Deliverable 3.2

Report on the regional strategies to valuate ecosystem services of the blue bioeconomy, including lessons learnt, overview of techniques, and best practices

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Author(s)	Suzannah-Lynn (Suzi) Billing, Ashley Shaji, Michele Stanley, SAMS
Editor	Alberto Terenzi, SUBMARINER
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Abstract	Deliverable 3.2 outlines the activities and data collection for Task 3.2, focused on reviewing valuation strategies for ecosystem services within the blue bioeconomy. An online questionnaire and scoping review revealed limited evidence for valuation strategies, particularly in sectors beyond research & development. Despite this, the results highlighted critical ecosystem services, emphasising gaps in valuation strategies for specific products.
Keywords	Bluebioclusters, blue bioeconomy, ecosystem services, blue bio value chains, valorisation.

HISTORY OF CHANGES		
Version	**Publication date**	**Changes**
1.0	12.01.2024	Initial version

2.0	30.01.2024	Edited based on internal project reviews

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Acronyms

BBC	Blue Bio Clusters
QSR	Quick Scoping Review
SAMS	Scottish Association for Marine Science
WP	Work Package
KG	Knowledge Gap

Executive summary

This Deliverable (3.2) presents the activities and data collected for Task 3.2, within Work Package 3 of the BBC project: Review valuation strategies for ecosystem services of blue bioeconomy.

This Task was led by SAMS and supported by all BBC project partners. The goal was to generate an extended list of ecosystem services associated with blue bioeconomy activities, aligned with the value chains identified in WP2. The objective also involved evaluating the existing gaps in knowledge regarding ecosystem services and valuation strategies for each biomass in the BBC value chains: bivalves, crustaceans, fish, macroalgae, marine bacteria, and microalgae. An online questionnaire was crafted to gather the absent information and sent out to ecosystem services experts and practitioners working within the blue bioeconomy and across several sectors such as research & development, industry, knowledge exchange and consultancy, and government// policy across Europe.

A Quick Scoping Review, conducted to create the list of ecosystem services across the BBC value chains, revealed a limited evidence base for valuation strategies and variation in methodologies for ecosystem services assessments. The online survey reinforced this finding, showing that very few respondents from across Europe were using any type of ecosystem services valuation strategy and those that were, were from the research & development sector. However, the results provide valuable insight into the ecosystem services that the blue bioeconomy supports, such as the critical provisioning services of food and raw materials, and the cultural services of recreational activities and mental and physical health (linked largely to food). Further, it provides evidence of ecosystem services knowledge gaps, with the overarching gap of valuation strategies for specific products being highlighted as missing across all BBC biomass value chains.

The final section of this deliverable provides two brief case studies of how regional blue bioeconomy strategies can support the sector across various value chains, using pathways for waste reduction, sustainable fuels, and circularity, rather than relying on ecosystem services assessments. This provides an optimistic outlook that progress can be made as the science required to conduct ecosystem services valuation catches up with the rapid expansion of blue bioeconomy industries across Europe.

1 Quick Scoping Review of Ecosystem Services of BBC value chains

Quick Scoping Reviews (QSR) are a systematic approach for conducting literature reviews, providing an overview of an evidence base, rather than a critical appraisal of the evidence (Zhang et al., 2018; Pham et al., 2014). They are not meant to be in-depth but provide enough of an understanding of the research to identify key topics, and knowledge gaps and are particularly useful where resources are limited (Bermejo *et al.*, 2022). The specific aim of the QSR exercise for this task was to establish an evidence-based list of ecosystem services of the blue bioeconomy of the BBC biomass value chains (value chain images can be seen in Annex 1: bivalves, crustaceans, fish, macroalgae, marine bacteria and, microalgae. This list informs a mixed-method survey of experts on the ecosystem services knowledge gaps for the blue bioeconomy across BBC partner countries and further afield, reported on in section 2. In this section, an overview of the QSR method is provided before the list of ecosystem services of the BBC biomass value chains is presented. It also provides a brief reflection on ecosystem services valuation methods, specifically highlighting the push by ecosystem services experts globally to increase the scope of valuation to include more holistic forms of use and knowledge, moving away from sole monetary valuation (IPBES: Pascual *et al.*, 2022).

1.1 Quick Scoping Review method

Two key terms, *Ecosystem Services* and *Blue Bioeconomy,* were used to conduct a preliminary and simultaneous query in *SCOPUS and Wed of Science* with the dates for results set to 2018 to 2023, to ensure any papers included were state of the art. These key terms provided insufficient evidence, which indicated the need for using more keywords to expand the dataset. It was agreed that the dates should remain the same, given the rapid development and focus on the blue bioeconomy sector, particularly over the past five years (Blue Bio Cofund, 2023). Supplementary searches were conducted with more primary and secondary keywords, selected based on the results obtained in the preliminary search and the six BBC biomass value chains. The combination of keywords is provided in Annex 2.

A total of 26,583 original articles published between 2018 to 2023 were identified in the search from both the databases. The data was then compiled together, and duplicates were eliminated. A screening criterion (Table 1) was designed to select the final dataset and 53 papers were selected for the QSR.

Table 1. Criteria for including or excluding papers from the QSR

Exclusion criteria	**Inclusion criteria**
Non-European regions	European region
Wild biomass that is not harvested	Cultivated biomass and wild biomass that is harvested
Laboratory experiments (<100L)	Aquaculture systems (>100L)
Focus on functions	Focus on services
Low TRL methodologies or products	Evaluation of actual services
Optimization of ES valuation techniques of non-BBC biomass value chains (excluding multi-use)	Risk or disservice of use of BBC biomass value chains
Description of associated biodiversity of low trophic aquaculture	Spatial and temporal ecosystem services assessment of BBC biomass value chains
	Studies on the biotic interplay related to seaweed aquaculture

1.2 Ecosystem Services Valuation Methods

Historically, policy and decision-making processes take account of traded goods and services (e.g. value of crops that land will produce) and ignore the services provided by the ecosystems that are fundamental to life on earth and human wellbeing (UK National Ecosystem Services Assessment, 2014). Since the mid-1990's valuation of ecosystem services has increasingly been looked to as a means to enable decision-makers to place a value on the changes in ecosystem services that are not currently captured by markets or policy tools (Díaz *et al.*, 2018).

Over the past two decades, there has been a significant increase in the diversity and methods for valuing ecosystem services, particularly from a market-based perspective (Maes *et al.*, 2021). However, there is tension between schools of thought on how to incorporate non-market values within assessments to ensure a holistic understanding of the services provided by our ecosystems and their benefits to humans (Pascual *et al.*, 2022).

The Millenium Ecosystem Assessment (2005), initiated by the United Nations in 2001, concluding in 2005, aimed to *"assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being."* (Millenium Ecosystem Assessment, 2005). The Millennium Ecosystem Assessment (MA, 2005) was a landmark in ecosystem service research, which indicated that human well-being is dependent on ecosystems and such linkages can be elucidated through the concept of ecosystem services. The Economics of Ecosystem and Biodiversity, hosted by the United Nations Environment Programme, defined ecosystem services as the *"direct and indirect contributions of ecosystems to human well-being"* (De Groot et al., 2012). This broad definition and call to action has been dominated by natural sciences and economics, resulting in much of the conceptualisation and practical work on ecosystem services taking a "production and function" and monetary valuation approach (Díaz *et al.*, 2018).

Despite this leap in understanding, the narrow range of stakeholders, experiences, and knowledge involved in developing these tools, and the subsequent uptake by policy, has resulted in the exclusion and voluntary self-exclusion of stakeholders, disciplines and worldviews, particularly local practitioners, social sciences and humanities and indigenous peoples (Díaz et al., 2018). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services is a global effort to address this challenge, recognising that ecosystem services, or rather, nature's contributions to people conceptualisation and valuation, should include a broad set of viewpoints and knowledge types (Pascual et al., 2022). The EU's Ecosystem Assessment provides a high-level conceptual framework for integrating

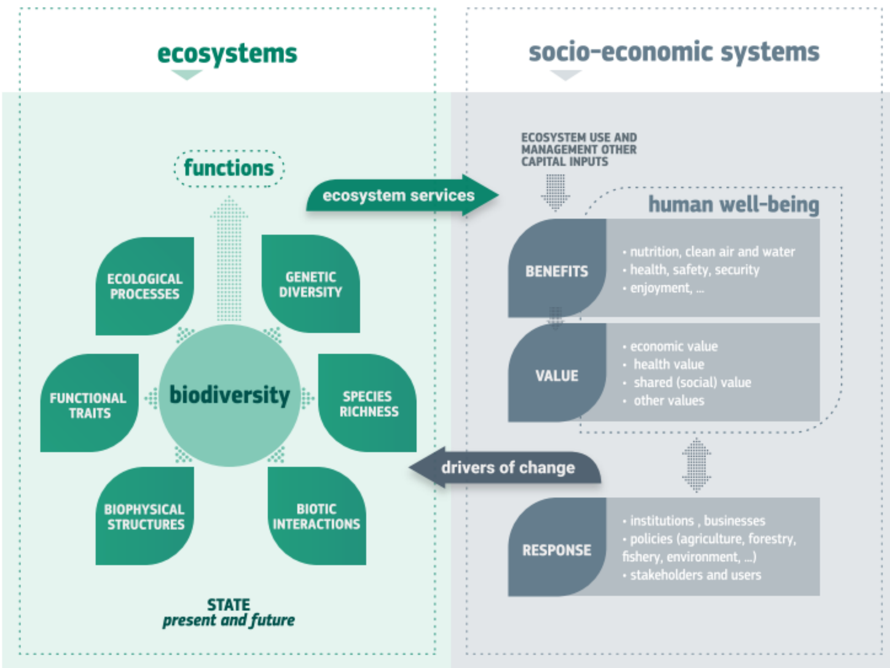

Figure 1. EU Ecosystem Assessment conceptual framework for assessment of ecosystem services (Maes et al., 2021)

ecosystems and ecosystem services with socio-economic systems, benefits and values for humans. This includes valuation methods outside of economic mechanisms, as seen in figure 1 (Maes et al., 2021). As the value of the blue bioeconomy to the EU increases, it is vital that the ecosystem services, and disservices of the value chains, are assessed from a holistic perspective. In order to do this, there needs to be an evidence base of the knowledge currently available on ecosystem services of the blue bioeconomy value chains and their valuation methods.

1.3 List of Ecosystem Services of BBC Value Chains

This section provides a summary (Table 2) of the ecosystem services of the BBC biomass value chains found in the 53 papers reviewed in the QSR. This list was also used in the online survey of experts described in section 2.

Table 2. List of ecosystem services provided by the blue bioeconomy from the BBC biomass value chains, derived from the QSR, where "●" shows ecosystem services the value chains contribute to.

Ecosystem Services	BBC value chain					
	Bivalves	Crustaceans	Fish	Macroalgae	Marine bacteria	Microalgae
Provisioning						
Food	●	●	●	●	●	●
Raw materials	●	●	●	●		●
Medicinal resources		●		●	●	●
Regulating						
Water filtration and nutrient assimilation	●			●		●
Coastal protection	●			●		
Carbon sequestration and storage	●					
Biochemical cycling	●			●		
Biological control				●		
Supporting						
Habitat protection and maintenance	●			●		
Maintenance of genetic diversity	●					
Sediment creation						
Water cycling	●					
Oxygen production				●		●
Cultural						
Recreational activities and mental and physical health	●	●	●	●	●	●
Tourism and ecotourism		●				
Sense of place and spiritual connection			●	●		
Aesthetic and spiritual appreciation and inspiration for culture, art, and design			●			

2 Identifying Ecosystem Services knowledge gaps through an online survey

This section presents the methods and results of an online survey of experts on the ecosystem services of the BBC blue bioeconomy value chains. There is currently limited assessment and valuation of ecosystem services within the EU (Maes *et al.*, 2021), let alone valuation of the ecosystem services (and disservices) of the EU's rapidly increasing blue bioeconomy (Blue Bio Cofund, 2023; EUMOFA, 2023). Understanding the ecosystem services of the sector could improve the likelihood of the sector contributing to the transition to a lower carbon economy, and may also provide mechanisms for increasing efficiency, reducing waste, and creating higher value, potentially more marketable products based on environmental credentials, and increased confidence in the sector by society-at-large, consumers and local stakeholders (Blue Bio Cofund, 2023). To increase the evidence base for the sector on ecosystem services, understanding the current use of ecosystem services assessments, and critically, the knowledge gaps in the sector, an online survey of blue bioeconomy experts was conducted in 2023. The survey was designed to answer the following four research questions:

1. What are the key ecosystem services of the EU blue bioeconomy?
2. What are the key ecosystem services knowledge gaps of the EU blue bioeconomy?
3. Has the blue bioeconomy adopted ecosystem services valuation, and if so, which methods are used?
4. What are the differences/ similarities between the value chains?

2.1 Online survey method

Using the ecosystem services list derived through the QSR, a survey was developed to elicit an understanding of the ecosystem services knowledge gaps for the BBC project countries and across each BBC biomass value chains. As the QSR, and discussions with project partners showed that the evidence base for assessing the ecosystem services and valuation strategies of the blue bioeconomy in Europe is limited, the survey was designed to be completed by experts in ecosystem services, and practitioners in the blue bioeconomy. This was to increase the likelihood of complete responses, and ensure data on the state of the art, rather than general opinion (Bryman, 2012). The cost of this purposive sampling approach is that the data are non-generalisable and analysis is limited to descriptive statistics supported by qualitative narrative (Bryman, 2012).

The survey was drafted in May 2023, receiving two rounds of comments and changes from BBC project partners before it was piloted in June 2023 with seven knowledgeable participants in SAMS network. Both the pilot and the live survey were hosted on an ethically approved and GDPR compliant survey platform, JISC Online Surveys.

The survey was then distributed via a unique link, to the BBC project partners via email and the BBC project Teams hosted by the project lead Submariner Network, which the project partners have access to. Each BBC partner then distributed the survey link to their expert and practitioner stakeholders. The survey was open for 10 weeks between the 14th September and the 24th November 2023.

The survey included 12 questions, most of which were ranking or choice selection question with an option for free text to add information. Drop-down lists of ecosystem services (17), ecosystem services knowledge gaps (14), and potential impacts of value chains (eight) were provided to a) ensure use of the same ecosystem services language across the participants, aiding analysis, b) to ground the responses in the evidence already provided in the literature and, c) reduce the burden of time filling out the survey. The survey was split across four pages, as can be seen in figure 3. The estimated time for completing the survey was approximately 20 mins. The full survey can be found in Annex 3, below are the survey questions:

1. What sector do you work in, in the blue bioeconomy? If it is not listed, please choose "other" and type in your sector in question 1a.
    a. If you selected Other, please specify:
2. Which country is your main place of work? If it is not listed, please choose “other” and type the country in question 2a.
    a. If you selected Other, please specify:
3. What blue bioeconomy value chain do you work with the most? Please look at this PDF of value chains and choose the closest matching biomass for your value chain. If it is not listed, please choose “other” and type in your value chain.
    a. If you selected Other, please specify:
4. Please select the three most important Ecosystem Services for the biomass you selected in question 1 (where 1 is the most important, 2 is slightly less important than 1, and 3 is less important than 1 and slightly less important than 2).
5. Are there other ecosystem services for the biomass value chain that you chose in question 1? If so, please describe them below using the broad ecosystem services categories (provisioning, regulating, supporting, cultural) before providing the detail (e.g. regulating; biological control of diseases).
6. Please choose the three most important Ecosystem Services knowledge gaps for the value chain you selected in question 1 (where 1 is the most important, 2 is slightly less important than 1, and 3 is less important than 1 and slightly less important than 2).
7. Are there are other ecosystem services knowledge gaps for the biomass value chain that you chose in question 1? If so, please describe them below using the broad ecosystem services categories (provisioning, regulating, supporting, cultural) before providing the detail.
8. Please list the three most critical negative impacts of the biomass you selected in question 1 (where 1 is the most important, 2 is slightly less important than 1, and 3 is less important than 1 and slightly less important than 2).
9. Are there are other negative impacts for the biomass value chain that you chose in question 1? If so, please describe them below.
10. Do you currently use an Ecosystem Services valuation strategy for your value chain (e.g. market valuation methods, revealed preference methods, cost methods, deliberative and participatory methods, etc.)?
    a. If you selected Yes, please add more details and links to more information, if possible:
11. Please describe any lessons on Ecosystem Services and their valuation from other sectors that have been useful to the value chain that you selected in question 1.

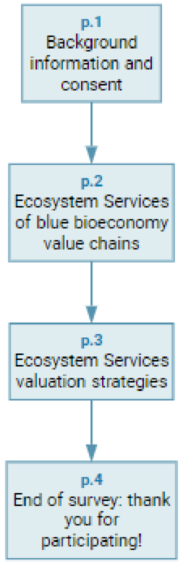

Figure 2. Schematic of the online survey pages and layout.

12. Have we missed anything? Please add more details below.

The survey results were downloaded from JISC Online Survey platform in a cvs. format and analysed using MS Excel. The data could be analysed through several filters, for example by country, sector, biomass, ecosystem services type etc. In the interest of resources and time, and in particular, to answer the research questions presented at the start of section 2, the data was analysed in depth, according to BBC value chains. A brief analysis of the overall results for ecosystem services and knowledge gaps was also conducted.

