D2.2

Ecosystem Services relevant for the Belgian Continental Shelf based on multi-actor lab

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Acronyms

BCS	Belgian Continental Shelf
ES	Ecosystem Services
MSP	Marine Spatial Plan
OWF	Offshore wind farm
SAB	Strategic Advisory Board
ScAB	Scientific Advisory Board

1. Executive summary

The Belgian Part of the North Sea (referred herein as the Belgian Continental Shelf) has a coastline of about 66 km and an area of approximately 3454 km². Despite having a relatively small exclusive economic zone, it is one of the most heavily exploited marine areas in the world. Numerous and diverse marine activities are occurring within its boundaries and some of them are expected to experience substantial growth. To ensure that all these activities can continue to develop while preserving the marine ecosystem and the flow of ecosystem services (ES), better sustainability assessment tools are necessary to inform future marine spatial plans. To this end, the SUMES project aims to develop a decision-support tool that uses available scientific data to inform stakeholders and decision-makers about the environmental sustainability of human activities in the Belgian Continental Shelf (BCS). It consists in the assessment of both negative and positive effects from marine activities on marine ES.

A key element of ES assessments is the engagement of stakeholders to better understand which ES are the most important to them and guarantee that their interests and needs are considered. With this goal in mind, Task 2.1 - *Selection of Ecosystem Services relevant for the Belgian Continental Shelf* - aimed at exploring exactly which ES are relevant to the BCS and how these should be prioritized based on stakeholders' perception and knowledge of the system. Following a stepwise approach, a group of stakeholders representing different marine-related sectors was engaged in a multi-actor workshop using a series of participatory exercises. Based on their inputs, a list of ranked ES was obtained from which *Coastal protection, Biodiversity*, *Renewable offshore energy*, *Navigation surface*, *Nursery & habitat maintenance,* and *Climate regulation* came up as the most important ES. Additionally, a linkage diagram representing the causal relationships between marine activities and the relevant ES was co-created, building upon stakeholders' knowledge and later complemented with the inputs of a group of scientific experts in a separate meeting. Overall, this work successfully elicited stakeholders' perceptions regarding which ES should be prioritized and how the different marine activities (focused on offshore wind energy, the first SUMES case-study) may affect each other and the different ES in the BCS.

2. Goal and scope of the deliverable

This deliverable is associated with Task 2.1 (*Selection of Ecosystem Services relevant for the Belgian Continental Shelf*) and it aims to prioritize marine ES for the SUMES project, based on the inputs from a group of stakeholders representing different marine-related sectors in Belgium.

Studying stakeholders' perceptions of the ES related to a specific geographical area (in this case the BCS) will help to better understand and acknowledge their relative importance (Lamarque et al., 2011; Martín-López et al., 2012; Rey-Valette et al., 2017). Assessing these perceptions is crucial within the scope of the SUMES project, whose main goal is to develop a decision-support tool that can quantify and assess ES trade-offs that result from the different uses of the marine space.

To effectively elicit perceptions, a stakeholder engagement process was carried out based on the prioritization method proposed by Rey-Valette et al. (2017). To do so, a stakeholder workshop was organized. This workshop was initially planned to take place at the Flanders Marine Institute (VLIZ), but due to COVID-19 restrictions, it had to be rescheduled as a virtual workshop.

Before the actual planning, preparation and execution of the workshop, two prior steps had to be accomplished. First, key stakeholders had to be listed and mapped and, second, the relevant ES from the BCS had to be identified. Following the workshop, two additional steps were carried out, namely a consultation with ES experts from the Scientific Advisory Board (ScAB) of SUMES and the analysis of the results.

The steps to perform Task 2.1 and the main outcomes from each step are summarized in Table 1 and are further described in the following sections. A timeline of the activities is presented in Figure 1.

Table 1: Workflow of Task 2.1.

