Phycology* 37: 75–986.

Pellegrom *et al.* (2016)[90] provided a useful summary of different aquaculture systems, including IMTA in open cage or multi-use systems, recirculated systems (RAS) and aquaponics; this latter applicable for small scale production and nutrient availability for agriculture.

Species with high potential for IMTA systems in marine temperate waters to be grown with finfish include:

- **Finfish** –*Argyrosomus regius, Dicentrarchus labrax, Diplodus cervinus, Diplodus puntazzo, Diplodus sargus, Diplodus vulgaris, Mugil cephalus, Pagrus major, Salmo salar, Scophthalmus maximus, Scopthalmus rhombus, Solea senegalensis , Solea solea, Sparus aurata*.

  Seaweeds – Brown seaweeds-Laminaria, Saccharina, Sacchoriza, Undaria, Alaria, Red seaweeds- Asparagopsis, Gracilaria, Gracilariopsis, Chondrus, Porphyra, Palmaria, Chondracanthus, Callophyllis, Sarcothalia, Green seaweeds-Ulva

  Molluscs – Haliotis, Crassostrea, Pecten, Argopecten, Placopecten, Mytilus, Choromytilus Tapes and Ruditapes
- **Sea cucumbers and sea urchins** – Strongylocentrotus, Paracentrotus, Psammechinus, Loxechinus, Cucumaria, Holothuria, Stichopus, Parastichopus, Apostichopus and Athyonidium;
- **Polychaete** marine worms – Nereis, Arenicola, Glycera and Sabella
- **Crustaceans** – Penaeus and Homarus

modified Barringbton et al. (2009)[91]-non exhaustive list

In Eilat, Israel several models combined flow-through and recirculation systems between primary (fed) and secondary (extractive) species. IMTA is practiced in seawater fishponds with continuous exchange with water from the open sea, to stabilize salinity and other water quality features[92]. The primary (fed) fish was mostly the seabream (*Sparus aurata*), seabass (*Dicentrarchus labrax*), shrimp (*Penaeus semisulcatus*) and mullets (*Mugil cephalus* and *Liza ramada*). At first, the extractive component included microalgae, oysters (*Crassostrea gigas*) and clams (*Ruditapes philippnmarum*). Several other species, for example: clams, seaweed (the macroalgae *Ulva* spp. and *Gracilaria* spp.), abalone (*Haliotis tuberculata* and *H. discus hannai*), sea urchins (*Paracentrotus lividus* and

[90] Q. Pellegrom, A. Ching, L. Kempchen, T. Stoffelen, A. Pratama, C. Nyelele, D. Oster, J. Farinha, W. Pelupessy (2016). A Horizon Scan on Aquaculture 2015: Management Practices, Brief for GSDR.

[91] K. Barringbton, T. Chopin, S. M.C Robinson (2009). Integrated multi-trophic aquaculture (IMTA) in marine temperate waters. *In:* Integrated Mariculture, a Global review, Eds D. Soto, Publisher: FAO.

[92] Neori A., Guttman L., Israel A., Shpigel M., (2019). Israeli-Developed Models of Marine Integrated Multi-Trophic Aquaculture (IMTA). *Journal of Coastal Research* 86 (SI): 11–20.

Tripneustes gratilla elatensis), shrimp, brine shrimp (*Artemia salina*) are used. Wetlands planted with the halophytes *Salicornia* sp. and *Sarcocrnia* sp. have been integrated as IMTA. Periphyton and drip-irrigated algal biofilters were examined and found to be practical.

Benthic IMTA seems to have interesting prospects; sea cucumbers, the favoured species, perform well in association with seaweeds such as *Ulva lactuca*, molluscs such as *Pacific oysters* and finfish such as sea bream (*Sparus aurata*)

Seaweeds predominantly are carried out at sea using floating lines, nets or rafts (Sahoo & Yarish, 2005)[93]. These culture systems are generally installed in coastal waters, which have strong water movement and are rich in inorganic nutrient concentrations (often from anthropogenic sources) to enhance nutrient uptake. Efforts are mainly concentrated in the Atlantic area and North Europe and only trials carried out at experimental scale exist in the Mediterranean, with few existing results. Pilot-scale and pre-commercial farming projects for selected brown and red algae exist in Europe (Peteiro *et al.,* 2016[94]), such as *Undaria pinnatifida "wakame"* and *Saccharina latissima* "sugar kombu", along the Atlantic coast of Europe, particularly in northern Spain. Efforts for large-scale cultivation of seaweed biomass along the Norvegian coast have been focusing largely on kelp species, particularly *S. latissima* because of the species' potential for high biomass and valuable nutritional content (Stévant *et al.,* 2017)[95]. One of the most encouraging experiences involves the development of seaweed farming for human consumption (*S. latissima*) in combination with mussel rafts in Galicia, NW Spain (Freitas *et al.* 2016)[96].

Different case studies include different culture environments affecting the growth of extractive species and leading to various bio-mitigation capacities. Hence, there are no general rules and guidance for practitioners, which is one of the main factors for the lack of trust by stakeholders in the field. The waste removal efficiency acquired in a land-based experiment is not suitable in estimating the bio-mitigation efficiency in same or different culture conditions with different biomasses of extractive species. As most of the land-based experiments are conducted under controlled conditions, interactions between co-cultured species and their natural physical and ecological environments cannot be well represented. For example, water flow in a field exerts a great influence on the IMTA system due to the current direction and velocity, e.g. the attachment of periphyton is influenced by the current velocity in the offshore environment.

There is a move towards concepts of "ecological engineering", spatial IMTA and other terms that suggest that the different trophic levels are not tightly co-located .The impact depends on the flushing rate and size of the farm, with some studies indicating low

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[93] Sahoo D and Yarish C. (2005). Mariculture of Seaweeds. *In*: Algal Culturing Techniques, pp. 210-237. DOI: 10.1016/B978-012088426-1/50016-0

[94] Peteiro C., Sánchez N., Martínez B. (2016). Mariculture of the Asian kelp Undaria pinnatifida and the native kelp Saccharina latissima along the Atlantic coast of Southern Europe::An overview. Algal Research 15: 9–23.

[95] Stévant P., Rebours C., Chapman A. (2017). Seaweed aquaculture in Norway: recent industrial developments and future perspectives. *Aquaculture International* vol. 25, pp. 1373–1390.

[96] Freitas JRC, Morrondo J.M.S., Ugarte J.C. (2016). Saccharina latissima (Laminariales, Ochrophyta) farming in an industrial IMTA system in Galicia (Spain). *Journal of Applied Phycolog,y* vol. 28, pp 377–385.

negative environmental impacts and others suggesting that nutrients released from offshore fish cages may be concentrated in locations far from the point of release (Giangrande *et al.,* 2021)[97]. The Regional Integrated Multitrophic Aquaculture (RIMTA) has been proposed by Sanz-Lazaro & Sanchez-Jerez (2020)[98] as a shift of paradigm in the way IMTA is used to sequester the dissolved exported waste and derived primary production generated by high trophic level cultures. RIMTA advocates for independent allocation of cultures of low and high trophic level species within the same water body.

Mediterranean coasts are densely populated and there is a high level of competition for coastal space utilization. Furthermore the scarcity of nutrients in Mediterranean seawater can be overcome by coupling offshore fishing production with the farming of filter feeder invertebrates and macroalgae feeding on the waste from the cages. Only a few examples of such IMTA plants are available, and very little is known about the restoration that they afford with the implementation in open Mediterranean waters. Giangrande *et al.* (2021) suggest that the employment of mussels and macroalgae for production can lead to the sequestration of CO2 and the fertilization of oligotrophic areas.

4.2 The Market context

Aquaculture is a fast growing animal food producing sector and an increasingly important contributor to economic growth, in spite of the fact that since 2000 no longer enjoys the high annual growth rates of the 1980s and 1990s (10.8 and 9.5% respectively) that declined to a moderate 5.8% during the period 2001–2016 (FAO, 2018). The estimated projection for EU aquaculture production in 2030 is roughly 1.7 Mtons, (FAO, 2018).

In 2016, EU Member States produced 330 ktons of marine finfish species with a value of €1.5 billion. Mediterranean fish farming focuses on the popular carnivorous finfish species with either a low production volume from capture fisheries or from over-fishing stocks; European sea bass (*Dicentrarchus labrax*) and Gilthead sea bream (*Sparus aurata*) are the main species grown. Total EU production is close to 150 ktons at a value of €800 million. The main EU producers are Greece with roughly 60% of EU production, Spain (20%) and Italy (7%). The cultivation of new similar species gained ground, farmed on a much smaller scale, such as red porgy (*Pagrus pagrus*), meager (*Argyrosomus regius*,) sharpsnout seabream (*Diplodus puntazzo*), common pandora (*Pagellus erythrinus*) common dentex (*dentex dentex*), flathead grey mullet (*Mugil cephalus*) and sole (*Solea solea* and *Solea senegalensis*).

The EU shellfish aquaculture sector produced almost 550 ktons in 2016 at a value nearing EUR 900 million, accounting for roughly half of EU aquaculture output, one fifth of which produced in the Mediterranean. Mussels dominate EU shellfish aquaculture with

[97] Giangrande A., Gravina M.F., Rossi S., Longo C., Pierri C. (2021). Aquaculture and Restoration: Perspectives from Mediterranean Sea Experiences. *Water* 13, 991. https://doi.org/10.3390/w13070991

[98] Sanz-Lazaro C., Sanchez-Jerez P. (2020). Regional Integrated Multi-Trophic Aquaculture (RIMTA): Spatially separated, ecologically linked. *Journal of Environmental Management* 271. doi.org/10.1016/j.jenvman.2020.110921

production nearing 450 ktons per year for a value of EUR 417 million. The main EU producer in the Mediterranean is Italy with almost 60% of the farmed mussel production; Greece is the second largest producer (20%). Other Member States with significant mussel production include France and Spain. Oyster is the second main shellfish species grown in the EU with approximately 95 ktons produced, valued at EUR 450 million and France is the single largest oyster producer (90% of EU production), however production in the Mediterranean is limited to 6 ktons. In the Mediterranean there is also a significant production of clams in Italy (approximately 30 ktons). Emilia-Romagna in Italy is the first region for shellfish production whereas regional mussel and clam production are nationally the firsts in quantity productions (22 and 15k tons/year) and they contribute, respectively, with the 33.6 and 53% of the country production. Similarly the region of Central Macedonia in Greece produces approx. the 85% of the country annual production in mussels (≈20ktons/year).

Table 11: A) aquaculture fish production B) aquaculture molluscs production in the B-BLUE countries. Average figures for the period 2010-2019.
(Figures refer to the whole Country production in France, Portugal and Spain and not only to the MED area).

A.

Country	Fish (tonnes)
1. Greece	**98,456**
2. Spain	62,429
3. Italy	52,024
4. France	45,832
5. Croatia	13,721
6. Portugal	5,538
7. Slovenia	1,035
8. Montenegro	703
Total	279,737

B.

Country	**Molluscs (tonnes)**
1. Spain	**220.898**
2. France	143.848
3. Italy	97.357
4. Greece	19.317
5. Portugal	5.308
6. Croatia	1.016
7. Slovenia	491
8. Montenegro	197
Total	**488.432**

In the MED area the extensive coastline and a well-established aquaculture sector offer suitable preconditions for developing large-scale cultivation of seaweed biomass and the development of Integrated Multi-Trophic Aquaculture (IMTA) systems. Aquaculture is increasingly expanding in coastal waters, including land- and sea-based cultures and more than 50% of the products of aquatic origin consumed by the world population are estimated to derive from aquaculture. However the rapid growth of the aquaculture industry has already led to growing concerns over environmental impacts and conflicts with other coastal activities. In order to achieve this target and retain a 'clean and green' image, aquaculture must be able to demonstrate that its practices are sustainable. Integrated multi-trophic aquaculture (IMTA) systems provide an avenue to address this challenge.

The use of IMTA could represent the main instrument to harmonize the development of the growing aquaculture sector, reducing the impact and achievement of the environmental quality objectives defined by the community policies (with particular reference to the Marine Strategy Framework Directive). IMTA is often characterised as a win-win situation where the twin benefits of increased productivity and reduced environmental impact are coupled together, very much in line with taking an ecosystem approach to aquaculture where consideration is given for managing the whole water body.

With respect to IMTA, a key question is how and how much the extractive aquaculture co-products will contribute to the overall economic performance of offshore IMTA systems. A central challenge of current large-scale fish aquaculture operations in cages is to date their low profit margins. This may impede the further development of offshore fish farming. For each species cultured, different markets exist with different demands, potentials and constraints, all of which add to the likelihood of increasing costs before revenues are generated[99]. However, in a broader and more long-term perspective, IMTA has the potential to provide ecosystem services and benefits not only at the farm level but rather at broader environmental and societal levels.

To calculate IMTA's value, extractive species need to be valued not only for their biomass and food trading values, but also for the ecosystem services they provide. For example, one of the key ecosystem services provided by seaweeds is nutrient biomitigation. It can be valued for the worldwide seaweed aquaculture (32.4 Mtons) at between US$1.21 billion and US$3.48 billion that is as much as 26% of their present commercial value, US$13.3 billion (Chopin 2021).[100]

One of the main challenges ahead is that aquaculture itself has to overcome a stagnated development and growth pattern and a failure to deliver value for money. Hence it is relevant to consider an increased pressure for change in the Mediterranean where marine fish farming has been defined as a "rising star". Unlocking the potential of sustainable aquaculture needs disruptive innovation to occur. The Mediterranean is eco-historically best placed to embrace disruptive innovation, engaging a broader group of stakeholders. Along the seafood value chain, the way Mediterranean aquaculture economies are organized may change, with consumers asking for sustainably farmed seafood from traceable and transparent sources, and aquaculture offering "on-demand" products from selective and safe farms.

IMTA challenges are very much focused at the level of the farm management and operation. Why fish farmers could invest in the development of IMTA? Probably the largest challenge faced by the companies is a short fall in 'know how a fin-fish farming company and a shellfish or seaweed company chose to develop a site together as a joint venture, especially when there is a question of available space. While there are obvious

[99] A.D. Hughes (2016). Integrated Multi-Trophic Aquaculture in Europe: will it work for us? *Aquaculture Europe* 41(1)

[100] Chopin 2021. Integrated Multi-Trophic Aquaculture (IMTA) is a concept, not a formula. International Aquafeed.

advantages to this approach, there is a need to ensure there is integration between the separate companies at an operational level management in order to deal with different production cycles, processing the different components of the IMTA system, the availability of infrastructure, finding markets and distribution networks for the additional extractive organisms.

4.3 Current situation in MED Countries - The Challenges and Bottlenecks

Although IMTA have received specific attention during the last two decades, it has not yet become a commercial reality in the MED area. Despite the fact that Europe represents a large fish market with consistently increased seafood consumption and a dynamic presence in the aquaculture sector, at present, integrated multi-trophic aquaculture is on a very small scale. The concept has received increasing academic attention during the last two decades however it has not yet become a broadly adopted commercial reality in the MED area and generally in Europe.

The IMTA approach has been more intensively addressed in the Atlantic area as a circular economy paradigm. However, despite been encouraged by EU policies such as the Blue Growth Strategy, the Atlantic Action Plan and RIS3, there are socio-economic, administrative and legislative bottlenecks hampering the development of IMTA as an eco-innovative aquaculture solution in area.

The reasons for this were explored in a recent specific work of Kleitou *et al.* (2018)[101], by interviewing farmers and scientists with previous experience and practical understanding on IMTA. The experience of respondents on IMTA involved a broad range of species, using various cultivation techniques either in land-based or marine-based systems. The survey covered many European countries including some of the B-BLUE countries: Greece, Italy, France, Portugal and Spain. A similar survey has been conducted in the frame of INTEGRATE Project[102], in the Atlantic area, including among the participating countries Spain, France, Portugal.

Additionally a survey has been conducted with a targeted questionnaire in the frame of B-BLUE among the interested PPs. In Greece a questionnaire was focused on fish farmers' views to understand the known and unknowns of IMTA in the country. The industry support and willingness to utilize IMTA methods are critical for adoption of the method on aquaculture farms. These culturists are the primary drivers and decision makers when it comes to adopting new aquaculture methods. It is essential to test the theoretical framework against expert knowledge from the aquaculture industry, in order to develop the concept of best practice for IMTA.

[101] Kleitou P., Kletou D., David J. (2018). Is Europe ready for integrated multi-trophic aquaculture? A survey on the perspectives of European farmers and scientists with IMTA experience. Aquaculture 490: 136-148. DOI: 10.1016/j.aquaculture.2018.02.035

[102] Layman's report, INTEGRATE (2020). Integrated Aquaculture: an eco- innovative solution to foster sustainability in the Atlantic area, Project EAPA 232-2016

Table 12: Major bottlenecks / obstacles during IMTA application

Category	Bottlenecks / Obstacles	Country
Biological	Lack of general knowledge regarding the species /Lack of available seed /Vandalism risks	France, Spain [1]
	Sustainable production for large periods (e.g. >1 year / not seasonal) is questionable	Portugal [1]
	Concerns about spread of diseases, poor understanding of species interaction	INTEGRATE[2] Spain-France-Portugal
	Limited knowledge for the species and the establishment of IMTA	B-BLUE-Italy, France, Greece
Environmental	Weather / Storms	Spain [1]
	Oligotrophic ecosystem	Italy [1]
	Environmental constraints in open sea -land based systems	INTEGRATE[2] Spain-France-Portugal
	The challenge of warm oligotrophic waters	B-BLUE- Greece
Legislation Regulatory system	Licencing / regulations	Spain, Italy [1]
	Complexity of Licensing puts off current license holders from applying for diversification Lack of visibility of the IMTA effects from the regulators	INTEGRATE[2] Spain-France-Portugal
	Complex and long legislative framework for the establishment of IMTA farming	B-BLUE Italy, France, Greece
Market	Uncertain profitable market, Lack of private investment	Portugal, Spain, Italy [1]
	Investment issues to convert existing aquaculture systems to IMTA systems	INTEGRATE[2] Spain-France-Portugal
Operational	Inadequate technology & lack of infrastructure to harvest / process / cleanse extractive species	Greece, Spain [1]
	Inadequate expertise	France, Greece, Spain [1]
	Difficulty to monitor the various environmental effects/ benefits Current IMTA models do not suit aquaculture specificities	INTEGRATE[2] Spain-France-Portugal
	Lack of trust for the economic and the ecological benefits. IMTA are still in development stage	B-BLUE, Italy, Greece
	Give raise to stiff objections from local communities practicing monocultures	B-BLUE-, France, Greece
R&D	Need to progress/ develop IMTA	Portugal [1]
	Limited Public, Knowledge, difficulty to communicate an 'academic' concept	INTEGRATE[2] Spain-France-Portugal

Source: P. Kleitou et. al., (2018)[1] , INTEGRATE project [2], B-BLUE

Several challenges in each country are presented and need to be overcome and promote the industrial transition towards IMTA. The most often reported challenges are related to economic and legislation issue as presented in the table below.

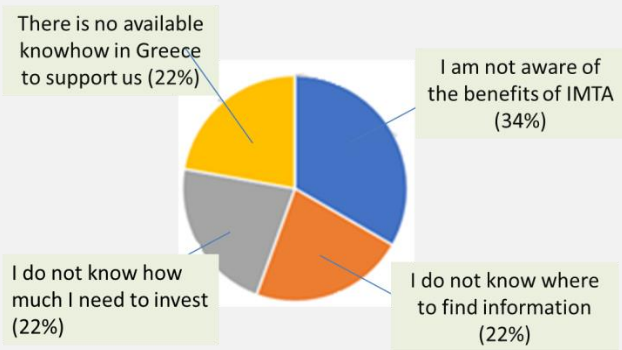
Table 13: Challenges and opportunities for IMTA

Category	Challenges to overcome	Country
Legislation	Legislation & regulation	France, Spain[1]
	Lengthy and difficult procedures, Lack of labels	Italy[1]
	Develop polluter-pay policies	Portugal[1]
	Polluter pay principles/valuation of ecosystem services	INTEGRATE[2]
	No regulations inhibiting the culture of multiple species at the same area	Spain-France-Portugal
	Adopt legislation (e.g. tax benefits or other financial incentives) to encourage aquaculturists to implement IMTA	B-BLUE- Italy, France, Greece
Market	Market development	Greece, Portugal[1]
	Stability of yields, Profitability, Valorisation of products-refining industry	France[1]
	Developing of new markets (sea cucumbers, seaweed)	INTEGRATE[2]
	Higher market value with or without Eco-Certification	Spain-France-Portugal
Interest	Attract funders & investors	Greece, Italy, Spain[1]
	Promotion from industry	Portugal, Spain[1]
	Promotion from governments	France[1]
	Funding IMTA systems as nature based solutions for environmental remediation supporting ecosystem goods and services.	B-BLUE – Italy, Greece
	Awareness of SMEs for the advantages of IMTA implementation (increasing their competitiveness and viability)	B-BLUE – Italy, France, Greece
Operational	Technological feasibility-Infrastructure/labour-Expertise	Portugal, Spain[1]
	Practicability	Portugal[1]
	Spatial configuration - new farming areas	Italy[1]
	Technical improvement	INTEGRATE[2]
	Job creation, up-skilling	Spain-France-Portugal
	Highly developed Aquaculture	B-BLUE, France, Greece
R&D	Improve scientific knowledge incl. economics	Portugal, Spain
	Modelling improvement would lead to better monitoring and proofs for IMTA benefits	INTEGRATE[2] Spain-France-Portugal
	Good mastery of the different species to be included and tests to integrate them in IMTA systems	

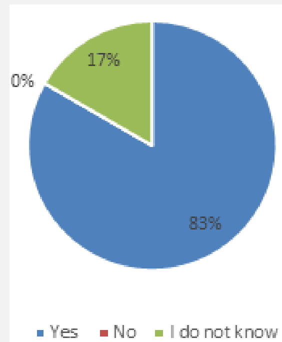
Source: P. Kleitou et. al., (2018)[10], INTEGRATE project [9], B-BLUE

The Greek survey with mails and telephones finally included six (6) medium and large sized enterprises growing sea bream, sea bass, red porgies and corvinas, important players in the sector, the share of which in total industry sales is approximately 15% based on 2019 data.

The main reasons they have not been in Integrated Multi-trophic Aquaculture (IMTA)



If an IMTA system allowed you to naturally reduce the level of nutrients/organic load in the marine area, would you consider developing such a system in the future?



All the companies stated that the adoption of a more eco-friendly approach to fish farms will take place in the future. As a result, it is highlighted the importance of sustainability in the industry.

From the above challenges and bottlenecks we can conclude that **there is a general lack of knowledge regarding the IMTA species, the benefits and technological feasibility.** IMTA is not a simple idea, and professionals often feel using the term 'Integrated Multi-Trophic Aquaculture' to describe the method to the general public is not effective. IMTA can include all types of organisms in different trophic levels and quantities, for different purposes, and in many different locations and environmental conditions alternative terms such as 'co-culture' or '3D ocean farming' is used. It is important to recognize the benefits of IMTA and educate stakeholders about this practice. **Once government, industry and the general population will become aware of the positive impacts of IMTA, they are likely to be more inclined to encourage the establishment of these culture systems.**

Establish a R&D continuum for IMTA is essential in order to understand the biological, biochemical, hydrographic, oceanographic, seasonal processes; suitable selection of species; adaption and development of new technologies; address the engineering, operational protocol and economics of these technologies; model development flexible and friendly enough so that they can be tailored and adjusted to the specifics of each particular site.

Regulatory and policy frameworks will have to be developed and harmonized among countries to enable the development of commercial scale IMTA operations in a more universal fashion. The development and adoption of technology often depends highly on the level of legislative pressure from a country's government.

Economic benefits are the main reason for initially trying IMTA and for choosing to continue using it, ensuring the stability of yields and market development. The aquaculture professionals need to experience an economic success with IMTA so that to accept choosing the method and continue using it. At the moment it seems that there is a mismatch in who bears the cost and who receives the benefits of IMTA. Most of the costs of adopting IMTA (and not just financial ones) are borne by the industry and yet their benefits are not being accrued by the industry. As such there is relatively little incentive for the industry to invest in its development. Only the scalability of IMTA, or ability to start growing a new species at a small scale before investing lots of time, money, and resources can be seen as a positive factor of IMTA.

Product diversification, opening the market to create opportunities for aquaculturists to sell at different times during the year or to sell to different people and reach more people is seen as a very promising aspect of IMTA. However environmental constraints in open sea -land based systems have to be overcome e.g. the warm oligotrophic waters, especially in the E. Mediterranean, is a big challenge for further development.

The majority of the ecological benefits are directed more toward IMTA systems that include fed-species. Closely connected to the algae value chain, seaweed is a crucial component of most IMTA systems and in order to make a significant contribution to nutrient reduction it needs to be grown in large volumes. These volumes of seaweed, though they have a high intrinsic value as a raw product, have a very limited market in the MED area and generally in Europe. The development of processing plants and seaweed bio-refineries could allow for the expansion of this important component of IMTA and for reaching its true economic value.

Funding IMTA systems as nature based solutions for environmental remediation supporting ecosystem goods and services is a challenge as well as analyzing seaweed as a climate change solution for carbon offsetting is important; globally seaweed can absorb 200Mtons of CO_2/year[103]. Seaweed can also help reduce greenhouse gas emissions in other ways, e.g. adding a small amount of *Asparagopsis taxiformis*—a red algal species—to cattle feed has the potential to reduce methane production from beef cattle by up to 99%. Furthermore seaweed is becoming trendy among some of the world's most famous chefs, with seaweed cookbooks appearing in book stores. Ronald Osinga of the Wageningen University in the Netherlands stated that *"sea-vegetable" farms totaling 180,000 km2—roughly the size of Washington State—could provide enough protein for the entire world*". However, there is also the opposite view that growing seaweed on a global scale also has ecological risks; too much seaweed could impact the amount of light that goes down to other species affecting photosynthesis processes and could have dangerous effects on ecosystems by removing too many nutrients from wild ecosystems.

[103] I. Gerretsen (2021). Future Planet - The remarkable power of Australian kelp

4.4 Case Studies and Innovative Projects

IMPAQT - Intelligent Management Systems for Integrated Multi-Trophic Aquaculture

Participating Countries: *Ireland, UK, France, Italy, Netherlands, Poland, Greece, Turkey, Spain, Portugal, Luxemburg, China*

IMPAQT aims to develop and validate in-situ a multi-purpose, multi-sensing and multi-functional management platform for sustainable Integrated Multi-Trophic Aquaculture production and long-term autonomous monitoring in the field.

The project includes six pilot sites covering geographical differences throughout EU (UK, Netherlands, Ireland, Turkey) and China and different scenarios from inland and coastal to offshore systems. The aim is to design and implement cost-efficient technologies in IMTA monitoring and management; design the architecture and progressing-validating models to better understand and plan IMTA set-ups; utilizing pilot systems to demonstrate reduced environmental impacts, sustainability and socio economic benefits.

- Seaweed and mussels on the same long lines (UK)
- Seaweed, floating solar panels, shellfish cultivation/shellfish-bank restoration, with passive fishery such as lobster cages (NL)
- Lobsters (stacked plastic trays), fish (*Salmo salar*) in plastic pens, seaweed across the pens and on long-lines, with potential to change seaweed from Ulva and add lumpfish and wrasse cultivation (IE)
- Commercial land-based RAS with perch (*Perca fluviatilis*), Artemia feed production on-site and duckweed (Lemna) bioremediation (IE);
- commercial sea bass in cages with mussels and later Ulva and Gracilaria on long-lines (TR)
- Multiple aquaculture industries, in Sanggou Bay offshore, using seaweed and shellfish on long-lines, benthic culture of sea cucumber, sea urchin, finfish, abalone, clam and sea snails, an artificial reef and seagrass beds

AQUAVITAE –Developing sustainable Aquaculture in the Atlantic

The Atlantic Consortium aiming to increase aquaculture production in and around the Atlantic Ocean by developing new species, processes and products. It **focuses on low trophic species (e.g. algae, echinoderms, shellfish), contributing to the circular economy.**

The project implements 11 case studies across the Atlantic basin (Europe, Africa, South America)

Land-based IMTA systems

- ✓abalone *Haliotis tubercula* production in (Spain)
- ✓abalone juvenile's production under organic certification (France).
- ✓abalone and macroalgae-*Ulva* sp (South Africa).

Sea based IMTA systems

- ✓macroalgae/Mussel co-culture (South Africa)
- ✓macroalgae as feed for abalone in terms of production, product quality and health benefits and product biosecurity.
- ✓commercial scale co-culture system of abalone, sea-cucumber, queen scallop and macroalgae (France).
- ✓salmon-mussels-macroalgae in a fjord ecosystem (Faroe Islands).
- ✓co-culture of oysters and lobster in sea cages (Sweden).