2.2 Online survey results

This section provides an overview of the results of the online survey including a brief analysis of the responses by sector and country and in-depth analysis of the BBC biomass value chains represented in the responses. It also presents the key ecosystem services of each value chain according to the participants, and critically, identifies ecosystem services knowledge gaps of the value chains.

The survey received a total of 47 responses, from across all of the BBC project partner countries (Figure 4). Responses were split as follows: Portugal (24%), Belgium (21%), Lithuania, Sweden and Scotland (11%), Norway and France (4%), Estonia, Iceland and Germany (2%). There was also representation from Italy, Denmark, the Faroe Islands, and Israel under the Other Countries category (8%). Most of the respondents were from the Research & Development category (48%), followed closely by Industry and Consultants/ Industry Knowledge Transfer at 24% and 22% respectively. The category of Government received only two responses (4%). There were originally four respondents who chose the category of Other and typed in their sector, which included *'municipal network'*, and *'aquaculture'.* These were re-categorised into Government and Industry, leaving two in the Other category (4%), describing their sectors as *'business support',* and *'sectoral association'.*

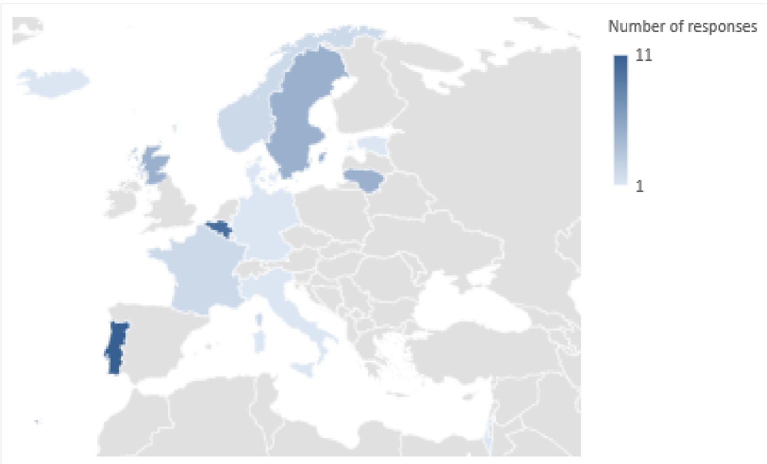

Figure 3. Location of survey responses across the European Union and beyond.

The survey received the most responses for the BBC biomass value chain of Fish (34%), followed by Bivalves (21%), Microalgae (17%), Macroalgae (13%), Crustaceans (6%), and Marine bacteria (3%). The category of Other received three responses (6%), where the participants typed in the value chain they most worked with, including *'blue carbon', 'marine modelling',* and *'all blue economy sectors'*. A summary of all of this information can be found in Table 3.

Table 3. Summary of the number of survey responses by country, sector, and BBC biomass value chains.

Country	Sector	BBC Biomass	Number of Responses
Portugal	Consultants/ Industry Knowledge Transfer	Fish	1
	Industry	Fish	2
		Bivalves	1
		Macroalgae	2
		Microalgae	1
		Marine bacteria	1
	Research & Development	Microalgae	1
	Other	Fish	1
		Microalgae	1
			11
Belgium	Research & Development	Microalgae	2
		Fish	1
		Crustaceans	1
		Bivalves	1
	Consultants/ Industry Knowledge Transfer	Other	2
		Bivalves	2
		Fish	1
			10
Lithuania	Research & Development	Fish	3
	Consultants/ Industry Knowledge Transfer	Crustaceans	2
			5
Scotland	Research & Development	Bivalves	2
		Fish	2
		Microalgae	1
			5
Sweden	Industry	Bivalves	1
	Research & Development	Fish	1
	Government	Fish	1
	Consultants/ Industry Knowledge Transfer	Bivalves	1
	Other	Fish	1
			5
Norway	Research & Development	Microalgae	1
		Fish	1
			2
France	Research & Development	Other	1
		Macroalgae	1
			2
Iceland	Consultants/ Industry Knowledge Transfer	Fish	1
Estonia	Research & Development	Bivalves	1
Germany	Industry	Macroalgae	1
Italy	Industry	Microalgae	1
Denmark	Other	Bivalves	1
Faroe Islands	Research & Development	Macroalgae	1
Israel	Research & Development	Macroalgae	1
TOTAL RESPONSES: 47			

2.2.1 Overview of ecosystem services, knowledge gaps, and valuation methods

This section provides descriptive statistics on all of the data collected on the ecosystem services, knowledge gaps, and valuation methods that participants provided in the survey. Following on from this section, the results are presented for each BBC biomass value chain (sections 2.2.2 to 2.2.7).

There were 17 ecosystem services options for respondents to rank in order of importance (one being the most important and three being less important than one and two), for question four. The provisioning service of food was ranked as the most important ecosystem service by most respondents (n=25). This was followed by a joint ranking of the provisioning services of raw materials and food as the second most important (n=8 each), and the third most important was also considered to be the provisioning service of raw materials (n=7). The other ecosystem services that received a notable number of votes included the regulating services of water filtration and nutrient assimilation (n=7, ranked second most important), and the supporting services of habitat protection and maintenance (n=7, ranked third most important). The cultural ecosystem services of aesthetic and spiritual appreciation and inspiration for culture, art, and design and sense of place, were the only ecosystem services options that received no votes. An overview of all of the ecosystem services rankings can be seen in Figure 6.

There were 14 ecosystem services knowledge gaps for respondents to rank in order of importance for question six. There was a joint ranking of the knowledge gap of influence of climate change on food webs and habitats for the value chain, and the overarching knowledge gap of life-cycle analysis of the value chain as the most important (n=8 each). The overarching knowledge gap of life cycle analysis of the value chain was ranked as the second most important by the most respondents (n=9). The overarching knowledge gap of integration of valuation approaches/ strategies was ranked third by the most respondents (n=11). An overview of all of the knowledge gap rankings can be seen in Figure 7.

Survey question eight asked respondents to rank the three most critical negative aspects of their selected value chain. There were eight options, of which conflict with other marine users and lack of social acceptability was ranked the most critical negative impact by the most respondents (n=14). N=7 respondents also ranked it as the second most important. The option with the most ranks for third was negative impacts on water quality (n=8). An overview of all of the negative aspects of the value chains can be seen in Figure 8.

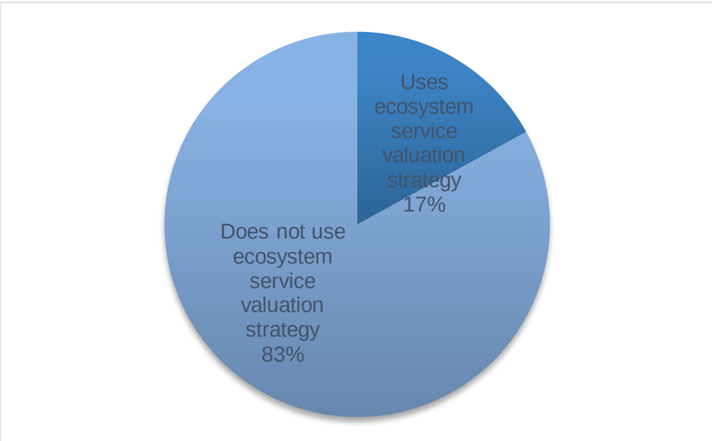

Figure 4. Percentage of respondents who do and do not use ecosystem services valuation strategies for their selected value chains.

Question 10 asked respondents if they currently use an ecosystem services valuation strategy for their value chain, and provided some examples of valuation methods (market valuation, revealed preference valuation etc.) Most responded that they do not use any ecosystem services valuation (see Figure 5), and of the eight that do, seven were from the research & development sector and one from industry. The response from industry stated that they used “eco-design”. Although this is an established method to achieve sustainability for infrastructure, as far as the authors are aware, it does not currently encompass ecosystem service valuation strategies or methods (European Commission, 2022). The two responses from the research & development sector noted that they were using market valuation for the ecosystem services of marine microalgae cultivation. The rest did not provide details on what type of valuation methods they were using.

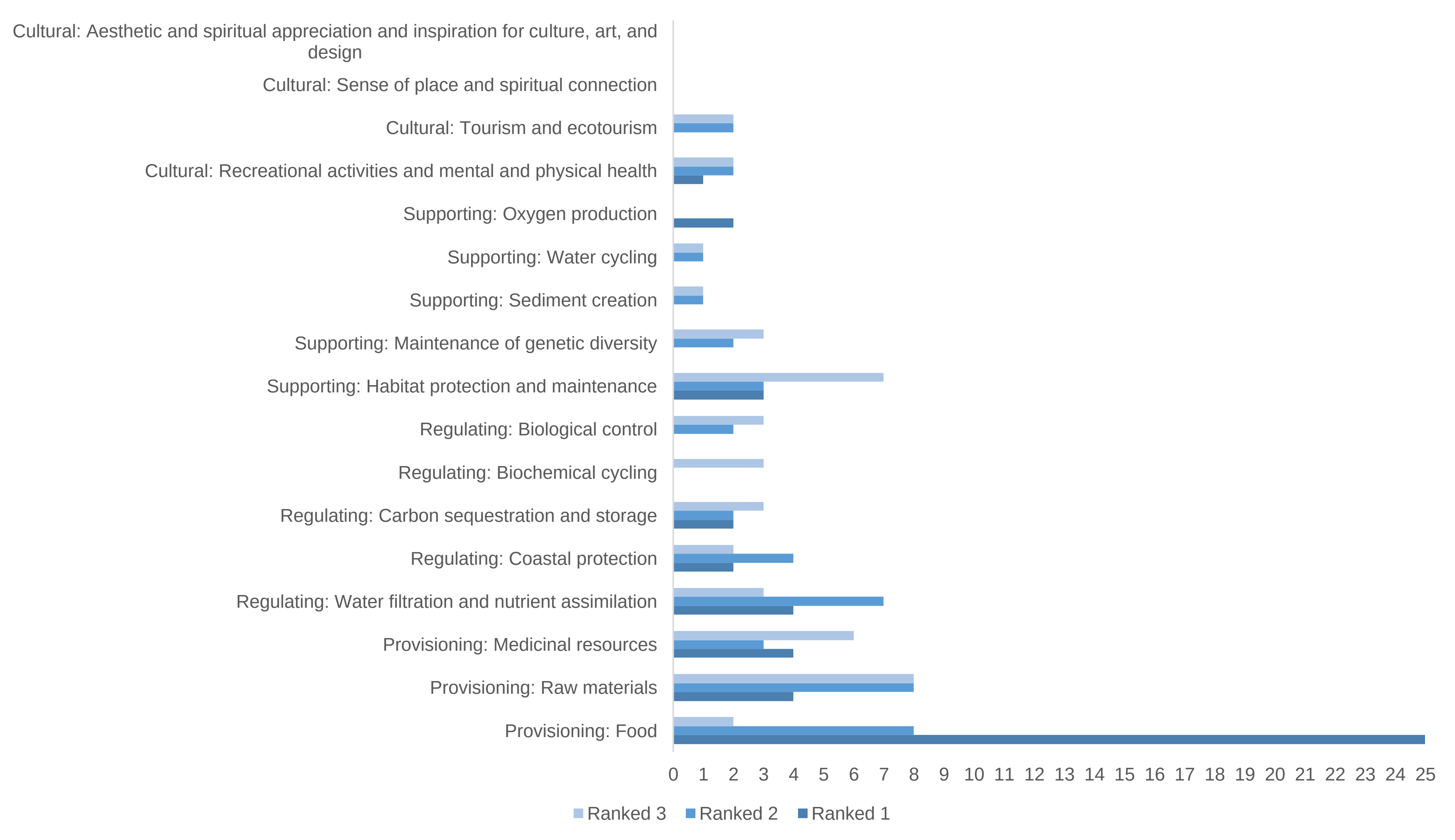

Figure 5. Responses to survey question four asking participants to rank the three most important ecosystem services of their selected value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

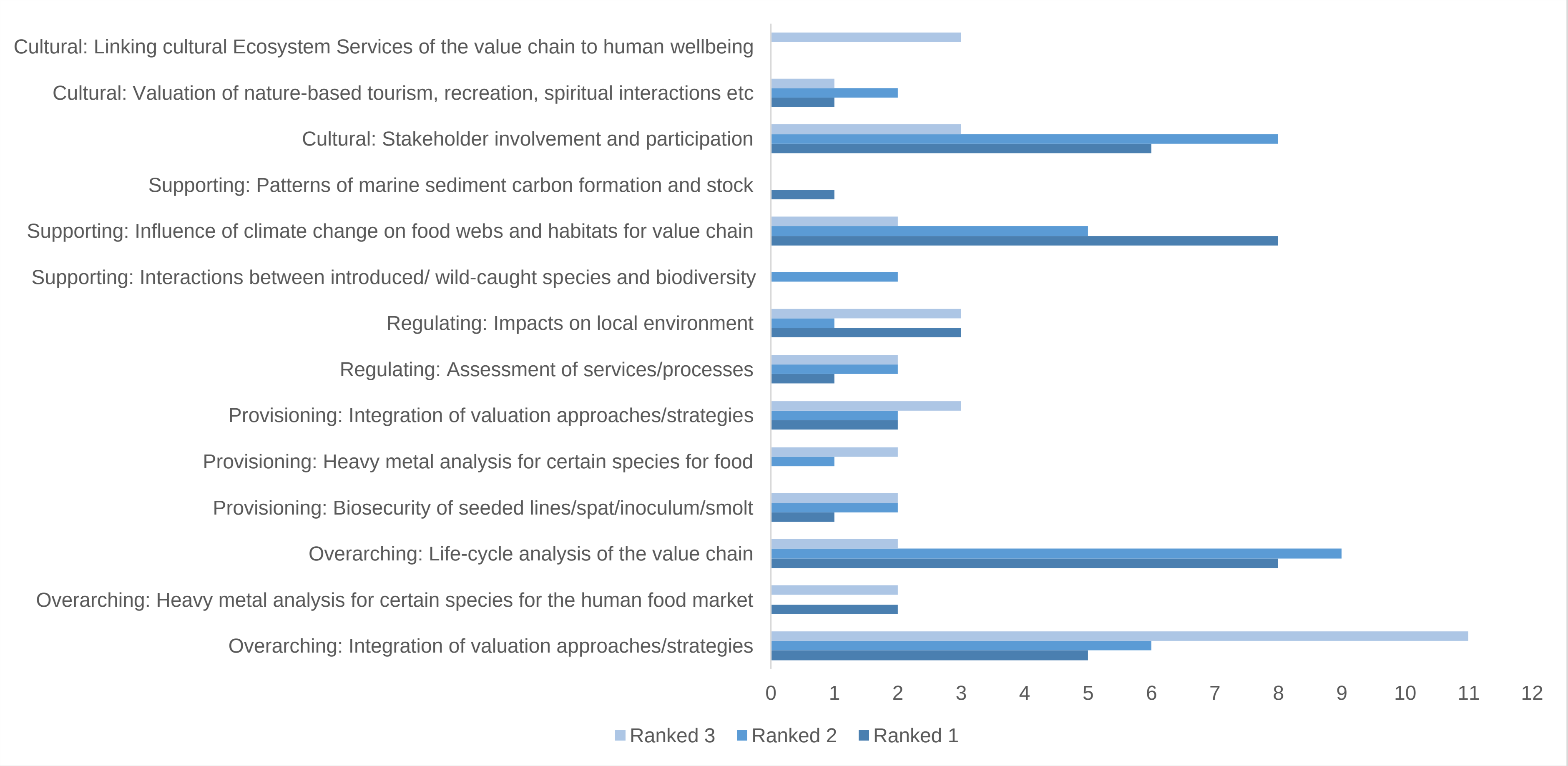

Figure 6. Responses to survey question six, asking participants to rank the three most important ecosystem services knowledge gaps of their selected value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

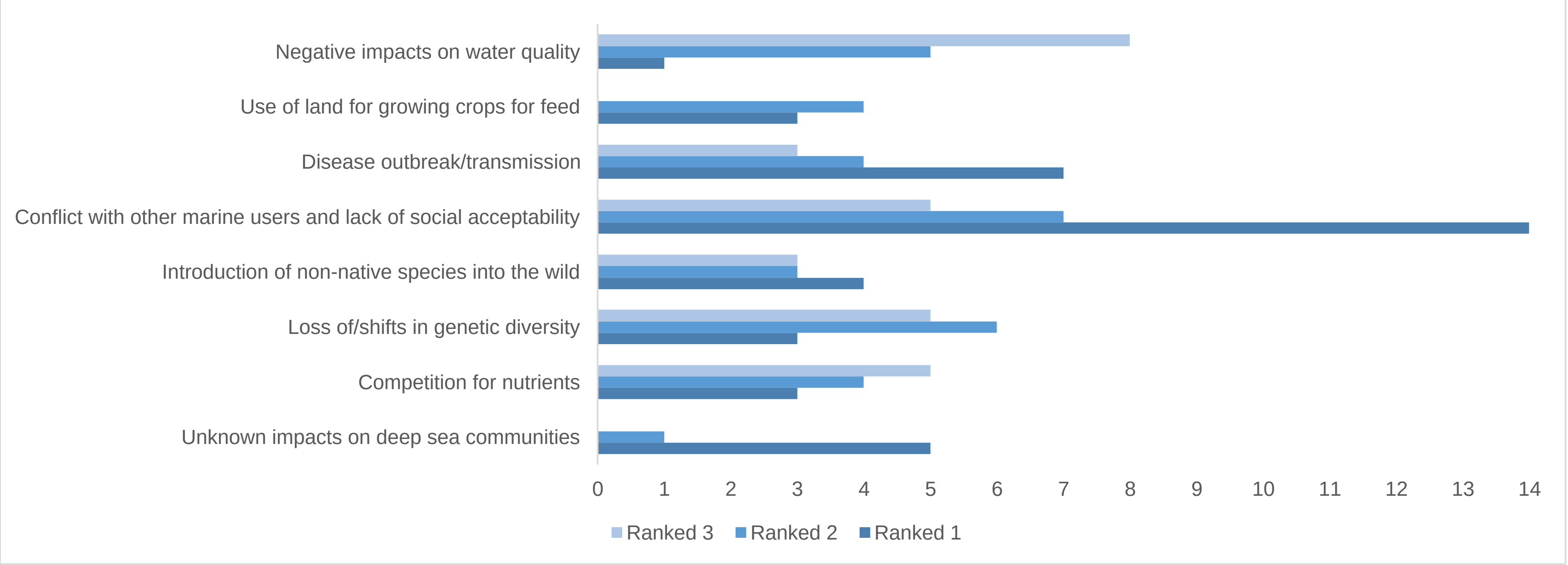

Figure 7. Responses to survey question eight asking participants to rank the three most critical negative aspects of their selected value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

2.2.2. Bivalves

There were 10 responses for the BBC biomass value chain of Bivalves, distributed across the BBC partner countries and sectors as is summarised in Table 4. When asked to rank the three most important ecosystem services of the bivalve value chain from a drop-down list in survey question four, the provisioning service of food was ranked as the most important (n=7), the regulating services of water filtration and nutrient assimilation were ranked second (n=3) and, the supporting services of habitat protection and creating were ranked as the third most important (n=4). Question five provided respondents the opportunity to list additional ecosystem services that were not ranked. These included *'biodiversity', 'provisioning: raw materials, regulating: coastal protection, supporting: maintenance of genetic diversity, cultural: tourism and ecotourism', 'supporting: habitat protection and maintenance',* and *'bio control FAVV monitoring'.* This last response was specifically about Belgian food standards. Figure 9 provides an overview of all of the rankings from all of the responses for the bivalve value chain.