Step	Outcome
1. Stakeholder selection process	18 stakeholders x 11 sectors
2. Identification of relevant ES of the BCS	CICES table of relevant ES
3. Workshop planning and preparation	Roadmap and structure of the workshop
4. Workshop execution	Ranking of ES and linkage diagram of ES and marine activities (+ demand indicators)
5. Consultation with ScAB	Guidance on the interpretation of workshop outputs
6. Analysis and reporting of the results	Synthesis report (shared with participants) & Deliverable 2.2

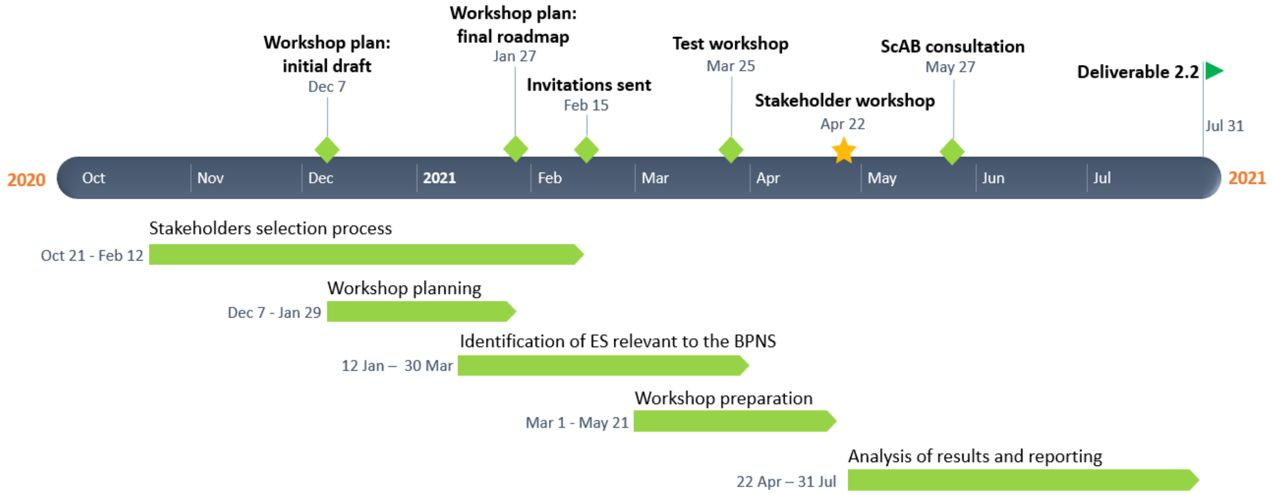


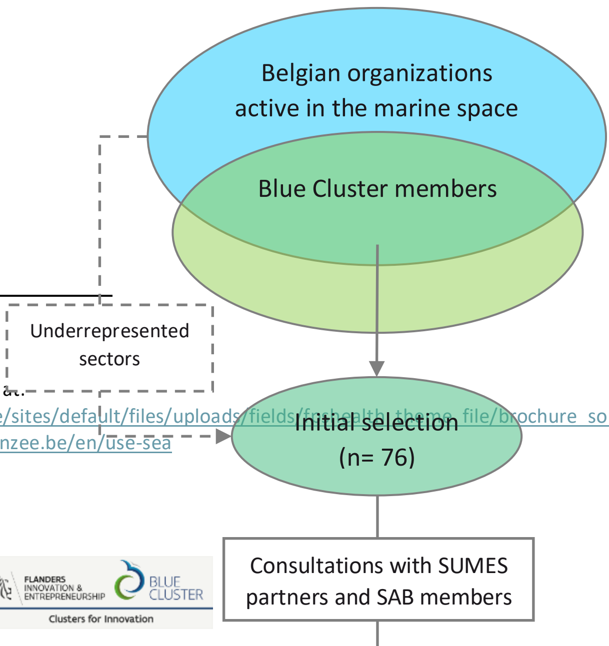
Figure 1: Timeline of Task 2.1.

3. Stakeholders selection

The selection of stakeholders usually follows a three-stage process (Durham et al., 2014): i) identification of all potential stakeholders and stakeholder groups, ii) assessment and prioritization of stakeholders, and iii) development of an understanding of the stakeholders. Before beginning the selection process, the boundaries of the study area were clarified. As stated in the SUMES proposal, the main goal was to identify, select and prioritize relevant ES from the BCS and, thus, potential stakeholders were considered as those that were directly involved with and/or dependent on the BCS (e.g. blue economy sectors).