Pond culture systems - BioFloc IMTA

- ✓ implemented in shrimp farming (Brazil)

https://aquavitaeproject.eu/

REMEDIA -LIFE

https://remedialife.eu/

The project presents an experimental system in the pre-industrial level; **an IMTA system including Sabellid polychaetes** (*Sabella spallanzanii),* **Porifera** (the horny sponge *Sargotragus spinosulus*), **Mussels and Macroalgae** *(Chaetomorpha linum, Gracilaria bursa-pastoris)* **co-cultured in** a Southern Italian In-Shore Mariculture Plant (Ionian Sea), a semi-enclosed basin with lagoon features. Mar Grande of Taranto is one of the most important coastal marine ecosystems along **the Apulian coast.**

The exploitation of the biomass of cultured species includes:





- ✓ edible biomass
- ✓ row material for the extraction of active ingredients in pharmaceuticals, nutraceuticals and cosmetics, particularly in relation to porifera and macroalgae.
- ✓ macroalgae turned into fertilizer to be used in horticulture.
- ✓ the worms polychaetes have an exploitation as bait for sport fishing and as ornamental animals for tropical and Mediterranean aquaria
- ✓ polychaetes /algae can be used as a component in the production of fooder, that can be included in the feed market.

Co-culture of the above described species (bio-remediators) lead to the reduction of marine pollution (microbiological contamination) due to mariculture plants, even in confined areas subject to anthropic stress. In the short / medium term a bioremediation of the waters as well as of the sediments surrounding the plant is expected.

ALGOLESCO -

A company Brittany – France dedicated to the cultivation of several species of algae since 2013. 150 hectares of crops in the open sea, in the heart of a site classified as Natura 2000. *Saccharina latissima*, *Undaria pinnatifida, Ulva* sp., *Himanthalia elongate*, *Ascophyllum* sp. *Fucus* sp., *Palmaria palmate , Chondrus crispus*, are cultivated in preserved waters off Lesconil, South Finistère, Brittany. From reproduction to harvesting, the entire cycle of cultivation is guaranteed, in 100% organic production.


ALGOLESCO attempts to diversify its activity, with an IMTA system developing an associated shellfish production on ropes.

ASTRAL - All Atlantic Ocean Sustainable, Profitable and Resilient Aquaculture

Northern and Southern Atlantic regions (Ireland, South Africa, Scotland and Brazil)

The project aims to develop innovative techniques and species combinations to validate cost-effective IMTA processes from a regional challenge-based perspective, including fish, mollusc, echinoderm, crustacean and algae species.

In Ireland, Atlantic salmon (*Salmo salar*), Lumpfish (*Cyclopterus lumpus*), Queen Scallops (*Aequipecten opercularis*) & King scallop (*Pecten maximus*), Varigated scallop (*Mimachlamys varia*), Seaweed (Order Laminariales and Rhodophyta such as *Palmaria palmata*), European lobster (*Homarus gammarus*), *Ostrea edulis*, Sea urchin (*Paracentrotus lividus*), Black sea cucumber (*Holothuria forskali*)

In Scotland, sugar kelp (*Saccharina latissima*), winged kelp (*Alaria esculenta*), oarweed (*Laminaria digitata*), native oysters (*Ostrea edulis*).

In South Africa, abalone (*Haliotis midae*), Sea lettuce (*Ulva rigida*), Collector sea urchin (*Tripneustes gratilla*), Cape urchin (*Parechinus angulosus*)

The aim is to provide farmers of aquatic organisms with a profitable IMTA production system, bringing revenue diversification and increasing profitability by at least 30% and to increase circularity by 50-60% through IMTA production, compared to monoculture baseline.

https://www.astral-project.eu/

3. The value chain of Aquaculture/fisheries/processing by-products and discards and by catch valorisation in the Mediterranean Sea

3.1. The Mediterranean value chain for FBP and discards, description of the value chain

The value chain of aquaculture/fisheries/processing by-products, unavoidable/unwanted catches and discards valorisation in the Mediterranean Sea is currently without doubt an underutilised sector despite the fact that there are several best practises in Northern Europe and overseas. One of the main challenges for the valorisation of discards and fish by-products is the available quantities for processing.

In the context of this report, the following definitions are adopted:

1) The term aquaculture/fisheries/processing by-products Category 3 refers to what results from the processing of fishery and aquaculture products in the commercial and processing chain. Many of the fishery, processing and aquaculture products sold in supermarkets, open public markets, fishmongers and in the central markets where seafood is sold are returned to customers after processing, i.e. the common "cleaning", that includes gutting, scaling, skinning, filleting, gill removal, head removal, etc.
2) Discards, or discarded catch is that portion of the total organic material of animal origin in the catch, which is thrown away, or dumped at sea for whatever reason. It does not include plant materials and post-harvest waste such as offal. The discards may be dead, or alive (Kelleher, 2005)[104].
3) By catch is "the part of the catch that is unintentionally captured during a fishing operation in addition to target species (Fig 18). It may refer to the catch of other commercial species that are landed, commercial species that cannot be landed (e.g. undersized, damaged individuals), discards of non-commercial species, as well as to incidental catch of endangered, vulnerable or rare species (GFCM, 2018)[105].

In 2003, the Common Fisheries Policy (CFP) of the European Commission (EC) introduced measures needed to reduce the high levels of unwanted catches and to gradually eliminate discards, adopting best practises from Norway and Iceland. Unwanted catches and discards constitute a substantial waste and negatively affect the sustainable exploitation of marine biological resources and marine ecosystems and the financial viability of fisheries. An obligation to land all catches ("the Landing Obligation") of species which are subject to catch limits and, in the Mediterranean Sea, also catches of species which are subject to minimum

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[104] Kelleher, K. (2005). Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper. No. 470. Rome, FAO. 2005. 131p.

[105] Bycatch definition as reported in the GFCM Data Collection Reference Framework (DCRF) (GFCM, 2018), GFCM. 2018. GFCM Data Collection Reference Framework (DCRF). Version: 20.1. [online]. Data Collection Reference Framework [Cited 7 December 2020]. http://www.fao.org/gfcm/data/dcrf/fr/

sizes was introduced[106]. With the Landing Obligation (LO), all catches of species subjected to catch quotas and/or Minimum Conservation Reference Size (MCRS) would have to be landed and counted against quota.

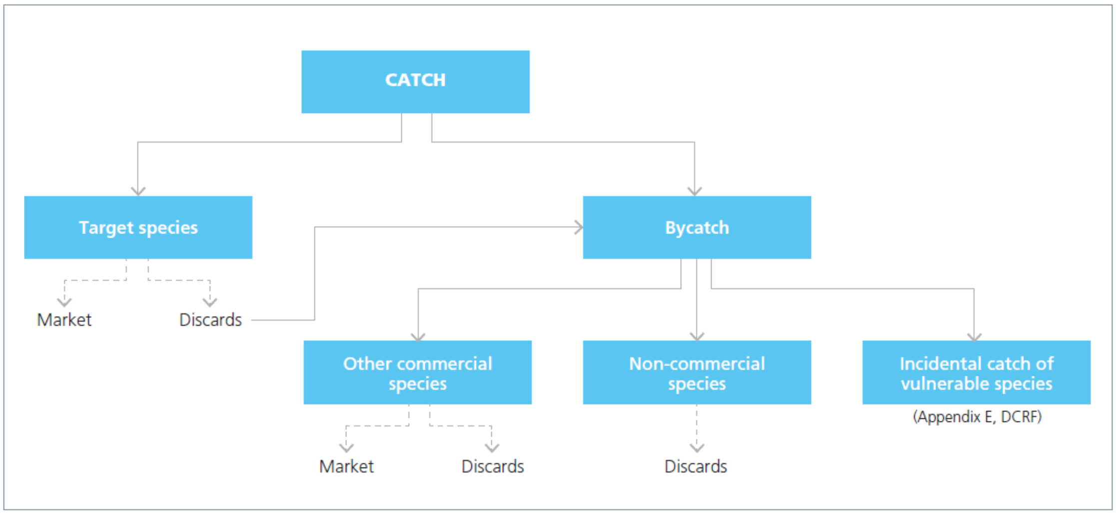


Fig. 18: Diagram of catch composition *Source: FAO, 2020*

The LO in the Mediterranean Sea concerns 20 fish species, 4 crustaceans and 3 bivalve molluscs that have a minimum landing size. It is important to note that catching unwanted fish species is an unavoidable consequence of commercial fishing in the Mediterranean Sea and currently the bulk of it is discarded at sea. In practise, the LO never applied in the Mediterranean Sea; exemptions were granted as the STECF considered that there was evidence of increased costs resulting from additional handling and sorting times on board, cost of handling unwanted catches ashore, which is difficult in the Mediterranean because the fleet mainly comprises small-scale vessels landing their catch in many ports spread out along the coast. The STECF concluded that, due to the small quantities and the very large number of landing places, even in the case that landed unwanted catches could be sold, the evidence indicated that the collection costs would be disproportionate.

Tsagarakis *et al.* (2014)[107] estimated that in the Mediterranean Sea, mid-water trawls, purse-seines and small-scale fisheries, despite their less proportion of discards per se, produce overall high discards quantities, since they are responsible for the majority of the landings. The Mediterranean discards estimation of Tsagarakis *et al.* (2014) is adopted also by FAO

[106] EC, Regulation (EU) No 1380/2013 of the European parliament and the Council of 11 December 2013 on the common fisheries policy, amending Council regulation (EC) No 1954/2003 and (EC) No 1224/2009 and replacing Council regulation (EC) No 2371/2002 and (EC) No 639/2004 and Council decision 2004/585/EC, Off. J. Eur. Union L 534 (2013) 22–61 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R1380&from=EN

[107] Tsagarakis, K.; Palialexis, A.; Vassilopoulou, V. (2014). Mediterranean fishery discards: review of the existing knowledge. ICES Journal of Marine Science, *71(5), 1219–1234.* doi:10.1093/icesjms/fst074

(2020)[108] at the latest edition of the State of the Mediterranean and Black Sea Fisheries where discards in the Mediterranean are estimated at around 230,000 tonnes per year, corresponding to approximately 18% of the catch.

Therefore, this report considers that not only the LO discards should be considered for valorisation but all "discarded" fish, including the unavoidable and unwanted catches.

3.2 Valorisation of discards and by catch

Defining by catch is particularly challenging in the Mediterranean due to the variety of fishing activities and species caught and the dynamic nature of the discarded components (FAO, 2020). By catch incurs additional costs without increasing revenues and it may hinder profitability, while also creating a negative perception of fishing activities within society.

For those unwanted catches (UWC) the H2020 project DiscardLess collected and proposed existing and innovative valorisation options for fish products (Table 14) where it is evident that there are at least 39 different possibilities. Each Country can build its own strategy in the context of a circular economy for territorial deployment of innovative solutions for creating circular economies through the valorisation of residual bio-resource streams. In addition, it is recommended to follow an environmental prioritization. Regarding unavoidable unwanted catches, the first option is to avoid or reduce their catch. But once landed, the preferred solution is always to maintain the product in the food chain, first for human consumption if not for animal. Some industrial uses can be of interest but lower value solutions like fertilisers and compost should not be prioritised as high value by-products and even fishmeal and fish oil production can always be produced.

It is now well known that various parts of fish can produce different substances and convert a product that used to be considered a waste, into high added value biomolecules.

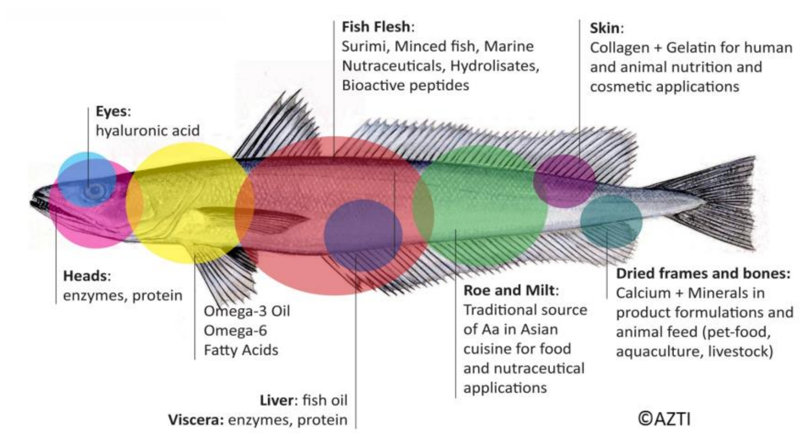


Fig. 19: Possible uses of fish beyond human consumption. *Source: DiscardLess project (AZTI).*

[108] FAO 2020. The State of Mediterranean and Black Sea Fisheries 2020. General Fisheries Commission for the Mediterranean. Rome. https://doi.org/10.4060/cb2429en. Last updated 10/03/2021.

Table 14: Main valorisation options by categories for discards and unavoidable and unwanted catches (bycatch) proposed by the DiscardLess Project.

Category	Valorisation option	No.
HUMAN FOOD	New Fish products	1
	Surimi	2
	Fish pulp	3
BIO-PRODUCTS	Bioactive Peptides	4
	Chitin / Chitosan	5
	Chondroitin sulphate	6
	Collagen	7
	Dye / pigments (Astaxanthin)	8
	Fat-soluble vitamins	9
	Gelatine	10
	Hyaluronic acid	11
	Insulin	12
	Minerals: Calcium, $CaCO_3$	13
	Pearl Essence	14
	Peptone	15
	Phospholipids	16
	Polyunsaturated fatty acids (PUFAs)	17
	Protamine	18
	Proteases and Proteolytic enzymes (Trypsin etc)	19
	Sterols	20
	Squalene	21
FEED	Fishmeal	22
	Fish oil	23
	Mink feed	24
	Marine beef/Bait	25
	Direct Pig Feed	26
	Protein concentrate (FPC)	27
	Protein Hydrolysate (PH)	28
	Silage	29
	Insects growth	30
INDUSTRIAL USES	Leather	31
	Fish oil	32
	Minerals: Calcium, $CaCO_3$	33
	Chitin / Chitosan	34
	Pearl Essence	35
ENERGY	Biogas	36
	Biodiesel	37
AGRONOMIC USES	Fertilisers	38
	Compost	39

With the introduction of the discard ban (synonym of the Landing Obligation), the purpose was a gradual decrease of the discards and a requirement to land all catches. Meanwhile, all

Member States should explore and put into practice different strategies, firstly to minimize the discards or unwanted catches (UWC), secondly to find the most appropriate uses for unavoidable unwanted catches which are subject to the landing obligation in order to prevent the impact that it may have on harbours and local economies (Iñarra et al., 2020)[109]. However, at this stage, infrastructures able to handle fish by-products produced by the catching sector are limited across the EU aquaculture/fisheries/processing by-products and discards and by catch valorisation in the Mediterranean Sea.

3.3 Waste streams biomass estimations for valorisation in Med B-Blue Countries

In order to be able to estimate the potential quantities for valorisation, a good overview of the produced fisheries and aquaculture quantities is needed in each Country. The following Tables summarise the situation in the B-BLUE countries and in the Mediterranean Sea.

3.3.1. Estimation of Discards

A. Fisheries production

A.

Country	Main species grouping	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Fish	51.267	69.652	62.514	73.255	77.127	70.681	70.352	67.348	68.038	62.308
Croatia	Molluscs	1.017	1.190	1.352	1.846	2.426	2.332	1.968	1.441	1.151	1.050
	Crustaceans	545	507	488	685	765	873	933	1.084	1.180	1.022
	Fish	336.990	355.965	346.220	383.620	418.082	407.400	433.777	419.711	451.422	392.588
France	Molluscs	74.770	80.102	70.743	71.847	63.710	65.743	67.254	70.118	106.926	74.495
	Crustaceans	17.758	18.374	14.555	15.347	16.271	14.854	16.373	16.533	15.394	14.314
	Fish	59.699	52.900	51.160	53.818	50.408	54.199	61.332	63.267	62.726	68.338
Greece	Molluscs	6.282	5.810	6.199	6.269	5.801	5.443	8.233	7.733	7.523	8.506
	Crustaceans	4.192	4.529	3.678	4.077	3.960	5.781	7.002	7.180	6.985	6.328
	Fish	156.830	144.487	137.270	117.986	125.548	138.258	136.683	133.639	139.821	123.088
Italy	Molluscs	50.399	48.720	44.242	38.545	38.389	38.264	39.362	39.807	42.283	40.635
	Crustaceans	26.321	23.412	19.708	20.173	18.699	21.037	20.690	22.648	23.549	20.706
	Fish	1.050	1.247	1.153	1.333	1.290	1.219	1.324	1.011	1.199	1.178
Montenegro	Molluscs	267	247	211	224	235	239	242	33	43	51
	Crustaceans	27	22	25	22	31	28	28	35	50	46
	Fish	201.429	198.220	179.999	175.640	162.275	168.456	165.856	160.943	158.334	168.589
Portugal	Molluscs	19.303	14.698	15.890	18.336	18.843	18.959	17.165	17.305	15.714	13.285
	Crustaceans	2.306	2.772	2.037	1.732	1.749	1.082	1.134	1.439	2.235	2.100
	Fish	871	830	436	366	370	315	271	256	229	248
Slovenia	Molluscs	65	57	48	34	38	26	33	23	34	32
	Crustaceans	5	4	1	0	2	2	7	1	1	1
	Fish	903.074	935.781	849.849	905.050	968.713	899.740	859.394	887.747	871.863	831.656
Spain	Molluscs	57.918	58.228	68.419	70.893	74.979	61.422	39.880	46.631	37.070	32.644
	Crustaceans	13.601	16.349	11.888	12.544	18.423	13.696	13.366	14.701	16.088	14.697
	Fish	1.711.210	1.759.082	1.628.601	1.711.068	1.803.813	1.740.268	1.728.989	1.733.922	1.753.632	1.647.993
TOTAL	**Molluscs**	210.021	209.052	207.104	207.994	204.421	192.428	174.137	183.091	210.744	170.698
	Crustaceans	64.755	65.969	52.380	54.580	59.900	57.353	59.533	63.621	65.482	59.214

[109] Iñarra, Bruno; Bald, Carlos; Cebrián, Marta; Peral, Irene; Llorente, Raquel; Zufía, Jaime (2020). Evaluation of unavoidable unwanted catches valorisation options: The Bay of Biscay case study. *Marine Policy*, Vol. 116, 103680–. doi:10.1016/j.marpol.2019.103680

Table 15: Fisheries production-main species grouping in the B-BLUE countries (in tonnes - live weight). Table A shows the whole production per Country whereas Table B shows the MED production of France and Spain and the respective total figures. Portugal, although not a MED Country, is added in the total figures for the purpose of the B-BLUE project.

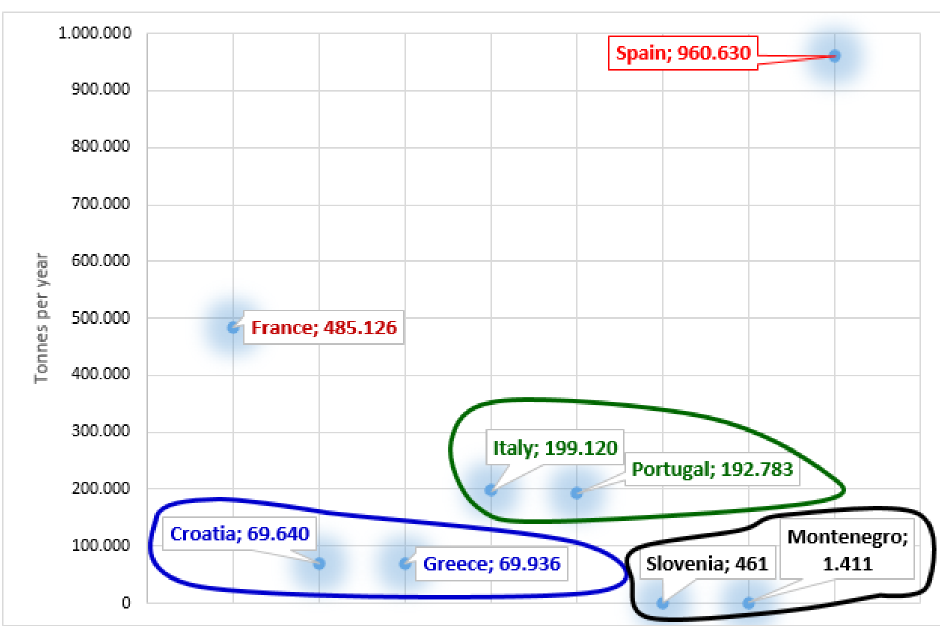
B.

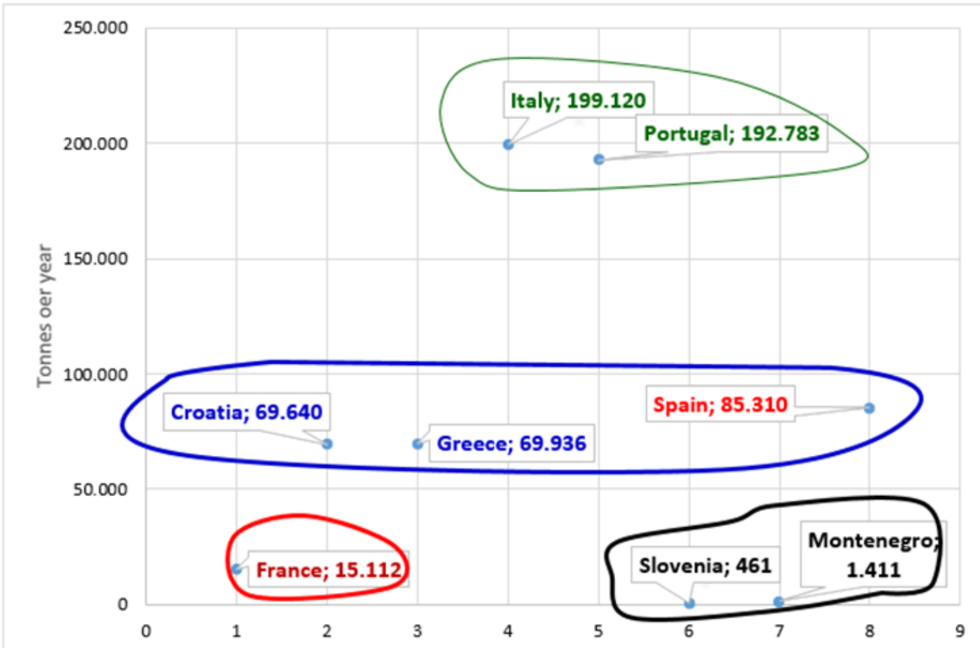
Country	Main species gro	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Fish	15.105	12.260	9.182	13.149	12.459	10.549	11.538	12.218	13.727	14.319
France	Molluscs	2.243	2.415	2.210	2.816	2.409	2.008	2.336	2.401	2.858	2.805
(Med Fisheries only)	Crustaceans	138	167	107	153	131	140	355	357	290	276
	Fish	85.886	89.637	69.752	72.858	70.559	66.400	67.583	75.540	77.590	65.118
Spain	Molluscs	9.284	10.395	5.736	6.984	6.042	6.125	6.756	6.186	7.481	5.841
(Med Fisheries only)	Crustaceans	4.547	4.271	3.052	2.616	2.193	4.779	4.109	4.578	6.249	4.957
	Fish	572.137	569.233	511.466	508.405	500.036	510.077	514.939	514.222	521.664	503.186
TOTAL	**Molluscs**	88.860	83.532	75.888	75.054	74.183	73.396	76.095	74.929	77.087	72.205
	Crustaceans	38.081	35.684	29.096	29.458	27.530	33.722	34.258	37.322	40.539	35.436

Source: FIGIS – FAO Fisheries Global Information System

On average, 1,721,858 tonnes of fish are produced in the 8 B-BLUE Countries, 196,969 tonnes of molluscs and 60,279 tonnes of crustaceans (average of the period 2010-2019). Five distinct groupings are formed, with Spain to be by far the largest producer with 960,630 tonnes/year, followed by France with 485,126 tonnes/year. Italy with 199,120 tonnes/year and Portugal with 192,783 tonnes/year form another group of countries, followed by Greece and Croatia with 69,936 and 69,640 tonnes/year respectively (Fig. 20). Montenegro and Slovenia with 1,411 and 461 tonnes/year have the smallest catches.

Fig. 20: Grouping of B-Blue Med Countries for fisheries production (average values for the period 2010-2019). The top figure shows groupings, if both Atlantic and Mediterranean fisheries are considered for France and Spain versus, the Mediterranean production only at the bottom.





It is highlighted that the largest mollusc producer from fisheries is France (74,571 tonnes/year), followed by Spain (54,808 tonnes) and Italy (42,065 tonnes). Italy is the largest producer of Crustaceans (21,694 tonnes/year), followed by France (15,977 tonnes) and Spain (14,535 tonnes).

However, if only the Mediterranean production is considered for France and Spain, the figures drop by 30.35% for fish, 39.15% for molluscs and 56.59% for crustaceans (Table 16). Then, the total falls from 1,721,858 tonnes of fish down to 522,537 tonnes, with Portugal taking the lead with 173,974 tonnes, followed by Italy with 135,361 tonnes and Spain with 74,092 tonnes. For molluscs, Italy takes the lead with 42,065 tonnes, followed by Portugal with 16,950 tonnes and Spain with 7,083 tonnes.

Table 16: Rankings of B-BLUE countries on fisheries production (fish, molluscs, crustaceans). The ranking changes if both Atlantic and Mediterranean fisheries are considered for France and Spain

	Fish	Fish Med only (FR & SP)			Molluscs	Molluscs Med only (FR & SP)	
1.Spain	891.287	1.Portugal	173.974	1.France	74.571	1.Italy	42.065
2.France	394.578	2.Italy	135.361	2.Spain	54.808	2.Portugal	16.950
3.Portugal	173.974	3.Spain	74.092	3.Italy	42.065	3.Spain	7.083
4.Italy	135.361	4.Croatia	67.254	4.Portugal	16.950	4.Greece	6.780
5.Croatia	67.254	5.Greece	57.785	5.Greece	6.780	5.France	2.450
6.Greece	57.785	6.France	12.451	6.Croatia	1.577	6.Croatia	1.577
7.Montenegro	1.200	7.Montenegro	1.200	7.Montenegro	179	7.Montenegro	179
8.Slovenia	419	8.Slovenia	419	8.Slovenia	39	8.Slovenia	39

	Crustaceans	**Crustaceans Med only (FR & SP)**	
1.Italy	21.694	**1.Italy**	21.694
2.France	15.977	**2.Greece**	5.371
3.Spain	14.535	**3.Spain**	4.135
4.Greece	5.371	**4.Portugal**	1.859
5.Portugal	1.859	**5.Croatia**	808
6.Croatia	808	**6.France**	211
7.Montenegro	31	**7.Montenegro**	31
8.Slovenia	2	**8.Slovenia**	2

Source: FIGIS – FAO Fisheries Global Information System

B. Discards estimation in the B-BLUE Countries

Estimating the exact amounts of discards is a difficult exercise and requires specialised knowledge and access to historic data that the B-Blue partners do not have easy access. Therefore, an approximate estimation method is used in order to estimate the amounts of discards in each B-BLUE country, given the weakness to engage the specific expertise required in a short timeframe. Several factors have been shown to affect discarded quantities, such as species and size composition of the catch, fishing strategies, environmental conditions, and cultural characteristics. These factors often act in synergistic effect which may not be straightforward to disentangle, especially in multispecies fisheries like most of those exerted in the Mediterranean. As a result high regional, seasonal, and interannual fluctuations are observed even within the same fishing gear.

From the available fisheries production data (Table 15) and based on the estimated percentage of 18.6% for the Mediterranean discards (Tsagarakis *et al.* 2014), the following Table 17 summarise the approximate quantities of discards for the eight B-Blue Countries. About 118,000 tonnes are estimated for the B-BLUE Countries (average for the years 2010-2019). This amount of discards is in accordance with the value of around 230,000 tonnes per year estimated by FAO (2020) for the whole Mediterranean, corresponding to approximately 18% of the catch. Our results for the B-BLUE countries consider only the Mediterranean production figures for Spain and France which are much lower compared to the yields from the Atlantic Ocean. In addition, Portugal is not a Mediterranean Country and in the Mediterranean its fleet is targeting mainly crustaceans (FAO FIGIS database).

Table 17: Discard estimation from fisheries production in the MED segments of B-BLUE countries (in tonnes - live weight).

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	AVERAGE
Croatia	9.826	13.271	11.970	14.096	14.939	13.743	13.625	12.996	13.089	11.975	**12.953**
France	3.252	2.761	2.139	2.998	2.790	2.362	2.647	2.786	3.139	3.236	**2.811**
Greece	13.052	11.762	11.353	11.935	11.191	12.169	14.241	14.541	14.366	15.470	**13.008**
Italy	43.440	40.291	37.427	32.867	33.970	36.746	36.593	36.473	38.251	34.304	**37.036**
Montenegro	250	282	258	294	289	276	296	201	240	237	**262**
Portugal	41.485	40.118	36.814	36.402	34.013	35.060	34.253	33.422	32.789	34.219	**35.858**
Slovenia	175	166	90	74	76	64	58	52	49	52	**86**
Spain	18.547	19.400	14.608	15.337	14.656	14.379	14.591	16.053	16.986	14.120	**15.868**
TOTAL	**130.029**	**128.052**	**114.660**	**114.003**	**111.925**	**114.798**	**116.304**	**116.524**	**118.908**	**113.614**	**117.882**

Of course, more targeted analysis is required by Country in order to estimate with more accuracy the discards per species, season and fishing gear. However this is a first estimate that allows a first approach for the potential valorisation of the value chain in the Mediterranean Sea.