When asked to rank the three most important ecosystem services knowledge gaps of the bivalve value chain from a drop-down list in survey question six, there was a joint ranking of the cultural ecosystem services of stakeholder involvement and participation (n=2) and the overarching knowledge gap of valuation strategies for specific products (n=2). The second most important knowledge gap was also the cultural ecosystem services of stakeholder involvement and participation (n=3), the third most important was the cultural ecosystem services of the value chain to human wellbeing (n=3). Question six provided respondents the opportunity to list additional ecosystem services knowledge gaps that were not ranked. These included *'regulating: assessment of services/ processes, supporting: influence of climate change on food webs and habitats for value chain, supporting: patterns of marine sediment carbon formation and stock,* and *'(blue) algae blooms in near/ offshore conditions'.* Figure 10 provides an overview of all of the rankings of the responses for the bivalve value chain.

When asked to rank the three most critical negative aspects of bivalve value chains in survey question eight, conflict with other marine users and lack of social acceptability was ranked as the most important by n=4 respondents and as the third most important by n=3 respondents. Competition for nutrients was ranked as the second most important negative aspect (n=3). Figure 11 provides and overview of the rankings of the responses for the bivalve value chain for this question.

The last three questions (10-12) provided respondents with the opportunity to add more information on the ecosystem services valuations they may be using, lessons learned from other sectors, and any further information they may want to provide. There were only two responses on ecosystem services valuation, one from industry noted *'We are just starting to do it [ecosystem services valuation]. We do not yet have the variables that we need to include.'* Suggesting that they are right at the start of the process. The second response was from research and development noting that they use *'ecodesign'*. Within the EU, this suggests that the product aims to follow requirements related to energy, resource efficiency, carbon and environmental footprints, and circularity, among others. This is a broad term, that does not currently have legislation associated with its use, as it does for energy use within buildings, for example (e.g. EU Directive 2009/125/EC) (European Commission, 2022). However, within literature 'ecodeisgn' focuses on production and service provision which has circularity thinking at its centre (Sierra-Pérez *et al.*, 2021). Thus, only two of respondents were thinking about ecosystem services valuation for the value chain, and neither were using established methodologies.

Table 4. Summary of the sector and countries represented by respondents for the BBC biomass value chain of bivalves.

Sector	**Country**
Consultants/ Industry Knowledge Transfer	Belgium
Consultants/ Industry Knowledge Transfer	Belgium
Research & Development	Belgium
Research & Development	Scotland
Research & Development	Scotland
Consultants/ Industry Knowledge Transfer	Sweden
Industry	Sweden
Industry	Portugal
Research & Development	Estonia
Other (Business support)	Denmark

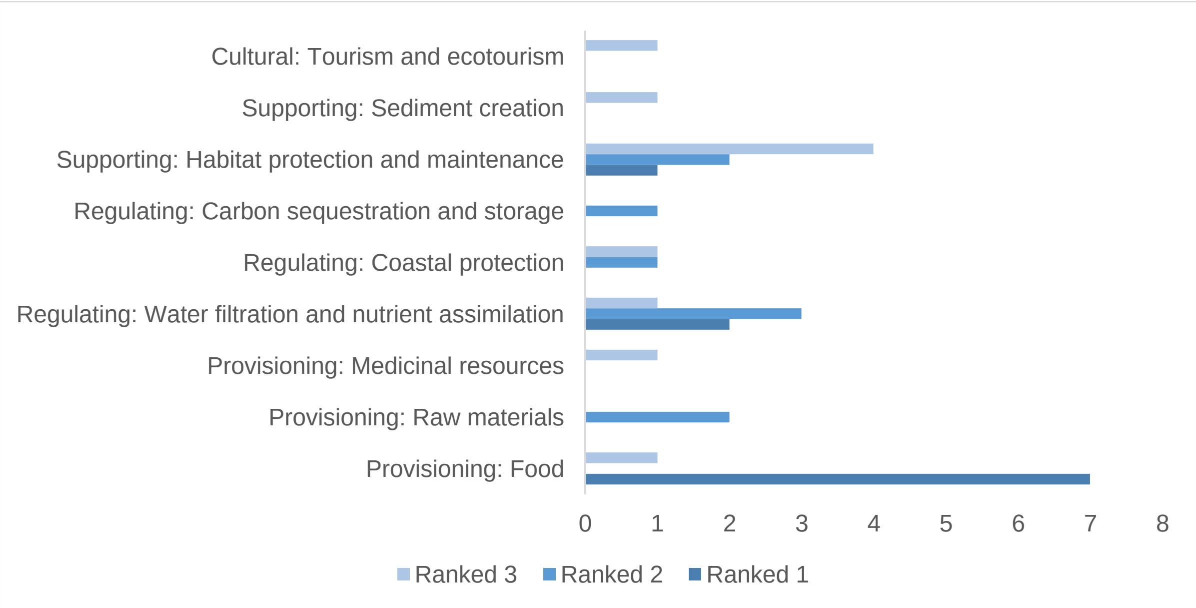

Figure 8. Responses to survey question four asking participants to rank the three most important ecosystem services of bivalves value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

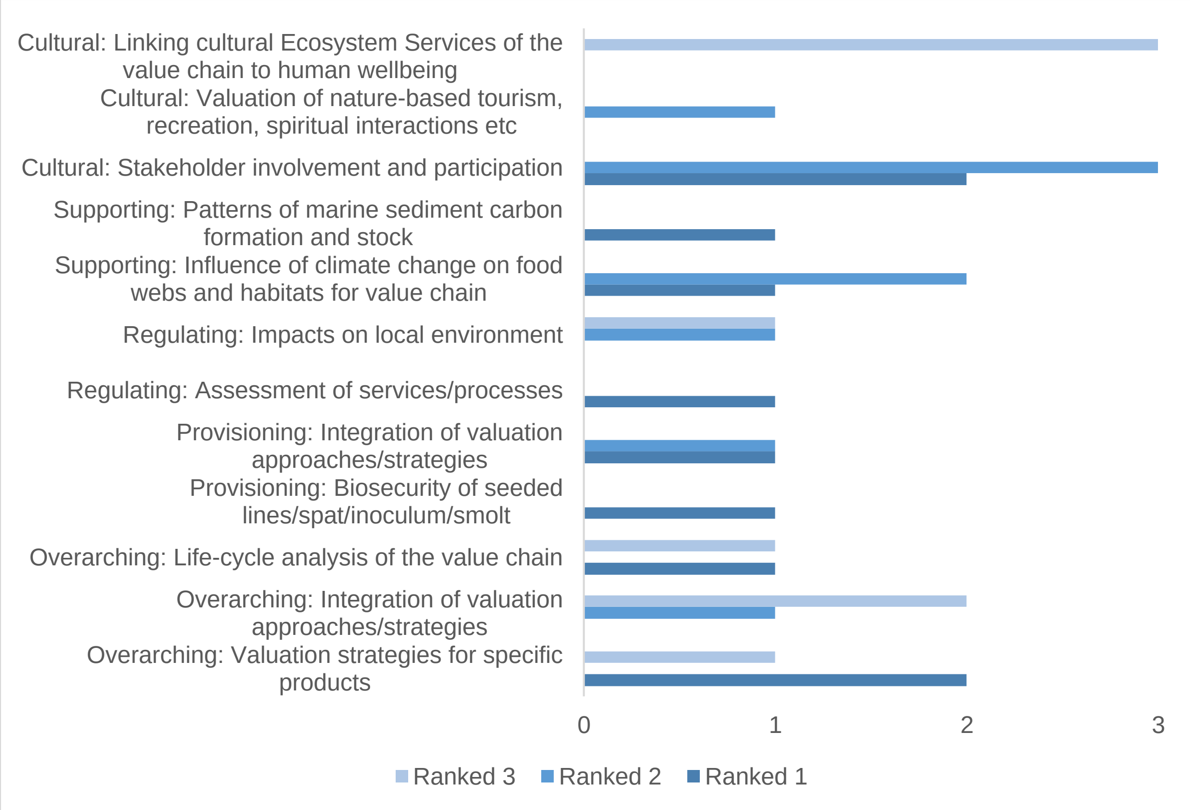

Figure 9. Responses to survey question six asking participants to rank the three most important ecosystem services knowledge gaps of bivalves value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

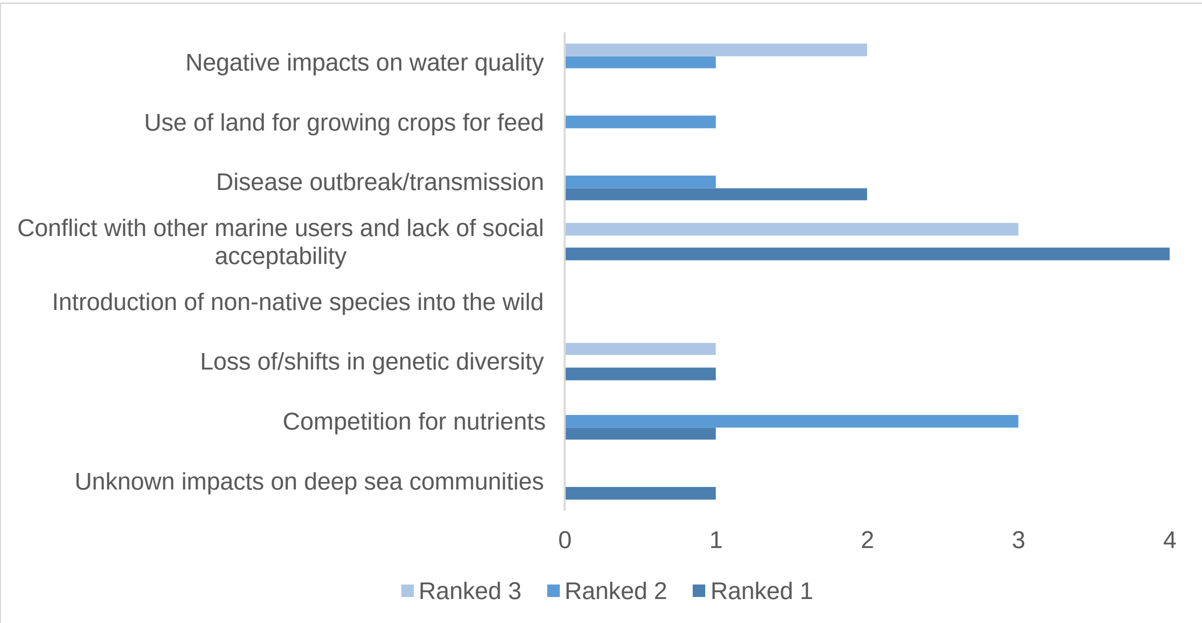

Figure 10. Responses to survey question eight asking participants to rank the three most critical negative aspects of bivalves value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

2.2.3 Crustaceans

There were three responses for the crustacean category, two from Lithuania (Consultants/ Industry Knowledge Exchange and Research & Development) and one from Belgium

(Research & Development). In response to survey question four, on ranking the top three ecosystem services of the biomass value chain from a drop-down list, food was ranked highest by all participants working in crustacean value chains. The ecosystem services ranked second and third included the supporting services of habitat protection and maintenance, the regulating services of coastal protection, and the provisioning services of raw materials and medicinal resources. An overview of the ranking can be seen in Figure 12.

In response to question six, requesting participants to rank the most important ecosystem services knowledge gaps for crustaceans, there was no consensus between respondents with all of them choosing different categories. These can be seen in Figure 13. However, two respondents chose the overarching category of integration of valuation approaches and strategies ranking them as the most important (1) and the third most important (3) knowledge gap.

When asked to rank the three most critical negative aspects of the value chain, respondents for crustacean value chains ranked disease outbreak and transmission as the most critical (n=2), followed by negative impacts on water quality (n=2). Conflict with other marine users and lack of social acceptability and competition for nutrients received one vote each ranked at second and third respectively. Figure 14 provides and overview.

The last three questions (10-12) provided respondents with the opportunity to add more information on the ecosystem services valuations they may be using, lessons learned from other sectors, and any further information they may want to provide. None of the respondents are using ecosystem services valuation methods, and there were no further responses for the other questions.

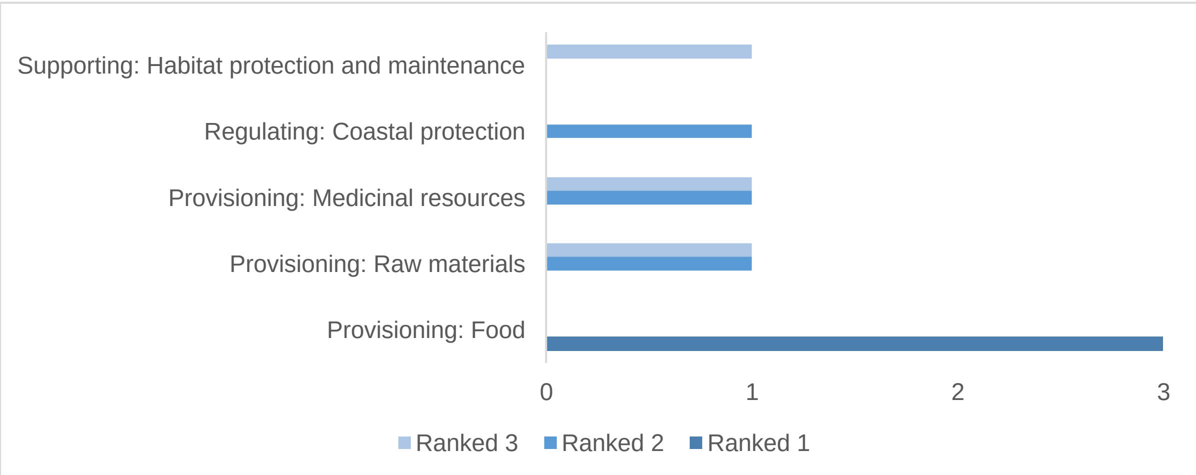

Figure 11. Responses to survey question four, asking participants to rank the three most important ecosystem services of crustacean value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