During the first stage, the stakeholder groups were defined as those socioeconomic sectors using the BCS. According to the Belgian Marine Spatial Plan for 2020-2026[1], the main sectors considered relevant in the BCS are Fisheries, Aquaculture, Wind farming, Sand extraction, Dredging, Shipping, Tourism, Scientific research, Cables & pipelines, Coastal defense, Conservation, and Cultural heritage. Therefore, organizations and companies active in those sectors were considered as potential participants for the stakeholder workshop. Additionally, other sectors were considered relevant to include in the selection process, given their importance and overlap with some of the MSP sectors, namely Ports, Civil society, Consultancy, Information technologies and Marine engineering. The stakeholders' selection process is illustrated in Figure 2.

Note that, considering some of the aforementioned sectors overlap considerably in terms of their activities, it was decided to merge some of them. More specifically, i) Coastal defense was included in Marine engineering, ii) Cultural heritage was included in Tourism, and iii) Wind farming and Cables & pipelines were merged into an Offshore energy & communication sector.



[1] More information is available at:
https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/brochure_something_is_moving_at_sea_2020.pdf
http://www.compendiumkustenzee.be/en/use-sea

Figure 2: Stakeholder selection process.

To identify the stakeholders belonging to the relevant sectors, the list of nearly 200 members and partner organizations associated with the Blue Cluster (https://www.blauwecluster.be/leden) was consulted. This list is composed of enterprises, knowledge institutions, industry associations, training centers and public agencies interested in the development of a sustainable blue economy in Flanders. All listed organizations were carefully screened concerning their sector of activity in order to establish a preliminary list of potential stakeholders. Organizations from under-represented sectors in the Blue Cluster list, namely nature conservation and civil society, were selected from the wider pool of stakeholders active in the marine space (blue circle in Figure 2).

In the following stages, a series of consultations were carried out with project partners and the SAB to arrive at a reasonable number of stakeholders that would be representative of the BCS sectorial landscape. According to Campagne and Roche (2018), the minimum number of participants for a stakeholder workshop should count at least 15 to 20 participants. Therefore, the aim was to obtain a list of around 30 stakeholders, assuming that some invitees would not reply or reject the invitation. Overall, 3 consultations were carried out, involving 7 scientific experts of the project and 4 SAB members, who provided their feedback on an iterative process. Note that the three partner institutions (University of Antwerp, Ghent University and VLIZ) and the eleven SAB members of SUMES were also included in the initial selection, as all of them represented relevant sectors. In total, 30 stakeholders were finally selected and invited to the workshop from which 18 participated in the workshop on the 22nd of April 2021.

The list of participants is presented in Table 2 and the sectorial representation is presented in Figure 3 (based on stakeholders' responses to the question *What sector are you representing in the workshop?*). The group of stakeholders represented a total of 11 sectors related to the BCS and the most represented ones were Research (3), followed by Conservation (2), Consultancy (2), Aquaculture (2), Offshore energy & communications (2), and Shipping (2). The sectors Fisheries, Marine engineering, Dredging, Ports and Civil society were represented by 1 participant each. The sectors Tourism, Information technologies and Sand extraction were not represented since the invited organizations were unavailable to participate in the workshop.

Table 2: Stakeholder participants

Representative	Stakeholder organization	Role in SUMES
Annelies Boerema	IMDC	SAB
Annemie Volckaert	Arcadis	-
Bert Groenendaal	Brevisco	-
Cara McHardy	Colruyt Group	SAB
Dirk Dewettinck	Parkwind	-
Hélène Smidt	KBRV	-
Katrien van der Biest	University of Antwerp	Partner
Laurens Hermans	MOW-Afdeling Maritieme Toegang	-
Marc Huygens	DEME	SAB
Miran Vanwonterghem	MDK - afdeling Kust	-
Nils Préat	Ghent University	Partner
Pascal Hablutzel	VLIZ	Partner
Paul Schroé	Haven Zeebrugge (MBZ)	SAB
Riet Durinck	Elia Group	-
Sarah Tilkin	4Sea	-
Steve Bauwens	Province/POM West Vlaanderen	SAB
Sylvie Because	Vlaamse Visveiling N.V.	SAB
Yves Peeters	Maritech	SAB