In Australia, a study with fishers and processors in New South Wales and Tasmania to detect opportunities for enterprises to increase the harvest of underutilised species for use in production of value added formats for new consumer markets, identified twelve underutilised species, six of which have commercial potential (Colquhoun, 2017)[110]. These six species could provide an additional 5,000 tonnes of fish with an estimated GVP of $31million.

[110]Colquhoun, E. (2017). FRDC Project Application 2016-224. Boosting fisher returns through smart value adding and greater use of underutilised species Fisheries Research & Development Corporation.

The activities are commercial in confidence[111] but the interesting outcome is that in Australia, 5,000 tonnes is a biomass that merits valorisation. In the Mediterranean, much larger quantities than 5,000 tonnes exist and therefore, given that there are more than 39 valorisation options by categories for discards and unavoidable and unwanted catches (see Table 14), there is good chance that this waste stream sooner or later will be valorised for the benefit of the Mediterranean fishers and citizens.

C. Aquaculture production

The aquaculture production in the B-Blue countries is presented in the following tables. Greece is the largest fish producer (mainly seabass and seabream) with 98,456 tonnes average production in the period 2010-2019. Spain follows with 62.429 tonnes, Italy is third with 52,024 tonnes and France is fourth with 45,832 tonnes (Table 18).

For molluscs, Spain is the largest producer with 220,898 tonnes, followed by France and Italy with 143,848 and 97,357 tonnes respectively (Table 19). Greece follows with 19,317 tonnes, with Portugal, Croatia, Slovenia and Montenegro with smaller quantities.

Table 18: Ranking of aquaculture fish production in the B-BLUE countries. Average figures for the period 2010-2019.

Country	Fish (tonnes)
1. Greece	**98,456**
2. Spain	62,429
3. Italy	52,024
4. France	45,832
5. Croatia	13,721
6. Portugal	5,538
7. Slovenia	1,035
8. Montenegro	703
Total	279,737

Table 19: Ranking of aquaculture molluscs production in the B-BLUE countries. Average figures for the period 2010-2019

Country	**Molluscs (tonnes)**
1. Spain	**220.898**
2. France	143.848
3. Italy	97.357
4. Greece	19.317
5. Portugal	5.308
6. Croatia	1.016
7. Slovenia	491
8. Montenegro	197
Total	**488.432**

For crustaceans, the aquaculture quantities are smaller with Spain taking the lead with 166 tonnes per year, followed by France and Greece with 53 tonnes, Italy with 19 tonnes and Portugal with 9 tonnes per year (Table 20).

[111] Stephens, L. 2019, A review of projects concerned with improved exploitation of underutilised species. Canberra 2019. See: https://www.frdc.com.au/Archived-Reports/FRDC%20Projects/2017-185-DLD.pdf

Country	Crustaceans (tonnes)
Spain	**166**
France	53
Greece	53
Italy	19
Portugal	9
Croatia	0
Montenegro	0
Slovenia	0
Total	**299**

Table 20. Ranking of aquaculture crustaceans production in the B-BLUE countries. Average figures for the period 2010-2019.

Table 21. Aquaculture (fish and shellfish) production in the B-BLUE countries (values in tonnes live weight). Figures refer to the whole Country production in France, Portugal and Spain and not only to the Mediterranean Sea.

Country	Main species grouping	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Fish	11.931	12.426	9.990	10.019	12.403	14.773	15.042	15.052	17.132	18.440
Croatia	Molluscs	2.060	420	451	2.000	746	798	763	982	935	1.005
	Crustaceans	0	0	0	0	0	0	0	0	0	0
	Total	13.991	12.846	10.441	12.019	13.149	15.571	15.805	16.034	18.067	19.445
	Fish	49.672	47.131	45.437	45.728	44.654	38.700	48.690	47.816	42.953	47.540
France	Molluscs	153.245	146.437	159.568	154.523	135.573	124.487	131.767	140.628	144.096	148.155
	Crustaceans	50	44	44	47	58	62	50	57	44	69
	Total	202.967	193.612	205.049	200.298	180.285	163.249	180.507	188.501	187.093	195.764
	Fish	104.096	93.407	94.149	95.245	87.836	88.334	100.291	106.165	110.162	104.874
Greece	Molluscs	17.148	17.196	16.613	18.639	16.701	18.629	23.291	19.246	22.010	23.697
	Crustaceans	0	9	38	22	0	50	29	11	62	109
	Total	121.244	110.612	110.800	113.906	104.537	107.013	123.611	125.422	132.234	128.680
	Fish	52.452	52.246	52.965	51.974	48.341	48.402	56.633	56.634	50.163	50.428
Italy	Molluscs	101.016	111.838	84.070	88.897	100.374	100.345	100.345	100.345	93.171	93.170
	Crustaceans	26	67	6	8	15	16	22	21	5	2
	Total	153.494	164.151	137.041	140.879	148.730	148.763	157.000	157.000	143.339	143.600
	Fish	590	640	630	630	680	624	737	808	852	834
Montenegro	Molluscs	150	200	181	181	179	189	192	214	245	240
	Crustaceans	0	0	0	0	0	0	0	0	0	0
	Total	740	840	811	811	859	813	929	1.022	1.097	1.074
	Fish	4.880	5.621	6.394	5.294	6.488	4.782	4.851	5.362	4.556	7.152
Portugal	Molluscs	3.342	3.544	3.924	4.768	4.842	4.766	4.916	7.093	9.382	6.501
	Crustaceans	3	1	0	5	5	13	18	21	18	2
	Total	8.225	9.166	10.318	10.067	11.335	9.561	9.785	12.476	13.956	13.655
	Fish	701	958	842	897	967	1.029	1.232	1.084	1.334	1.310
Slovenia	Molluscs	78	438	312	329	430	588	627	666	609	834
	Crustaceans	0	0	0	0	0	0	0	0	0	0
	Total	779	1.396	1.154	1.226	1.397	1.617	1.859	1.750	1.943	2.144
	Fish	59.484	59.263	57.233	58.662	59.533	61.810	64.111	66.591	60.535	77.066
Spain	Molluscs	192.764	212.558	206.763	164.976	222.543	227.805	219.539	244.233	287.020	230.774
	Crustaceans	104	140	164	70	162	204	177	199	258	185
	Total	252.352	271.961	264.160	223.708	282.238	289.819	283.827	311.023	347.813	308.025

Source: FIGIS – FAO Fisheries Global Information System

3.3.2. Estimation of waste from the fish retail, commercial and processing industry

Another potential source of raw material for valorisation and production of high value added biomolecules (HVAB) are the fish by-products category 3 (FBP) from the processing of fishery and aquaculture fish in the retail, commercial and processing chain. Many of the fishery and aquaculture products sold in supermarkets, public markets, neighbourhood fishmongers and central markets where seafood is sold are given to customers after being processed, i.e. the common "cleaning". "Cleaning", depending on the type of fish, may include gutting, removal of scales, skinning, filleting, gill removal, head removal, etc. After this treatment, about 15-25% is discarded (offal, scales, backbone and heads).

The biomass from this procedure is difficult to be estimated accurately. In the B-BLUE Countries, the apparent consumption of fishery and aquaculture products (fish, molluscs and crustaceans in fresh, frozen or processed form) presented in Table 22 Table 22 takes into account all forms consumed, even canned or smoked products, etc.

Table 22: Apparent Consumption of seafood estimates in the B-BLUE countries.

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average
Croatia	17,66	19,81	18,66	20,65	21,09	19,62	19,79	19,86	21,40	19,84
France	21,98	22,38	21,05	21,78	22,03	21,17	22,00	22,44	23,16	22,00
Greece	23,95	21,77	21,49	22,15	23,21	23,40	25,94	25,35	27,10	23,82
Italy	21,07	21,23	19,59	19,33	19,84	20,66	21,31	21,55	21,50	20,68
Monteneg	8,25	8,77	8,37	9,16	8,96	9,05	10,06	10,12	10,63	9,26
Portugal	42,45	41,21	39,22	39,98	38,45	38,82	43,43	44,18	42,82	41,17
Slovenia	7,11	7,50	6,84	6,82	6,92	7,20	6,61	7,49	7,75	7,14
Spain	39,07	39,39	35,34	36,31	39,17	38,44	38,01	39,04	38,36	38,13

The following calculations have been made for the determination of FBPs from the processing of fishery and aquaculture products in the retail, commercial and processing chain, which can be summarized in Table 23.

From the production data of Table 15 (fisheries), Table 21 (fish produced from aquaculture), ANNEX-1 (fish imports and exports) the apparent consumption is calculated from the following formula:

Apparent consumption= Fish from fisheries production + Fish from aquaculture production + Imports of fish – Exports of fish.

The apparent per capita consumption is calculated if the apparent consumption will be divided with the population in each Country (Eurostat data) (Table 24).

Table 23: Estimation of apparent consumption for the determination of fish by-products (FBP) category 3 from the processing of fishery and aquaculture products, in the retail and processing chain.

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018
Croatia	14,93	17,06	16,04	17,90	18,34	16,77	17,14	16,98	18,23
France	14,56	15,13	14,07	14,98	15,67	15,04	15,61	15,90	16,19
Greece	19,53	17,56	18,05	18,09	19,47	19,33	20,82	20,48	22,14
Italy	12,43	12,43	11,93	11,56	11,82	12,17	12,83	13,10	13,30
Montenegro	6,52	6,90	6,50	7,24	7,02	7,08	7,81	8,04	8,27
Portugal	34,35	34,30	33,21	34,19	32,24	32,47	35,38	35,06	33,95
Slovenia	5,29	5,52	5,19	5,05	5,11	5,25	4,46	5,48	5,49
Spain	25,55	25,53	22,49	24,33	25,39	25,11	25,31	25,61	24,64

Table 24. Population figures for the B-BLUE Countries.

Country	2014	2015	2016	2017	2018
Croatia	4.246.809	4.225.316	4.190.669	4.154.213	4.105.493
France	66.165.980	66.458.153	66.638.391	66.809.816	67.026.224
Greece	10.926.807	10.858.018	10.783.748	10.768.193	10.741.165
Italy	60.782.668	60.795.612	60.665.551	60.589.445	60.483.973
Montenegro	621.521	622.099	622.218	622.387	622.359
Portugal	10.427.301	10.374.822	10.341.330	10.309.573	10.291.027
Slovenia	2.061.085	2.062.874	2.064.188	2.065.895	2.066.880
Spain	46.512.199	46.449.565	46.440.099	46.528.024	46.658.447

Source: EUROSTAT

Following these calculations of a per capita consumption in kg per inhabitant per year, if we will assume that the same percentages of fish from fishery and aquaculture are consumed throughout the regions of the B-BLUE Countries, then based on the fish apparent consumption (Table 14) and the population figures provided by Eurostat (Table 15) the following Table 16 emerge if we assume that a conservative average percentage of 15% is removed from the fish during the "cleaning" at the retail and processing points.

Table 25. Estimation of fish by-products category 3 from the processing of fish from fishery and aquaculture in the retail, commercial and processing chain.

Country	Fish Apparent Consumption (tonnes)					Fish by-products Category 3 (tonnes)				
						15,00%				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Croatia	77.888	70.876	71.840	70.542	74.841	11.683	10.631	10.776	10.581	11.226
France	1.036.563	999.498	1.040.548	1.062.024	1.085.402	155.484	149.925	156.082	159.304	162.810
Greece	212.691	209.885	224.488	220.555	237.807	31.904	31.483	33.673	33.083	35.671
Italy	718.255	740.029	778.181	793.466	804.363	107.738	111.004	116.727	119.020	120.654
Montenegro	4.366	4.406	4.862	5.005	5.149	655	661	729	751	772
Portugal	336.190	336.912	365.874	361.460	349.347	50.429	50.537	54.881	54.219	52.402
Slovenia	10.538	10.832	9.204	11.312	11.340	1.581	1.625	1.381	1.697	1.701
Spain	1.181.005	1.166.504	1.175.479	1.191.756	1.149.757	177.151	174.976	176.322	178.763	172.464
TOTAL	**3.577.496**	**3.538.942**	**3.670.476**	**3.716.120**	**3.718.006**	**536.624**	**530.841**	**550.571**	**557.418**	**557.701**

The above Table 25 shows that throughout the B-BLUE countries there is a potential source of raw material for the production of high value-added biomolecules from fish by-products (FBP) category 3 of the order of 546,631 tonnes from the processing of fish in the retail, commercial and processing streams. It is obvious that the largest quantities of FBP from the processing of fish is in the countries with the higher consumption and population, with the ranking to be Spain, France, Italy, Portugal, Greece, Croatia, Slovenia and Montenegro.

In most B-BLUE countries, currently, there is limited valorisation of this untapped source and a significant portion ands up in landfills along with other municipal waste.

An EUMOFA (2018)[112] report assumes that there will be little incentive for public or private investment in processes and technologies to valorise otherwise wasted fisheries and aquaculture outputs unless a) there are markets for the resulting products, b) the supply chain allows appropriate interventions at the most appropriate points, and c) policies can be put in place that are not expensive or onerous to follow. For these reasons, a consideration of the dynamics of wastes is important.

Analysis of waste production suggests that the largest proportions occur at the stage of catch or during aquaculture, during distribution and retailing, and during consumption itself with the total to be in the region of 35% of original landings (Jouvenot, 2015)[113]. Caruso (2015)[114] reported that experts in the field of fisheries and aqua feeds have estimated that about a quarter of wastes coming from fishery are discarded, so causing not only a significant environmental impact but also a loss of the potential value of such products. This consideration stresses the importance of finding adequate modalities for fish wastes management, taking into account the possibility to use them not only as fish feeds but also

[112] EUMOFA 2018. "Blue bioeconomy: situation report and perspectives"

[113] Jouvenot L. (2015). Utilisation of rest raw materials from the fish industry: Business opportunities and logistics requirements Master's Thesis Norwegian University of Science and Technology NTNU Trondheim June 2015 https://brage.bibsys.no/xmlui/bitstream/handle/11250/2351183/13467_FULLTEXT.pdf?sequence=1.

[114] Caruso G (2015). Fishery Wastes and By-products: A Resource to Be Valorised https://www.fisheriessciences.com/fisheries-aqua/fishery-wastes-and-byproducts-a-resource-to-be-valorised.php?aid=8210

as a potential source of bioactive compounds. Kotzamanis et al. (2001)[115] reported that about 9,000 tonnes of by-products from the Greek seafood processors were burnt or buried every year, deriving from the processing of trout *Salmo trutta* (L.), sardine *Sardina pilchardus* (Walbaum), mackerel *Scomber scombrus* (L.), tuna *Thunnus thynnus thynnus* (L.), eel *Anquilla anquilla* (L.), gilthead bream *Sparus aurata* (L.), sea bass *Dicentrarchus labrax* (L.), anchovy *Engraulis encrasicolus* (L.), octopus *Octopus vulgaris* (Cuvier) and squid *Illex coindetii* (Verany). They demonstrated also that trout offal could be used successfully in sea bream diets for aquaculture.

The estimated 117,882 tonnes of discards, the 546,631 tonnes of fish by-products and the thousands of tonnes of shells from mussels, oysters and other molluscs, is a significant quantity that can support the development of Blue Biotechnologies in the Mediterranean Sea in the years to come. Fish waste management is one of the problems having the greatest impact on the environment for more than 2 decades now (Arvanitoyannis and Kassaveti, 2008)[116] and given the know-how and experience that exists in Europe and overseas, the future seems to be very promising for such activities.

3.4. Main challenges for implementation of aquaculture/fisheries/processing by-products and discards valorisation in the Mediterranean Sea

The main challenges for implementation of aquaculture/fisheries/processing by-products and discards valorisation in the Mediterranean Sea have been identified in each Country through a dedicated questionnaire that the B-BLUE partners requested to be filled in for their Country (Annex 2). The questionnaire has been answered by all Countries except Montenegro and Portugal.

One of the main challenges for the valorisation of discards and fish by-products is the available quantities for processing, as estimated in the previous chapter but it is important also to present below the estimates from the various B-BLUE countries.

All Countries but Slovenia have fish landing sites (Croatia less than 3, France 4, Greece 11, Italy and Spain more than 16 (Table 26), a fact that facilitates the central concentration of discards and unwanted catches.

The volume of seafood traded in the fish landing sites is significant in Greece (about 74,000 tonnes), Italy (between 80,000 and 100,000 tonnes) and Spain (more than 100,000 tonnes annually) –Table 27. The largest fleet operating in the Mediterranean from the B-BLUE countries (in terms of numbers) is the Greek with 12,807 vessels, followed by Italy (10,909

[115] Kotzamanis Y P; M N Alexis; A Andriopoulou; I Castritsi-Cathariou; G Fotis (2001). Utilization of waste material resulting from trout processing in gilthead bream (*Sparus aurata* L.) diets. 32(Supplement s1), 288–295. doi:10.1046/j.1355-557x.2001.00042.x

[116] Ioannis S. Arvanitoyannis; Aikaterini Kassaveti (2008). Fish industry waste: treatments, environmental impacts, current and potential uses. 43(4), 726–745. doi:10.1111/j.1365-2621.2006.01513.x

vessels), Croatia (6,211 vessels), Spain (2,056 vessels), France (1,418 vessels), Montenegro (224 vessels) and Slovenia (72 vessels) (data from FAO 2020). These vessels catch a number of discards and UWC during their operation and their estimated quantities are shown in Table 28.

Table 26: Number of fish landing sites with auction system in your Country (Mediterranean coast).

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
None	0	0	0	0	0	0	√	0
1-3	√	0	0	0	0	0	0	0
4-10	0	√	0	0	0	0	0	0
11-15	0	0	√	0	0	0	0	0
16-20	0	0	0	√	0	0	0	0
More than 20	0	0	0	0	0	0	0	√
If you know the number, please put it here:	0	4	11	0	0	0	0	0

Table 27: Volume of seafood traded in the fish landing sites with auction system in your Country (Mediterranean coast).

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• None	0	0	0	0	0	0	√	0
• up to 10,000 tonnes	√	√	0	0	0	0	0	0
• 10,000 – 20,000 tonnes	0	0	0	0	0	0	0	0
• 20,000 – 40,000 tonnes	0	0	0	0	0	0	0	0
• 40,000 – 60,000 tonnes	0	0	0	0	0	0	0	0
• 60,000 – 80,000 tonnes	0	0	√	0	0	0	0	0
• 80,000 – 100,000 tonnes	0	0	0	√	0	0	0	0
• More than 100,000 tonnes	0	0	0	0	0	0	0	√
• If you know the number, please put it here:	0	7.641	74.000	0	0	0	0	0

Table 28. Estimated annual quantities of discards in the B-BLUE Countries per fleet segment (in tonnes).

Coastal vessels	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• 0-100 tonnes per year	√	0	0	√	0	0	√	0
• 101-500 tonnes per year	0	0	0	0	0	0	0	0
• 501-1000 tonnes per year	0	0	0	0	0	0	0	0
• 1001-2000 tonnes per year	0	0	0	0	0	0	0	0
• 2001-3000 tonnes per year	0	0	0	0	0	0	0	0
• 3001-4000 tonnes per year	0	0	√	0	0	0	0	0
• More than 4001 tonnes per year	0	0	0	0	0	0	0	√

Trawlers	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• 0-100 tonnes per year	0	0	0	√	0	0	√	0
• 101-1000 tonnes per year	√	0	0	0	0	0	0	0
• 1001-4000 tonnes per year	0	0	0	0	0	0	0	0
• 4001-6000 tonnes per year	0	0	√	0	0	0	0	0
• 6001-8000 tonnes per year	0	0	0	0	0	0	0	0
• 8001-10.000 tonnes per year	0	0	0	0	0	0	0	0
• More than 10.001 tonnes per year	0	0	0	0	0	0	0	√

Purse seiners	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• 0-100 tonnes per year	0	0	0	√	0	0	√	0
• 101-500 tonnes per year	0	0	0	0	0	0	0	0
• 501-1000 tonnes per year	√	0	0	0	0	0	0	0
• 1001-2000 tonnes per year	0	0	√	0	0	0	0	0
• 2001-3000 tonnes per year	0	0	0	0	0	0	0	0
• 3001-4000 tonnes per year	0	0	0	0	0	0	0	0
• More than 4001 tonnes per year	0	0	0	0	0	0	0	√

Note: ME and PT did not respond to the questionnaire.

In addition, there are numerous aquaculture processing units that operate in the B-BLUE countries (Table 29).

Table 29: Aquaculture processing units operating in the B-BLUE Countries.

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• Aquaculture processing units. Please add the number:	204	3500	118	800	0	0	345	5 105

Note: ME and PT did not respond to the questionnaire.

The estimated quantities of fish by-products from the aquaculture processing units operating in the B-BLUE Countries are shown in Table 30.

Table 30: Estimated quantities of fish by-products from the aquaculture processing units operating in the B-BLUE Countries.

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• 0-100 tonnes per year	0	0	0	√	0	0	√	0
• 101-500 tonnes per year	0	0	0	0	0	0	0	0
• 501-1000 tonnes per year	√	0	0	0	0	0	0	0
• 1001-2000 tonnes per year	0	0	0	0	0	0	0	0
• 2001-3000 tonnes per year	0	0	0	0	0	0	0	0
• 3001-4000 tonnes per year	0	0	0	0	0	0	0	0
• More than 4001 tonnes per year	0	√	√	0	0	0	0	√

Note: ME and PT did not respond to the questionnaire.

Moreover, there are numerous seafood processing units that operate in the B-BLUE countries and are depicted in Table 31.

Table 31. Seafood processing units operating in the B-BLUE Countries.

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• Seafood processing units. Please add the number:	45	217	375	413	0	0	26	601

Note: ME and PT did not respond to the questionnaire.

The estimated quantities of fish by-products from the seafood processing units operating in the B-BLUE Countries are shown in Table 32.

Table 32. Estimated quantities of fish by-products from the aquaculture processing units operating in the B-BLUE Countries.

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• 0-100 tonnes per year	0	0	0	√	0	0	√	0
• 101-500 tonnes per year	√	0	0	0	0	0	0	0
• 501-1000 tonnes per year	0	0	0	0	0	0	0	0
• 1001-2000 tonnes per year	0	0	0	0	0	0	0	0
• 2001-3000 tonnes per year	0	0	0	0	0	0	0	0
• 3001-4000 tonnes per year	0	0	√	0	0	0	0	0
• More than 4001 tonnes per year	0	0	0	0	0	0	0	√

Note: FR, ME and PT did not respond to this question.

Significant quantities exist in Greece and Spain. Italy declared up to 100 tonnes per year but this is an apparent underestimation as the Country has 413 seafood processing units. Therefore, significant quantities must be available in France, Greece, Italy, Portugal and Spain.

A qualitative estimation of the available quantities from aquaculture/fisheries/processing by-products and discards in the B-BLUE Countries are depicted in the following Table 33.

Table 33. Qualitative estimation of available quantities from aquaculture/fisheries/processing by-products and discards for valorisation in the B-BLUE Countries.

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• Are too few and scattered in order to be valorised	0	0	0	0	0	0	0	0
• Are important but scattered in many areas in order to be valorised	√	0	0	0	0	0	0	√
• Are few but could be valorised in some areas	0	0	√	√	0	0	0	0
• Are important but there is no infrastructure to valorise them	0	0	0	0	0	0	√	0
• Not Important	0	√	0	0	0	0	0	0

Note: ME and PT did not respond to this question.

Only France believes that the quantities are not important (perhaps for the Mediterranean coast as COPALIS is already valorising large quantities in the Atlantic based Boulogne-sur-Mer). Croatia and Spain believe that they are important but scattered in many areas, whereas Greece and Italy believe that the quantities are few but could be valorised in some areas.

Another major challenge is the willingness of the fishing industry to cooperate for the valorisation of discards and by-products in the B-BLUE countries. The following summarises the responses gathered from the B-BLUE countries.

Table 34: Fishing industry's willingness to cooperate for valorisation in the B-BLUE Countries.

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• Excellent	0	0	0	0	0	0	0	0
• Good	0	0	√	0	0	0	√	0
• Average	0	√	0	√	0	0	0	√
• Poor	√	0	0	0	0	0	0	0

Note: ME and PT did not respond to this question.

Only Croatia replied that the fishing industry willingness for cooperation is poor. France, Italy and Spain reported average willingness for cooperation, and Greece and Slovenia good willingness for cooperation. No Country reported an excellent fishing industry's willingness to cooperate for valorisation of discards and fish by-products.

So in principle, most Countries tend to report that the fishing industry is willing to cooperate, provided that the proper incentives to fishermen will be provided of course.

3.5. Research efforts & type of markets

3.5.1 Level of research and cooperation for aquaculture/fisheries/processing by-products and discard valorisation in the B-BLUE Countries

The level of research for aquaculture/fisheries/processing by-products and discards valorisation in the B-BLUE Countries is depicted in the following Table. Only Croatia reports a poor level, average level is reported by Italy and Slovenia whereas Greece and Spain report a good level of cooperation between the Fishing industry and scientists.

Table 35: Level of research for aquaculture/fisheries/processing by-products and discards valorisation in the B-BLUE Countries.

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• Excellent	0	0	0	0	0	0	0	0
• Good	0	0	√	0	0	0	0	√
• Average	0	0	0	√	0	0	√	0
• Poor	√	0	0	0	0	0	0	0
• Very poor	0	0	0	0	0	0	0	0

Note: ME and PT did not respond to this question.

The level of cooperation between the Fishing industry and scientists in the B-BLUE Countries is depicted in the following Table. No Country reports a very poor or an excellent level of cooperation. Only Italy reports a poor level, whereas average level is reported by Croatia and Slovenia and Greece and Spain report a good level of cooperation between the Fishing industry and scientists.

Table 36. Level of cooperation between the Fishing industry and scientists in the B-BLUE Countries.

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• Excellent	0	0	0	0	0	0	0	0
• Good	0	0	√	0	0	0	0	√
• Average	√	0	0	0	0	0	√	0
• Poor	0	0	0	√	0	0	0	0
• Very poor	0	0	0	0	0	0	0	0

Note: ME and PT did not respond to this question.

2.5.2 Where the products can be used?

In the question, where the products can be used if the aquaculture/fisheries/processing by-products and discards will be valorised, the B-BLUE countries responses are depicted in the following Table.

Table 37. Use of the valorised products from fisheries in the B-BLUE Countries.

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• In activities in my Country	√	0	0	0	0	0	0	0
• They will be primarily exported	0	0	0	0	0	0	0	0
• They can be used in my Country and for exports also	0	√	√	√	0	0	√	√

Note: ME and PT did not respond to this question.

Only Croatia replies that products can be used only in activities inside Croatia. Most Countries believe that the valorised products can be used to cover the national needs as well as for exports. The envisaged activities from the valorisation of fisheries discards and by-products can be used in the sectors of pharmaceuticals, cosmetics, as feed additives for animal rearing and for human consumption (after processing e.g. surimi, fish burgers, fish sausage etc). The following Table summarise the results of the questionnaire for the B_BLUE Countries.

Table 38. Activities where the aquaculture/fisheries/processing by-products and discards valorisation products could be used in the B-BLUE Countries.

	Croatia	France	Greece	Italy	Montenegro	Portugal	Slovenia	Spain
• In pharmaceuticals	0	√	√	√	0	0	0	√
• In cosmetics	0	√	0	√	0	0	0	√
• As feed additives for animal rearing	√	√	√	√	0	0	√	√
• Human consumption (after processing e.g. surimi, fish burgers, fish sausage etc)	√	0	√	√	0	0	0	√
• Other (please name it)	0	0	0	0	0	0	fertilizers	0

Note: ME and PT did not respond to this question.

3.6. The international experience Case studies TRL >7

The Norwegian approach to manage and valorise discards

By-products from Norwegian fisheries and fish farming consist of viscera (liver, roe, stomachs, etc.), heads, backbones, cuts and rejected fish from processing. The by-products are generated when the fish is gutted, headed and further processed - either on-board fishing vessels or in processing plants on shore. Silage production, i.e. formic acid hydrolysis of ground by-products, has become a simple and cheap way of preservation of wastes at the local fish processing factory that produce fish protein concentrate (FPC). FPC is used as a component of fish and livestock feed. Norwegian plants produce fresh salmon oil from by-products. The oil is extracted before any acid preservation for silage. Salmon oil is considered a high quality product and is exploited as an ingredient in food products, as a dietary supplement and for technical uses. Raw/frozen offal is supporting the fur industry as feed for fox and mink. Human food from fish by-products includes liver oil from cod and other white fish species, cod liver, heads of cod, wolf-fish and salmon, minced cut-off, cod roe, etc.

RUBIN was a Norwegian research fund that was operated in Norway from 1992 until 2012 which had the sole purpose of contributing to increased utilisation of by-products[117]. Much of the advances that have been made in utilising Rest Raw Materials (RRMs) that have come from projects funded by RUBIN. These include for example production of silage, Fish Protein

[117] See: https://www.rubin.no/index.php/en/facts-about-rubin

Hydrolysate, FPC, drying of heads and bones, collection of RRMs, marketing of by-products etc. The Norwegian Seafood Research Fund (FHF) has now taken over the responsibilities of RUBIN. This approach is considered as a good practise to fine-tune and coordinate actions across the MED area to increase utilisation and valorisation of discards, aquaculture/fisheries/processing by-products and by-catch in the Mediterranean Sea.