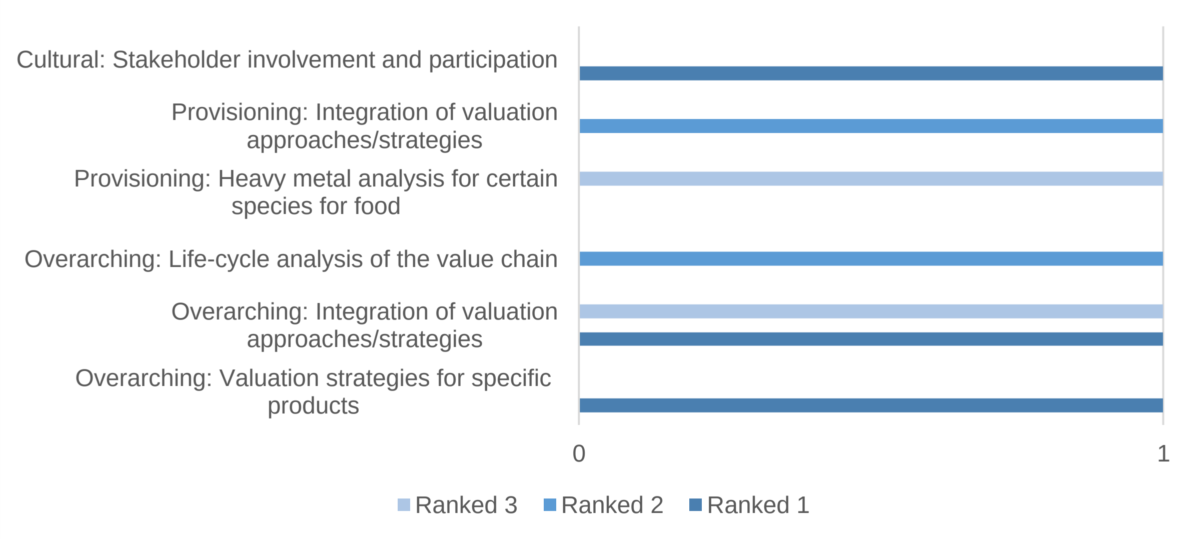

Figure 12. Responses to survey question six, asking participants to rank the three most important ecosystem services knowledge gaps of crustacean value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

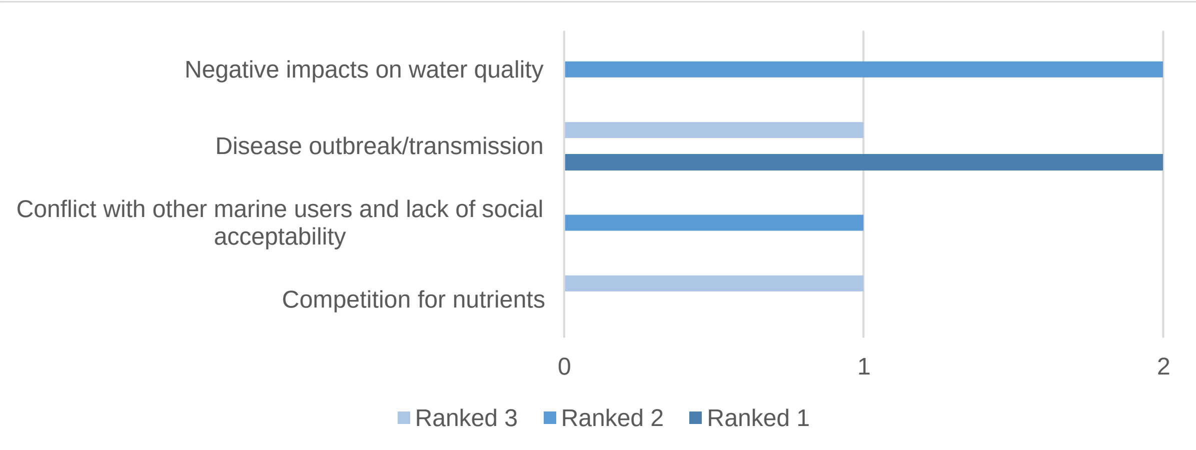

Figure 13. Responses to survey question eight asking participants to rank the three most critical negative aspects of crustaceans value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

2.2.4 Fish

There were 16 responses for the BBC biomass value chain of fish. Eight were working in Research & Development, four were Consultants/ Industry Knowledge Transfer, three from Industry, and two from Government. Table 5 provides an overview of the category and country of respondents.

When asked to rank the ecosystem services of fish value chains in survey question four, the provisioning service of food was ranked as the most important (n=12), followed by the provisioning service of raw materials, ranked as both second (n=5) and third (n=5) most important. A summary of the results for question four can be seen in Figure 15.

Responses to question six, asking participants to rank their top three most important ecosystem services knowledge gaps, the supporting services of influence of climate change on food webs and habitats was ranked the highest (n=5), followed by the overarching knowledge gaps of life cycle analysis of the value chains (n=4), and integration of valuation approaches and strategies. An overview of the rankings can be seen in Figure 16.

When asked to rank the three most critical negative aspects of the value chain, respondents chose conflict with other marine users and lack of social acceptability as the most critical (n=5), joint second rank for the same as loss of/ shifts in genetic diversity (n=3), and a shared third rank across several negative aspects as can be seen in Figure 17.

The last three questions (10-12) provided respondents with the opportunity to add more information on the ecosystem services valuations they may be using, lessons learned from other sectors, and any further information they may want to provide. Only two respondents stated that they were using ecosystem services valuation methods/strategies, both from the Research & Development category and Lithuania. They did not provide any information on which valuation method/ strategy they were using. There were four comments about additional negative impacts, not included in the drop-down list. Three out of these related to negative impacts to habitats or species such as wintering birds, marine mammals, and the seabed in general. One comment was related to climate change in general but provided no further specificities. There were no lessons learned from other sectors, however there was a comment suggesting that for aquaculture *'R&D can help improve our production, in terms of animal welfare and growth performance.'* Finally, one comment advised that there is very little evidence base for ecosystem services in the Icelandic region, making it challenging to conduct valuation activities.

Table 5. Summary of the sector and countries represented by respondents for the BBC biomass value chain of fish.

Sector	Country
Research & Development (R&D)	Lithuania
Research & Development (R&D)	Lithuania
Research & Development (R&D)	Lithuania
Industry	Portugal
Industry	Portugal
Industry	Portugal
Consultants/ Industry Knowledge Transfer	Portugal
Consultants/ Industry Knowledge Transfer	Belgium
Research & Development (R&D)	Belgium
Research & Development (R&D)	Scotland
Research & Development (R&D)	Scotland
Government	Sweden
Government	Sweden
Research & Development (R&D)	Sweden
Research & Development (R&D)	Norway
Consultants/ Industry Knowledge Transfer	Iceland

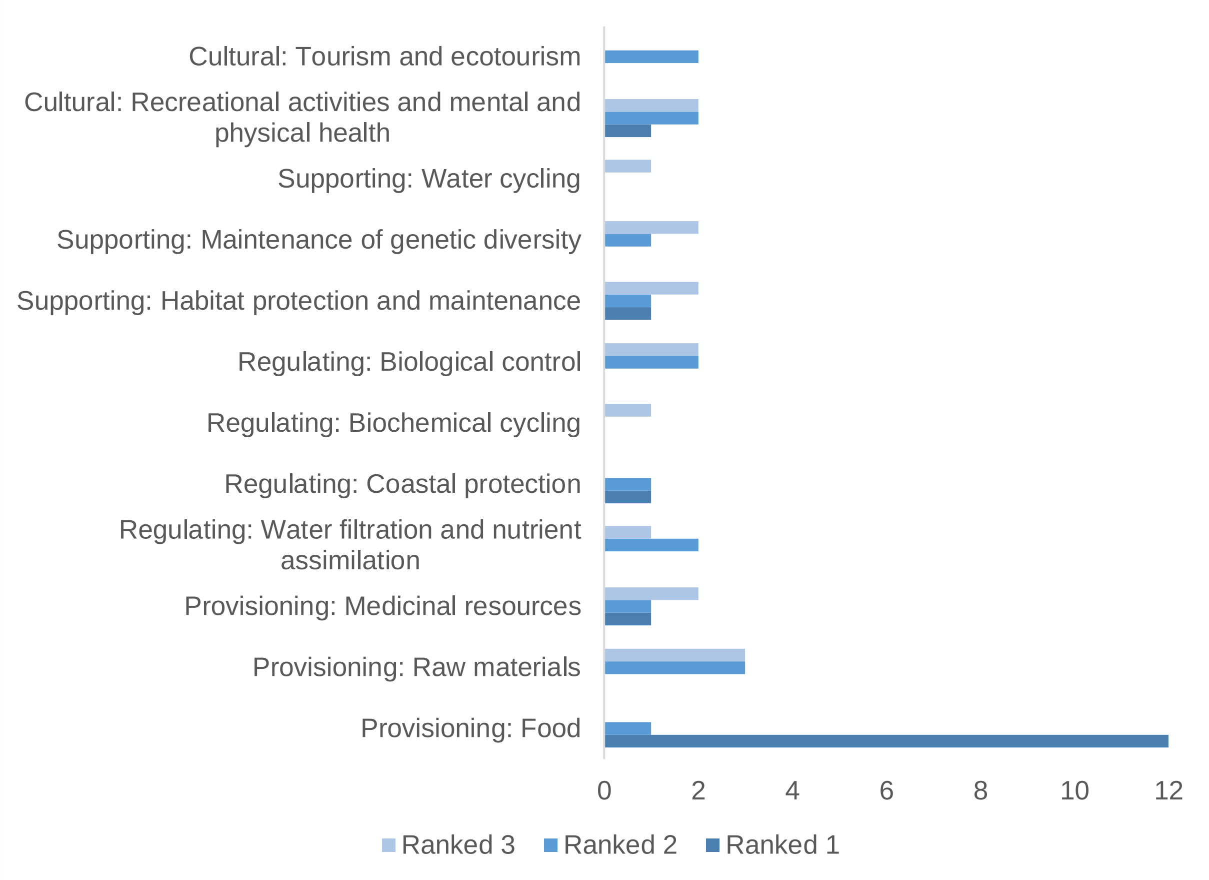

Figure 14. Responses to survey question four, asking participants to rank the three most important ecosystem services of fish value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

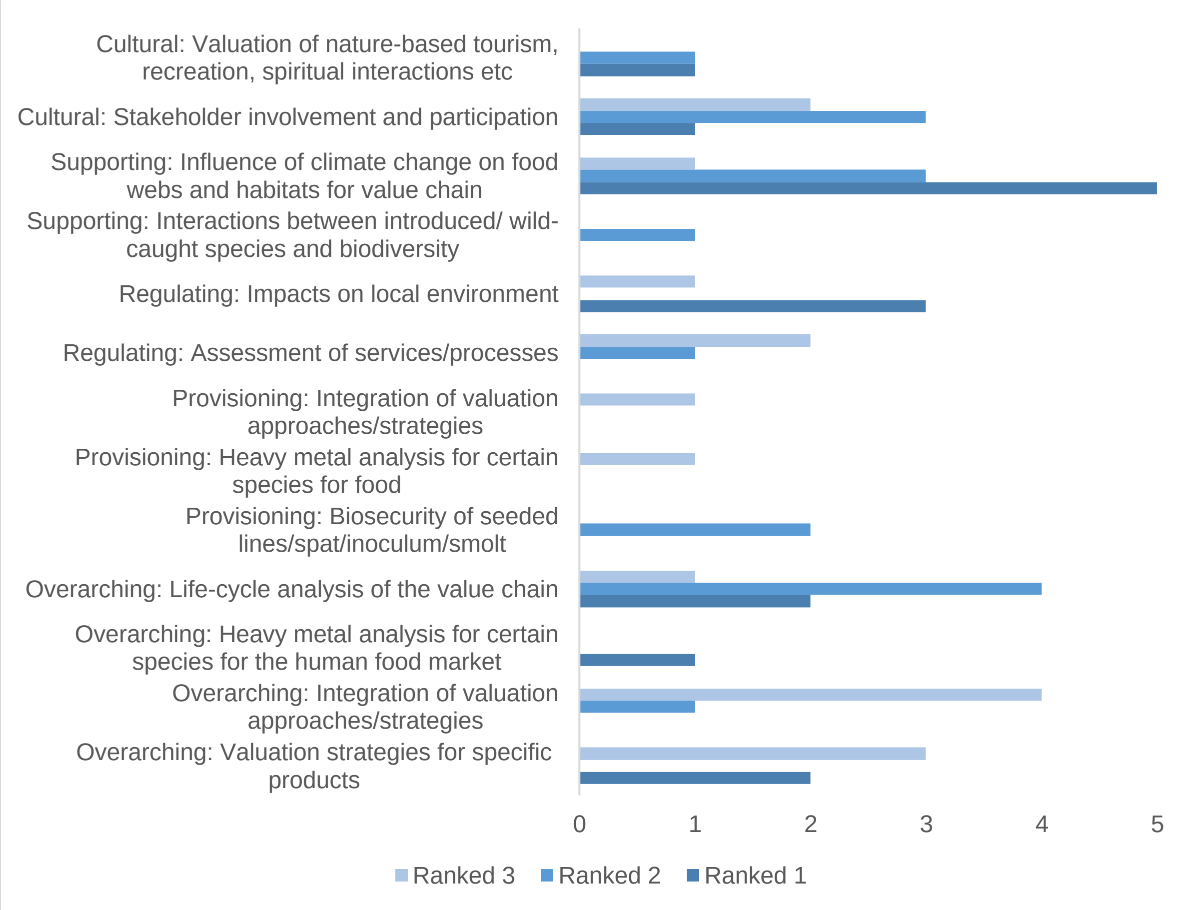

Figure 15. Responses to survey question six, asking participants to rank the three most important ecosystem services knowledge gaps of fish value chains, where one is the most important, two is less important than one, and three is less important than both.

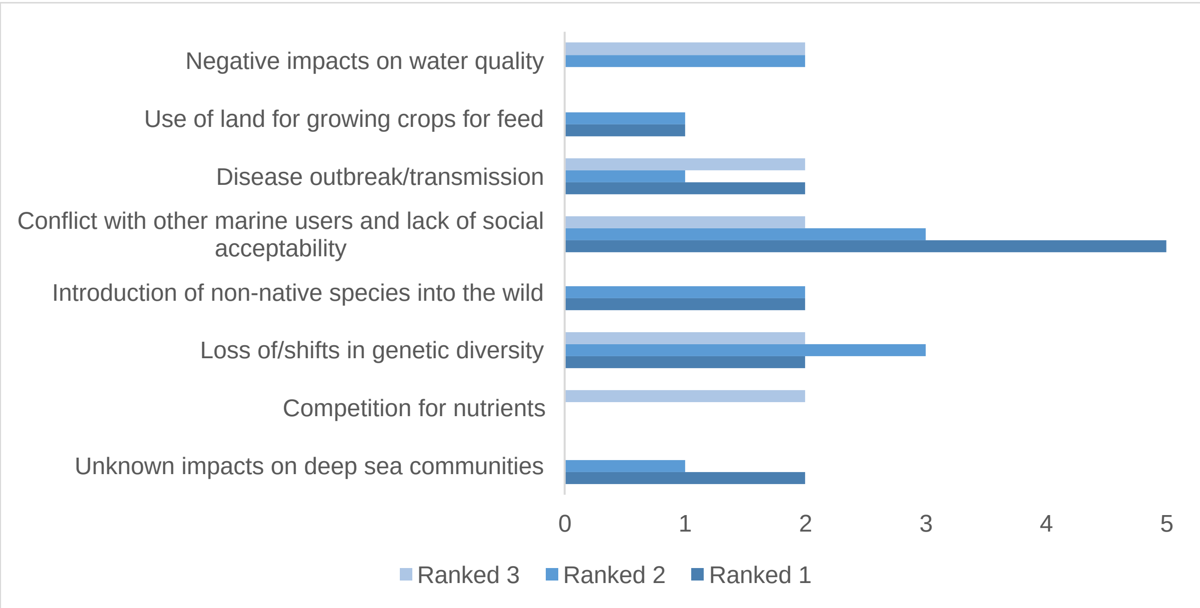

Figure 16. Responses to survey question eight asking participants to rank the three most critical negative aspects of fish value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

2.2.5 Macroalgae

There were six respondents for the macroalgae value chain, representing Industry (n=3) and Research & Development (n=3) from Portugal (n=2), Germany, France, Faroe Islands, and Israel (all n=1). In response to question four, asking participants to rank the three most important ecosystem services of the value chain, the highest ranked was the provisioning service of raw materials (n=3) followed by the provisioning service of food (n=2) and the regulating serve of carbon sequestration and storage (n=2). A summary of all of the ranking for this value chain and question can be seen in Figure 18.

When asked to rank the three most important ecosystem services knowledge gaps for their value chain, the supporting knowledge gap of the influence of climate change on food webs and habitats ranked the highest (n=2) the overarching knowledge gap of integration of valuation approaches and strategies was ranked third by the most respondents (n=3). The rest of the rankings fell relatively evenly over eight knowledge gap options and can be seen in Figure 19.

In question eight, participants were asked to rank the three most critical negative aspects of their value chain. For macroalgae, respondents ranked unknown impacts on deep sea communities as the most important (n=2), followed by loss of shifts in genetic diversity (n=2). The introduction of non-native species into the wild was ranked as joint third most important along with competition for nutrients (n=2). An overview of the rankings can be seen in Figure 20. In the free text section for this question there were two responses, one suggesting that the macroalgae cultivation requires a significant amount of marine space, and the second advising that the challenges with disease outbreaks, genetic diversity, and invasive species are all related to regulations *'what seaweed species is allowed to be cultivated [and where]'.*

The last three questions (10-12) provided respondents with the opportunity to add more information on the ecosystem services valuations they may be using, lessons learned from other sectors, and any further information they may want to provide. Of the six respondents, two advised that they are using ecosystem services valuation strategies, both from the Research & Development category, working in Faroe Islands and Israel (neither are BBC partner countries). One advised that they are currently attempting to monetarily value *'biodiversity, carbon sequestration and water filtration'*, of macroalgae through the EU project SeaMark (https://seamark.eu/). The same respondent suggested that evaluation of ecosystem services is more established for shellfish than macroalgae, and further, that *'ES value isn't enough to financially cover [seaweed] cultivation. ES can be a good side effect, but the provisioning value should be exploited and guarantee the production.'* They suggested that understanding the value of ecosystem services of macroalgae may *'help promote production'* from the angle of the transition to greener and more restorative production systems.