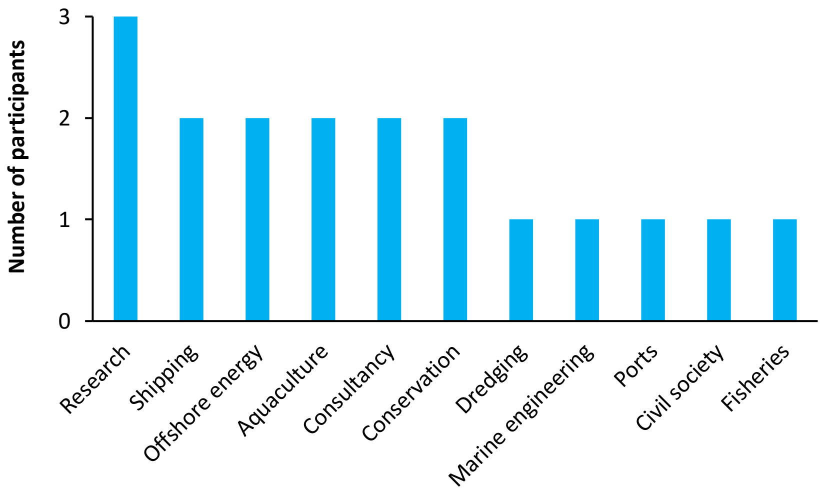


Figure 3: Sectors represented in the workshop (based on stakeholders' responses).

4. Method for selecting and prioritizing ES

In order to select and prioritize ES, the method proposed by Rey-Valette et al. (2017) – the Rapid Ecosystem Services Participatory Appraisal (RESPA) – was followed. In a nutshell, the RESPA method provides a framework for the appraisal of perceptions of a group of stakeholders which allows for the prioritization of ES to help decision-making. Due to its simplicity and rapidness, this method was considered appropriate to elicit stakeholders' perceptions during a virtual workshop. The relevance of this method greatly depends on the diversity of stakeholders engaged and is based on the assumption that diversity enables a more accurate picture of the range of ES relevant to the geographical area in question and how they should be prioritized. Therefore, the characteristics of the stakeholder group (e.g. sectoral representativeness) should always be taken into consideration when interpreting the results.

The RESPA is typically divided into 6 steps, but in the present work, the method was carried out up to Step 4 and the steps are further described below. The last two steps (Step 5 and 6, which pertain to the confrontation of stakeholders' perceptions with scientific knowledge in a follow-up workshop and the communication of results to decision-makers) were considered out of the scope of this deliverable since the main goal was to gather stakeholders' perceptions (outputs from Step 4) to inform the SUMES project on which ES to prioritize during the assessment. It is important to note that the ES that will be assessed also depend on the showcases, as some ES might not be relevant to specific BCS areas (e.g. the ES of *coastal protection* is not produced offshore and is therefore not relevant to assess in a case-study focusing on offshore wind energy).

Step 1 - *Creation of a reference list of potential ES for a given geographical area:*
Following the CICES classification (Haines-Young & Potschin-Young, 2018), a reference list of ES from the BCS was created based on scientific literature from the geographical area under study. It is important to keep in mind that SUMES focuses on assessing the impacts of marine activities in the ecosystem structures and functions that supply ES within the horizontal boundaries of the BCS that are permanently submerged (which excludes the land and intertidal areas) and the reference list was compiled taking this into consideration. The creation of this reference list is further explained in section 5 of this document.

Step 2 - *Carrying out perception surveys among a diverse set of stakeholders:*
The group of stakeholders was confronted with the list of ES compiled in Step 1. Instead of surveys, perceptions were collected through live polls, using the polling tool Slido (https://www.sli.do/). Details about this step are presented in section 6 of this document.

Step 3 - *Identifying differences and sources of bias:*
The outputs from Step 2 are normally biased by the characteristics of the stakeholders engaged in the process. In this case, biases could be related to the quantity and diversity of sectors represented in the workshop, as different sectorial groups might prioritize different ES. To capture differences in prioritization based on the sectors, participants were asked about which sectors they belong to (Figure 3). In this way, each stakeholder's contributions were framed within the sector they considered themselves in and, later on in Step 4, it would be possible to pin down the responses of each participant to their respective sector. With this information, it is possible to have a better understanding of which ES the different sectors are more likely to prioritize and also to normalize the responses per sector to decrease the weight of overrepresented sectors in the analyzes.