Utilisation of cod in Iceland (100% Fish Project)

Utilization of cod in Iceland is amongst the highest in the world. In the last 20 years. Traditional fishing technologies and fish processing have evolved rapidly, which has substantially increased the revenue of Icelandic fisheries. Icelandic fisheries have evolved strategies and techniques to make money out of many by-products. In most parts of the world the other products of the fish are still treated as waste. Studies by the Iceland Ocean Cluster have shown that Iceland is using over 80% of each fish while most fisheries nations use around 50%. Leading fisheries in Iceland have announced their aim is to utilize 100% of the fish[118].

Iceland is a great example of what can be achieved with more fish utilization. The use of more by-products in the Icelandic fisheries which (which increased by around 3000% in the last 25 years) has led to an independent industry creating at least around 6-700 direct jobs and an annual value which exceeds USD 500 million. Many of these jobs are in rural areas - coastal towns.

The Iceland Ocean Cluster has played a crucial role as they have brought more investors into this field and invested also themselves in start-ups. The Ocean Cluster Network, initiated by the Iceland Ocean Cluster, consists of ocean cluster organizations in the US, Iceland and Norway which aim is to strengthen innovation in seafood and full utilization of seafood products. As of now various projects which aim to use more of whitefish, salmon and shellfish are underway within the Ocean Cluster Network, ranging from creating skin care products from whitefish skins to deriving protein from lobster shells.

In Iceland they believe it is only a matter of time when fisheries will stop value discarding. The 100% Fish Project can hopefully enhance the speed of this change. Looking back 20 years, the liver was the only part of the rest of the raw material that had some “value.” The rest of the fish was mostly treated as waste with no value. Over these 20 years, new markets and companies capable of handling by-products have been developed in various areas. A good example of a company is Copalis at Boulogne-sur-Mer in northern France[119]. The original aim of Copalis was to add value to by-products generated by fisheries. What began

[118] See Mission of the 100% Fish Project in Iceland: https://www.sjavarklasinn.is/en/wp-content/uploads/2018/05/100-percent-fish-utilization.pdf

[119] See: https://www.copalis.fr/

as a smelly by-product reduction plant has become a world class by-product producer for one of Europe's leading fish processing ports. Another example is Haustak in Iceland, a leading fish drying plant that uses geothermal heat[120]. In collaboration with the Iceland Ocean Cluster, Haustak established Codland, a company which aim is to create more value from each fish.

In Iceland, many small plants are processing cod by-products for fish leather plant, enzymes, protein, omega, canning and an upcoming fish collagen plant. Codland[121] utilizes biotechnical solutions to create valuable, new products from underutilized raw material from the fishing industry (fish meal, fish oil, mineral supplements and Hydrolyzed Marine Collagen) [122].

Icelandic seafood start-ups are making new products from seafood by-products. For example, fish skin can be made into fish leather. This fish leather is worth wholesale around USD 8 per skin. The skin can also be developed into fish collagen which is a protein good for skin and joints. A kilo of fish collagen is USD 14 in bulk. If the fish collagen is sold in retail packaging, the kilo is worth much more. A new fish collagen plant which is being designed in Iceland is owned by four of the large fisheries in Iceland. Finally, the fish skin can be developed as wound care. Bound into dressings for human wounds, the fish skin acts as a structure around which healthy cells can grow. The company Kerecis in Iceland are already global leaders in this field[123]. This product has shown to have some superior qualities for wound care – and successfully used where traditional methods of wound care have been inadequate

The technological evolution in the seafood industry means a much stronger and competitive industry in the years to come. But the need for the superb natural seafood proteins can make the industry not only more competitive but also the next generation of fishermen may become pharmacists or skin care manufacturers! This is the core message of the 100% Fish Project. Can we inspire our stakeholders in the Mediterranean to use more of each fish?

Valorisation of bivalve shells, an important residue from the bivalve aquaculture industry

The H2020 GAIN project "Green Aquaculture Intensification" (https://www.unive.it/pag/33897) developed innovative processes for valorising shellfish by-products, as it is estimated that discarded mussel shells account for 147,000 tons per year in

[120] See: https://haustak.is/

[121] Codland (founded in 2012) is a company that emerged when the Iceland Ocean Cluster brought together seven fishing and ocean-related companies and set the course to create maximum value from every part of the fish. See: https://codland.is/ and http://www.sjavarklasinn.is/en/

[122] See the products of Codland at: https://codland.is/products/

[123] See: https://www.kerecis.com/

the EU (Soula et al., 2019)[124]. ANFACO estimated that the mussel shell accounts for 30-35 % of total mussel weight. Four candidate processes were identified at the proposal preparation stage:

1) as packaging material in recirculating aquaculture systems (RAS) biofilters, using coarsely crushed mussel shell as a possible alternative substrate for bacterial growth and nitrification-denitrification processes, substituting the usual plastic rings,

2) by developing a filtration column containing crushed and calcined mussel shell for phosphorus removal from RAS effluents,

3) the use of shells in the production of seaweed seedlings,

4) the potential use of shells as filler for the cement industry.

In France, the company Ostrealia developed innovative processes for valorising oyster shells, which are considered as a waste, for cosmetic products. Oyster shells provide mineral salts and trace elements that promote micro-circulation and help to maintain optimal hydration.

Oyster aquaculture farms in Occitanie, the southernmost administrative region of metropolitan France neighbouring Spain, collaborate with the company Ostrealia (see https://www.ostrealia.fr/) which in a partnership with the University of Montpellier (IBMM and ICGM), the CNRS and the "ENSCM", developed the concept of Ostreathotherapy®. The concept of Ostreathotherapy® highlights the benefits of unique treatments made up of active ingredients derived, in particular, from the oyster and its environment[125].

For more than three years Ostrealia has been developing products and treatment protocols inspired by the virtues of the oyster, a thousand-year-old heritage of Chinese medicine. Many active ingredients whose benefits are no longer to be proven have been studied: aragonite, marine collagen, silk marine etc. Investing in well-being, Tarbouriech Ostreathotherapy® brings to its customers all the benefits of oyster shells, sublimated by the solar tide. Resulting from years of research in partnership with cutting-edge laboratories, exclusive formulas and treatments bring balance and energy to the interested clients. The company promotes the oyster flesh as a "super food" naturally rich in energy, proteins and antioxidants, and low in fat that contains also vitamins, minerals and trace elements. Raised between sky and sea under the patented "Solar Tide" process, Ostrealia's Tarbouriech Special Oysters concentrate the quintessence of all these benefits.

[124] Soula Mohamed, Leticia Regueiro, Diego Mendez, Martina Ferreira, Johan Johansen (2019). Report on Innovative processes for valorising shellfish by-products. Deliverable 2.4. GAIN – Green Aquaculture INtensification in Europe. EU Horizon 2020 project grant no. 773330. 24 pp.

[125] See: https://spa.domaine-tarbouriech.fr/

4. SWOT Analysis of the value chains in the B-BLUE Med area

The SWOT or Strengths, Weaknesses, Opportunities and Threats analysis, is a snapshot of the current state of affairs that can serve as guidance to strategic alternatives. Despite the fact that swot analysis is commonly known as a business management tool has been also vastly applied in a number of strategies and policies evaluations (Mulligan *et al.*, 2017[126]; Freire-Gibb *et al.,* 2014[127]). For the current report, SWOT analysis was suggested as a useful tool to outline the current status and the prospective of the selected value chains by visualizing the strengths, weaknesses opportunities and threats of participants' countries.

4.1 Methodology

For the needs of this report a SWOT analysis questionnaire was created for algae market and valorisation of fish by-products and discards value chains. All partners were requested to respond to the same questionnaire (per value chain), in order to depict the overall picture of the examined value chains in B-BLUE Med countries. The final selections of Strengths, Weaknesses, Opportunities and Threats were evaluated by PPs from 1 to 10 and presented in descending order of importance in Swot analysis results, followed by a set of diagrams (Annex 2).

Furthermore, attempting to have the overall picture of the examined value chains among the B-BLUE countries, all responses per category were gathered at a common table and based on the overall (all countries) evaluation of each selection, the stronger selections in each category emerged.

The collected information was analysed in combination between the participating countries, trying to detect the synergies that can be developed. A combination between Strengths and Weaknesses among the countries, led to the creation of a table which demonstrates how the Weaknesses in one country can be balanced by the Strengths of another MED Country. This table might be considered as a guide for the transnational action plans among the participating countries in order to lay the foundation of a strong MED Blue Biotechnology network.

4.2 Results

[126] Mulligan M., Keulertz M. and McKee M. (2017). Environmental factors in the MENA region: a SWOT analysis. *MENARA Working Papers*, 4.

[127] Frere Gibb L., Koss R., Margonski P. and Papadopoulou N. (2014). Governance strengths and weaknesses to implement the marine strategy framework directive in European waters. *Marine Policy*, 44, pp. 172-178.

4.2.1 Algae market value chain

A. Individual approach

According to PPs contribution, the swot analysis presents the strengths, weaknesses, opportunities and threats of the specific value chain for each one of the B-BLUE countries. France, Spain and Portugal are the most experienced MED countries in micro and macroalgae cultivation. France and Portugal dispose strong research and development teams in combination with highly qualified manufacturing and technical expertise, while Spain fully supports the algae market value chain due to significant contribution to Sustainable Development Goals. On the other hand, the poor speed to market and difficulties to access capital and funding are the main weaknesses in algae market value chain, for the three leading countries.

Italy, Greece and Slovenia are less skilled in macroalgae cultivation but they can play a dynamic role in microalgae production. One of the main strengths for Italy and Greece is the highly convenient environmental conditions whereas the algae value chain is viewed as highly innovative by Slovenia. On the contrary the difficulty to access to capital and funding (as it also mentioned above) is the main problem which Greece and Slovenia need to overcome and Italy has to find ways to handle difficulties with biomass scaling up.

Finally, Croatia and Montenegro are in a very early stage of the value chain development nevertheless, Croatia has already done the first step towards microalgae production. Montenegro has no production units yet but due to the growing natural environmental concerns and the low capital investments required in the country, a great interest for the development of this sector is recorded. However, the limited ability to keep up with technology and the difficulties in production scaling up are the main obstacles for the development of that value chain for Montenegro and Croatia respectively.

Except of strengths and weaknesses it is very important to examine the Opportunities (O) and Threats (T) that can arise. O and T are not only necessary for completing SWOT analysis but are essential in case of advancing the SWOT analysis with a TOWS analysis in order to provide guidance for the available strategic choices.

B. The overall picture

The overall picture for all countries is summarized in Tables 39-42. Taking into account the overall weighting (SUM score) and the 'times selected' (no) of each evaluation we can arrive at the top 5 selections which in most of the cases have been chosen by the majority of B-BLUE countries. The average score of each selection is shown as well representing the total score divided by the times of selections.

Strengths

Twenty one (21) strengths have been chosen for the algae value chain (Table 39). **The highly innovative aspect** of the sector seems to be the most strong point as it has been selected by 5 countries with an average score of 8.2. **Strong R&D expertise, customer preference for natural products, growing natural environmental concerns and weak existing competitors** are also selected from at least 4 countries with an average score of 5.0-7.2 representing the top 5 strengths.

Table 39: List of Strengths among B-BLUE countries, for the Algae market value chain

	List of strengths	FR	ME	SL	ES	GR	IT	HR	PT	SUM	no	mean
1	Highly innovative	8		10	10	5			8	41	5	8.2
2	Strong R&D expertise and team	10		6	3	7			10	36	5	7.2
3	Customer preference for natural products	4		2	8	10	8			32	5	6.4
4	Growing natural environmental concerns	1	10	3	7	4				25	5	5.0
5	Weak existing competitors		8	8			5	1		22	4	5.5
6	Biomass production available at commercial/industrial scale in the country			5		2		3	4	14	4	3.5
7	Create new jobs			9		6		2		17	3	5.7
8	Significant contribution to SDGs				9	3			5	17	3	5.7
9	Broad product range			1	6	8				15	3	5.0
10	Unique product features	3		7	2					12	3	4.0
11	International linkages			4	4	1				9	3	3.0
12	Highly convenient environmental conditions					9	10			19	2	9.5
13	Strong technical expertise	7							9	16	2	8.0
14	Manufacturing expertise	9							6	15	2	7.5
15	Attracting many new customers				5		6			11	2	5.5
16	Good understanding of the market	6							3	9	2	4.5
17	Reaching emerging market segments	5							1	6	2	3.0
18	Low capital investment		9							9	1	9.0
19	Regulatory simplicity		7							7	1	7.0
20	Success in entering new markets								2	2	1	2.0
21	Well regarded in the industry	2								2	1	2.0

It is important to note that all selections are factors the can support the development of algae market value chain in the Med area. So even if a selection has been chosen only from one country but has a high evaluation number should be taken into consideration in building the transnational B -BLUE network.

Weaknesses

The examination of weaknesses reveals that difficulty to access to capital and funding is the most important weakness in almost all countries (7 out of 8) with an average score of 7.3. Among the top 5 weaknesses Poor speed-to-market, Regulatory complexity, High capital investment and Biomass production available at pilot scale in the country / Difficulties with scaling up are selected by 4-6 countries showing an average score of 5.3-7.8 (Table 40)

Table 40 List of Weaknesses among B-BLUE countries, for Algae market value chain

	List of Weaknesses	**FR**	**ME**	**SL**	**ES**	**GR**	**IT**	**HR**	**PT**	**SUM**	**no**	**mean**
1	Difficult access to capital and funding	2	4	10	9	10	7		9	51	7	7.3
2	Poor speed-to-market	10		1	8	3	9		1	32	6	5.3
3	Regulatory complexity /Lack of legislation and authorization	7	5		10	9	8			39	5	7.8
4	High capital investment			8	6	7			8	29	4	7.3
5	Biomass production available at pilot scale. Difficulties with scaling up	6			3		10	6		25	4	6.3
6	Poor understanding of the market		7	6		6		2		21	4	5.3
7	Inefficient logistics system		3	7		5	4			19	4	4.8
8	Lack of customer awareness		8	4			1		6	19	4	4.8
9	Cannot access emerging market segments	8	6	2		2				18	4	4.5
10	Limited R&D expertise and team		9				5	4		18	3	6.0
11	Poor manufacturing expertise			9		4		4		18	3	6.0
12	Poorly regarded in the industry			5	5	8				18	3	6.0
13	Strong existing competitors				7		6		2	15	3	5.0
14	Limited market share	3		3					5	11	3	3.7
15	Limited ability to keep up with technology		10					3		13	2	6.5
16	A high-cost logistics system	4			4					8	2	4.0
17	Limited number of new customers							1	7	8	2	4.0
18	Recent failures in entering new markets	9								9	1	9.0
19	Limited International linkages	5								5	1	5.0
20	Unexploited estimation of PESTLE benefit						3			3	1	3.0
21	Lack of coordination with other sectors						2			2	1	2.0
22	Limited product range		2							2	1	2.0
23	Inappropriate environmental conditions		1							1	1	1.0
24	Significant channel conflict	1								1	1	1.0
25	Underestimate natural environmental concerns					1				1	1	1.0

Opportunities

Overall, thirty (30) opportunities have been selected for the algae value chain whereas the dispersal and scoring of choices is quite high, reflecting the different point of view of its country about the potential and perspectives of the sector.

Table 41: List of Opportunities among B-BLUE countries, for Algae market value chain

	List of Opportunities	FR	ME	SL	ES	GR	IT	HR	PT	SUM	no	mean
1	**Raise capital funding to invest in new ventures**	3	6	6	5	5	5			30	6	5.0
2	**Leverage knowledge from relevant fields**	5		10	1	6			10	32	5	6.4
3	**Growing end user applications**	8		1	4	2			3	18	5	3.6
4	**Introduce new modern technology or systems**	10		8		8			9	35	4	8.8
5	**Improve manufacturing expertise / experience**		5	9		3			8	25	4	6.3
6	Government subsidies/incentives					10	4		7	21	3	7.0
7	Become a first-mover in an emerging market	9		5			6			20	3	6.7
8	Unique product features/design		4		10				4	18	3	6.0
9	Identify market gaps		9			4		4		17	3	5.7
10	Lobby the government for improved legislation					9	3	3		15	3	5.0
11	Build product awareness		10		2			2		14	3	4.7
12	Improve cultivation / downstream processing		1	3	7					11	3	3.7
13	Challenge new players	1						1	1	3	3	1.0
14	Develop a clear value proposition	6	8							14	2	7.0
15	Use cross-functional teams to develop products			7		7				14	2	7.0
16	Build International linkages				6				5	11	2	5.5
17	Use environmental issues to develop added value products				9		2			11	2	5.5
18	Develop environmentally-friendly products			2	8					10	2	5.0
19	Develop strategic alliances			4					6	10	2	5.0
20	Combination of natural /synthetic production	4							2	6	2	3.0
21	Utilize key sponsorships/investments	2	2							4	2	2.0
22	Develop protocol for new products such as fertilizers, polymer, bioactive compounds						10			10	1	10
23	Increase the IMTA production by edible and not edible species						9			9	1	9.0
24	Use the bioremediation in industrial site						8			8	1	8.0
25	Create appropriate outsourcing partnerships		7							7	1	7.0
26	Develop a cross cutting system among Blue-Green and Circular Economy						7			7	1	7.0
27	Target high growth markets	7								7	1	7.0
28	Improve customers attitude				3					3	1	3.0
29	Streamline product features to reduce costs		3							3	1	3.0
30	Generate license revenue streams from patents						1			1	1	1.0

The top 5 opportunities which are believed to be more likely to arise are: increasing of capital funding to invest in new ventures, leverage existing knowledge from relevant fields, growing end user applications , introduce new modern technology and/or systems, improvement of manufacturing expertise and have been selected by 4-6 counties showing an average score of 3.6-8.8 (Table 41).

Threats

Most of the countries (7 out of 8) fear the uncertain market conditions although they do not admit it as the most powerful threat. The higher scores have been given to the Inflexible legislative framework (selected by 5 countries) and the threat of being too slow to adapt to change, a common selection between 4 countries. Looking closely at the total list of threats (Table 42) it is obvious that most of the threats are in close relation with time.

Table 42: List of Threats among B-BLUE countries, for Algae market value chain

	List of Threats	FR	ME	SL	ES	GR	IT	HR	PT	SUM	no	mean
1	Uncertain market conditions		3	5	6	6	4	1	4	29	7	4.1
2	Inflexible legislative framework	7			10	9	1 0		7	43	5	8.6
3	New more efficient competitors, on new products-low prices	6		6	9	7	5			33	5	6.6
4	Poor fit to local market		2	4		5	3	3		17	5	3.4
5	Too slow in the development of new products	5	6	7		8	1			27	5	5.4
6	Being too slow to adapt to change	9	10	10		10				39	4	9.8
7	Being leap-frogged by competitors' technology	10	8	9						27	3	9.0
8	Intense competition has increased the number of players in the industry	4		8	8					20	3	6.7
9	Being under - priced by more efficient competitors	2					7		5	14	3	4.7
10	Inexperienced staff – lack of skills		9			2	2			13	3	4.3
11	Negative attitude to the products		5	2	4					11	3	3.7
12	Poor fit to international market	1	4	3						8	2	4.0
13	Limited profit levels			1	7					8	2	4.0
14	Loss of market share				5	3				8	2	4.0
15	No regular supply of innovative products					4		2		6	2	3.0
16	High level of taxation						9			9	1	9.0
17	Complexity of regulatory framework/lack of clear strategic development						8			8	1	8.0
18	High staff turnover	8								8	1	8.0
19	Loss of unique product features		7							7	1	7.0
20	Authorization process too long						6			6	1	6.0
21	Declining economic conditions	3								3	1	3.0
22	Retailers not accepting products					1				1	1	1.0

Most of the countries believe that their current regulatory complexity and other weaknesses, might lead to a significant delay thus the country is at risk of falling out of the game and the developing markets. Uncertain market conditions, , New-more efficient competitors, competing on new products and lowering prices, Poor fit to local market, Be too slow in the development of new products complete the list of the top threats, selected by 4-7 countries with an average score of 3.4-9.8.

C. Cooperation between B-BLUE countries

B-BLUE project is a unique opportunity for the creation of a strong BBt network. The target of this network is to bring in contact the stakeholders, at national and transnational level, aiming at a fruitful interaction in order to move a step forward the Blue BBt sector in the MED area. For the needs of the current report, a combination between Strengths and Weaknesses of the algae market value chain among the countries could set the frame for optimum transnational synergies in order to build a strong MED Blue Biotechnology network.

B-BLUE countries are not at the same stage of readiness; France and Portugal could transfer knowledge and research results in the field of R&D as well as technical and manufacturing expertise mainly to countries that are at a very early stage of development such as Montenegro, Slovenia and Croatia. France can share its experience on good understanding of algae market and how they have succeeded to set algae market well regarded in the industry especially to Montenegro Slovenia and Greece which seem to fail in these sectors.

Portugal can lead the way for successful entering in new markets and Greece, Spain and Italy can share their experience of how these countries succeeded to make consumers more familiar to algae based natural products. Montenegro and Portugal could be a great "audience" as it is believed there is a lack of customer awareness about natural products

Spain and Slovenia could help the other participants to develop strategies for creating international linkages between markets and players with a direct impact in enhancing the algae market value chain.

Fig. 21: Combination of Strengths and Weaknesses between B-BLUE countries, for the Algae market value chain

STRENGHTS		WEAKNESSES	
FR-PT	Strong R&D expertise and team	Limited R&D expertise and team	ME
	Strong technical expertise	Limited ability to keep up with technology	
	Manufacturing expertise	Poor manufacturing expertise	SL-HR
GR-ES-IT	Customer preference for natural products	Lack of customer awareness	ME -PT

ES-SL	**International linkages**	**Limited International linkages**	**FR**
PT	**Success in entering new markets**	**Recent failures in entering new markets**	
FR	**Well regarded in the industry**	**Poorly regarded in the industry**	**GR**
	Good understanding of the market	**Poor understanding of the market**	**ME-SL**

4.2.2 Discards and fish by-products valorisation

The SWOT analysis and the diagrams for each B-BLUE country are shown in Annex 2. Tables 43-46 show the total (all countries) evaluation of each selection, based on which the stronger selections in each category emerged.

Overall, 13 strengths have been selected from a list of 14 choices. The top 6 strengths in the B-BLUE countries have collected a score of 21-42 and were selected from 3-6 countries (Table 18), including: 1) strong R&D expertise and team in the Country 2) adequate raw material (biomass) available at commercial/industrial scale in the country 3) highly innovative products 4) growing environmental concerns of the public and 5) international linkages for transferring know how on fish by-products and discards.

The top strength of France is that the necessary legislative framework for the valorisation of discards and aquaculture/fisheries/processing by-products exists, while Croatia states that currently there are no competitors in the valorisation field of fish by-products and discards. The top strength of Greece is that fishermen are in agreement to cooperate if proper incentives will be provided and in Italy that adequate raw material (biomass) is available at commercial/industrial scale in the country. Slovenia, Portugal and Spain rank high that highly innovative products from fish by-products and discards can be produced. The top strength is Portugal and Spain is the strong R&D expertise and team in the Country to valorise fish by-products and discards.

Table 43: Strengths identified in the B-BLUE countries for the valorisation of discards and aquaculture/ fisheries / processing by-products.

		FR	HR	GR	IT	ME	SL	PT	SP	SUM	*no*
1	Adequate raw material (biomass) available at commercial/industrial scale in the country	2		7	9	9		7	5	**39**	**6**
2	Strong R&D expertise and team in the Country	7		9	6			10	10	**42**	**5**
3	Highly innovative	5		5			10	9	9	**38**	**5**
4	Growing environmental concerns of the public	8				10	8		6	**32**	**4**
5	International linkages for transferring know how			8			7	6		**21**	**3**
6	Easy access to funding blue technologies for fish by-products and discards valorisation	9						5	7	**21**	**3**
7	Fishermen are in agreement to cooperate if proper incentives will be provided	3		10			6			19	3
8	Good understanding of the market for products related to the sector	4		6					8	18	3
9	No competitors in the sector		3		5		9			17	3
10	The necessary legislative exists	10				7				17	3
11	Good fit to customer's needs	6	2			8				16	3
12	Low-cost logistics		1			6				7	3
13	Efficient logistics system for the raw material collection, storage and transfer	1								1	1

17 weaknesses have been identified across B-BLUE countries from a list of 17 choices. The top 5 weaknesses in the B-BLUE countries have collected a score of 22-43 and were selected from 3-7 countries (Table 19, including 1) high capital investment for valorising fish by-products and discards, 2) regulatory complexity, 3) significant channel conflict (fishermen, fishmongers etc are reluctant to cooperate), 4) Poor access to finance blue technologies on fish by-products and and 5) difficult to access capital and funding for valorisation of fish by-products and discards.

The top weakness of France is the regulatory complexity for valorising fish by-products and discards which scores high also in Italy, Slovenia and Spain. The top weakness of Croatia is the poor expertise to handle and process fish by-products and discards which scores also high in Montenegro that scores first a significant channel conflict (fishermen, fishmongers etc are reluctant to cooperate). The top weakness of Italy, Slovenia and Spain is the high capital investment for valorising fish by-products and discards whereas in Portugal it is the limited International linkages for valorising fish by-products and discards.

Table 44: Weaknesses identified in the B-BLUE countries for the valorisation of discards and aquaculture / fisheries / processing by-products.

		FR	HR	GR	IT	ME	SL	PT	SP	SUM	*no*
1	**High capital investment**			6	10	7	10		10	**43**	**5**
2	**Regulatory complexity**	5	2	4	9	1	9		8	**38**	**7**
3	**Significant channel conflict (fishermen, fishmongers etc are reluctant to cooperate)**	4		8		10			5	**27**	**4**
4	**Poor access to finance blue technologies on fish by-products and discards**			9			8		7	**24**	**3**
5	**Difficult to access to capital and funding**						7	6	9	**22**	**3**
6	Inefficient logistics system			7		5	6			18	3
7	Poor expertise to handle and process fish by-products and discards		4	5		8				17	3
8	Poor understanding of the market		3				2	5	6	16	4
9	Biomass from fish by-products and discards is too small and scattered in the country	1		10		3				14	3
10	Limited International linkages	2				4		7		13	3
11	Limited R&D expertise and team in the Country		1			9				10	2
12	Ineffective new product development process					6	4			10	2
13	Biomass is available at pilot scale in the country			3		2				5	2
14	A high-cost logistics system						5			5	1
15	Poor overall fit to customer's needs								4	4	1
16	Cannot access emerging market segments						3			3	1
17	Strong existing	3								3	1

23 opportunities have been identified across B-BLUE countries from a list of 27 choices. The top 5 opportunities in the B-BLUE countries have collected a score 27-52 and were selected from 3-7 countries (Table 20), including 1) Introduce new innovative technology for valorising fish by-products and discards 2) provide new employment, 3) utilize existing Knowledge from relevant fields, 4) improve existing manufacturing procedures for valorising fish by-products and discards and 5) use environmental issues to develop added value products.

The top opportunity of France is to introduce new innovative technologies which scores also high in Portugal and Spain. The top opportunity in Croatia and Greece is that valorising fish by-products and discards may become a reality with the appropriate incentives for those involved. The top opportunity in Italy is to improve existing manufacturing procedures, while Montenegro declares the use of environmental issues to develop added value products from valorising fish by-products and discards. In Slovenia and Portugal the top opportunity is to utilize the existing knowledge from relevant fields and in Spain is the provision of knowledge and resources for the utilization of species with low market value

Table 45: Opportunities identified in the B-BLUE countries for the valorisation of discards and aquaculture/ fisheries / processing by-products.

		FR	HR	GR	IT	ME	SL	PT	SP	SUM	*no*
1	**Introduce new innovative technologies**	9	5	6		6	8	9	9	**52**	**7**
2	**Provide new employment opportunities**	7		9	9	5	5	3	8	**46**	**7**
3	**Utilize existing Knowledge from relevant fields**	3	4	7		8	10	10	2	**44**	**7**
4	**Improve existing manufacturing procedures**	1	3		10	7		8	5	**34**	**6**
5	**Use environmental issues to develop added value products**	6	6	5		10				**27**	**4**
6	Raise awareness towards environmental issues	8		8	2	4				22	4
7	Develop environmentally-friendly products		1		7	2	4		7	21	5
8	Provide the knowledge and resources for the utilization of species with low market value						6	5	10	21	3
9	Government subsidies/incentives			1	5			7	4	17	4
10	Build International linkages						9	6		15	2
11	Valorisation would mitigate an environmental issue by reducing the overall waste from fish by-products and discards				6				6	12	2
12	Become a first-mover in an emerging market	2			8		1			11	3
13	Develop new products for international / global markets				4		7			11	2
14	With the appropriate incentives for those involved, the valorising of fish by-products and discards may become a reality			10						10	1
15	Use environmental issues to reduce cost structure					9				9	1

Nineteen (19) threats have been identified across B-BLUE countries from a list of 21 choices. The top 7 threats in the B-BLUE countries have collected a score of 23-38 and were selected from 4-6 countries (Table 19), including 1) the risk of limited profit levels, 2) poor fit to local market 3) inadequate level of expertise in the field of valorising fish by-products and discards, 4) uncertain investment, 5) uncertain market conditions, 6) being leap-frogged by competitor's technology, 7) fishing industry fails to cooperate with the scientific community.