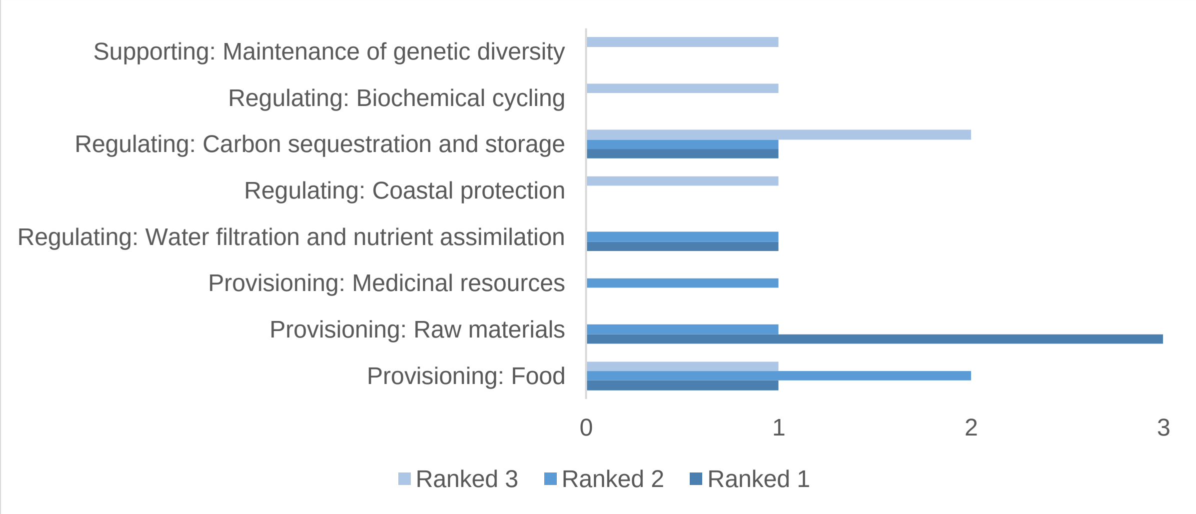

Figure 17. Responses to survey question four, asking participants to rank the three most important ecosystem services of macroalgae value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

Figure 18. Responses to survey question six, asking participants to rank the three most important ecosystem services knowledge gaps of macroalgae value chains, where one is the most important, two is less important than one, and three is less important than both.

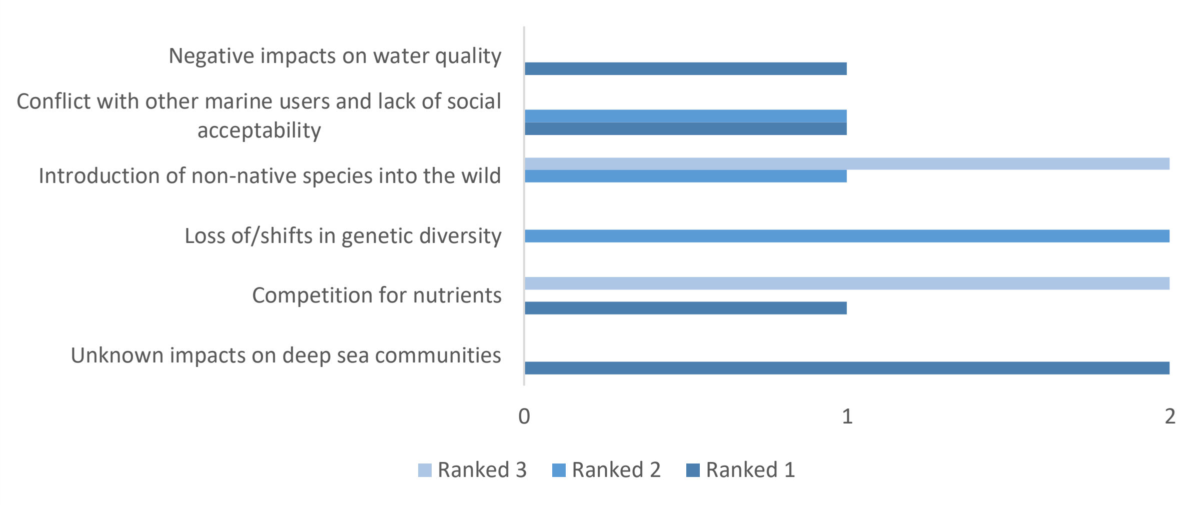

Figure 19. Responses to survey question eight asking participants to rank the three most critical negative aspects of macroalgae value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

2.2.6 Marine bacteria

There was one response for the marine bacteria value chain from Industry in Portugal. The respondent ranked the provisioning services of raw materials as the most important, food as the second, and medicinal resources as third. They ranked the overarching knowledge gap of life-cycle analysis for the value chain as the most important, followed by integration of valuation strategies/ approaches, and then valuation for specific products as the third most important. They ranked negative impacts on water quality as the most critical negative impact of the value chain, followed by disease outbreak/ transmission as second, and introduction of non-native species into the wild as third most important. They were not using any ecosystem services valuation strategies and provided no further information for questions 11-12.

2.2.7 Microalgae

There were eight participants that represented the microalgae biomass value chains, from Belgium (n=2), Portugal (n=3), Norway, Scotland, and Italy (all n=1), Research & Development (n=5), Industry (n=2), and a sectoral association (summarised in Table 6). Jointly ranked as the most important ecosystem service of the value chains were the provisioning services of raw materials and food and the supporting service of oxygen production (n=2) for each ecosystem service category). Ranked second was the provisioning service of food (n=4), followed by raw materials in third (n=3). A summary of the rankings can be seen in Figure 21. Two respondents provided four more ecosystem services: provisioning – feed, cosmetics, wastewater treatment and, nutraceuticals.

When asked to rank the three most important ecosystem services knowledge gaps, respondents ranked the overarching knowledge gap of lifecycle analysis of the value chain (n=3), followed jointly by the same category (n=2) and integration of valuation approaches/ strategies (n=2) as the second most important. The third most important was the provisioning knowledge gap of biosecurity (n=2). A summary of the rankings can be found in Figure 22. In the free text option for this question there were two responses; one from industry in Scotland advising the *'lack of clarity on legislation causes the value chain to be limited or* *underdeveloped'* and the other from research & development in Belgium advising that *'commercialisation in Europe is still problematic'.*

The rankings for the most critical negative impacts of the value chains were jointly use of land for growing crops/ feed and conflict with other marine users and lack of social acceptability as the most important (n=2 each), negative impacts on water quality as the second most important (n=2), and introduction of non-native species and loss/ shifts in genetic diversity as the third most important (n=1 each). A summary of the rankings can be found in Figure 23. In the free text option for this question there was one response from research development in Belgium stating *'use of energy'* as a critical negative impact. This is likely to be in relation to the energy consumption of photobioreactors. The same respondent was the only one to respond that they used an ecosystem services valuation strategy. There were no further data for questions 10-12.

Table 6. Summary of the sectors and countries represented by respondents for the microalgae biomass value chains.

Sector	Country
Research & Development	Belgium
Research & Development	Belgium
Research & Development	Portugal
Industry	Portugal
Sectorial Association	Portugal
Research & Development	Norway
Research & Development	Scotland
Industry	Italy

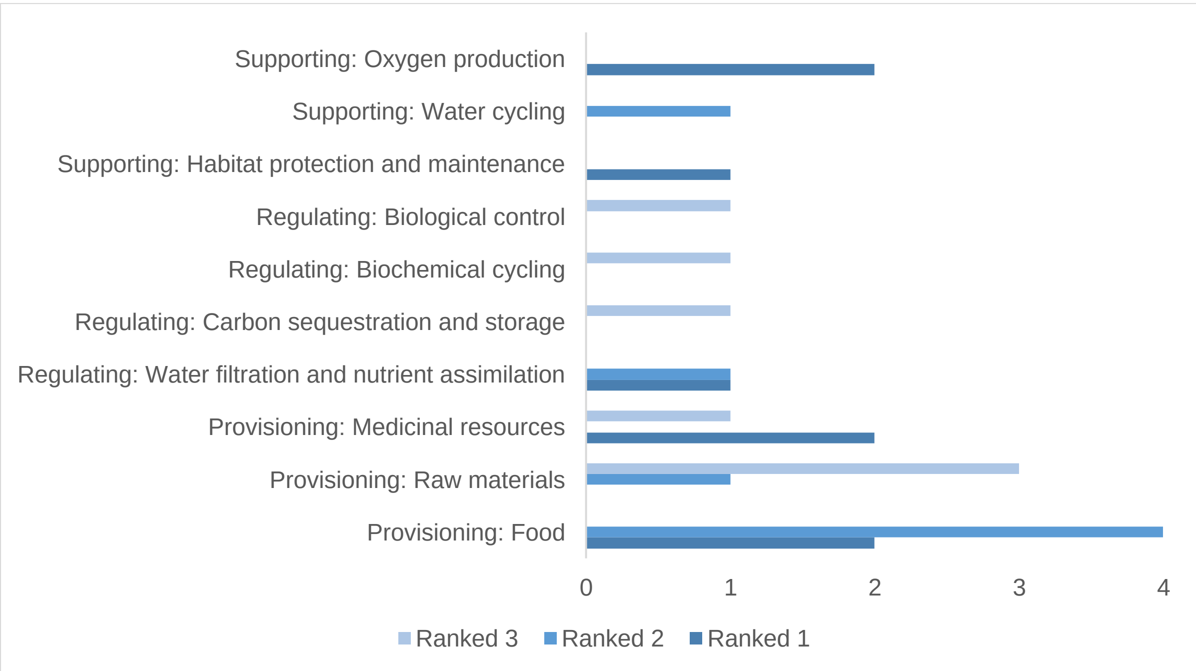

Figure 20. Responses to survey question four, asking participants to rank the three most important ecosystem services of microalgae value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

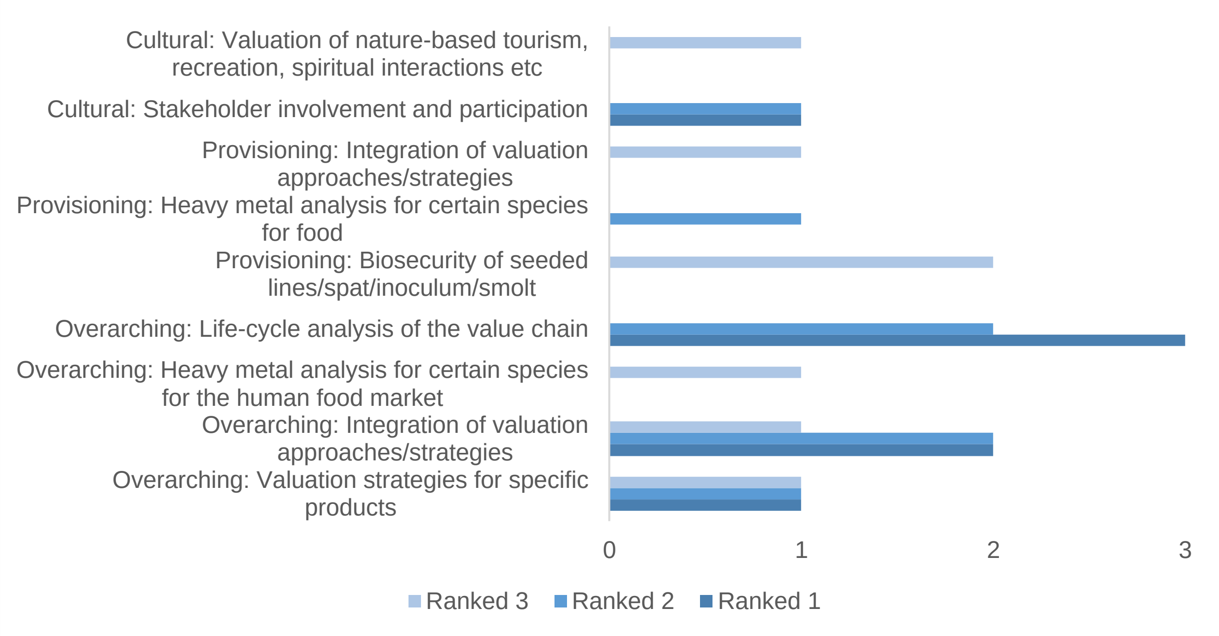

Figure 21. Responses to survey question six, asking participants to rank the three most important ecosystem services knowledge gaps of microalgae value chains, where one is the most important, two is less important than one, and three is less important than both.

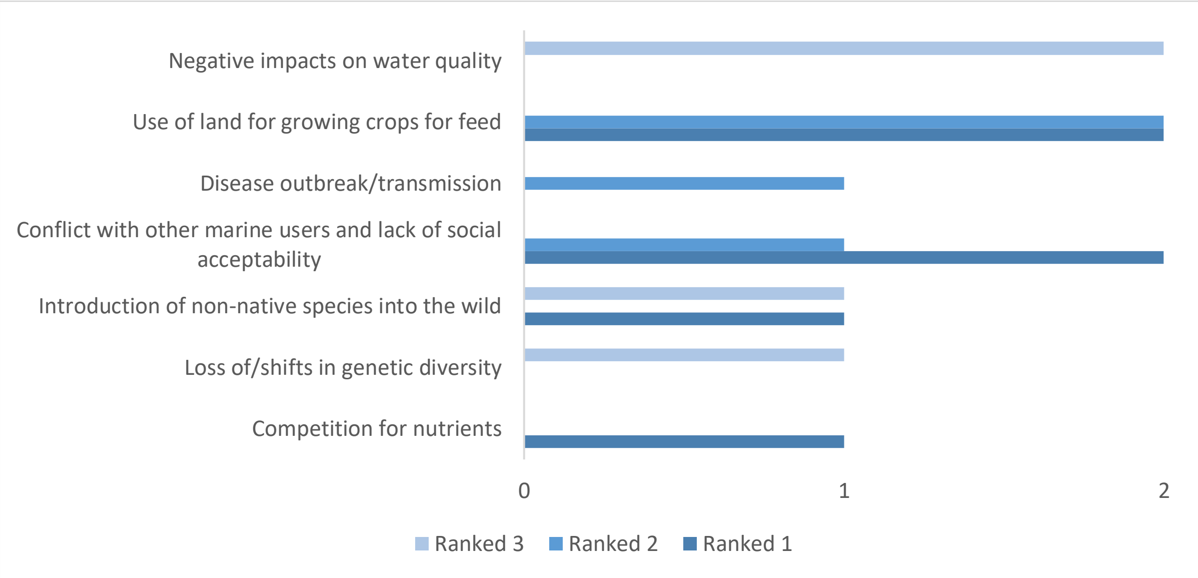

Figure 22. Responses to survey question eight asking participants to rank the three most critical negative aspects of microalgae value chains, where one is the most important, two is less important than one, and three is less important than both one and two.

3 Key Ecosystem Services knowledge gaps for the Blue Bioeconomy in Europe

The aim of this deliverable was to highlight the ecosystem services of the BBC value chains, including the knowledge gaps, providing an overview of the different valuation strategies and ecosystem services for each value chain, and region. However, our survey results found that only 18% of the respondents were using valuation strategies, one of which has limited evidence of ecosystem service use (eco-design), and the rest either use monetary valuation or did not list their valuation methods. Further, all but one of the responses was from the research & development sector. Our QSR also found limited peer-reviewed evidence of ecosystem services valuation strategies for the BBC value chains, and most related to research & development within the cultivated macroalgae industry (Bermejo *et al.*, 2022). Although there an increasing amount of research on the ecosystem services of bivalves, attempts at valuation are likely to be underestimates, due to significant gaps in knowledge that remain (van der Schatte Olivier *et al.*, 2020). We found no evidence of payments for ecosystem services of any of the BBC value chains through the QSR and survey, nor any recorded company behaviour change, as an outcome of ecosystem services assessments. Within some value chains, such as micro and macroalgae, this is somewhat unsurprising, given the nascent nature of both production and application across the EU and Associate countries (Bermejo *et al.*, 2022; Sharma and Arya, 2023). Much of the ecosystem services valuation work for macroalgae is being conducted within publicly funded research projects, such as SeaMark (https://seamark.eu/) and GENIALG (https://genialgproject.eu/).

It is clear from the survey that the blue bioeconomy industry across Europe is aware of ecosystem services, but the next step of valuation has not yet been taken. This suggests that there is a significant amount of research that needs to be conducted before blue bioeconomy businesses can start to assess and value the ecosystem services of their diverse value chains. This was backed up by some of the comments in the survey. One respondent advised that they “did not yet know which variables [to include]” (industry) and another noted the challenging process of ecosystem service evaluation “For another project, we are doing the (incredibly difficult) assessment of biodiversity, carbon sequestration and water filtration…” (research & development).