Step 4 - *Statistical processing of the ranking indicators proposed:*
Based on the individual responses, two indicators could be calculated for each ES: i) the *selection frequency* (i.e. the percentage of respondents that selected a particular ES), and ii) the *ranking score* (i.e. the overall ranking score obtained by each ES, based on individual ranking scores). A cross-analysis of the two indicators can help to divide ES into different 'priority categories' to facilitate prioritization. The results from this step are presented in section 7.

5. Identification of relevant ES from the BCS

The ecosystem components and functions present in the BCS deliver a wealth of ES that contribute to human health and wellbeing, in particular to the Flemish and the broader Belgian population. According to the Common International Classification of Ecosystem Services (CICES v5.1) (Haines-Young & Potschin-Young, 2018), which has been designed to help measure, account for, and assess ES, these can be divided into three main categories: provisioning services (e.g. animals and plants used for food, materials and energy), regulating and maintenance services (e.g. remediation of wastes, carbon sequestration), and cultural services (e.g. enabling physical and passive interactions, education, heritage). These categories can be disaggregated into sub-categories, delivering an adaptable and detailed structure of classification to identify ES and apply (semi-)quantification and valuation methods.

Even though other ES classification systems exist in the literature (e.g. MA, TEEB), CICES was chosen as the reference classification system in the context of the SUMES project. To carry out the prioritization of ES, we had to first make a comprehensive identification of ES relevant to the BCS (RESPA Step 1). These were defined by the horizontal boundaries of the BCS (Figure 4) and, thus, only those being supplied by the ecosystem structures and functions within these boundaries were considered. The scientific literature was consulted, and more specifically those studies addressing the topic of ES in the context of the BCS and adjacent marine areas. Most literature on this topic was associated with the Offshore wind energy sector, in terms of its impacts and contributions to ES. This is an important detail given that the first case-study being addressed by SUMES will be the Offshore wind energy sector (more details will be available on Deliverable 4.1 - *Description and (semi-) quantification of a first selected case study: a showcase*).

The ES were identified either at the Group or Class levels, depending on the specificities of each case, and the list of relevant ES selected for the workshop is presented in Table 3 (a more comprehensive table with references is available in the Annex section, as Table 6).

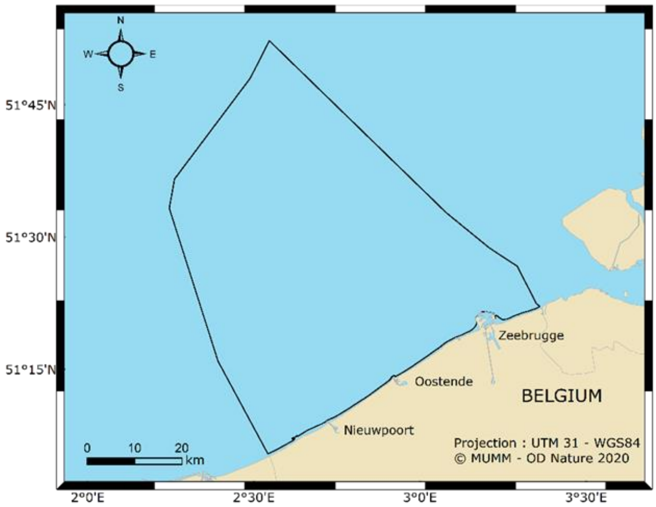


Figure 4: Horizontal boundaries of the BCS.

Table 3: Summary table of relevant ES from the BCS.

Section	Terminology
Provisioning ES (biotic and abiotic)	Farmed aquatic plants (for food, materials and energy uses)
	Farmed aquatic animals (for food, materials and energy uses)
	Wild aquatic animals (for food, materials and energy uses)
	Surface for navigation
	Sand and other minerals
	Renewable offshore energy
Regulating & maintenance ES (biotic and abiotic)	Mediation of wastes
	Coastal protection
	Nursery and habitat maintenance
	Climate regulation

Cultural ES (biotic and abiotic)	Recreation
	Scientific research
	Cultural heritage
	Aesthetic value

6. The stakeholder workshop and the prioritization of ES

Before the actual workshop took place, a test was run on the 25th of March 2021, to which participated some members of the SUMES scientific consortium. The main goal of this test was to provide training to the facilitators and receive feedback from colleagues on the presentation and the different participatory exercises. One of the main modifications based on this feedback was on the number of ES to be selected and ranked (RESPA Step 2). Initially, it was intended that each stakeholder selects and ranks 10 ES from the reference list. However, this number was considered too high (increasing cognitive load on participants), which made it more difficult to rank the ES. In the end, it was decided to reduce the number to 5 ES.