The top threat for France, Italy and Portugal is the inflexible legislative framework for valorising fish by-products and discards. For Croatia the major threat is being leap-frogged by competitor's technology which scores also high in Slovenia. In Greece the top threat is the collection of the scattered resources that would raise the prices of the end products, whereas in Montenegro it is the inadequate level of expertise in the field of valorising fish by-products and discards. In Slovenia the top threat is the fact that the necessary infrastructure doesn’t yet exist. In Spain the top threat is being too slow to adapt to changes, a fact that makes them to believe that this valorisation is apparently almost a reality that is coming fast.

Table 46: Threats identified in the B-BLUE countries for the valorisation of discards and aquaculture / fisheries / processing by-products.

		FR	HR	GR	IT	ME	SL	PT	SP	SUM	*no*
1	**Poor fit to local market**	4		7		4	4	3	6	**28**	**6**
2	**Limited profit levels**	8		9	5	9			7	**38**	**5**
3	**Inadequate level of expertise in the field**	6	3		4	10			5	**28**	**5**
4	**Uncertain investment**	1				2	6	4	9	**22**	**5**
5	**Uncertain market conditions**	2				8	7		8	**25**	**4**
6	**Being leap-frogged by competitor's technology**		4			6	9		4	**23**	**4**
7	**Fishing industry is failing to cooperate with the scientific community**		1	8		7		7		**23**	**4**
8	Inflexible legislative framework	10			10			8		28	3
9	Being too slow to adapt to change				7		8		10	25	3
10	The necessary infrastructure doesn’t yet exist		2	6			10			18	3
11	Poor fit to international market	5				5	5			15	3
12	Negative public attitude towards the products	7					1	6		14	3
13	The collection of the scattered resources would raise the prices of the end products			10			2			12	2
14	Impact of logistical inefficiencies			5					3	8	2
15	The market for the products doesn't yet exist					3	3			6	2
16	Declining economic conditions for the sector	9								9	1
17	Deteriorating strategic alliances								5	5	1
18	Valorisation methods are not cost-effective	3								3	1
19	Competitors provide low cost alternatives of products					1				1	1

ANNEX 1

Seafood Imports - Exports in the B-BLUE countries.

Seafood imports in the B-BLUE countries.

Country	ISSCAAP division (Name)	2010	2011	2012	2013	2014	2015	2016	2017	2018
Croatia	Diadromous fishes	959	941	992	1.113	1.268	1.595	1.745	1.633	1.807
	Marine fishes	31.869	26.422	25.739	23.454	30.483	32.765	34.348	34.717	37.576
	Crustaceans	1.150	1.113	1.435	1.194	1.312	1.435	1.531	1.754	1.939
	Molluscs	8.527	10.095	8.936	7.855	9.488	9.962	9.479	10.126	11.379
	Miscellaneous aquatic animals	2	8	296	223	162	153	73	23	11
	Freshwater fishes	677	711	793	928	1.000	803	738	731	622
	Croatia TOTAL	43.184	39.290	38.191	34.767	43.713	46.713	47.914	48.984	53.334
France	Crustaceans	152.046	143.950	143.489	138.733	138.051	138.074	141.386	141.806	139.649
	Molluscs	143.131	136.573	120.617	117.501	118.803	121.860	127.681	132.235	126.391
	Diadromous fishes	165.416	163.433	175.163	167.878	163.751	169.812	174.510	175.892	183.920
	Marine fishes	625.950	629.559	613.955	624.243	635.379	634.804	641.877	671.731	667.435
	Miscellaneous aquatic animals	5.586	5.049	2.666	2.276	2.464	3.292	1.462	958	1.013
	Freshwater fishes	27.138	28.365	27.808	27.203	21.309	18.245	17.069	17.676	16.194
	France TOTAL	1.119.267	1.106.929	1.083.698	1.077.834	1.079.757	1.086.087	1.103.985	1.140.298	1.134.602
Greece	Crustaceans	7.827	7.067	6.625	6.644	6.907	6.436	7.350	8.822	8.934
	Molluscs	29.993	30.186	24.437	27.387	28.367	27.286	32.413	32.558	30.577
	Diadromous fishes	8.736	8.994	9.640	8.968	11.146	11.042	13.045	13.641	15.551
	Marine fishes	156.776	135.176	148.933	142.942	154.611	147.245	151.974	152.680	165.610
	Miscellaneous aquatic animals	28	16	74	25	30	1.072	203	186	166
	Freshwater fishes	7.078	6.569	7.572	7.545	7.353	6.652	6.588	5.634	6.027
	Greece TOTAL	210.438	188.008	197.281	193.511	208.414	199.733	211.573	213.521	226.865
Italy	Freshwater fishes	29.537	31.102	30.490	30.795	28.917	30.953	29.791	23.758	27.472
	Diadromous fishes	44.428	48.539	57.033	56.705	72.436	81.887	76.342	77.599	86.502
	Marine fishes	550.149	550.996	520.962	532.945	560.172	561.742	592.140	613.103	617.917
	Crustaceans	101.542	101.877	90.206	89.153	96.107	94.027	100.398	96.173	102.522
	Molluscs	274.506	278.144	255.929	266.800	276.469	299.146	292.348	291.145	269.977
	Miscellaneous aquatic animals	1.596	1.784	793	910	1.198	1.299	1.574	1.560	1.050
	Italy TOTAL	1.001.758	1.012.442	955.413	977.308	1.035.299	1.069.054	1.092.593	1.103.338	1.105.440
Montenegro	Crustaceans	108	137	148	160	146	163	193	262	288
	Molluscs	531	564	580	586	593	586	729	741	820
	Diadromous fishes	167	157	262	327	289	300	374	321	370
	Marine fishes	2.345	2.260	1.900	2.145	2.054	2.242	2.399	2.816	2.672
	Miscellaneous aquatic animals	0	0	16	19	18	20	15	10	19
	Freshwater fishes	2	1	91	62	62	22	49	63	60
	Montenegro TOTAL	3.153	3.119	2.997	3.299	3.162	3.333	3.759	4.213	4.229
Portugal	Miscellaneous aquatic animals	429	654	391	63	51	22	22	74	59
	Diadromous fishes	9.093	9.756	14.665	13.625	20.505	19.448	16.954	17.300	17.417
	Marine fishes	278.557	290.231	325.193	351.962	344.315	339.579	362.416	369.470	362.138
	Crustaceans	33.767	29.913	32.001	27.845	34.277	33.850	35.220	36.831	38.315
	Molluscs	57.066	56.959	55.291	59.150	65.481	72.388	75.956	89.312	83.394
	Freshwater fishes	12.513	11.353	12.306	13.296	10.849	12.301	12.278	10.332	11.000
	Portugal TOTAL	391.425	398.866	439.847	465.941	475.478	477.588	502.846	523.319	512.323
Slovenia	Freshwater fishes	2.346	1.837	1.239	1.613	2.152	2.454	2.648	2.396	1.649
	Miscellaneous aquatic animals	29	30	86	89	64	56	177	23	28
	Diadromous fishes	928	1.052	1.081	1.288	1.369	1.516	1.400	1.654	1.580
	Marine fishes	10.936	11.210	10.682	10.917	11.302	11.657	13.355	13.861	13.935
	Crustaceans	571	538	512	495	557	551	693	717	841
	Molluscs	3.345	3.329	2.884	2.872	3.011	3.554	4.545	3.848	4.468
	Slovenia TOTAL	18.155	17.996	16.484	17.274	18.455	19.788	22.818	22.499	22.501
Spain	Freshwater fishes	68.217	61.292	50.971	49.353	48.675	41.040	36.044	20.071	18.513
	Marine fishes	912.308	926.639	844.995	825.477	899.892	924.091	969.280	1.002.882	993.689
	Diadromous fishes	54.397	54.719	56.838	52.198	63.640	73.417	73.184	76.131	75.187
	Molluscs	384.218	363.887	352.123	359.169	376.627	390.534	397.742	430.702	429.850
	Crustaceans	207.015	213.800	184.810	179.429	186.623	193.619	194.342	197.260	189.708
	Miscellaneous aquatic animals	2.217	2.762	1.681	3.367	3.407	3.145	2.662	2.426	1.912
	Spain TOTAL	1.628.372	1.623.099	1.491.418	1.468.993	1.578.864	1.625.846	1.673.254	1.729.472	1.708.859

Source: FIGIS – FAO Fisheries Global Information System

Seafood exports in the B-BLUE countries.

Country	Commodity	2010	2011	2012	2013	2014	2015	2016	2017	2018
Croatia	Marine fishes	31.683	35.229	30.034	31.503	42.671	46.595	47.315	46.880	48.867
	Diadromous fishes	118	84	74	109	97	522	857	607	516
	Molluscs	1.362	1.334	1.595	1.872	2.900	3.167	3.246	2.942	2.959
	Crustaceans	119	110	123	162	257	282	322	398	454
	Miscellaneous aquatic animals	51	59	53	50	48	80	66	100	155
	Freshwater fishes	679	1.670	1.318	872	1.625	2.624	2.213	1.452	951
	Croatia TOTAL	34.012	38.486	33.197	34.568	47.598	53.270	54.019	52.379	53.902
France	Molluscs	44.293	40.569	38.540	35.904	35.345	42.053	41.058	45.788	47.175
	Crustaceans	20.720	16.822	17.211	18.190	18.299	18.653	19.011	18.665	19.205
	Marine fishes	238.246	215.406	259.824	231.828	214.129	238.450	241.032	240.508	246.690
	Diadromous fishes	21.369	22.000	25.187	27.544	27.860	28.817	32.374	27.866	27.612
	Miscellaneous aquatic animals	1.962	1.876	314	314	235	215	217	444	377
	Freshwater fishes	3.858	4.220	5.167	6.658	4.623	2.196	1.969	2.427	2.219
	France TOTAL	330.448	300.893	346.243	320.438	300.491	330.384	335.661	335.698	343.278
Greece	Molluscs	14.256	15.439	17.926	15.509	17.614	15.996	18.469	20.047	19.606
	Crustaceans	2.137	2.434	1.614	2.476	2.671	3.289	3.838	2.706	2.774
	Marine fishes	115.558	97.575	104.269	102.155	93.169	90.192	102.400	114.339	114.647
	Diadromous fishes	3.334	3.859	6.214	5.804	5.228	7.039	6.005	5.644	6.414
	Miscellaneous aquatic animals	11	16	61	437	515	1.182	1.015	561	582
	Freshwater fishes	279	328	840	1.483	266	356	337	849	1.208
	Greece TOTAL	**135.575**	**119.651**	**130.924**	**127.864**	**119.463**	**118.054**	**132.064**	**144.146**	**145.231**
Italy	Freshwater fishes	2.568	2.322	2.069	2.160	2.072	1.300	1.222	1.008	1.239
	Marine fishes	84.726	75.890	76.382	85.912	102.657	106.581	99.727	98.440	102.830
	Diadromous fishes	10.365	11.483	11.510	12.480	12.430	13.332	12.459	11.819	13.443
	Molluscs	37.653	36.903	34.579	34.794	38.164	32.856	35.071	33.785	31.799
	Crustaceans	4.710	4.515	4.106	4.286	3.818	3.724	3.618	4.289	3.855
	Miscellaneous aquatic animals	1.430	1.536	1.354	1.349	1.476	1.813	1.382	1.120	1.153
	Italy TOTAL	**141.452**	**132.649**	**130.000**	**140.981**	**160.617**	**159.606**	**153.479**	**150.461**	**154.319**
Montenegro	Molluscs	13	11	6	1	0	0	0	0	1
	Crustaceans	0	0	0	0	0	0	0	0	0
	Marine fishes	118	31	0	2	7	1	2	7	1
	Diadromous fishes	0	0	2	0	2	0	18	7	3
	Miscellaneous aquatic animals	0	0	0	0	0	0	0	0	0
	Freshwater fishes	0	0	0	0	0	0	1	0	0
	Montenegro TOTAL	**131**	**42**	**8**	**3**	**9**	**1**	**21**	**14**	**5**
Portugal	Miscellaneous aquatic animals	494	1.033	885	220	79	92	239	164	185
	Marine fishes	140.677	150.143	185.070	196.738	204.297	202.154	191.948	197.757	200.743
	Diadromous fishes	560	824	936	1.027	1.447	1.583	2.225	3.136	2.094
	Molluscs	21.948	24.546	32.473	40.511	48.824	51.532	41.530	47.752	46.101
	Crustaceans	8.046	9.865	12.881	10.436	11.555	13.638	9.419	10.108	11.522
	Freshwater fishes	2.074	1.592	2.395	3.488	2.498	3.917	2.308	1.054	1.261
	Portugal TOTAL	**173.799**	**188.003**	**234.640**	**252.420**	**268.700**	**272.916**	**247.669**	**259.971**	**261.906**
Slovenia	Freshwater fishes	1.582	1.359	391	766	1.314	1.688	2.009	1.915	1.106
	Miscellaneous aquatic animals	2	0	0	0	0	1	26	5	5
	Marine fishes	3.207	3.069	3.079	3.697	3.977	4.170	7.435	5.815	6.081
	Diadromous fishes	169	147	148	214	331	281	258	209	200
	Molluscs	329	285	401	136	308	682	1.479	954	1.120
	Crustaceans	32	56	48	36	70	68	145	154	171
	Slovenia TOTAL	**5.321**	**4.916**	**4.067**	**4.849**	**6.000**	**6.890**	**11.352**	**9.052**	**8.683**
Spain	Freshwater fishes	2.446	2.840	4.781	3.799	4.421	4.187	4.782	5.561	5.079
	Diadromous fishes	10.287	9.335	11.784	11.805	15.619	16.871	19.370	17.574	16.542
	Marine fishes	796.782	833.974	790.559	738.181	839.407	812.536	802.382	838.531	848.409
	Crustaceans	36.312	44.754	41.963	42.273	39.676	45.948	51.341	55.250	55.922
	Molluscs	183.925	168.143	179.553	186.415	200.401	223.852	224.884	253.251	263.334
	Miscellaneous aquatic animals	9.197	8.121	2.324	2.151	1.878	1.832	1.838	2.842	2.378
	Spain TOTAL	**1.038.949**	**1.067.167**	**1.030.964**	**984.624**	**1.101.402**	**1.105.226**	**1.104.597**	**1.173.009**	**1.191.664**

Source: FIGIS – FAO Fisheries Global Information System

ANNEX 2

SWOT Analysis for the

Algae Market Value Chain

&

Aquaculture/fisheries/processing by-products and discards valorisation Value Chain

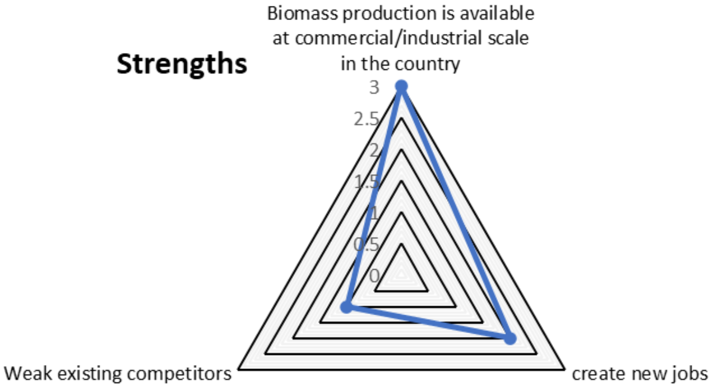
in the B-BLUE

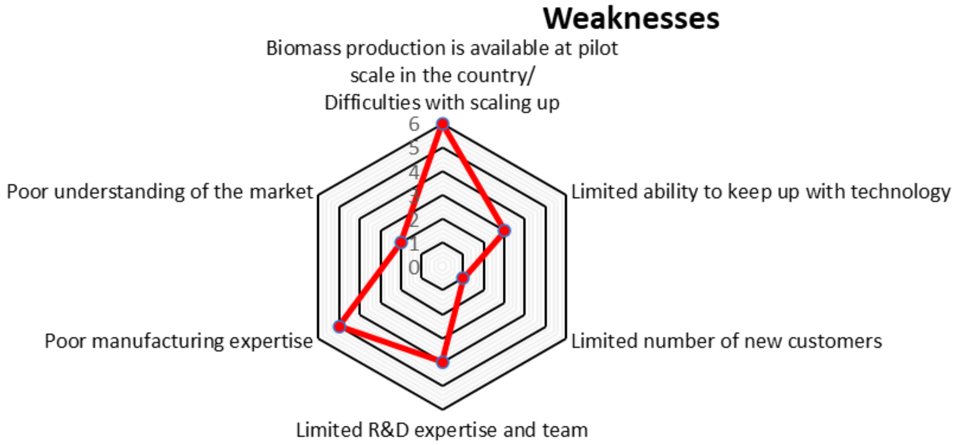
countries.

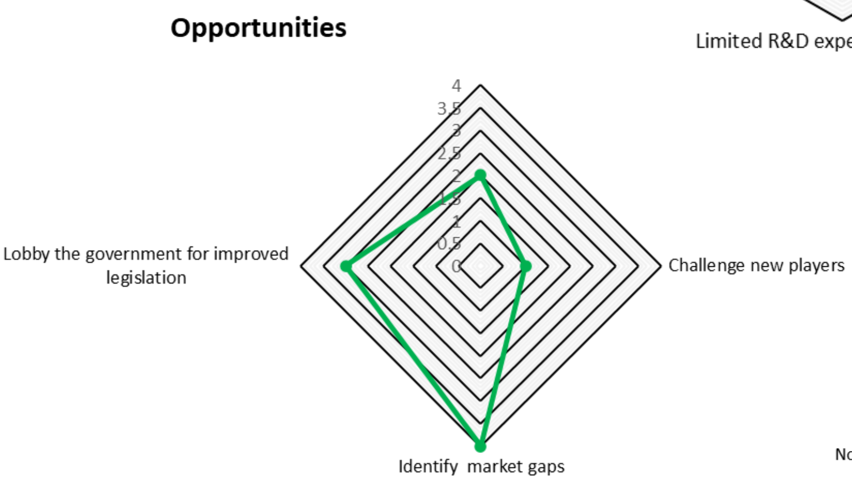
SWOT Analysis for the Algae Market Value Chain

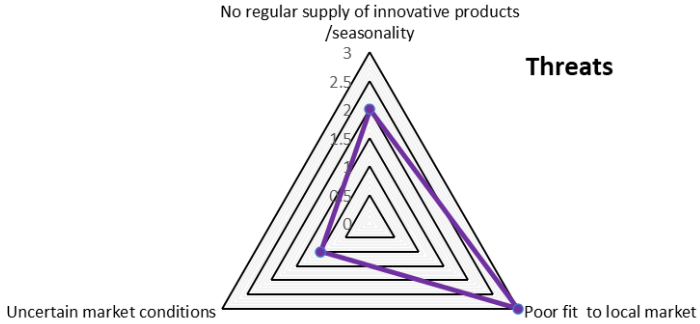
Croatia
SWOT Analysis for Algae Market Value Chain

Strengths	Weaknesses
• Biomass production is available at commercial/industrial scale in the country • create new jobs • Weak existing competitors	• Biomass production is available at pilot scale in the country/ • Difficulties with scaling up" • Poor manufacturing expertise • Limited R&D expertise and team • Limited ability to keep up with technology • Poor understanding of the market • Limited number of new customers
Opportunities	**Threats**
• Identify market gaps • Lobby the government for improved legislation • Build product awareness • Challenge new players	• Poor fit to local market • No regular supply of innovative products /seasonality • Uncertain market conditions


Strengths
Biomass production is available at commercial/industrial scale in the country
3
2.5
2
1.5
1
0.5
0
create new jobs
Weak existing competitors

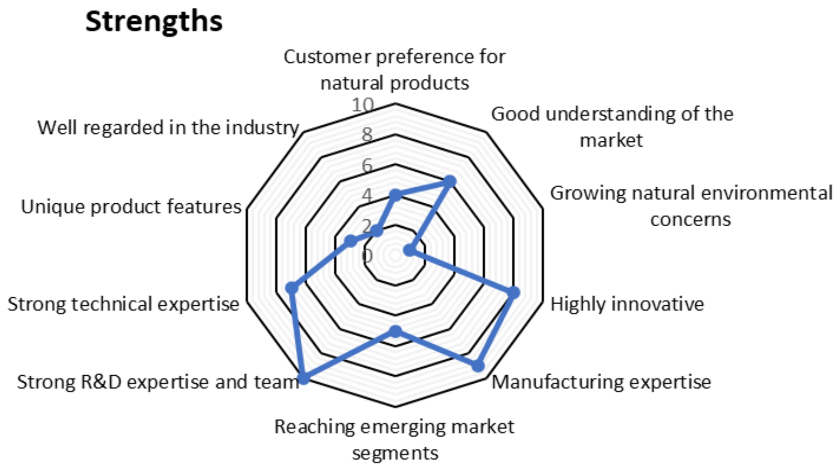

Weaknesses
Biomass production is available at pilot scale in the country/ Difficulties with scaling up
6
5
4
3
2
1
0
Limited ability to keep up with technology
Limited number of new customers
Limited R&D expertise and team
Poor manufacturing expertise
Poor understanding of the market

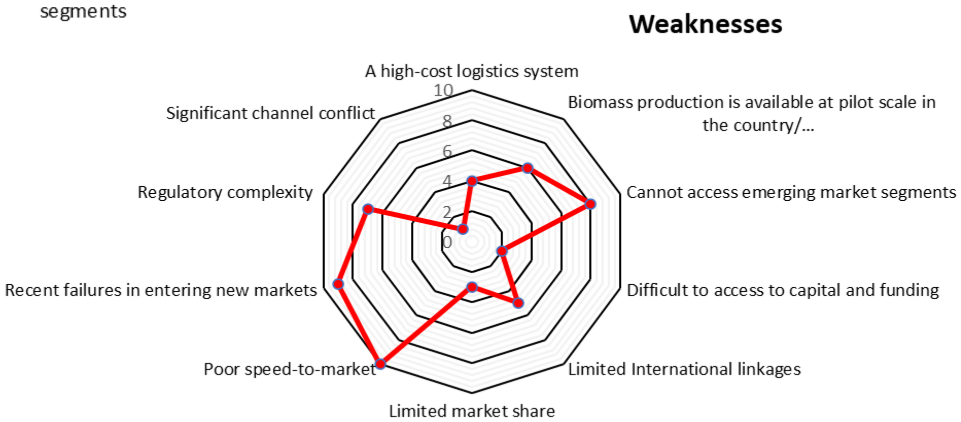

Opportunities
4
3.5
3
2.5
2
1.5
1
0.5
0
Challenge new players
Identify market gaps
Lobby the government for improved legislation

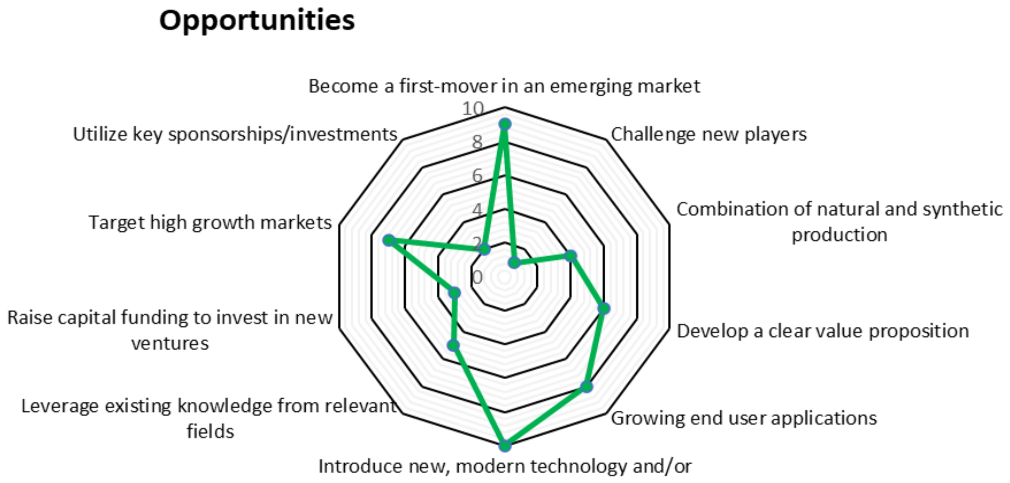

Threats
No regular supply of innovative products /seasonality
3
2.5
2
1.5
1
0.5
0
Poor fit to local market
Uncertain market conditions

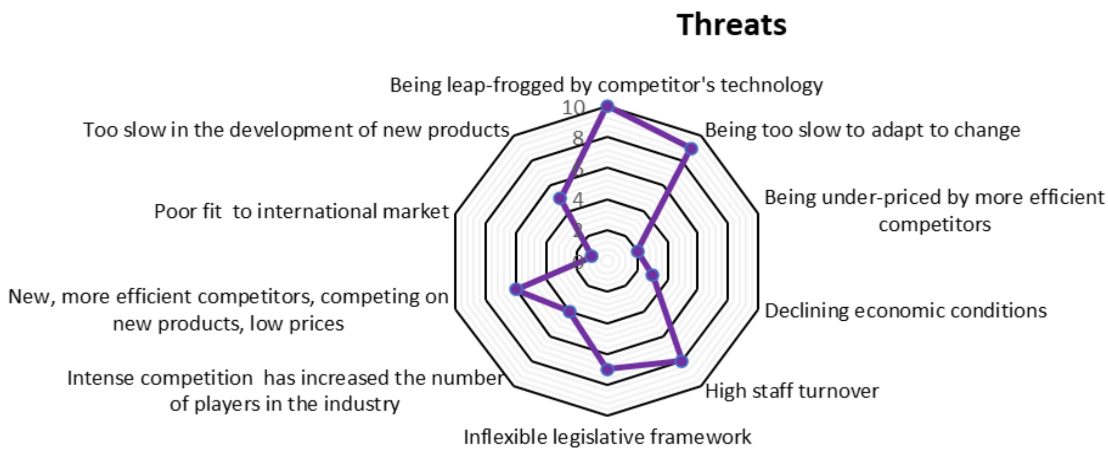
FRANCE
SWOT Analysis for Algae Market Value Chain

Strengths	Weaknesses
• Strong R&D expertise and team • Manufacturing expertise • Highly innovative • Strong technical expertise • Good understanding of the market • Reaching emerging market segments • Customer preference for natural products • Unique product features • Well regarded in the industry • Growing natural environmental concerns	• Poor speed-to-market • Recent failures in entering new markets • Cannot access emerging market segments • Regulatory complexity • "Biomass production is available at pilot scale in the country/ • Difficulties with scaling up" • Limited International linkages • A high-cost logistics system • Limited market share • Difficult to access to capital and funding • Significant channel conflict
Opportunities	**Threats**
• Introduce new, modern technology and/or systems • Become a first-mover in an emerging market • Growing end user applications • Target high growth markets • Develop a clear value proposition • Leverage existing knowledge from relevant fields • Combination of natural and synthetic production • Raise capital funding to invest in new ventures • Utilize key sponsorships/investments • Challenge new players	• Being leap-frogged by competitor's technology • Being too slow to adapt to change • High staff turnover • Inflexible legislative framework • New, more efficient competitors, competing on new products, low prices • Too slow in the development of new products • Intense competition has increased the number of players in the industry • Declining economic conditions • Being under-priced by more efficient competitors • Poor fit to international market


Strengths
Customer preference for natural products
Good understanding of the market
Growing natural environmental concerns
Highly innovative
Manufacturing expertise
Reaching emerging market segments
Strong R&D expertise and team
Strong technical expertise
Unique product features
Well regarded in the industry
10
8
6
4
2
0


Weaknesses
A high-cost logistics system
Biomass production is available at pilot scale in the country/...
Cannot access emerging market segments
Difficult to access to capital and funding
Limited International linkages
Limited market share
Poor speed-to-market
Recent failures in entering new markets
Regulatory complexity
Significant channel conflict
10
8
6
4
2
0


Opportunities
Become a first-mover in an emerging market
Challenge new players
Combination of natural and synthetic production
Develop a clear value proposition
Growing end user applications
Introduce new, modern technology and/or
Leverage existing knowledge from relevant fields
Raise capital funding to invest in new ventures
Target high growth markets
Utilize key sponsorships/investments
10
8
6
4
2
0