Below, we present our findings from the QSR and survey in a summary table (Table 7) of both the ecosystem services and the ecosystem services knowledge gaps of the BBC value chains, (rather than the regional differences in ecosystem services valuation strategies). These results contribute to evidence of the importance of blue bioeconomy value chains in the ecosystem services of food production, raw materials, medicinal resources, and recreational activities, mental and physical health. Critically, they show that across all biomass value chains, there is an overarching gap in knowledge of valuation strategies for specific products. This reflects the challenges laid out in the EUMOFA (2023) report on the Blue Bioeconomy on macro and microalgae. The report finds that these value chains are not yet developed to scale, making it tricky to assess ecosystem services, or use valuation strategies. However, the report also highlights the potential opportunity of carbon or nitrogen credits through ecosystem services (macro and micro algae only).

As the momentum for creating private markets and/ or new revenue streams out of ecosystem services increases (for example on markets for restorative aquaculture: Blue Marine

Foundation *et al.*, 2023), it is important that these mechanisms are grounded in sound science, are monitored as industry changes, expands, and new technologies come online, and are accredited by trustworthy institutions (Hasselstrom and Grondahl, 2021). The data collected and presented in this deliverable contributes to evidence showing that more biophysical and social science research is needed to understand the ecosystem services of the diverse value chains within the blue bioeconomy across Europe (Hasselstrom and Grondahl, 2021), before being able to capture and utilise their valuation efficiently and effectively.

Despite significant knowledge gaps in the ecosystem services of various marine and coastal organisms, including those that are cultivated, and the lack of a widely accepted framework for assessing their economic value (Heckwolf *et al.*, 2021), there is a consensus across many regions that the blue bioeconomy can contribute to society's goals for sustainability (Blue Bio Cofund, 2023). The next section (section 4) provides a brief overview of one supranational region, the Nordic Co-operation, and one small, devolved nation, Scotland, both of which are striving to support their blue bioeconomy through mechanisms that do not require full ecosystem services valuation.

Table 7. Table of the ecosystem services for each of the BBC value chains identified through the Quick Scoping Review and the online survey, including the knowledge gaps (KG) identified by the online survey.

Ecosystem Services	**Value chain**					
	Bivalves	Crusta-ceans	Fish	Macroalgae	Marine bacteria	Microalgae
Provisioning						
Food						
Raw materials						
Medicinal resources						
KG: Biosecurity of seeded lines/ spat/ inoculum/ smolt						
Regulating						
Water filtration and nutrient assimilation						
Coastal protection						
Carbon sequestration and storage						
Biochemical cycling						
Biological control						
KG: Assessment of services/ processes						
KG: Impacts on local environment						
Supporting						

Habitat protection and maintenance						
Maintenance of genetic diversity						
Sediment creation						
Water cycling						
Oxygen production						
KG: Interactions between introduced/ wild-caught species and biodiversity						
KG: Influence of climate change on food webs and habitats						
KG: Patterns of marine sediment carbon formation and stock						
Cultural						
Recreational activities and mental and physical health						
Tourism and ecotourism						
Sense of place and spiritual connection						
Aesthetic and spiritual appreciation and inspiration for culture, art, and design						
KG: Stakeholder involvement and participation						
KG: Valuation of nature-based tourism, recreation, spiritual interactions						

KG Linking cultural ecosystem services of the value chain to human wellbeing						
Overarching Knowledge Gaps						
Valuation strategies for specific products						
Integration of valuation approaches/ strategies						
Heavy metal analysis for certain species for food						
Life-cycle analysis of the value chain						

4 Regional blue bioeconomy strategies

This section provides two regional examples (one larger scale and supranational, the Nordic Co-operation, and one small-scale and national, Scotland) of how the blue bioeconomy can be strategically supported, despite evidence gaps in ecosystem services assessments and valuation. This section intends to highlight how progress can be made towards a sustainable blue bioeconomy, while research is still filling the ecosystem services knowledge gaps. The cases serve as brief examples, rather than in-depth studies.

The Nordic Co-operation involves Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands, Greenland, and Åland. In 2016, the Nordic Council of Ministers and the Nordic Bioeconomy Panel developed a proposal for a sustainable bioeconomy in the region (Nordic Co-operation, 2017). The proposal includes links with the United Nations Sustainable Development Goals, as well as the Food and Agriculture Organisation's principals for a sustainable bioeconomy (Food and Agriculture Organisation of the United Nations, 2023). The Nordic Co-operation's four pillars that ground the proposal are: 1) competitive bio-based industries, 2) sustainable resource management, 3) resilient and diverse ecosystems, 4) inclusive economic development (Nordic Council of Ministers, 2018). The proposal includes land-based and marine biomass and presents case studies of marine biomass including Ocean Rainforest, based in the Faroe Islands. Ocean Rainforest uses a biorefinery approach for their seaweed cultivation business, providing seaweed products for feed, food, and cosmetics (Ocean Rainforest, 2023). It is provided as an example of diversifying value chains from a single type of biomass, and a success story for the European macroalgae cultivation sector.

The Nordic Co-operation bioeconomy proposal also encompasses policy instruments aimed at fostering the development of the biobased sector, which includes support for bioeconomy clusters throughout the region (Nordic Co-operation, 2017). An example of the success of industry clusters in aiding development of the blue bioeconomy is Iceland Ocean Cluster's 100% fish programme. Companies within the cluster use improved processing techniques for caught fish biomass, which has allowed innovation and establishment of new value chains from fish processing biproducts. These include nutraceuticals, pharmaceuticals, and cosmetics (Iceland Ocean Cluster, 2023).

The Nordic Co-operation's strategy for development of the bioeconomy does not mention valuation of the ecosystem services of different value chains or production methodologies. Rather it focuses on innovation and policy instruments towards reduction in waste, fossil fuel use, and circularity (Nordic Council of Ministers, 2018).

Scotland is a nation within the UK with devolved powers, including setting national priorities and budget allocation (the National Strategy for Economic Transformation can be found here: https://www.gov.scot/publications/scotlands-national-strategy-economic-transformation/ Scottish Government, (2022)). The Scottish Government acknowledges the potential of the bioeconomy, including marine biomass value chains, in facilitating innovation and achieving transformational goals that align with its blue economy vision (Marine Scotland, 2022). The National Plan for Industrial Biotechnology uses six overarching themes to direct implementation and actions: policy, industry engagement, innovation, skills, sustainable manufacturing, and infrastructure (IBioIC, 2022). Scotland has an established industrial biotechnology sector, supported by a networking organisation (Industrial Biotechnology

Innovation Centre) that connects academia, industry, and government to accelerate bioeconomy innovation. Scotland's plan for biotechnology, as with the Nordic Co-operation's, does not mention valuation of ecosystem services of the various value chains either established or in development. Instead, it focuses on waste reduction, sustainable fuels, and circularity (IBioIC, 2022).

Both of these brief case studies show that although the valuation of ecosystem services has the potential to unlock new financial mechanisms for funding startups and scaling macro and microalgae cultivation in particular (EUMOFA, 2023), there are other instruments available in the meantime, that can effectively support the development of the blue bioeconomy across Europe. Further, our QSR and survey show that although there is interest in ecosystem services across several value chains, the scale of the knowledge gaps and the time it would take to fill them seem to be limiting the uptake of ecosystem services valuation by businesses. Considering this, we suggest conducting a critical analysis of the effectiveness of leveraging ecosystem services and their valuation as a strategy to bolster sustainable support of blue bioeconomy sectors, in the short-term. Additionally, exploring alternative methods that require fewer time and resource investments for similar support is advisable, as the research and development sector continues to fill ecosystem services knowledge gaps.

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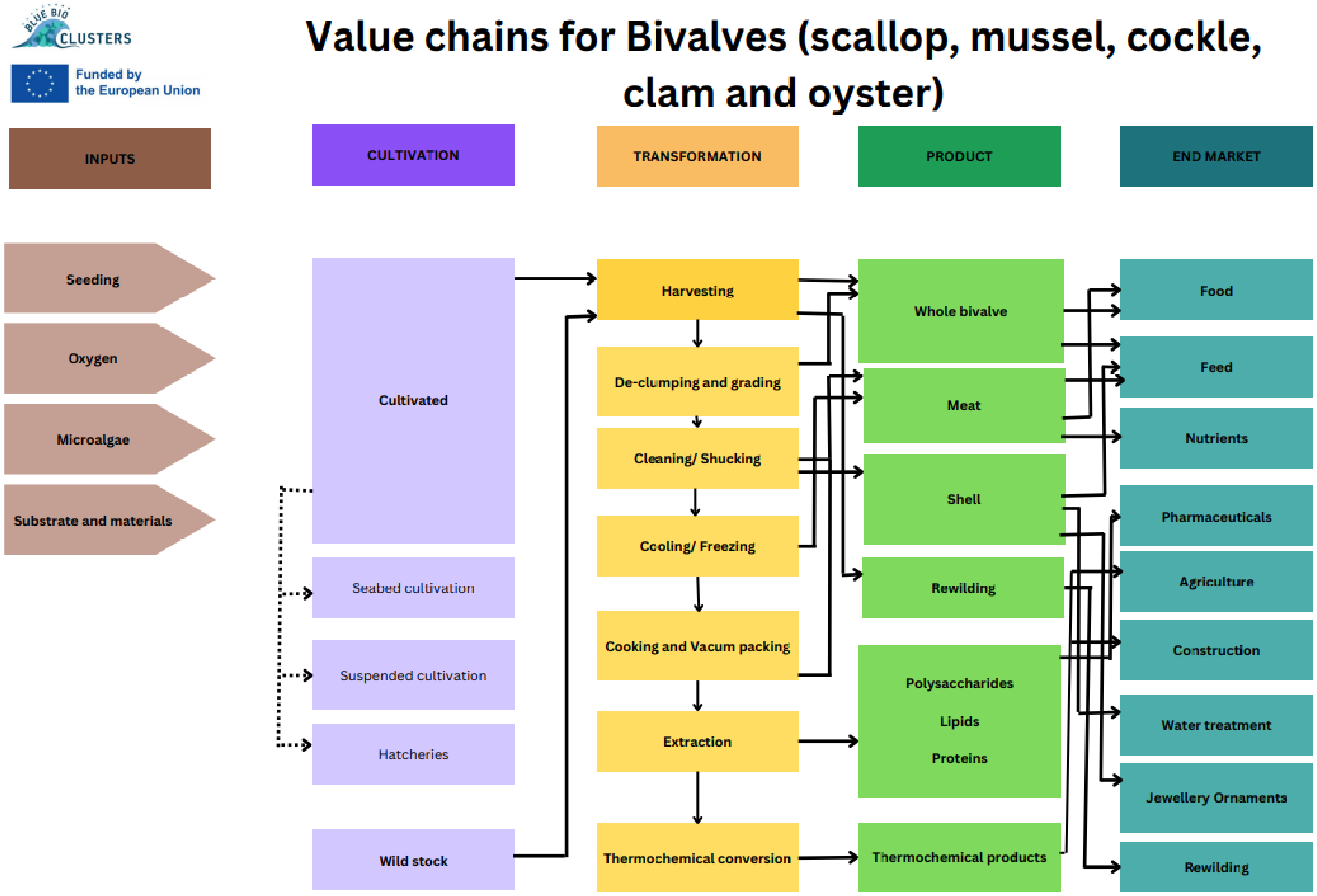
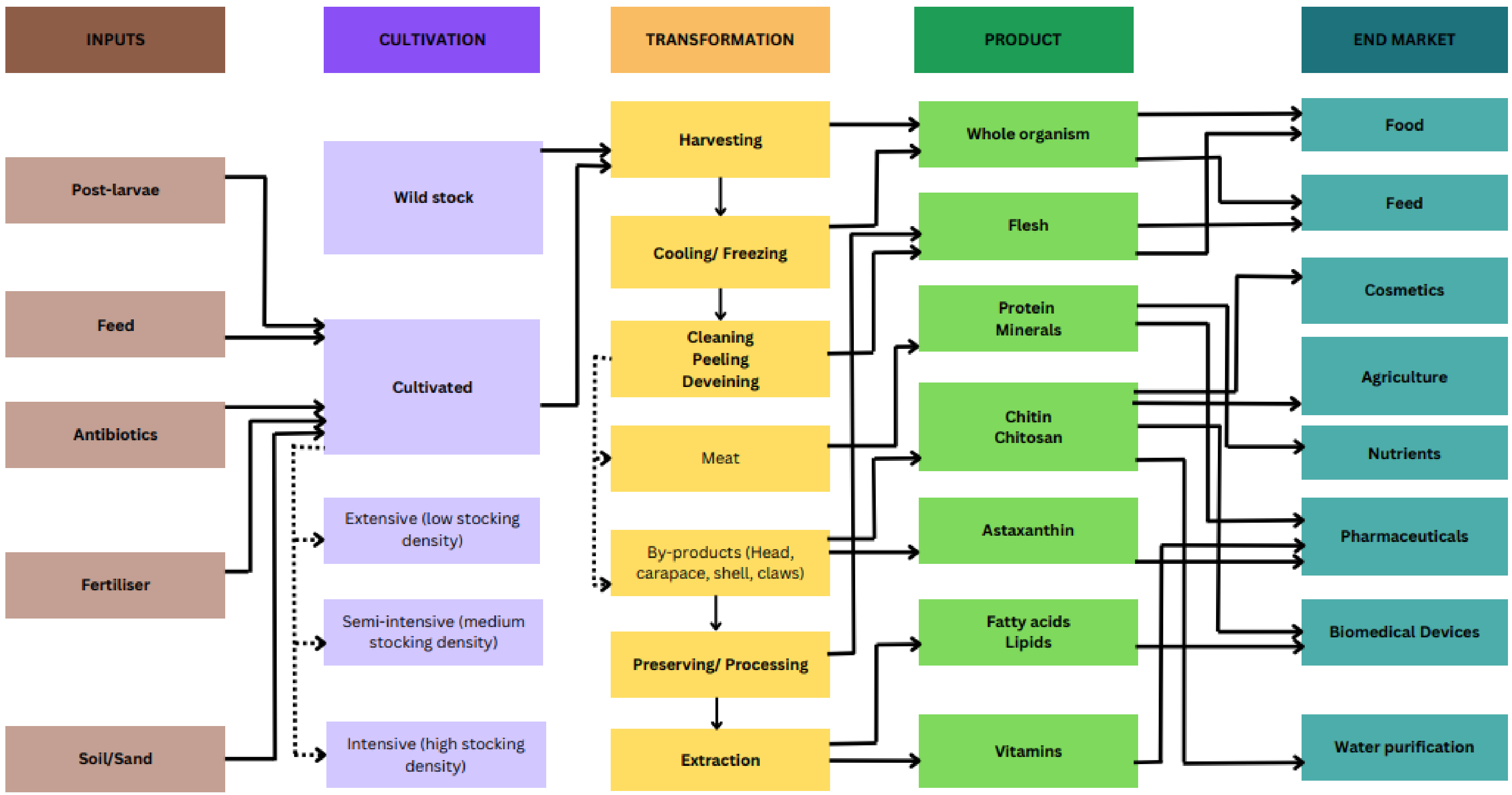
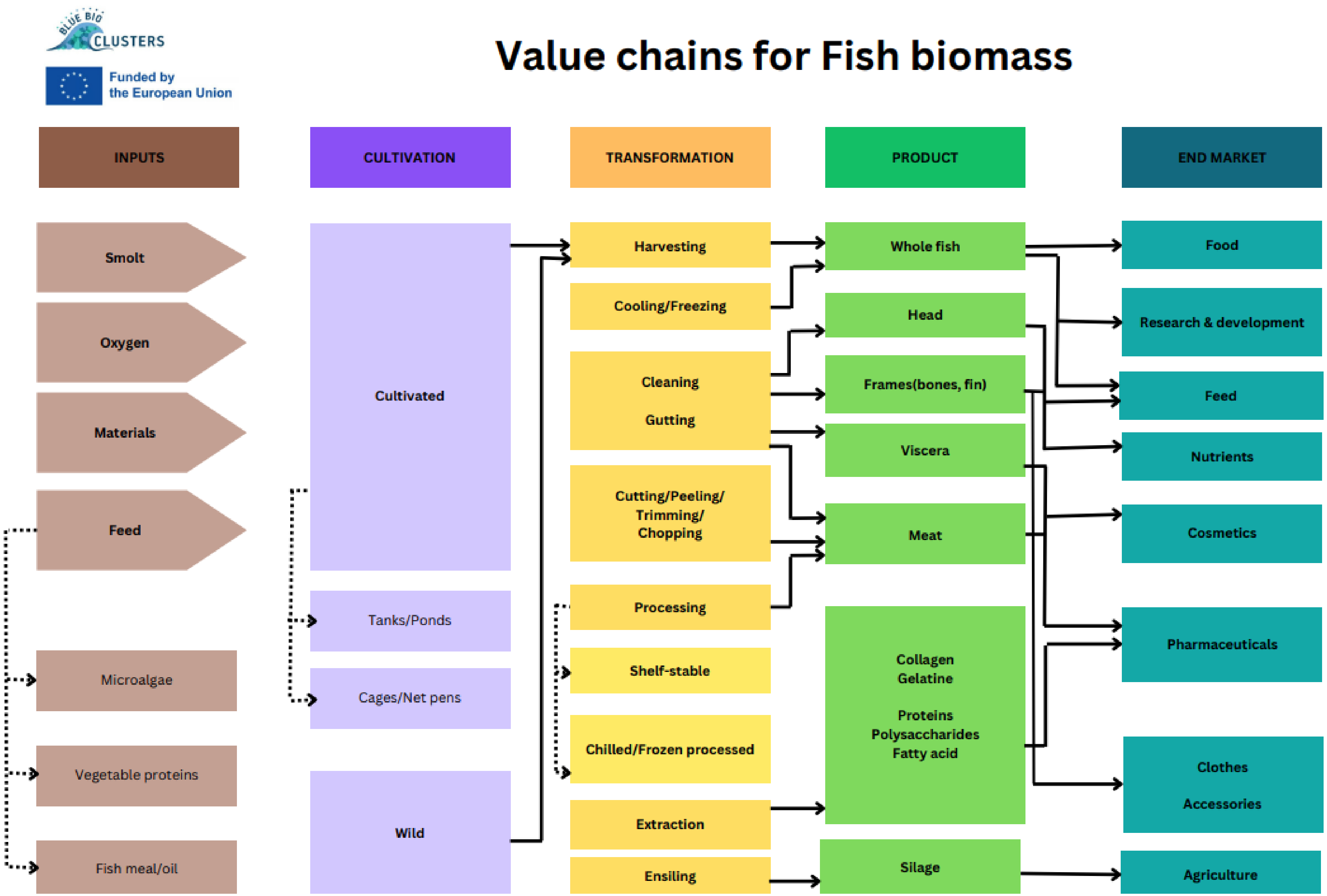
Annexes