The actual stakeholder workshop took place on the 22nd of April 2021 through the video conferencing app Zoom (version 5.6.0) and was facilitated from the premises of VLIZ. A total of 18 stakeholders participated and provided their inputs, which were mainly collected through multiple participatory exercises. Three different exercises were designed for this workshop, feeding not only into the objectives of Task 2.1 but also of Task 2.3. Besides the ranking of ES (RESPA Step 2), participants also contributed to the creation of a linkage diagram illustrating the links (i.e. causal relationships) between the relevant ES and the marine activities in the BCS, and contributed to the selection of indicators to quantify the demand for those ES (more details below). The event lasted 3 hours (from 9:30 to 12:30 am), the overall agenda is presented in Table 4.

Table 4: Workshop agenda

Time	Activity
9:30	Introduction
10:05	Selection and ranking of ES (first exercise)
10:30	Coffee-break
10:40	Linking ES and marine activities (second exercise)
11:45	Selection of ES *demand* indicators (third exercise)
12:15	Conclusion

6.1. Introduction

After welcoming all participants, the workshop started with the establishment of some housekeeping rules for the duration of the event. Next, all the participants presented themselves in a quick *tour-de-table* (i.e. stakeholders, facilitators, and assistants). An icebreaker session followed, where different types of polling questions (e.g. multiple choices, open text, ranking) were posed to stakeholders with Slido, for them to get acquainted with the polling tool. Lastly, a general introduction was presented to the stakeholders, explaining the main goals of the SUMES project, the concept of ES and its relevance to the context of the BCS, as well as the objectives of the workshop and the process of ES prioritization.

6.2. First exercise: Selection and ranking of ES

The first exercise of the workshop was designed to collect stakeholders' perspectives on which are the most significant ES provided by the BCS, following the RESPA method introduced in section 4. Stakeholders were asked to select a subset of the most relevant ES from a reference list and rank them in order of priority, considering how significant they are from the point of view of their sectors, in the present and the future (time horizon: 2021 – 2050).

In practice, stakeholders were first confronted with the reference list of ES from the BCS, where each ES was properly explained and illustrated (e.g. Figure 5), to guarantee that all stakeholders were offered balanced information on all ES and had the same understanding about each of them. Afterward, two questions were asked to the stakeholders in the polling tool *Slido*. The first question intended to gather additional ES that the stakeholders thought were missing from the reference list (Question: *Do you know other ES relevant to the BCS that are missing in the reference list?*). The objective of this question was to give the opportunity to the stakeholders to help define the reference list of relevant ES before their prioritization. The second question directly asked participants which ES from the reference list should be prioritized (Question: *What are the 5 ES from the BCS you think should be prioritized? Select and rank them from 1 to 5 (1- highest priority, 5 - lowest priority)*). More precisely, each participant was asked to select the 5 most important ES and rank their selection from highest (1) to lowest (5) priority.

This exercise resulted in a series of ranking scores per participant, where the ES at the top (ranked first) was assigned 5 points, the second in the rank received 4 points, the third received 3 points, the fourth and the fifth received 2 and 1 points, respectively, and finally, the non-ranked ES received 0 points. The responses were then summarized using the two ranking indicators referred to in section 4: i) *Selection frequency* (% of sectors), which reflects the frequency each ES was selected to be in the top 5, normalized by sector; and ii) *Sum of ranking scores*, which corresponds to the total ranking score obtained by each ES. Both indicators were normalized by sector, using the mode for the *Selection frequency* (categorical variable) and the mean for the *Sum of ranking scores* (numerical variable). The ranking data normalized by sector highlights heterogeneity in perceptions according to stakeholder category (i.e. sector) and determine which sectors are clustered together (i.e. similar) based on their selection and ranking of ES. The results are presented in section 8.

Figure 5: Slide illustrating the ES of 'Renewable offshore energy'.