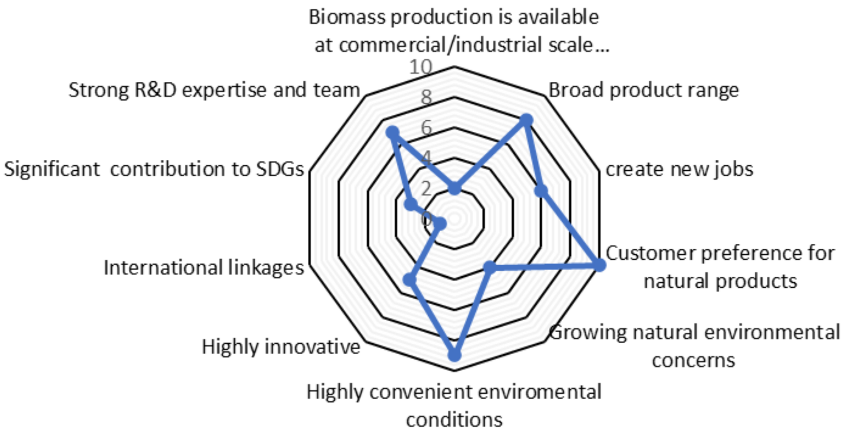

Threats
Being leap-frogged by competitor's technology
Being too slow to adapt to change
Being under-priced by more efficient competitors
Declining economic conditions
High staff turnover
Inflexible legislative framework
Intense competition has increased the number of players in the industry
New, more efficient competitors, competing on new products, low prices
Poor fit to international market
Too slow in the development of new products
10
8
4

Greece
SWOT Analysis for Algae Market Value Chain

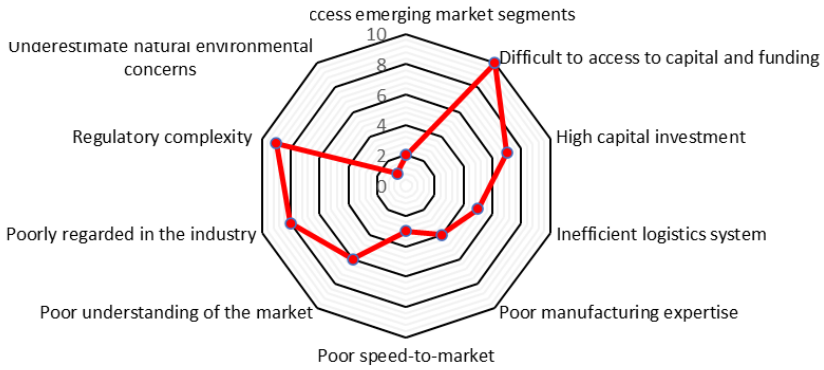
Strengths	Weaknesses
• Customer preference for natural products • Highly convenient environmental conditions • Broad product range • Strong R&D expertise and team • create new jobs • Highly innovative • Growing natural environmental concerns • Significant contribution to SDGs • Biomass production is available at commercial/industrial scale in the country • International linkages	• Difficult to access to capital and funding • Regulatory complexity • Poorly regarded in the industry • High capital investment • Poor understanding of the market • Inefficient logistics system • Poor manufacturing expertise • Poor speed-to-market • Cannot access emerging market segments • Underestimate natural environmental concerns

Opportunities	Threats
• Government subsidies/incentives • Lobby the government for improved legislation • Introduce new, modern technology and/or systems • Use cross-functional teams to develop new products • Leverage existing knowledge from relevant fields • Raise capital funding to invest in new ventures • Identify market gaps • Improve manufacturing expertise and experience • Growing end user applications • Leverage superior logistics system	• Being too slow to adapt to change • Inflexible legislative framework • Too slow in the development of new products • New, more efficient competitors, competing on new products, low prices • Uncertain market conditions • Poor fit to local market • No regular supply of innovative products /seasonality • Lost of market share • Inexperienced staff -lack of skills • Retailers not accepting the value chain products

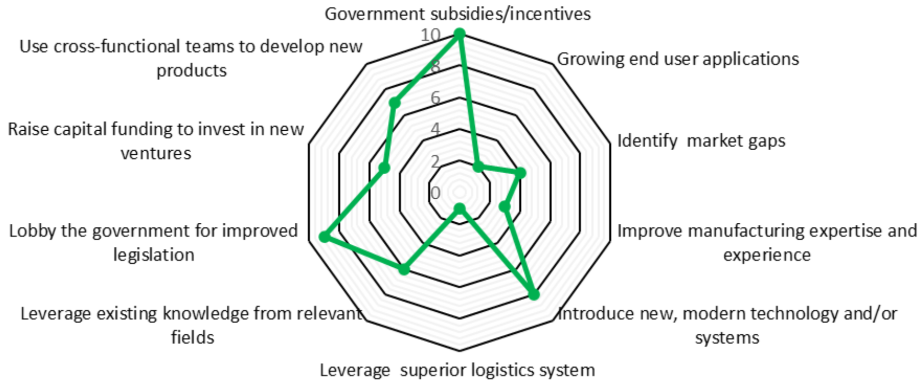
Strengths



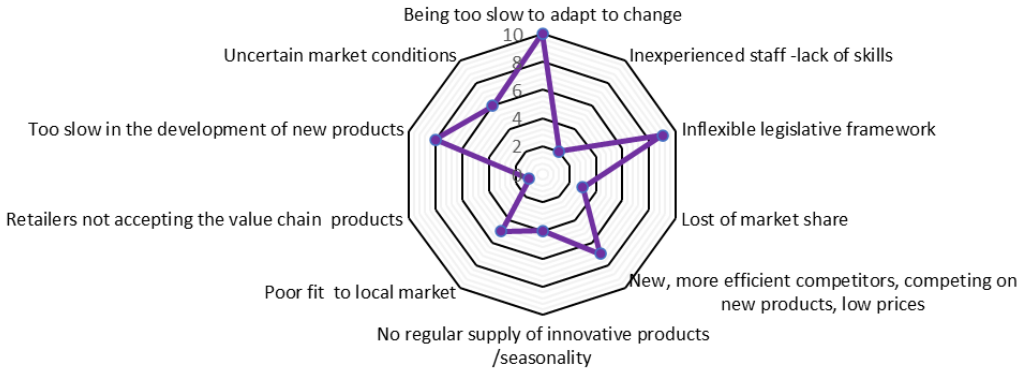
Weaknesses



Opportunities



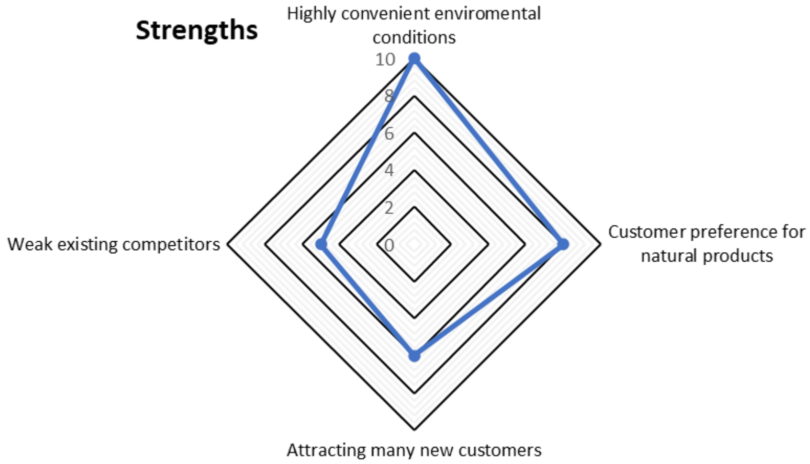
Threats

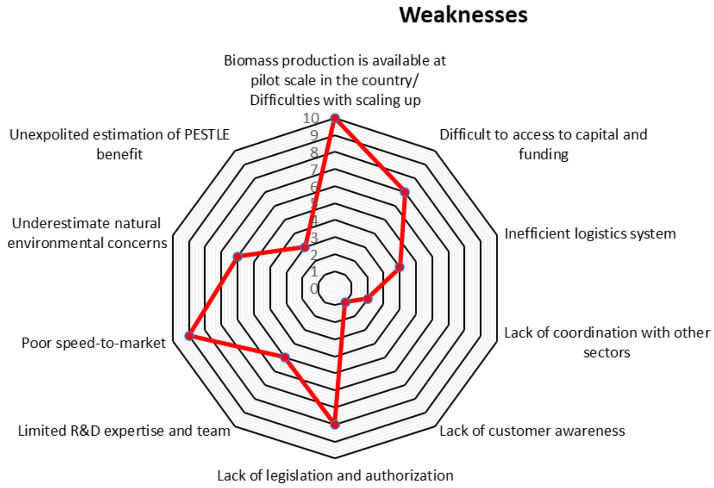


Italy
SWOT Analysis for Algae Market Value Chain

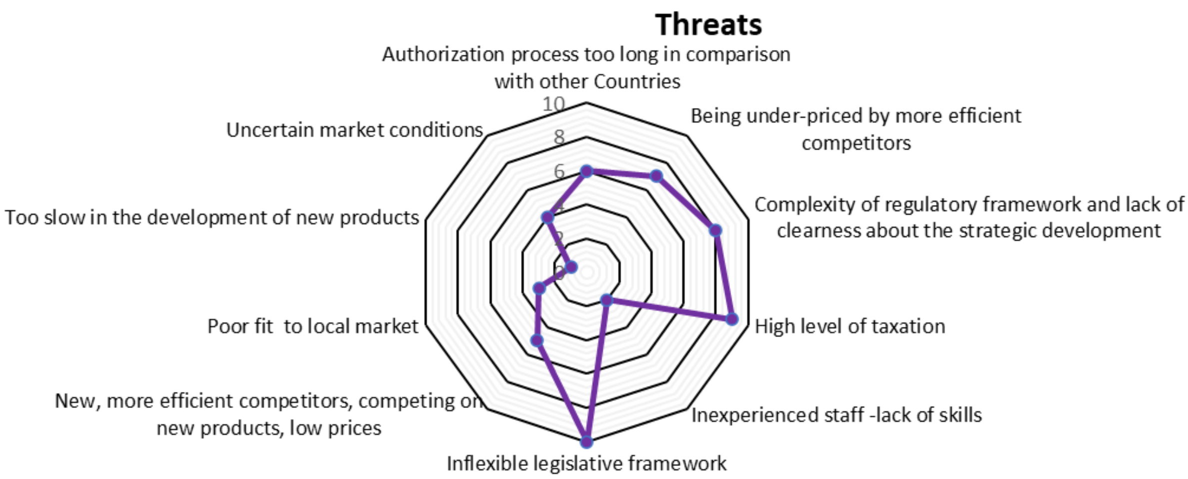
Strengths	Weaknesses
• Highly convenient environmental conditions • Customer preference for natural products • Attracting many new customers • Weak existing competitors	• Biomass production is available at pilot scale in the country/ • Difficulties with scaling up" • Poor speed-to-market • Lack of legislation and authorization • Difficult to access to capital and funding • Underestimate natural environmental concerns • Limited R&D expertise and team • Inefficient logistics system • Unexploited estimation of PESTLE benefit • Lack of coordination with other sectors • Lack of customer awareness

Opportunities	Threats
• Develop protocol for new products such as fertilizers, polymer and bioactive compounds extraction • Increase the IMTA production by edible and not edible species • Use the bioremediation in industrial site • Develop a cross cutting system among Blue-Green and Circular Economy • Become a first-mover in an emerging market • Raise capital funding to invest in new ventures • Government subsidies/incentives • Lobby the government for improved legislation • Use environmental issues to develop added value products • Generate license revenue streams from key patents	• Inflexible legislative framework • High level of taxation • Complexity of regulatory framework and lack of clearness about the strategic development • Being under-priced by more efficient competitors • Authorization process too long in comparison with other Countries • New, more efficient competitors, competing on new products, low prices • Uncertain market conditions • Poor fit to local market • Inexperienced staff -lack of skills • Too slow in the development of new products


Strengths
Highly convenient enviromental conditions
Customer preference for natural products
Attracting many new customers
Weak existing competitors


Weaknesses
Biomass production is available at pilot scale in the country/ Difficulties with scaling up
Difficult to access to capital and funding
Inefficient logistics system
Lack of coordination with other sectors
Lack of customer awareness
Lack of legislation and authorization
Limited R&D expertise and team
Poor speed-to-market
Underestimate natural environmental concerns
Unexpolited estimation of PESTLE benefit

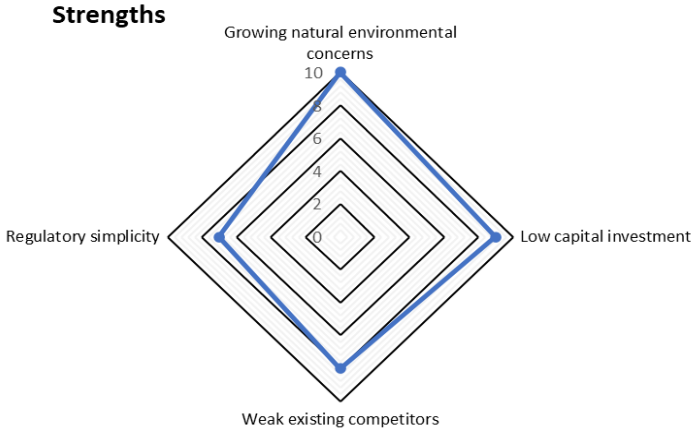

Opportunities
Become a first-mover in an emerging market
Develop a cross cutting syste Blue-Green and Circular Ec
Develop protocol for new products such as fertilizers, polymer and bioactive compounds extraction
Generate license revenue streams from key patents
Government subsidies/incentives
Increase the IMTA production by edible and not edible species
Lobby the government for improved legislation
Raise capital funding to invest in new ventures
Use environmental issues to develop added value products
Use the bioremediation in industrial site


Threats
Authorization process too long in comparison with other Countries
Being under-priced by more efficient competitors
Complexity of regulatory framework and lack of clearness about the strategic development
High level of taxation
Inexperienced staff -lack of skills
Inflexible legislative framework
New, more efficient competitors, competing on new products, low prices
Poor fit to local market
Too slow in the development of new products
Uncertain market conditions

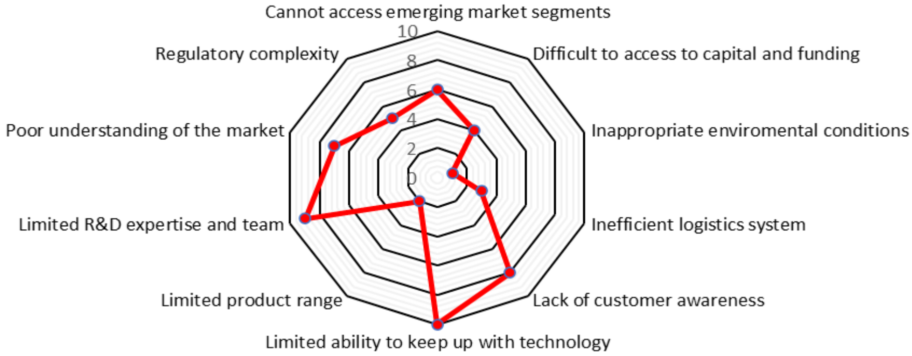
MONTENEGRO
SWOT Analysis for Algae Market Value Chain

Strengths	Weaknesses
• Growing natural environmental concerns • Low capital investment • Weak existing competitors • Regulatory simplicity	• Limited ability to keep up with technology • Limited R&D expertise and team • Lack of customer awareness • Poor understanding of the market • Cannot access emerging market segments • Regulatory complexity • Difficult to access to capital and funding • Inefficient logistics system • Limited product range • Inappropriate environmental conditions
Opportunities	**Threats**
• Build product awareness • Identify market gaps • Develop a clear value proposition • Create appropriate outsourcing partnerships • Raise capital funding to invest in new ventures • Improve manufacturing expertise and experience • Unique product features/design • Streamline product features to reduce costs • Utilize key sponsorships/investments • Improve cultivation and downstream processing	• Being too slow to adapt to change • Inexperienced staff -lack of skills • Being leap-frogged by competitor's technology • Lost of unique product features • Too slow in the development of new products • Negative attitudes to the products • Poor fit to international market • Uncertain market conditions • Poor fit to local market

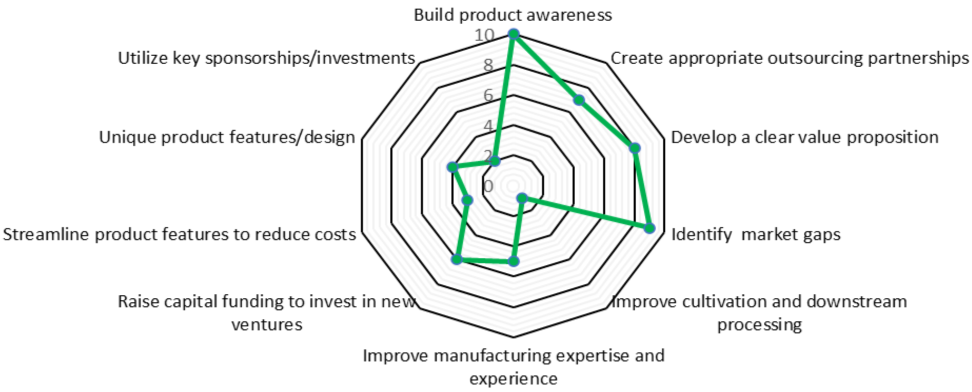
Strengths



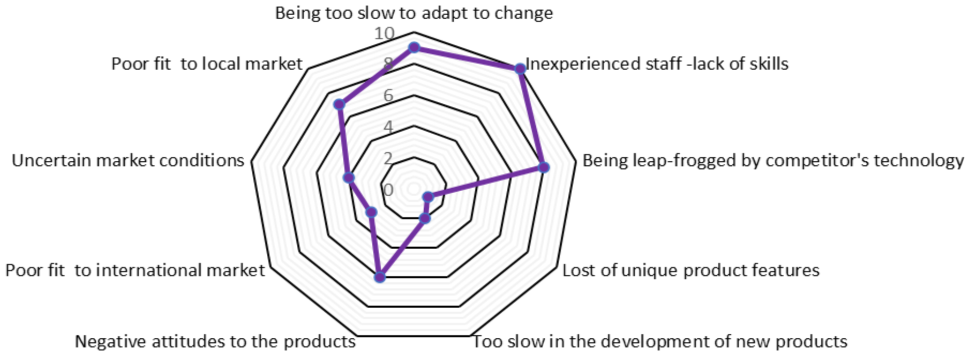
Weaknesses



Opportunities



Threats



Portugal
SWOT Analysis for Algae Market Value Chain

Strengths

- Strong R&D expertise and team
- Strong technical expertise
- Highly innovative
- Manufacturing expertise
- Significant contribution to SDGs
- Biomass production is available at commercial/industrial scale in the country
- Good understanding of the market
- Success in entering new markets
- Reaching emerging market segments

Weaknesses

- Difficult to access to capital and funding
- High capital investment
- Limited number of new customers
- Lack of customer awareness
- Limited market share
- Underestimate natural environmental concerns
- Poor speed-to-market

Opportunities

- Leverage existing knowledge from relevant fields
- Introduce new, modern technology and/or systems
- Improve manufacturing expertise and experience
- Government subsidies/incentives
- Develop strategic alliances
- Build International linkages
- Unique product features/design
- Growing end user applications
- Combination of natural and synthetic production
- Challenge new players

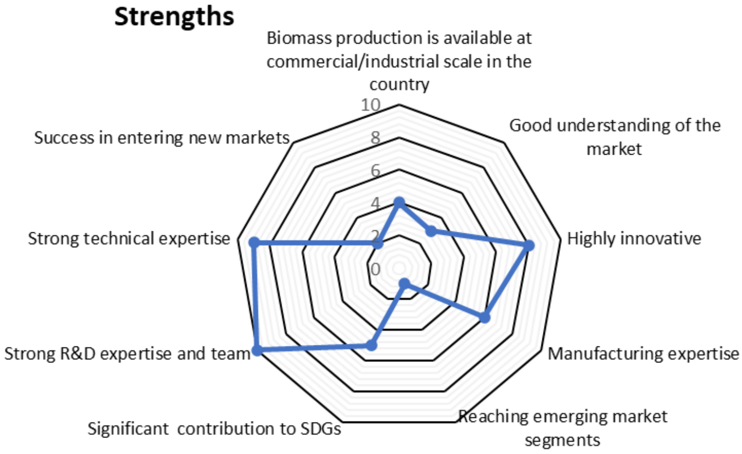
Threats

- Inflexible legislative framework
- Being under-priced by more efficient competitors
- Uncertain market conditions

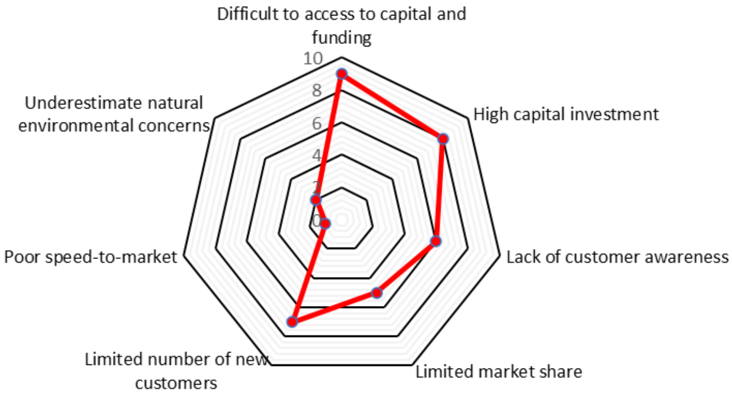
SLOVENIA

T Analysis for Algae Market Value Chain

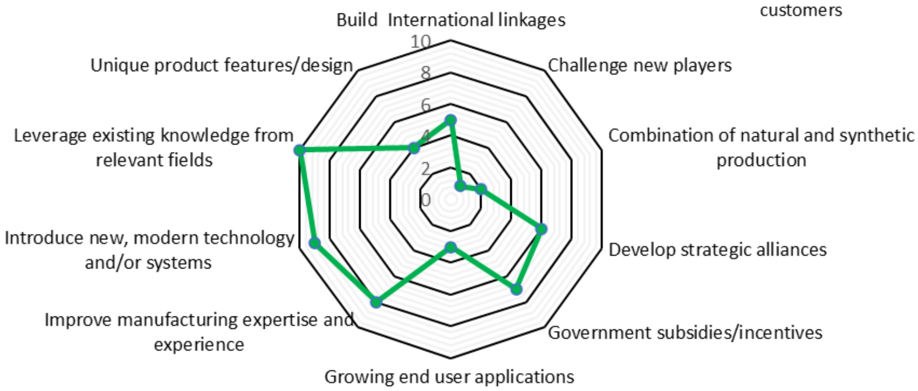
Strengths



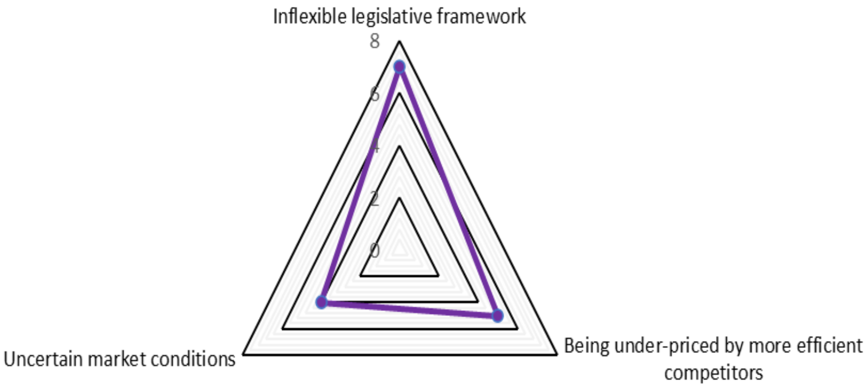
Weaknesses



Opportunities

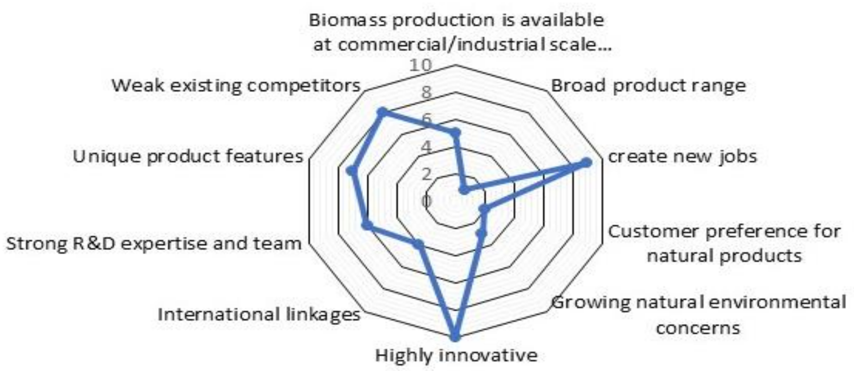


Threats

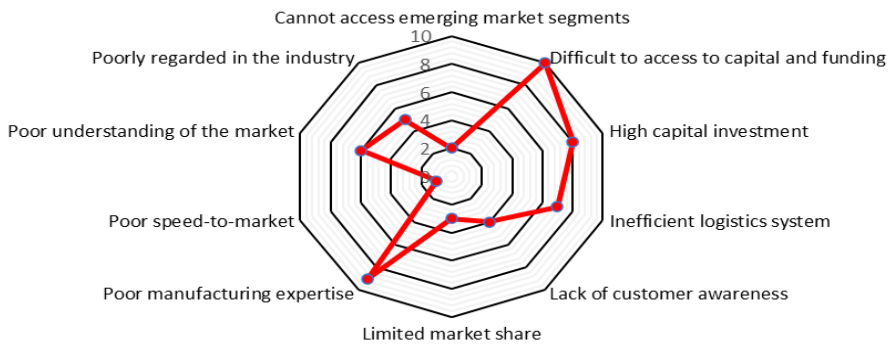


Strengths	Weaknesses
• Highly innovative • create new jobs • Weak existing competitors • Unique product features • Strong R&D expertise and team • Biomass production is available at commercial/industrial scale in the country • International linkages • Growing natural environmental concerns • Customer preference for natural products • Broad product range	• Difficult to access to capital and funding • Poor manufacturing expertise • High capital investment • Inefficient logistics system • Poor understanding of the market • Poorly regarded in the industry • Lack of customer awareness • Limited market share • Cannot access emerging market segments • Poor speed-to-market
Opportunities	**Threats**
• Leverage existing knowledge from relevant fields • Improve manufacturing expertise and experience • Introduce new, modern technology and/or systems • Use cross-functional teams to develop new products • Raise capital funding to invest in new ventures • Become a first-mover in an emerging market • Develop strategic alliances • Improve cultivation and downstream processing • Develop environmentally-friendly products • Growing end user applications	• Being too slow to adapt to change • Being leap-frogged by competitor's technology • Intense competition has increased the number of players in the industry • Too slow in the development of new products • New, more efficient competitors, competing on new products, low prices • Uncertain market conditions • Poor fit to local market • Poor fit to international market • Negative attitudes to the products • Limited profit levels