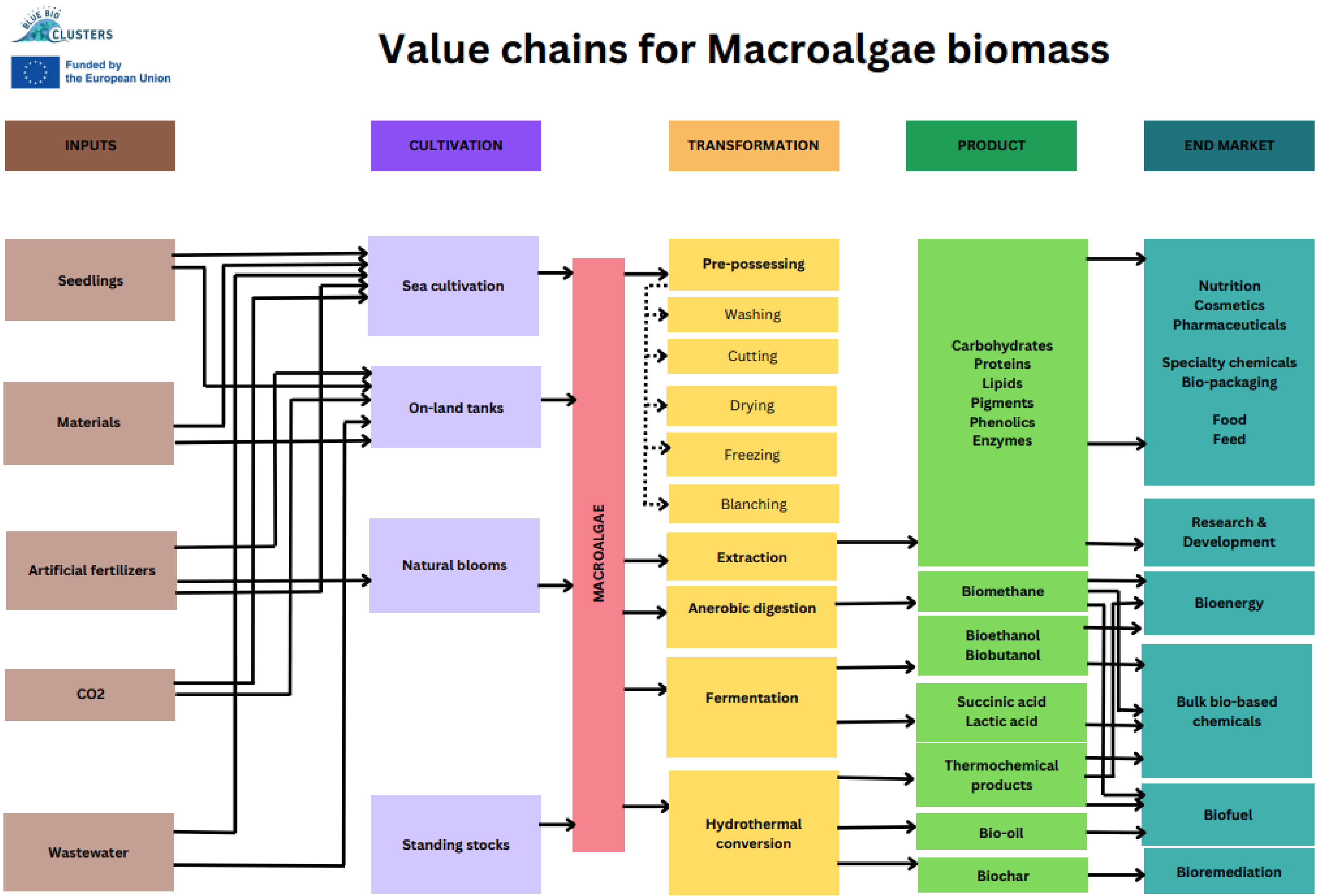
Annex 1 – BBC Value Chains



Value chains for Crustaceans (shrimp, prawn, lobster and crab)

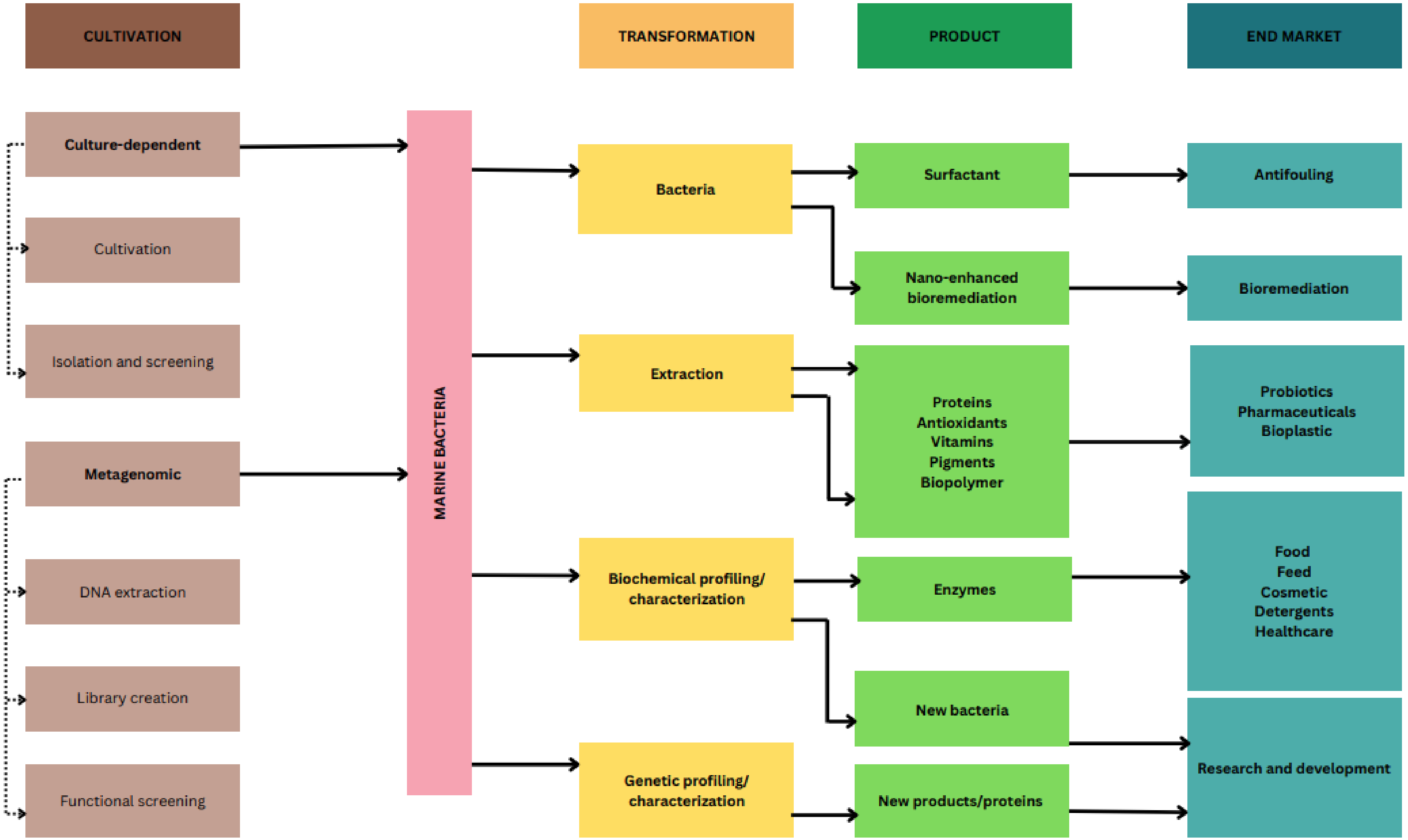


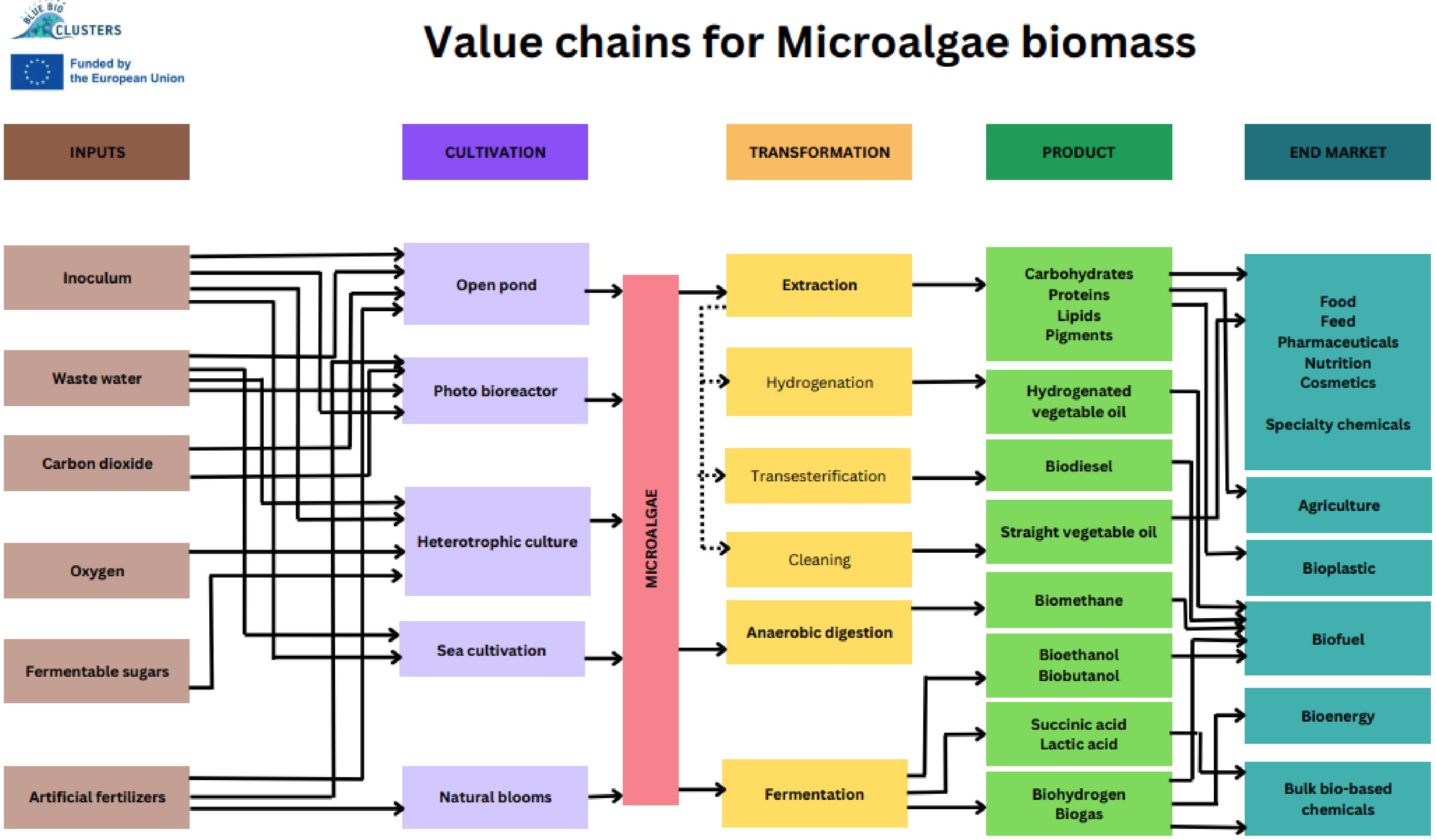

BLUE BIO CLUSTERS
Funded by the European Union
Value chains for Fish biomass
INPUTS
CULTIVATION
TRANSFORMATION
PRODUCT
END MARKET
Smolt
Oxygen
Materials
Feed
Microalgae
Vegetable proteins
Fish meal/oil
Cultivated
Tanks/Ponds
Cages/Net pens
Wild
Harvesting
Cooling/Freezing
Cleaning
Gutting
Cutting/Peeling/
Trimming/
Chopping
Processing
Shelf-stable
Chilled/Frozen processed
Extraction
Ensiling
Whole fish
Head
Frames(bones, fin)
Viscera
Meat
Collagen
Gelatine
Proteins
Polysaccharides
Fatty acid
Silage
Food
Research & development
Feed
Nutrients
Cosmetics
Pharmaceuticals
Clothes
Accessories
Agriculture


CLUSTERS
Funded by the European Union
Value chains for Macroalgae biomass
INPUTS
CULTIVATION
TRANSFORMATION
PRODUCT
END MARKET
Seedlings
Materials
Artificial fertilizers
CO2
Wastewater
Sea cultivation
On-land tanks
Natural blooms
Standing stocks
MACROALGAE
Pre-possessing
Washing
Cutting
Drying
Freezing
Blanching
Extraction
Anerobic digestion
Fermentation
Hydrothermal conversion
Carbohydrates
Proteins
Lipids
Pigments
Phenolics
Enzymes
Biomethane
Bioethanol
Biobutanol
Succinic acid
Lactic acid
Thermochemical products
Bio-oil
Biochar
Nutrition
Cosmetics
Pharmaceuticals
Specialty chemicals
Bio-packaging
Food
Feed
Research & Development
Bioenergy
Bulk bio-based chemicals
Biofuel
Bioremediation

Funded by the European Union

Value chains for Marine bacteria





Value chains for Microalgae biomass
INPUTS
CULTIVATION
TRANSFORMATION
PRODUCT
END MARKET
Inoculum
Waste water
Carbon dioxide
Oxygen
Fermentable sugars
Artificial fertilizers
Open pond
Photo bioreactor
Heterotrophic culture
Sea cultivation
Natural blooms
MICROALGAE
Extraction
Hydrogenation
Transesterification
Cleaning
Anaerobic digestion
Fermentation
Carbohydrates
Proteins
Lipids
Pigments
Hydrogenated vegetable oil
Biodiesel
Straight vegetable oil
Biomethane
Bioethanol
Biobutanol
Succinic acid
Lactic acid
Biohydrogen
Biogas
Food
Feed
Pharmaceuticals
Nutrition
Cosmetics
Specialty chemicals
Agriculture
Bioplastic
Biofuel
Bioenergy
Bulk bio-based chemicals

Annex 2 – QSR supplementary materials

Table 8. List of keywords using within the QSR search in both SCOPUC and Web of Science. These key words word determined by the inclusion criteria for the QSR set out in section 1.1., determined by the BBC biomass value chains.