6.3. Second exercise: Linking ES supply and marine activities

The goal of the second exercise was to create a linkage diagram that reflected the causal relationships between the relevant ES and marine activities in the BCS, based on stakeholders' knowledge of the system. This exercise goes beyond the selection and prioritization of relevant ES from the BCS by providing a visual representation of how these ES relate to each other and marine activities, providing a better understanding of the complexity of the interlinkages between ES and the socioeconomic system.

The concepts of *supply* and *demand* in the context of ES were first introduced here to the stakeholders, given that understanding these is key to this exercise as well as the third. Briefly, the *supply* of ES refers to the capacity of a particular area to provide specific ES within a given time period (Burkhard et al., 2012). The *demand* of ES refers to the ES currently consumed, used, or desired in a particular area over time, and the *demand* can change over time and space independently from the *supply* and can be located in a different geographical area than *supply* (Burkhard et al., 2012). In the case of this exercise, ES are looked upon from the *supply* side.

To carry on this exercise in a virtual environment, participants were divided into 4 breakout rooms, ensuring that stakeholders from different sectors worked together. Each group was assigned a facilitator knowledgeable in the topic of ES and trained to use the diagramming tool Diagram.net (https://app.diagrams.net/). An overview of the interface is presented in Figure 6.

During the breakout discussions, participants were presented with specific guiding questions and their verbal inputs were translated into the different nodes and arrows of the diagram by the facilitator. The causal relationships were represented by arrows, whose orientation depicted the direction of the effect, and the color indicated the type of effect, namely if it is positive (green), negative (red), mixed (yellow) or unknown (grey). The generic guiding questions were as follows:

- *How does the increase of one ES (supply) affect another ES (supply)?*
- *How does the increase of one ES (supply) affect a particular marine activity?*
- *How does the increase of one marine activity affect a particular ES (supply)?*

Groups were given instructions to start their diagrams with the marine activity ‘Offshore wind farming’, as this is the first case study of SUMES. From that first node, groups were encouraged to freely discuss and draw a linkage diagram with as many ES and additional marine activities as they would like, as long as they had sufficient knowledge about the nature of those links. After 30 minutes, the groups returned to the main room to present their linkage diagrams in a plenary session.

After the workshop, a unified linkage diagram was created by combining the 4 diagrams created by each group. The rules for merging the links were as follows:

A. If a given link had the same colour across the 4 diagrams, the colour was kept the same in the unified diagram (e.g. green + green + green + green = green), indicating that stakeholders expressed the same effect;
B. If a given link had at least two different colours across the 4 diagrams, the colour was changed to yellow in the unified diagram (e.g. red + red + red + green = yellow), indicating that stakeholders expressed mixed effects.

The unified diagram was then extended to incorporate the inputs from the Scientific Advisory Board. The results are presented in section 8.

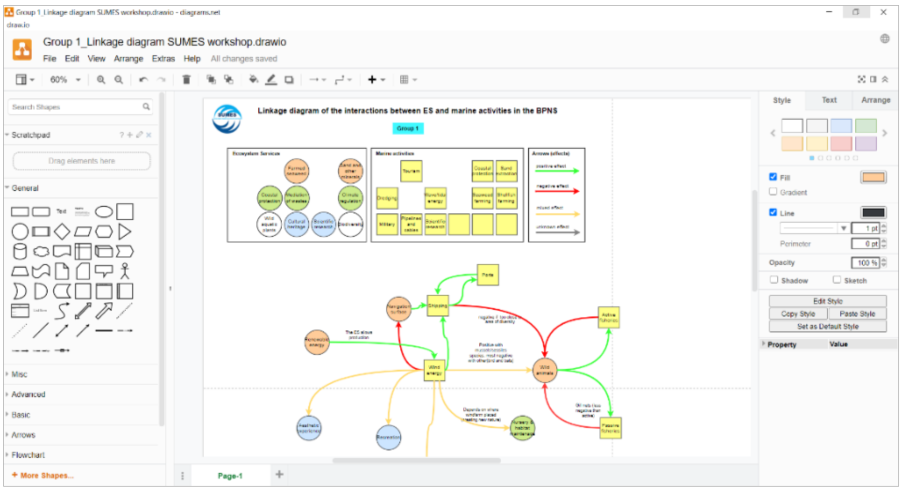


Figure 6: User interface of the diagramming tool Diagram.net.