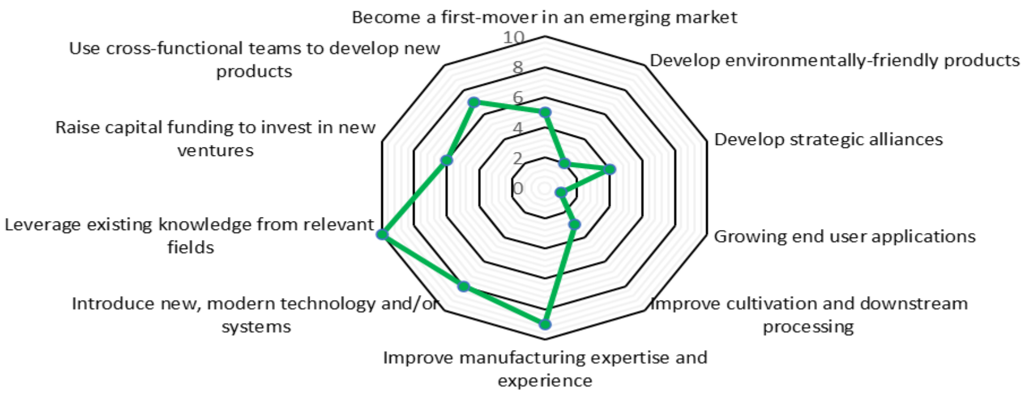
Strengths



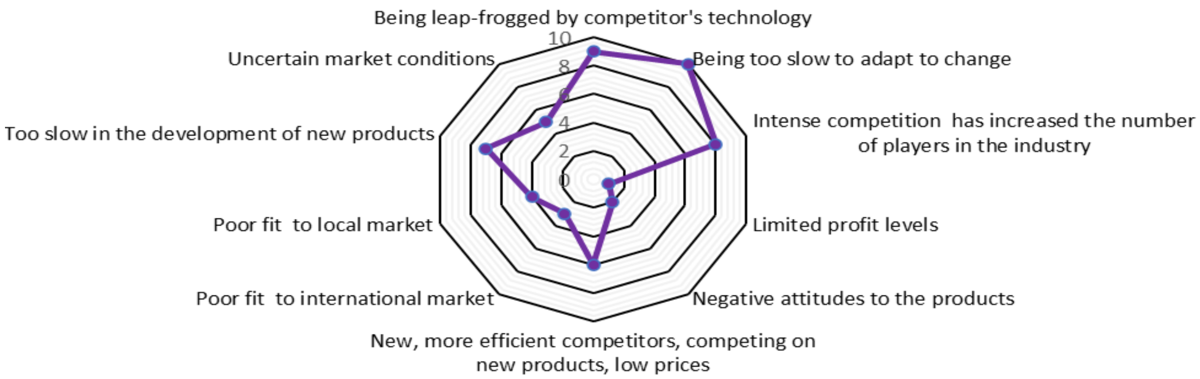
Weaknesses



Opportunities



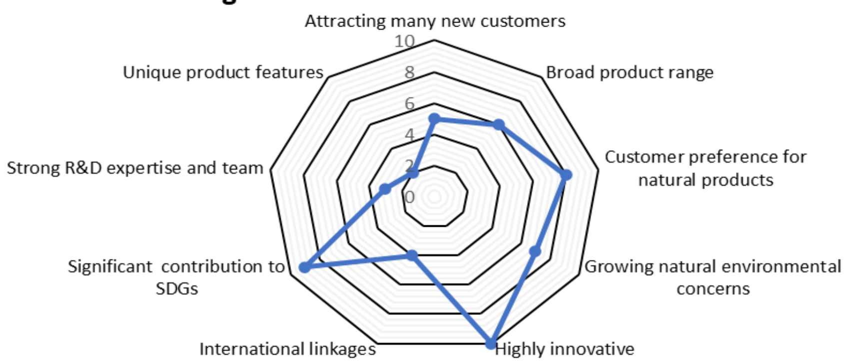
Threats



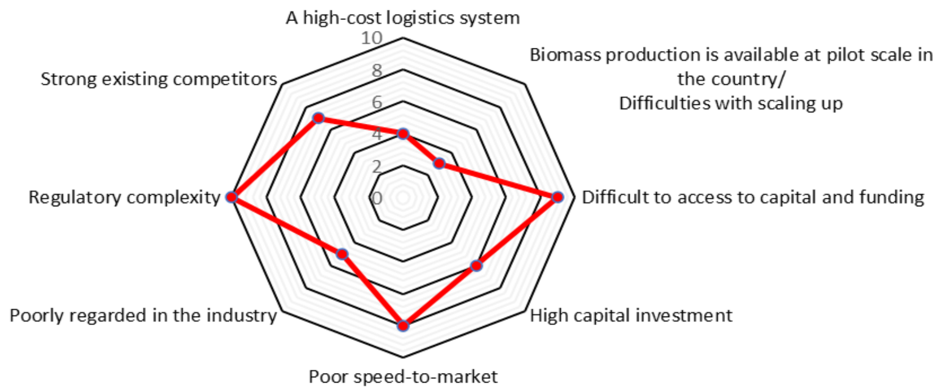
SPAIN
SWOT Analysis for Algae Market Value Chain

Strengths	Weaknesses
• Highly innovative • Significant contribution to SDGs • Customer preference for natural products • Growing natural environmental concerns • Broad product range • Attracting many new customers • International linkages • Strong R&D expertise and team • Unique product features	• Regulatory complexity • Difficult to access to capital and funding • Poor speed-to-market • Strong existing competitors • High capital investment • Poorly regarded in the industry • A high-cost logistics system • Biomass production is available at pilot scale in the country/ Difficulties with scaling up
Opportunities	**Threats**
• Unique product features/design • Use environmental issues to develop added value products • Develop environmentally-friendly products • Improve cultivation and downstream processing • Build International linkages • Raise capital funding to invest in new ventures • Growing end user applications • Improve customers attitude towards value chain products • Build product awareness • Leverage existing knowledge from relevant fields	• Inflexible legislative framework • New, more efficient competitors, competing on new products, low prices • Intense competition has increased the number of players in the industry • Limited profit levels • Uncertain market conditions • Lost of market share • Negative attitudes to the products

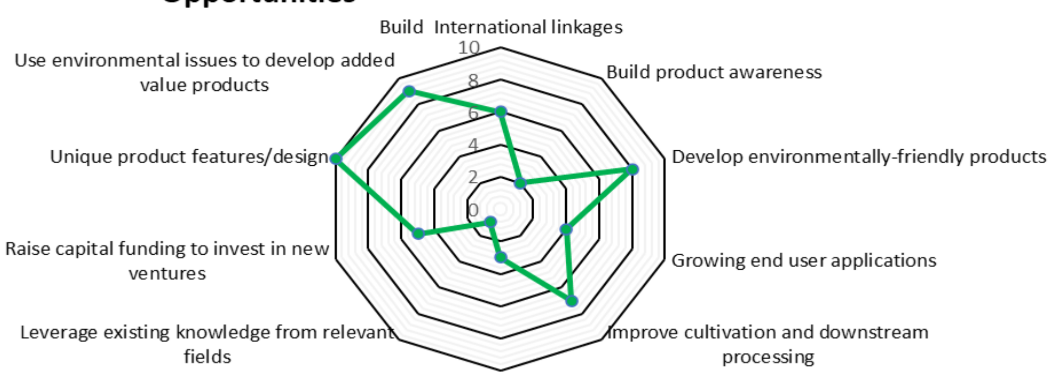
Strengths



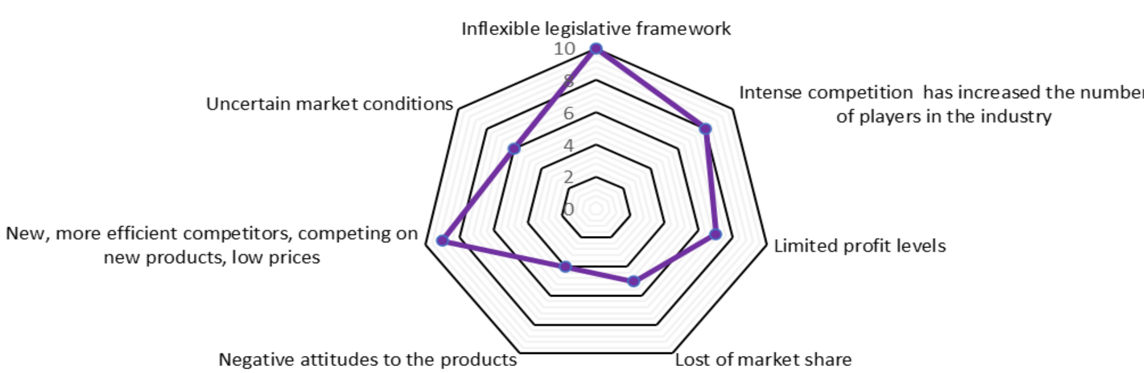
Weaknesses



Opportunities



Threats

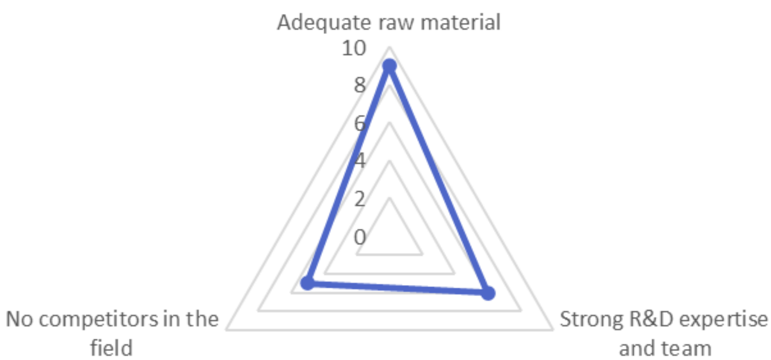


SWOT Analysis for Aquaculture/fisheries/processing by-products and discards valorisation Value Chain

ITALY
SWOT Analysis for Aquaculture/fisheries/processing by-products and discards valorisation Value Chain

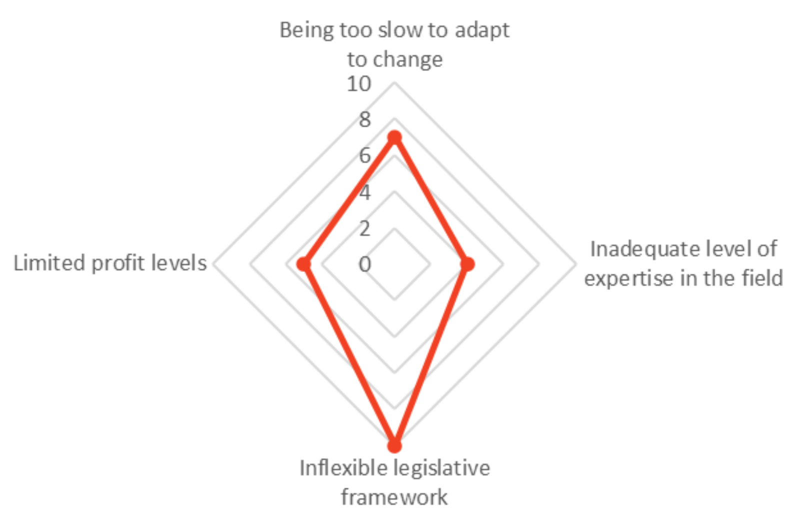
Strengths	Weaknesses
• Adequate raw material (9) • Strong R&D expertise and team (6) • No competitors in the field (5)	• Capital and funding are difficult to access (10) • Regulatory complexity (9)
Opportunities	**Threats**
• Improve existing manufacturing procedures (10) • Provide new employment opportunities (9) • Become a first mover in an emerging market (8) • Develop environmentally friendly products (7) • Mitigation of an environmental issue (6) • Government subsidies/incentives (5) • Develop new products for international markets (4) • Raise capital to invest in new ventures in the valorisation field (3) • Raise awareness towards environmental issues (2) • Improve customers attitude towards valorisation by-products (1)	• Inflexible legislative framework (10) • Being too slow to adapt to change (7) • Limited profit levels (5) • Inadequate level of expertise in the field (4)

Strengths



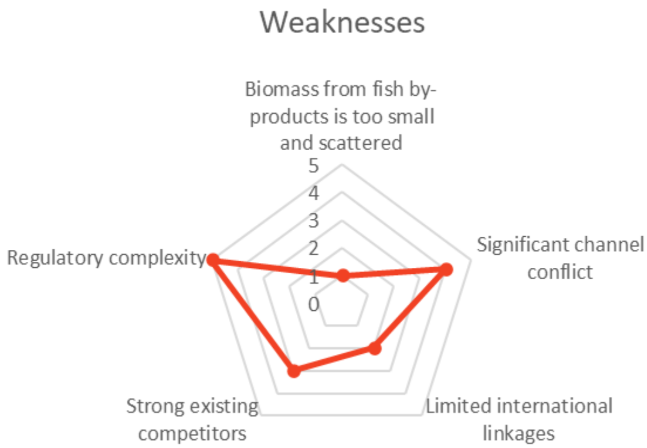
Opportunities

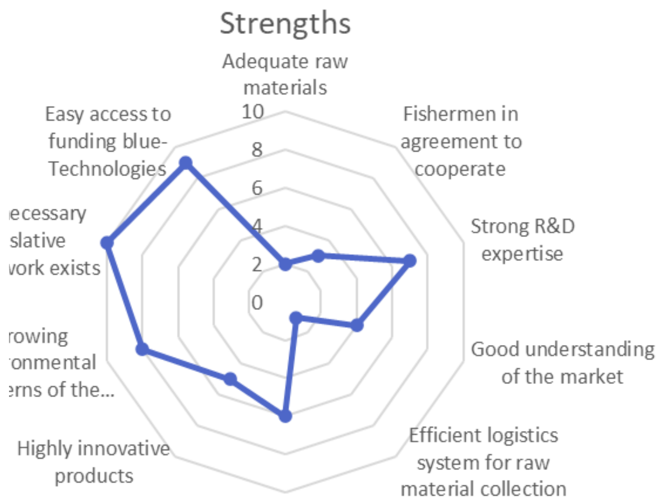
Threats



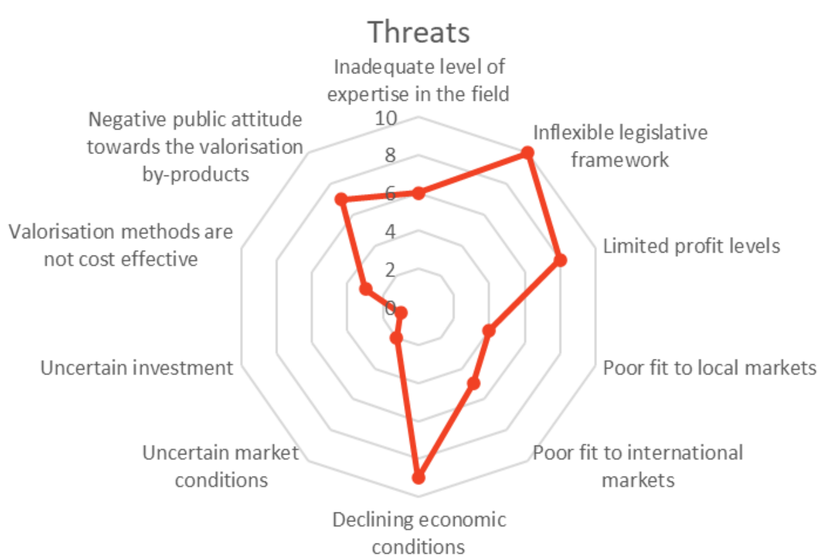
FRANCE
SWOT Analysis for Aquaculture/fisheries/processing by-products and discards valorisation Value Chain

Strengths	Weaknesses
• The necessary legislative framework exists (10) • Easy access to funding blue-Technologies (9) • Growing environmental concerns of the public (8) • Strong R&D expertise (7) • Good fit to customer's needs (6) • Highly innovative products (5) • Good understanding of the market (4) • Fishermen in agreement to cooperate (3) • Adequate raw materials (2) • Efficient logistics system for raw material collection (1)	• Regulatory complexity (5) • Significant channel conflict (4) • Strong existing competitors (3) • Limited international linkages (2) • Biomass from fish by-products is too small and scattered (1)
Opportunities	**Threats**
• Introduce new innovative technology (9) • Raise awareness towards environmental issues (8) • Provide new employment opportunities (7) • Use environmental issues to develop added value products (6) • Target high growth markets (5) • Leverage superior logistics system (4) • Utilize existing knowledge from relevant fields (3) • Become a first-mover in an emerging market (2) • Improve existing manufacturing procedures (1)	• Inflexible legislative framework (10) • Declining economic conditions (9) • Limited profit levels (8) • Negative public attitude towards the valorisation by-products (7) • Inadequate level of expertise in the field (6) • Poor fit to international markets (5) • Poor fit to local markets (4) • Valorisation methods are not cost effective (3) • Uncertain market conditions (2) • Uncertain investment (1)

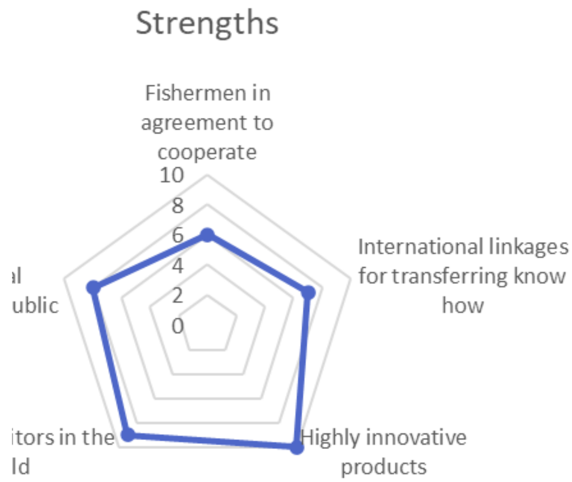

Weaknesses
Biomass from fish by-products is too small and scattered
Significant channel conflict
Limited international linkages
Strong existing competitors
Regulatory complexity
5
4
3
2
1
0


Strengths
Adequate raw materials
Fishermen in agreement to cooperate
Strong R&D expertise
Good understanding of the market
Efficient logistics system for raw material collection
Highly innovative products
rowing onmental erns of the...
ecessary slative vork exists
Easy access to funding blue-Technologies
10
8
6
4
2
0

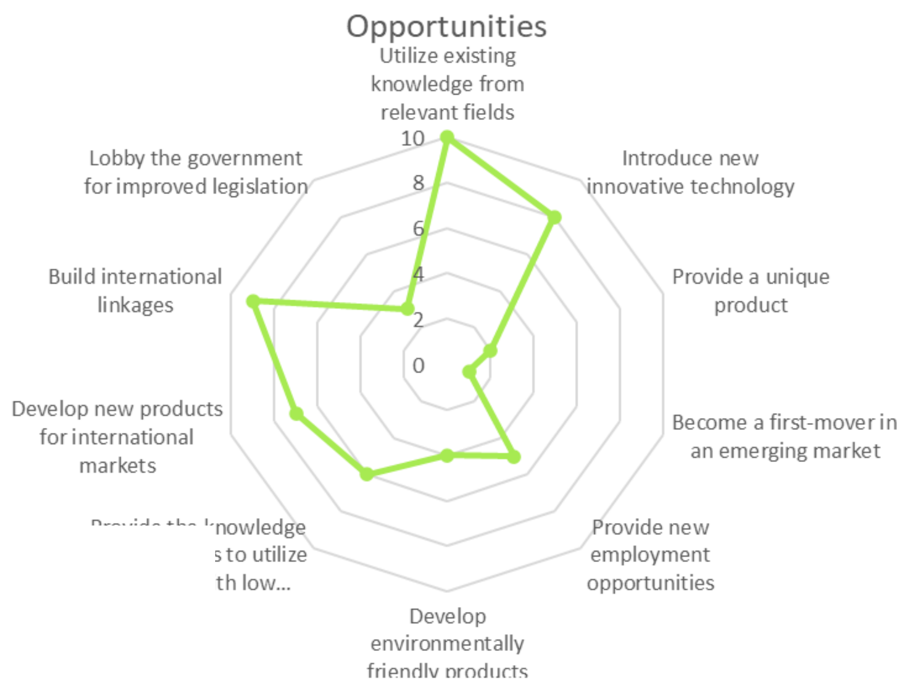

Opportunities
Utilize existing knowledge from relevant fields
Improve existing manufacturing procedures
Introduce new innovative technology
Become a first-mover in an emerging market
Raise awareness towards environmental issues
Provide new employment opportunities
Target high growth markets
Leverage superior logistics system
Use environmental issues to develop added value products
10
8
6
4
2
0


Threats
Inadequate level of expertise in the field
Inflexible legislative framework
Limited profit levels
Poor fit to local markets
Poor fit to international markets
Declining economic conditions
Uncertain market conditions
Uncertain investment
Valorisation methods are not cost effective
Negative public attitude towards the valorisation by-products
10
8
6
4
2
0

SLOVENIA **SWOT Analysis for Aquaculture/fisheries/processing by-products and discards valorisation Value Chain**	
Strengths	**Weaknesses**
• Highly innovative products (10) • No competitors in the field (9) • Growing environmental concerns of the public (8) • International linkages for transferring know how (7) • Fishermen in agreement to cooperate (6)	• High capital investment (10) • Regulatory complexity (9) • Poor access to finance blue technologies (8) • Capital and funding are difficult to access (7) • Inefficient logistics system (6) • A high-cost logistics system (5) • Ineffective new product development process (4) • Cannot access emerging market segments (3) • Poor understanding of the market (2)
Opportunities	**Threats**
• Utilize existing knowledge from relevant fields (10) • Build international linkages (9) • Introduce new innovative technology (8) • Develop new products for international markets (7) • Provide the knowledge and resources to utilize species with low market value (6) • Provide new employment opportunities (5) • Develop environmentally friendly products (4) • Lobby the government for improved legislation (3) • Provide a unique product (2) • Become a first-mover in an emerging market (1)	• The necessary infrastructure doesn't yet exist (10) • Being leap-frogged by competitor's technology (9) • Being too slow to adapt to change (8) • Uncertain market conditions (7) • Uncertain investment (6) • Poor fit to international markets (5) • Poor fit to local market (4) • The market doesn't yet exist (3) • The collection of the scattered resources would raise the prices of the end products (2) • Negative public attitude towards the valorisation by-products (1)


Strengths
Fishermen in agreement to cooperate
International linkages for transferring know how
Highly innovative products
10
8
6
4
2
0


Weaknesses
Poor understanding of the market
Cannot access emerging market segments
Ineffective new product development process
Inefficient logistics system
A high-cost logistics system
Capital and funding are difficult to access
High capital investment
Regulatory complexity
Poor access to finance blue technologies
10
8
6
4
2
0

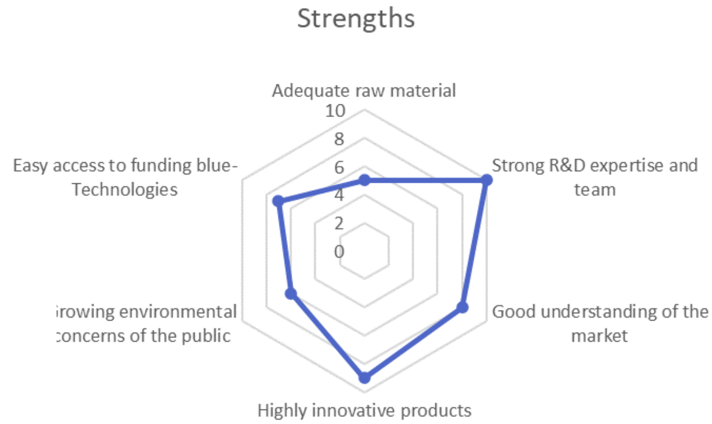

Opportunities
Utilize existing knowledge from relevant fields
Introduce new innovative technology
Provide a unique product
Become a first-mover in an emerging market
Provide new employment opportunities
Develop environmentally friendly products
Develop new products for international markets
Build international linkages
Lobby the government for improved legislation
10
8
6
4
2
0

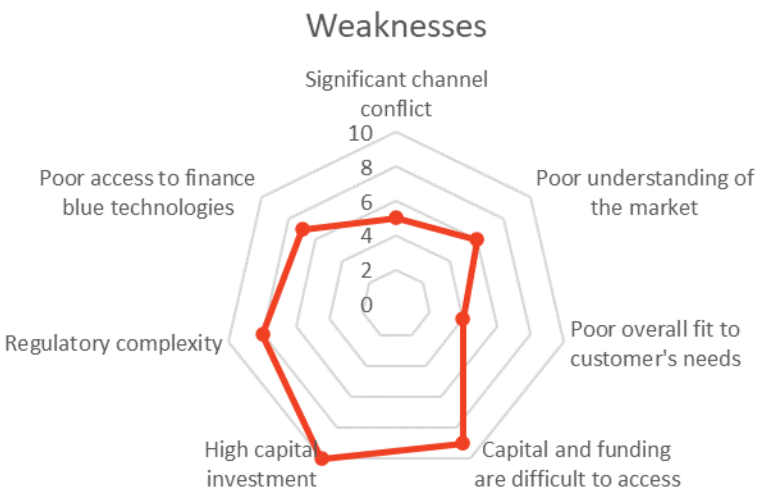

Threats
Being leap-frogged by competitor's technology
Being too slow to adapt to change
Poor fit to local market
Poor fit to international markets
Uncertain market conditions
Uncertain investment
The market doesn't yet exist
The collection of the scattered resources would raise the prices...
The necessary infrastructure doesn't yet exist
Negative public attitude towards the valorisation by-products
10
8
6
4
2
0

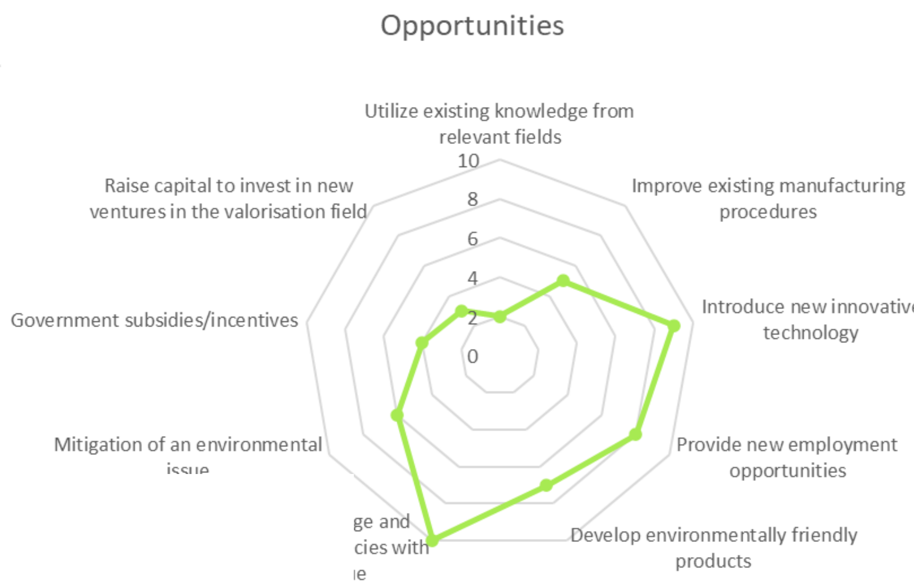
SPAIN

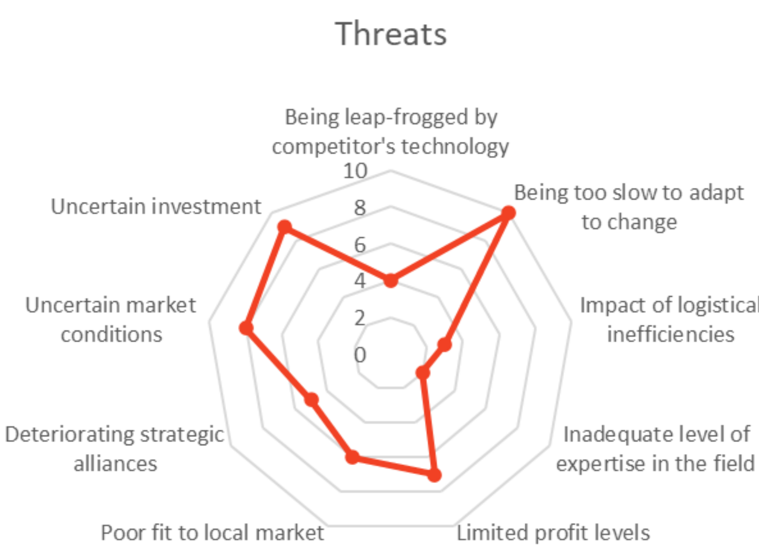
SWOT Analysis for Aquaculture/fisheries/processing by-products and discards valorisation Value Chain

Strengths	Weaknesses
• Strong R&D expertise and team (10) • Highly innovative products (9) • Good understanding of the market (8) • Easy access to funding blue-Technologies (7) • Growing environmental concerns of the public (6) • Adequate raw material (5)	• High capital investment (10) • Capital and funding are difficult to access (9) • Regulatory complexity (8) • Poor access to finance blue technologies (7) • Poor understanding of the market (6) • Significant channel conflict (5) • Poor overall fit to customer's needs (4)
Opportunities	**Threats**
• Provide the knowledge and resources to utilize species with low market value (10) • Introduce new innovative technology (9) • Provide new employment opportunities (8) • Develop environmentally friendly products (7) • Mitigation of an environmental issue (6) • Improve existing manufacturing procedures (5) • Government subsidies/incentives (4) • Raise capital to invest in new ventures in the valorisation field (3) • Utilize existing knowledge from relevant fields (2)	• Being too slow to adapt to change (10) • Uncertain investment (9) • Uncertain market conditions (8) • Limited profit levels (7) • Poor fit to local market (6) • Deteriorating strategic alliances (5) • Being leap-frogged by competitor's technology (4) • Impact of logistical inefficiencies (3) • Inadequate level of expertise in the field (2)


Strengths
Adequate raw material
Strong R&D expertise and team
Good understanding of the market
Highly innovative products
Easy access to funding blue-Technologies
10
8
6
4
2
0

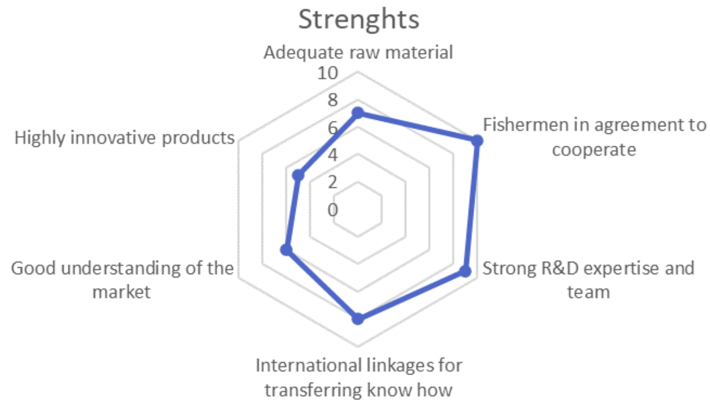

Weaknesses
Significant channel conflict
Poor understanding of the market
Poor overall fit to customer's needs
Capital and funding are difficult to access
High capital investment
Regulatory complexity
Poor access to finance blue technologies
10
8
6
4
2
0