Keywords
"Marine bacteria cult*" OR "marine derived bacteria cult*"
(Marine bacteria OR marine derived bacteria) industry
(Marine bacteria OR marine derived bacteria) ecosystem service
(Marine bacteria OR marine derived bacteria) food
(Marine bacteria OR marine derived bacteria) feed
(Marine bacteria OR marine derived bacteria) valuation
(Marine bacteria OR marine derived bacteria) bioremediation
(Marine bacteria OR marine derived bacteria) climate change
(Marine bacteria OR marine derived bacteria) value chain
(Marine bacteria OR marine derived bacteria) carbon
(Marine bacteria OR marine derived bacteria) invasive species
(Marine bacteria OR marine derived bacteria) (offshore OR terrestrial)
(Marine bacteria OR marine derived bacteria) biotechnology
(Marine bacteria OR marine derived bacteria) enzyme
"Shellfish farm*" OR "Mussel farm*" OR "oyster farm*"
"Shellfish cult*" OR "Mussel cult*" OR "oyster cult*"
"Shellfish aquaculture*" OR "Mussel aquaculture*" OR "oyster aquaculture*"
(shellfish* OR mussel* OR oyster) industry
(shellfish* OR mussel* OR oyster) ecosystem service
(shellfish* OR mussel* OR oyster) food
(shellfish* OR mussel* OR oyster) feed
(shellfish* OR mussel* OR oyster) valuation
(shellfish* OR mussel* OR oyster) bioremediation
(shellfish* OR mussel* OR oyster) climate change
(shellfish* OR mussel* OR oyster) value chain
(shellfish* OR mussel* OR oyster) carbon
(shellfish* OR mussel* OR oyster) invasive species
(shellfish* OR mussel* OR oyster) (offshore OR terrestrial)
"Shrimp farm*" OR "marine prawn farm*" OR "lobster farm*" OR "marine crab farm*"
"Shrimp cult*" OR "marine prawn cult*" OR "lobster cult*" OR "marine crab cult*"
"Shrimp aquaculture*" OR "marine prawn aquaculture*" OR ""marine crab aquaculture*"
(Shrimp* OR marine prawn* OR lobster OR marine crab) industry

(Shrimp* OR marine prawn* OR lobster OR marine crab) ecosystem service
(Shrimp* OR marine prawn* OR lobster OR marine crab) food
(Shrimp* OR marine prawn* OR lobster OR marine crab) feed
(Shrimp* OR marine prawn* OR lobster OR marine crab) valuation
(Shrimp* OR marine prawn* OR lobster OR marine crab) bioremediation
(Shrimp* OR marine prawn* OR lobster OR marine crab) climate change
(Shrimp* OR marine prawn* OR lobster OR marine crab) value chain
(Shrimp* OR marine prawn* OR lobster OR marine crab) carbon
(Shrimp* OR marine prawn* OR lobster OR marine crab) invasive species
(Shrimp* OR marine prawn* OR lobster OR marine crab) (offshore OR terrestrial)
"salmon farm*" OR “white fish farm*"
"Salmon cult*" OR “white fish cult*"
"Salmon aquaculture*" OR “white fish aquaculture*"
(salmon OR white fish) industry
(salmon OR white fish) ecosystem service
(salmon OR white fish) food
(salmon OR white fish) feed
(salmon OR white fish) valuation
(salmon OR white fish) bioremediation
(salmon OR white fish) climate change
(salmon OR white fish) value chain
(salmon OR white fish) carbon
(salmon OR white fish) invasive species
(salmon OR white fish) (offshore OR terrestrial)
"Microalgae* farm*"
"Microalgae* cult*"
"Microalgae* aquaculture"
Microalgae* ecosystem service
Microalgae* food
Microalgae* feed
Microalgae* biofuel
Microalgae* valuation
Microalgae* bioremediation
Microalgae* climate change
Microalgae* value chain
Microalgae* effluents
Microalgae* carbon

Microalgae* invasive species
Microalgae* (offshore OR terrestrial)
"Seaweed farm*" OR "Macroalgae farm*"
"Seaweed cult*" OR "Macroalgae cult*"
"Seaweed aquaculture*" OR "Macroalgae aquaculture*"
(Seaweed OR Macroalgae) ecosystem service
(Seaweed OR Macroalgae) food
(Seaweed OR Macroalgae) feed
(Seaweed OR Macroalgae) biofuel
(Seaweed OR Macroalgae) valuation
(Seaweed OR Macroalgae) bioremediation
(Seaweed OR Macroalgae) climate change
(Seaweed OR Macroalgae) value chain
(Seaweed OR Macroalgae) effluents
(Seaweed OR Macroalgae) carbon
(Seaweed OR Macroalgae) invasive species
(Seaweed OR Macroalgae) (offshore OR terrestrial)

Table 9. Full list of papers included in the QSR, as limited by the BBC Biomass value chains and the inclusion criteria set out in the main body of text, and between the years of 2018 and 2023 inclusive. This list is not meant to be exhaustive, but rather a rapid approach to a literature review, which provides a systematic overview of the evidence, limited by narrow inclusion criteria. An explanation of the QSR methodology can be found in the main body of text, section 1.1.

Title	BBC Biomass	Year
Social-cultural ecosystem services of sea trout recreational fishing in Norway. Frontiers in Marine Science	Fish	2019
‘Offshore’ salmon aquaculture and identifying the needs for environmental regulation	Fish	2022
A case study of local ecological knowledge of shellfishers about edible cockle (Cerastoderma edule) in the Ria de Aveiro lagoon, Western Iberia	Bivalve	2022
A generalised marine planning framework for site selection based on ecosystem services	Bivalve	2021
Assessing Environmental Impacts of Sea Bass Cage Farms in Greece and Albania Using Life Cycle Assessment	Fish	2020
Assessing the importance of kelp forests for small-scale fisheries under a global change scenario	Seaweed	2022
Biological, socio-economic, and administrative opportunities and challenges to moving aquaculture offshore for small French oyster-farming companies	Bivalve	2020
Can IMTA provide added ecosystem value services in the fish farms of Greece?	Fish	2023
Cleaning up seas using blue growth initiatives: Mussel farming for eutrophication control in the Baltic Sea	Bivalve	2020

Commercially available kelp and seaweed products – valuable iodine source or risk of excess intake?	Seaweed	2021
Consumer knowledge and attitudes towards microalgae as food: The case of Spain	Microalgae	2021
Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy	Micro and Macroalgae	2021
Direct effects of climate change on productivity of European aquaculture	Fish and Bivalve	2021
Dispersal of alien invasive species on anthropogenic litter from European mariculture areas	Bivalve	2018
Ecological priming of artificial aquaculture structures: kelp farms as an example	Seaweed	2019
Economic and environmental sustainability analysis of seaweed farming: Monetizing carbon offsets of a brown algae cultivation system in Ireland	seaweed	2022
Ecosystem accounting's potential to support coastal and marine governance	All	2020
Environmental impact of kelp (Saccharina latissima) aquaculture	Seaweed	2020
Fish as feed: Using economic allocation to quantify the Fish In : Fish Out ratio of major fed aquaculture species	Fish	2020
Food and Beverages Containing Algae and Derived Ingredients Launched in the Market from 2015 to 2019: A Front-of-Pack Labeling Perspective with a Special Focus on Spain	Seaweed	2021
How can ocean warming at the NW Iberian Peninsula affect mussel aquaculture?	Bivalve	2020
Increased oyster aquaculture in Sado Estuary (Portugal)	Bivalve	2023
Integrating Cultural Ecosystem Services in an Ecosystem Satellite Account: A Case Study in the Gulf of Saint-Malo (France)	Valuation	2018
Lost in Translation? Multiple Discursive Strategies and the Interpretation of Sustainability in the Norwegian Salmon Farming Industry	Fish	2020
Manila clam and Mediterranean mussel aquaculture is sustainable and a net carbon sink	Bivalve	2022
Mismatches in spatial scale of supply and demand and their consequences for local welfare in Scottish aquaculture	Fish	2019
Participatory qualitative modeling to assess the sustainability	Bivalve	2021
Public attitudes toward aquaculture: An Irish and Norwegian comparative study	All Aquaculture	2018
Quantifying use of kelp forest habitat by commercially important crustaceans in the United Kingdom	Seaweed	2022
Resilience and Social Adaptation to Climate Change Impacts in Small-Scale Fisheries	Bivalve	2022
Return of the native: Survival, growth and condition of European oysters reintroduced to German offshore waters	Bivalve	2021
Seaweed Value Chain Stakeholder Perspectives for Food and Environmental Safety Hazards	Seaweed	2022
Socioeconomic prospects of a seaweed bioeconomy in Sweden	Seaweed	2020
Mussel shells: A canning industry by-product converted into a bio-based insulation material	Bivalve	2020

Stakeholder participation in sustainability assessment of non-wicked problems: The case of a future seaweed industry in Sweden	Seaweed	2021
Stakeholder Perspectives on Blue Mussel Farming to Mitigate Baltic Sea Eutrophication	Bivalve	2021
Temporal variations in the nutrient content of Norwegian farmed Atlantic salmon (Salmo salar), 2005–2020	Fish	2022
The development of seaweed-derived fuels in the UK: An analysis of stakeholder issues and public perceptions	Seaweed	2019
The economic value of mussel farming for uncertain nutrient removal in the Baltic Sea	Bivalve	2019
The effects of climate change on Baltic salmon: Framing the problem in collaboration with expert stakeholders	Fish	2020
The environmental impact of the consumption of fishery and aquaculture products in France	Fish	2021
The impact of seaweed cultivation on ecosystem services - a case study from the west coast of Sweden	Seaweed	2018
The rise of aquaculture by-products: Increasing food production, value, and sustainability through strategic utilisation	Fish	2018
Trade-offs in the transition to a blue economy-Mapping social acceptance of aquaculture expansion in Norway	Fish	2023
Transition Pathways for the Farmed Salmon Value Chain: Industry Perspectives and Sustainability Implications	Fish	2021
UK public perceptions of Ocean Acidification – The importance of place and environmental identity	All	2018
Vulnerability of the Small-Scale Fishery to Climate Changes in the Northern-Central Adriatic Sea (Mediterranean Sea)	Fish	2022
Wild Atlantic salmon enter aquaculture sea-cages: A case study	Fish	2021

Annex 3 – Ecosystem Services and knowledge gaps survey

Ecosystem Services Knowledge Gaps in the Blue Bioeconomy

Page 1: Background information and consent

What this survey is for: The BlueBioClusters project is about supporting European coastal regions in their transition to a sustainable blue bioeconomy. The aim of this part of the project is: 1) to assess the knowledge gaps in understanding the ecosystem services of different blue bioeconomy value chains, 2) to identify the challenges to the blue bioeconomy in conducting ecosystem service assessments and, 3) to identify lessons learned on the application of ecosystem services assessments, specifically targeting collection of 'good practice' examples. Ecosystem services are the direct and indirect benefits to humans provided by the natural environment and are divided into four types: provisioning, regulating, cultural and supporting services. More information on the project and project partners can be found here.

What this survey involves: If you choose to participate, this survey will ask you about the value chain you work with the most, before asking questions about gaps in knowledge of the ecosystem services of the value chain you work with. Finally there is an open question asking if we have missed anything or if you would like to provide further comments. The survey will take aproximately 20 mins.

Your right to anonimity: All responses to this survey are anonymous, we won't be asking for any personal data and we also ask that you don't provide any personal details

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in the open questions. You can opt out of submitting your responses at any point during the survey by closing the window. Once your responses have been submitted we won't be able to withdraw them as they won't be identifiable to you.

How the data will be used: Thank you very much for considering taking this survey. Your responses will help progress understanding of knowledge gaps in ecosystem services valuation in the blue bioeconomy, will contribute to a report to the EU that will be publically available, conference presentations, and potenitally, a peer-reviewed paper.

Futher information: This survey is being run by the Scottish Association for Marine Science. If you have any further questions about this survey or would like to get in touch please contact: Suzi Billing

Funding source: This survey and the wider project are funded by the European Union under Grant Agreement ID 101060703. The survey content is the sole responsibility of the BlueBioClusters project and does not necessarily reflect the views of the European Union.

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Page 2: Ecosystem Services of blue bioeconomy value chains

1. What sector do you work in, in the blue bioeconomy? If it is not listed please choose "other" and type in your sector in question 1a.

Please select exactly 1 answer(s).

- Industry
- Research & Development (R&D)
- Government
- Consultants/ Industry Knowledge Transfer (IKT)
- Other

1.a. If you selected Other, please specify:

2. Which country is your main place of work? If it is not listed please choose "other" and type in the country in question 2a. * *Required*

Please select exactly 1 answer(s).

- Belgium
- Estonia
- France
- Iceland
- Lithuania
- Norway
- Portugal
- Sweden

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- [ ] Scotland
- [ ] Other

2.a. If you selected Other, please specify:

3. What blue bioeconomy value chain do you work with the most? Please look at this PDF of value chains and choose the closest matching biomass for your value chain. If it is not listed please choose "other" and type in your value chain.

Please select exactly 1 answer(s).

- [ ] Bivalves
- [ ] Crustaceans
- [ ] Fish
- [ ] Macroalgae
- [ ] Marine bacteria
- [ ] Microalgae
- [ ] Other

3.a. If you selected Other, please specify:

4. Please select the three most important Ecosystem Services for the biomass you selected in question 1 (where 1 is the most important, 2 is slightly less important than 1,

and 3 is less important than 1 and slightly less important than 2). You may select a minimum of one option or up to a maximum of three options.

Please don't select more than 1 answer(s) per row.

Please select between 1 and 3 answers.

Please don't select more than 1 answer(s) in any single column.

	1	2	3
Provisioning: Food	☐	☐	☐
Provisioning: Raw materials	☐	☐	☐
Provisioning: Medicinal resources	☐	☐	☐
Regulating: Water filtration and nutrient assimilation	☐	☐	☐
Regulating: Coastal protection	☐	☐	☐
Regulating: Carbon sequestration and storage	☐	☐	☐
Regulating: Biochemical cycling	☐	☐	☐
Regulating: Biological control	☐	☐	☐
Supporting: Habitat protection and maintenance	☐	☐	☐
Supporting: Maintenance of genetic diversity	☐	☐	☐
Supporting: Sediment creation	☐	☐	☐
Supporting: Water cycling	☐	☐	☐
Supporting: Oxygen production	☐	☐	☐
Cultural: Recreational activities and mental and physical health	☐	☐	☐
Cultural: Tourism and ecotourism	☐	☐	☐
Cultural: Sense of place and spiritual connection	☐	☐	☐
Cultural: Aesthetic and spiritual appreciation and inspiration for culture, art, and design	☐	☐	☐

5. Are there are other Ecosystem Services for the biomass value chain that you chose in question 1? If so, please describe them below using the broad ecosystem services categories (provisioning, regulating, supporting, cultural) before providing the detail (e.g. regulating: biological control of diseases).

6. Please choose the three most important Ecosystem Services knowledge gaps for the value chain you selected in question 1 (where 1 is the most important, 2 is slightly less important than 1, and 3 is less important than 1 and slightly less important than 2). You may select a minimum of one option or up to a maximum of three options.

Please don't select more than 1 answer(s) per row.

Please select between 1 and 3 answers.

Please don't select more than 1 answer(s) in any single column.

	1	2	3
Overarching: Valuation strategies for specific products - e.g., Valuation of nacre	☐	☐	☐
Overarching: Integration of valuation approaches/strategies	☐	☐	☐
Overarching: Heavy metal analysis for certain species for the human food market	☐	☐	☐
Overarching: Life-cycle analysis of the value chain	☐	☐	☐
Provisioning: Biosecurity of seeded lines/spat/inoculum/smolt	☐	☐	☐
Provisioning: Heavy metal analysis for certain species for food	☐	☐	☐
Provisioning: Integration of valuation approaches/strategies	☐	☐	☐

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Regulating: Assessment of services/processes- e.g. water filtration rates of oysters,	☐	☐	☐
Regulating: Impacts on local environment- e.g. increase in local biodiversity	☐	☐	☐
Supporting: Interactions between introduced/ wild-caught species and biodiversity	☐	☐	☐
Supporting: Influence of climate change on food webs and habitats for value chain	☐	☐	☐
Supporting: Patterns of marine sediment carbon formation and stock	☐	☐	☐
Cultural: Stakeholder involvement and participation	☐	☐	☐
Cultural: Valuation of nature-based tourism, recreation, spiritual interactions etc	☐	☐	☐
Cultural: Linking cultural Ecosystem Services of the value chain to human wellbeing	☐	☐	☐

7. Are there are other Ecosystem Services knowledge gaps for the biomass value chain that you chose in question 1? If so, please describe them below using the broad ecosystem services categories (provisioning, regulating, supporting, cultural) before providing the detail (e.g. provisioning: heavy metal analysis for certain species for food).

8. Please list the three most critical negative impacts of the biomass you selected in question 1 (where 1 is the most important, 2 is slighlty less important than 1, and 3 is less important than 1 and slightly less important than 2).You may select a minimum of one option or up to a maximum of three options.

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Please don't select more than 1 answer(s) per row.

Please select between 1 and 3 answers.

Please don't select more than 1 answer(s) in any single column.

	1	2	3
Unknown impacts on deep sea communities	☐	☐	☐
Competition for nutrients	☐	☐	☐
Loss of/shifts in genetic diversity	☐	☐	☐
Introduction of non-native species into the wild	☐	☐	☐
Conflict with other marine users and lack of social acceptability	☐	☐	☐
Disease outbreak/transmission	☐	☐	☐
Use of land for growing crops for feed	☐	☐	☐
Negative impacts on water quality	☐	☐	☐

9. Are there are other negative impacts for the biomass value chain that you chose in question 1? If so, please describe them below.

Page 3: Ecosystem Services valuation strategies

10. Do you currently use an Ecosystem Services valuation strategy for your value chain (e.g. market valuation methods, revealed preference methods, cost methods, delibarative and participatory methods, etc.)?

- Yes
- No

10.a. If you selected Yes, please add more details and and links to more information, if possible:

11. Please describe any lessons on Ecosystem Services and their valuation from other sectors that have been useful to the value chain that you selected in question 1.

12. Have we missed anything? Please add more details below:

Page 4: End of survey: thank you for participating!

Many thanks for supporting the Blue BioCluster project by filling in this survey! If you wish to participate in the survey again for a different value chain please contact Suzi. Look out for project outputs on the Blue BioClusters webpage.

If you are interested in knowledge exchange and connecting with other businesses and researchers operating in the blue bioeconomy in Europe, check out the Blue Bioeconomy Hub.

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