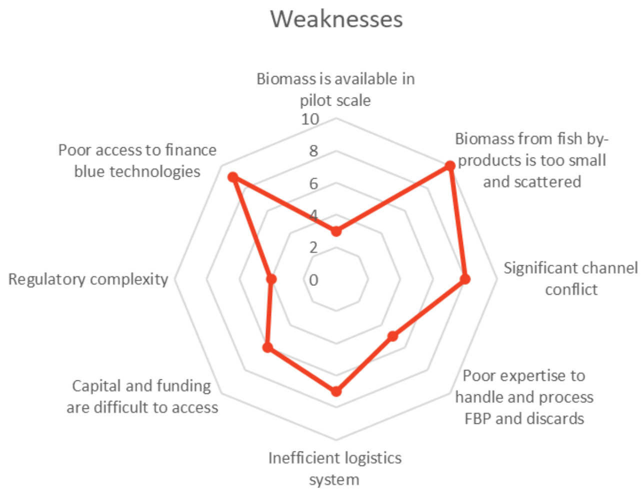

Opportunities
Utilize existing knowledge from relevant fields
Improve existing manufacturing procedures
Introduce new innovative technology
Provide new employment opportunities
Develop environmentally friendly products
Mitigation of an environmental
Government subsidies/incentives
Raise capital to invest in new ventures in the valorisation field
10
8
6
4
2
0

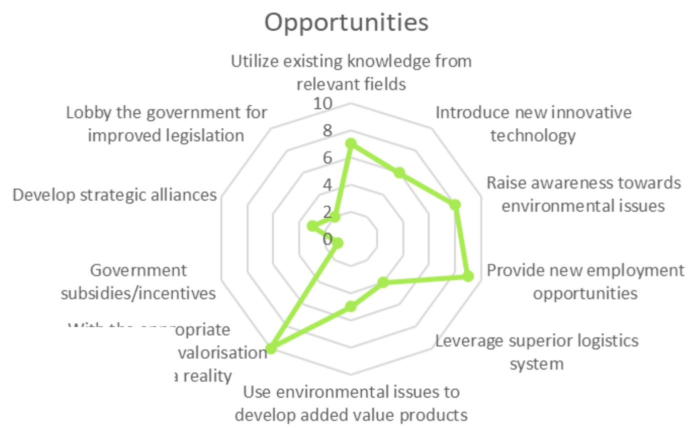

Threats
Being leap-frogged by competitor's technology
Being too slow to adapt to change
Impact of logistical inefficiencies
Inadequate level of expertise in the field
Limited profit levels
Poor fit to local market
Deteriorating strategic alliances
Uncertain market conditions
Uncertain investment
10
8
6
4
2
0

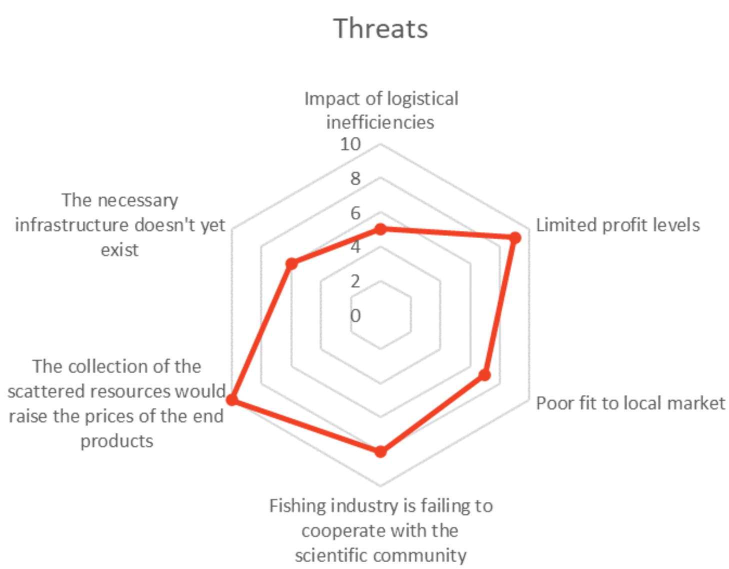
GREECE
SWOT Analysis for Aquaculture/fisheries/processing by-products and discards valorisation Value Chain

Strengths	Weaknesses
• Fishermen in agreement to cooperate (10) • Strong R&D expertise and team (9) • International linkages for transferring know how (8) • Adequate raw material (7) • Good understanding of the market (6) • Highly innovative products (5)	• Biomass from fish by-products is too small and scattered (10) • Poor access to finance blue technologies (9) • Significant channel conflict (8) • Inefficient logistics system (7) • Capital and funding are difficult to access (6) • Poor expertise to handle and process FBP and discards (5) • Regulatory complexity (4) • Biomass is available in pilot scale (3)
Opportunities	**Threats**
• With the appropriate incentives, discard valorisation may become a reality (10) • Provide new employment opportunities (9) • Raise awareness towards environmental issues (8) • Utilize existing knowledge from relevant fields (7) • Introduce new innovative technology (6) • Use environmental issues to develop added value products (5) • Leverage superior logistics system (4) • Develop strategic alliances (3) • Lobby the government for improved legislation (2) • Government subsidies/incentives (1)	• The collection of the scattered resources would raise the prices of the end products (10) • Limited profit levels (9) • Fishing industry is failing to cooperate with the scientific community (8) • Poor fit to local market (7) • The necessary infrastructure doesn't yet exist (6) • Impact of logistical inefficiencies (5)


Strenghts
Adequate raw material
Fishermen in agreement to cooperate
Strong R&D expertise and team
International linkages for transferring know how
Good understanding of the market
Highly innovative products


Weaknesses
Biomass is available in pilot scale
Biomass from fish by-products is too small and scattered
Significant channel conflict
Poor expertise to handle and process FBP and discards
Inefficient logistics system
Capital and funding are difficult to access
Regulatory complexity
Poor access to finance blue technologies


Opportunities
Utilize existing knowledge from relevant fields
Introduce new innovative technology
Raise awareness towards environmental issues
Provide new employment opportunities
Leverage superior logistics system
Use environmental issues to develop added value products
opriate
valorisation
reality
Government subsidies/incentives
Develop strategic alliances
Lobby the government for improved legislation

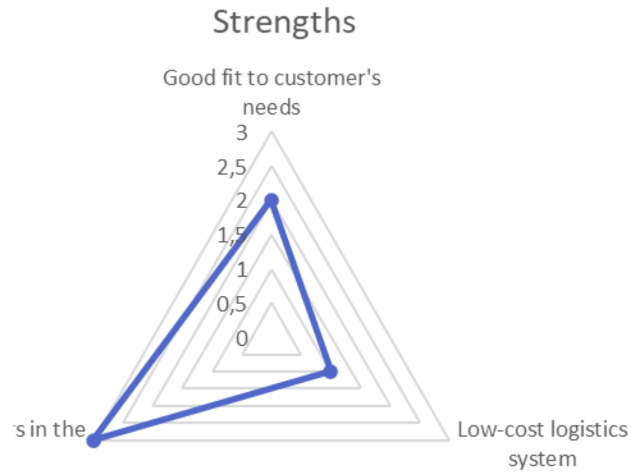

Threats
Impact of logistical inefficiencies
Limited profit levels
Poor fit to local market
Fishing industry is failing to cooperate with the scientific community
The collection of the scattered resources would raise the prices of the end products
The necessary infrastructure doesn't yet exist

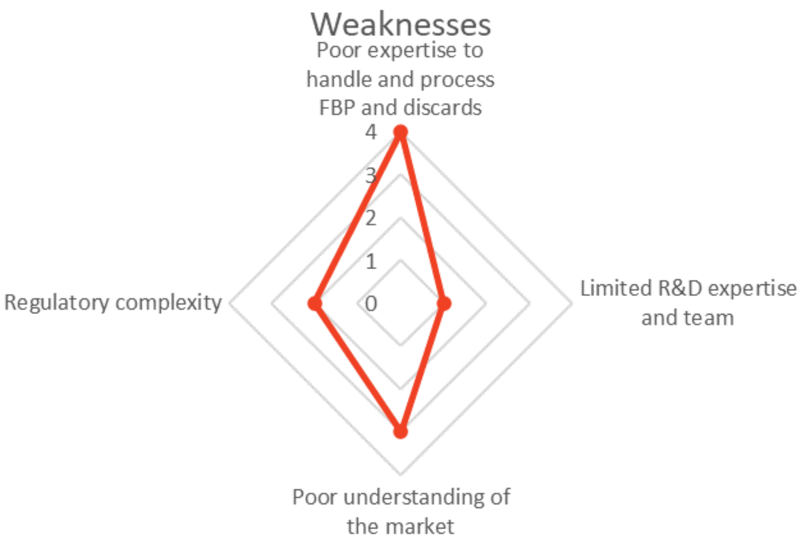
CROATIA

SWOT Analysis for Aquaculture/fisheries/processing by-products and discards valorisation Value Chain

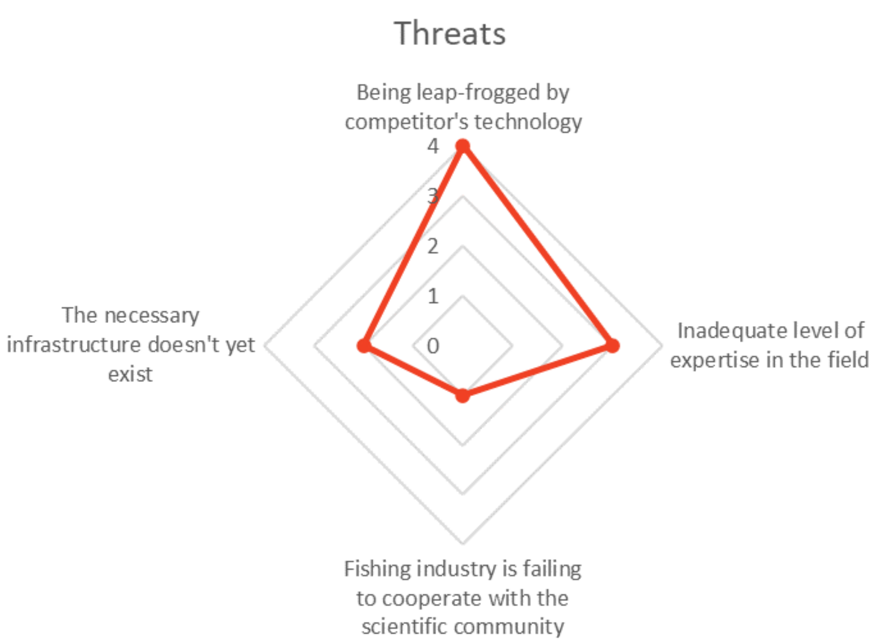
Strengths	Weaknesses
• No competitors in the field (3) • Good fit to customer's needs (2) • Low-cost logistics system (1)	• Poor expertise to handle and process FBP and discards (4) • Poor understanding of the market (3) • Regulatory complexity (2) • Limited R&D expertise and team (1)

Opportunities	Threats
• Use environmental issues to develop added value products (6) • Introduce new innovative technology (5) • Utilize existing knowledge from relevant fields (4) • Improve existing manufacturing procedures (3) • Develop strategic alliances (2) • Develop environmentally friendly products (1)	• Being leap-frogged by competitor's technology (4) • Inadequate level of expertise in the field (3) • The necessary infrastructure doesn't yet exist (2) • Fishing industry is failing to cooperate with the scientific community (1)


Strengths
Good fit to customer's needs
Low-cost logistics system
3
2,5
2
1,5
1
0,5
0

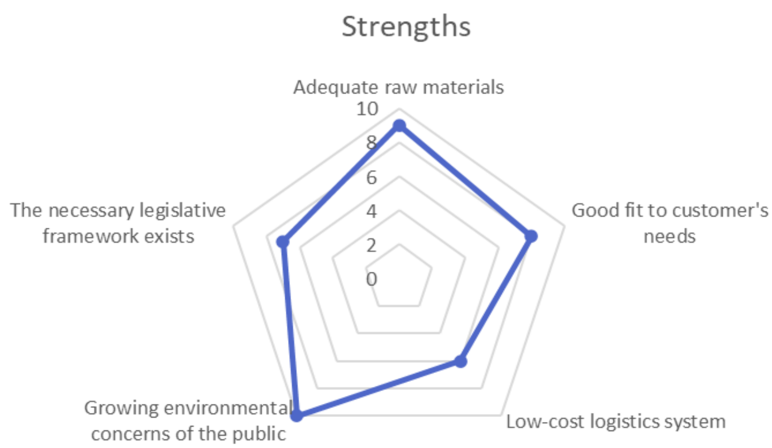

Weaknesses
Poor expertise to handle and process FBP and discards
Limited R&D expertise and team
Poor understanding of the market
Regulatory complexity
4
3
2
1
0

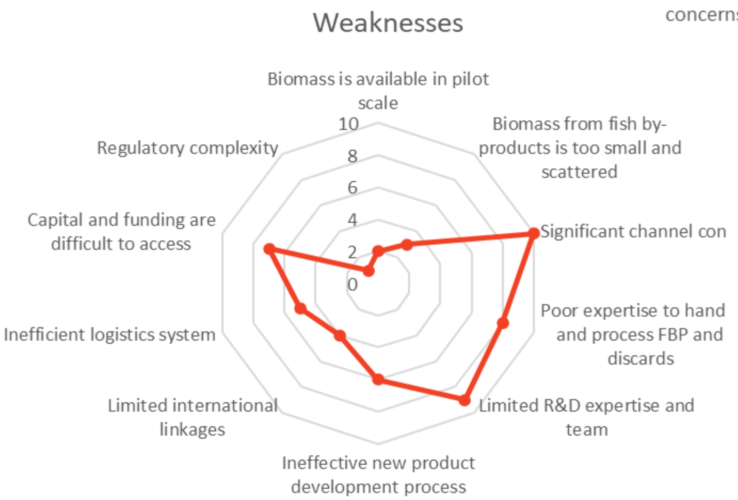

Opportunities
Utilize existing knowledge from relevant fields
Improve existing manufacturing procedures
Introduce new innovative technology
Use environmental issues to develop added value products
Develop
products
Develop strategic alliances
6
5
4
3
2
1
0


Threats
Being leap-frogged by competitor's technology
Inadequate level of expertise in the field
Fishing industry is failing to cooperate with the scientific community
The necessary infrastructure doesn't yet exist
4
3
2
1
0

MONTENEGRO
SWOT Analysis for Aquaculture/fisheries/processing by-products and discards valorisation Value Chain

Strengths	Weaknesses
• Growing environmental concerns of the public (10) • Adequate raw materials (9) • Good fit to customer's needs (8) • The necessary legislative framework exists (7) • Low-cost logistics system (6)	• Significant channel conflict (10) • Limited R&D expertise and team (9) • Poor expertise to handle and process FBP and discards (8) • Capital and funding are difficult to access (7) • Ineffective new product development process (6) • Inefficient logistics system (5) • Limited international linkages (4) • Biomass from fish by-products is too small and scattered (3) • Biomass is available in pilot scale (2) • Regulatory complexity (1)
Opportunities	**Threats**
• Use environmental issues to develop added value products (10) • Use environmental issues to reduce cost structure (9) • Utilize existing knowledge from relevant fields (8) • Improve existing manufacturing procedures (7) • Introduce new innovative technology (6) • Provide new employment opportunities (5) • Raise awareness towards environmental issues (4) • Target high growth markets (3) • Develop environmentally friendly products (2) • Develop strategic alliances (1)	• Inadequate level of expertise in the field (10) • Limited profit levels (9) • Uncertain market conditions (8) • Fishing industry is failing to cooperate with the scientific community (7) • Being leap-frogged by competitor's technology (6) • Poor fit to international markets (5) • Poor fit to local market (4) • The market does not yet exist (3) • Uncertain investment (2) • Competitors provide low-cost alternatives (1)

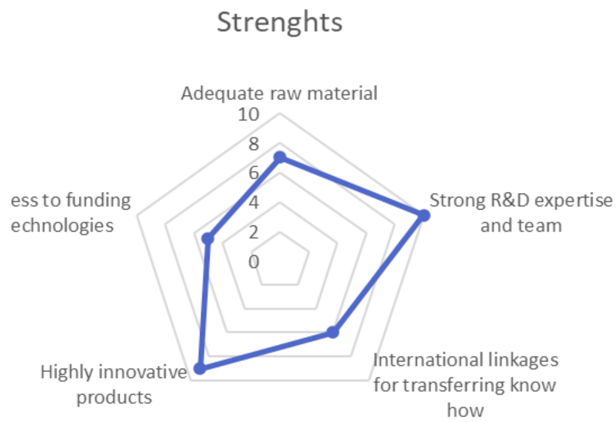

Strengths
Adequate raw materials
Good fit to customer's needs
Low-cost logistics system
Growing environmental concerns of the public
The necessary legislative framework exists
10
8
6
4
2
0

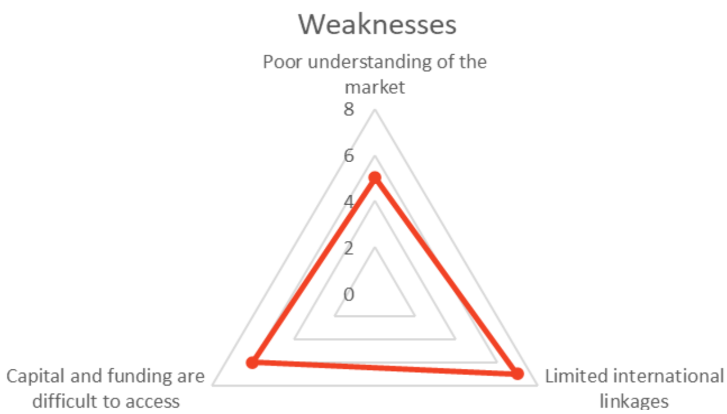

Weaknesses
Biomass is available in pilot scale
Biomass from fish by-products is too small and scattered
Significant channel con
Poor expertise to hand and process FBP and discards
Limited R&D expertise and team
Ineffective new product development process
Limited international linkages
Inefficient logistics system
Capital and funding are difficult to access
Regulatory complexity
10
8
6
4
2
0


Opportunities
Utilize existing knowledge from relevant fields
Improve existing manufacturing procedures
Introduce new innovative technology
Raise awareness towards environmental issues
Provide new employment opportunities
Target high growth markets
Use environmental issues to develop added value products
Use environmental issues to reduce cost structure
Develop environmentally friendly products
Develop strategic alliances
10
8
6
4
2
0


Threats
Being leap-frogged by competitor's technology
Inadequate level of expertise in the field
Limited profit levels
Poor fit to local market
Poor fit to international markets
Uncertain market conditions
Fishing industry is failing to cooperate with the scientific community
Uncertain investment
The market doesn't yet exist
Competitors provide low cost alternatives
10
8
6
4
2
0

	PORTUGAL **SWOT Analysis for Aquaculture/fisheries/processing by-products and discards valorisation Value Chain**
Strengths	**Weaknesses**
• Strong R&D expertise and team (10) • Highly innovative products (9) • Adequate raw material (7) • International linkages for transferring know how (6) • Easy access to funding blue-Technologies (5)	• Limited international linkages (7) • Capital and funding are difficult to access (6) • Poor understanding of the market (5)
Opportunities	**Threats**
• Utilize existing knowledge from relevant fields (10) • Introduce new innovative technology (9) • Improve existing manufacturing procedures (8) • Government subsidies/incentives (7) • Build international linkages (6) • Provide the knowledge and resources to utilize species with low market value (5) • Raise awareness towards environmental issues (4) • Provide new employment opportunities (3)	• Inflexible legislative framework (8) • Fishing industry is failing to cooperate with the scientific community (7) • Negative public attitude towards the valorisation by-products (6) • Uncertain investment (4) • Poor fit to local market (3)


Strenghts
Adequate raw material
Strong R&D expertise and team
International linkages for transferring know how
Highly innovative products
ess to funding
echnologies
10
8
6
4
2
0


Weaknesses
Poor understanding of the market
Limited international linkages
Capital and funding are difficult to access
8
6
4
2
0


Opportunities
Utilize existing knowledge from relevant fields
Improve existing manufacturing procedures
Introduce new innovative technology
Provide new employment opportunities
Raise awareness towards environmental issues
Provide the knowledge and
cies with
ie
Government subsidies/incentives
Build international linkages
10
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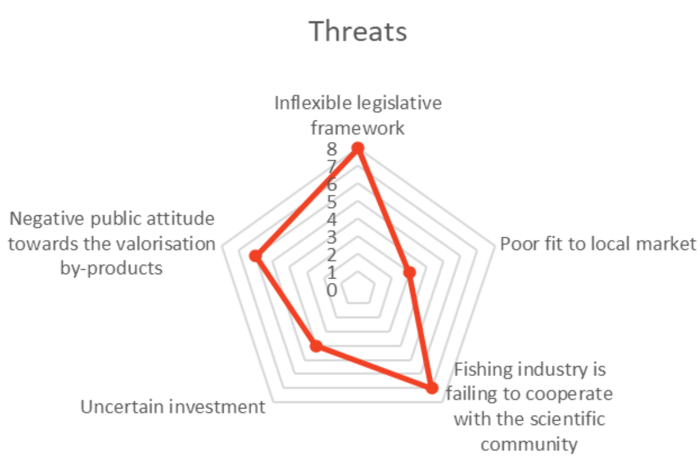
Threats
Inflexible legislative framework
Poor fit to local market
Fishing industry is failing to cooperate with the scientific community
Uncertain investment
Negative public attitude towards the valorisation by-products
8
7
6
5
4
3
2
1
0

ANNEX 3

Questionnaires addressed to the PPs of B-BLUE Project

1. Algae Market value chain
2. Aquaculture/fisheries/processing by-products & discards valorisation
3. IMTA

ALGAE MARKET

1. **How many companies are active in my country in the sector of algae production?**

2. **Please indicate the size (tonnage) of production (national level)**

3. **The algae produced are :** **(use √)**

Microalgae	
Macroalgae	
Both	

4. **Where are algae production units mainly found?** **(use √)**

Sea	
Ponds	
Shore installations	

5. **What types of algae production systems are mainly used** **(use √)**

Offshore	
Open ponds	
Photo-bioreactors	
Thin layer cultivators	
Other	

In case of other please specify…………………………………………………………………………………………………

6. **Which countries do you see as the main competition countries in the sector?**

7. **The produced algae biomass is used in commercial sectors** (Please prioritize your selection from 1-7)

Nutraceuticals	
Animal Feeds	
Pharmaceuticals	
Cosmetics	
Agriculture	
Industrial processes	
Energy	
Other (please specify)	

8. **Algae Biomass is imported in my country** **(use √)**

Yes	
No	

9. **If yes can you indicate the country of origin and how it is used?**

________________________e.g. raw material for food industry, raw material for other products, as final product for consumption.

10. **Please report the source of information used**

Aquaculture/fisheries/processing by-products & discards valorisation

Part A: Main challenges for implementation of aquaculture/fisheries/processing by-products and discards valorisation in the Mediterranean Sea

-Number of fish landing sites with auction system in your Country (Mediterranean coast) (use √)

• None	
• 1-3	
• 4-10	
• 11-15	
• 16-20	
• More than 20	
• If you know the number, please put it here:	

-Volume of seafood traded in the fish landing sites with auction system in your Country (Mediterranean coast) (use √)

• None	
• up to 10,000 tonnes	
• 10,000 – 20,000 tonnes	
• 20,000 – 40,000 tonnes	
• 40,000 – 60,000 tonnes	
• 60,000 – 80,000 tonnes	
• 80,000 – 100,000 tonnes	
• More than 100,000 tonnes	

• If you know the number, please put it here:

-Please estimate the annual quantities of aquaculture/fisheries/processing by-products and discards in your Country (in tonnes) (use √)

• Coastal segment. No. of vessels (please add the number):…………

Weight of discards: **(use √)**

• 0-100 tonnes per year
• 101-500 tonnes per year
• 501-1000 tonnes per year
• 1001-2000 tonnes per year
• 2001-3000 tonnes per year
• 3001-4000 tonnes per year
• More than 4001 tonnes per year

• Trawlers. No. of vessels (please add the number):…………

Weight of discards: **(use √)**

• 0-100 tonnes per year
• 101-1000 tonnes per year
• 1001-4000 tonnes per year
• 4001-6000 tonnes per year
• 6001-8000 tonnes per year
• 8001-10.000 tonnes per year

- More than 10.001 tonnes per year ☐

- Purse seiners. No. of vessels (please add the number):…………

Weight of discards: **(use √)**

- 0-100 tonnes per year ☐
- 101-500 tonnes per year ☐
- 501-1000 tonnes per year ☐
- 1001-2000 tonnes per year ☐
- 2001-3000 tonnes per year ☐
- 3001-4000 tonnes per year ☐
- More than 4001 tonnes per year ☐

- Aquaculture processing units. Please add the number:…………

Weight of by-products: **(use √)**

- 0-100 tonnes per year ☐
- 101-500 tonnes per year ☐
- 501-1000 tonnes per year ☐
- 1001-2000 tonnes per year ☐
- 2001-3000 tonnes per year ☐
- 3001-4000 tonnes per year ☐
- More than 4001 tonnes per year ☐

- Seafood processing units. Please add the number:…………

Weight of by-products: **(use √)**

• 0-100 tonnes per year	
• 101-500 tonnes per year	
• 501-1000 tonnes per year	
• 1001-2000 tonnes per year	
• 2001-3000 tonnes per year	
• 3001-4000 tonnes per year	
• More than 4001 tonnes per year	

-Apparent consumption of seafood in your Country (in kgr/per capita/per year)

-The seafood consumption in my country (%)

Please add percent and source of information

• Fresh fish	
• Frozen fish	
• Mussels, molluscs (fresh and frozen)	
• Shrimps, crustaceans (fresh and frozen)	
• Can	
• Smoked, salted, processed	

- Other

Source:………………………………………

- Main places where people purchase and consume seafood (%)

Please add percent and source of information

• Super market	
• Fish monger	
• Open markets	
• Restaurant (HORECA)	
• Other (please mention what)	

Source:………………………………………

- Fishing industry's willingness to cooperate for valorisation in my Country:

(use √)

• Excellent	
• Good	
• Average	
• Poor	

-The quantities of aquaculture/fisheries/processing by-products and discards in my Country (use √):

• Are too few and scattered in order to be valorised	
• Are important but scattered in many areas in order to be valorised	
• Are few but could be valorised in some areas	
• Are important but there is no infrastructure to valorise them	
• Not Important	

-Degree of access to finance for blue technologies in my Country (use √):

• Excellent	
• Good	
• Average	
• Poor	
• Very poor	

Part B: Research efforts & type of markets

-Level of research for aquaculture/fisheries/processing by-products and discards valorisation in my Country (use √):

- Excellent ☐
- Good ☐
- Average ☐
- Poor ☐
- Very poor ☐

- Level of cooperation between the Fishing industry and scientists in my Country (use √):

- Excellent ☐
- Good ☐
- Average ☐
- Poor ☐
- Very poor ☐

-If the aquaculture/fisheries/processing by-products and discards will be valorised, the products can be used (use √):

- In activities in my Country ☐
- They will be primarily exported ☐
- They can be used in my Country and for exports also ☐

-Please name activities where the aquaculture/fisheries/processing by-products and discards valorisation could be used (use √ - You may select more than one option):

• In pharmaceuticals	
• In cosmetics	
• As feed additives for animal rearing	
• Human consumption (after processing e.g. surimi, fish burgers, fish sausage etc)	
• Other (please name it)	

Sustainable Integrated Multi-trophic Aquaculture IMTA

1. Do you have any IMTA in your country?

Yes, in commercial scale	
Yes, in pilot scale	
No	

2. If NO, what is the main reason that impede the development of IMTA systems in your country

..
.....

3. If YES

3.1 what is the approach followed?

Open water	
Land Based	
Other	

Other please specify……………………………………………………………………………………

3.2 What organisms are co-cultivated (use X to indicate the combination)

	Combined cultivation					
Main Culture	Fish	Macroalgae	Shellfish	Invertebrates	Sponges	Other
fish						
Macroalgae						
Shellfish						
Inverterbrates						
Sponges						
Other						

4. Does your national legislation impose to the fish farms the monitoring of the nutrient and organic loads level in the water column?

Yes	
No	

N/A ☐

5. Please select the 3 most important factors that:

- **impede the development of IMTA in your country**

1. Complex and long legislative framework for the establishment of IMTA farming	
2. Give raise to stiff objections from local communities practicing monocultures	
3. Conflicts raise when IMTA are placed in fishing areas/ Lack of support from the fishing sector due to indirect competition	
4. Lack of trust for the economic and the ecological benefits of IMTA are still in development stage	
5. Limited knowledge for the establishment of IMTA	
6. Alternative technologies are more cost effective - and as such more attractive for investors.	

Other (please specify)

……

……

- **could boost the development of IMTA in your country**

1. Strong fish farming sector - Highly developed Aquaculture	
2. Funding IMTA systems as nature based solutions for environmental remediation supporting ecosystem goods and services.	
3. Adopt legislation (e.g. tax benefits, exemption from State fees or other financial incentives) to encourage aquaculturists to implement IMTA	
4. Technological development, innovation	
5. Capital cost decrease by co-cultivating different species (diversification of final products)	
6. Awareness of small and medium-sized aquaculture enterprises (SMEs) for the advantages of IMTA implementation (increasing their competitiveness and viability).	

Other please specify

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