6.4. Third exercise: Selection of ES-demand indicators

In the third and last exercise of the workshop, participants were asked to select from a list of proposed *demand* indicators for each of the relevant ES, the ones deemed most useful or relevant to the demand side of ES. For some ES, no indicators were found from the literature and stakeholders were asked to propose possible indicators. The results from this exercise are most relevant to Task 2.3 and will be addressed in the future Deliverable 2.4 (*Valuation of ES demand from the BCS*).

6.5. Conclusion

The workshop was concluded with a presentation of the SUMES timeline, a summary of the workshop outputs and an elucidation on how these outputs would tie into the upcoming activities of SUMES.

7. Results

This section presents the results from the first and second exercises of the stakeholder workshop.

7.1. Selection and ranking of ES

Overall, 9 out of the 18 stakeholders suggested additional ES. In total, 10 additional ES were suggested, with some participants suggesting more than one ES (the number of participants that suggested the given ES is mentioned between brackets): *Biodiversity* (3), *Wild aquatic plants* (1), *Intrinsic value* (1), *Education* (1), *Birds* (1), *Minerals* (1), *Biotic materials* (1), *Biofuels* (1), *Water quality* (1) and *Air quality* (1). From this list of additional ES, it became evident that some were analogous to ES already presented in the reference list. This mix-up might be due to some stakeholders being more familiarized with other classification systems (e.g. MA, TEEB), which use different terminologies for some ES. Therefore, in order not to duplicate ES in the reference list, to avoid ambiguity and maintain consistency with the CICES classification, screening and filtering of the suggested ES was performed.

Six of the suggested ES seemed to correspond (or were related) to one or more ES already in the reference list or overlapped with other suggested ES, and were therefore not included in the reference list. These were: *Minerals* (= *Sand and other minerals*), *Biotic materials* (= *Wild aquatic animals, Farmed aquatic animals, Farmed aquatic plants* and *Wild aquatic plants*), *Biofuels* (= *Farmed aquatic plants* and *Wild aquatic plants*), *Water quality* (= *Mediation of wastes*), *Air quality* (= *Climate regulation*) and *Birds* (= *Biodiversity*). Furthermore, *Intrinsic value* was also not included because there is still a strong debate about whether or not this should be considered as an ES. It is normally argued that intrinsic value is incompatible with the concept of ES because it relates to benefits to nature instead of benefits to humans as the definition of ES implies (Davidson, 2013). Additionally, *Education* was also left out as an ES in itself as it is sometimes combined or used interchangeably with *Scientific research* (Mocior & Kruse, 2016; van Oudenhoven et al., 2012), which could lead to confusion. For that matter, *Education* will be considered within *Scientific research* in the context of SUMES.

In the end, two additional ES were added to the reference list, namely *Wild aquatic plants* and *Biodiversity*. These were not initially included in the reference list because, in the case of *Wild aquatic plants*, even though some macroalgae do occur naturally in the area in small patches, data on their harvest is uncommon and angiosperms such as seagrasses are not typically found in Belgian waters (Belgische Staat, 2012). In the case of *Biodiversity*, this is typically considered as a supporting service (intermediary ES that mediates the production of final ES), yet the classification of these underpinning services is not covered in CICES[2], which seeks mainly to identify the final ES that link to the goods and benefits that are valued by people. Yet, some stakeholders strongly felt that this ES should still be included in the final reference list.

The ranking results are presented in Figure 7. The order in the *X*-axis is defined here by the *Sum of ranking scores* values (green bars), but it could also be defined using the *Selection frequency* values (red dots), resulting in a slight change in the ranking order. By overlaying these two indicators in a graph, it is possible to see that some ES can present both a

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[2] CICES guidelines available at: https://cices.eu/content/uploads/sites/8/2018/01/Guidance-V51-01012018.pdf

high score and high frequency (e.g. *Coastal protection*) and can be considered as major services, while other ES have both a low score and low frequency (e.g. *Wild aquatic plants*) and can be considered as minor services. In some cases, scores and frequencies diverge. Where ES have a low score but high frequency (e.g. *Farmed aquatic plants*), that indicates stakeholders do valorize that ES but do not consider it of the highest priority. Meanwhile, where ES have a high score but low frequency (e.g. *Farmed aquatic animals*), the ES is not so important to most stakeholders but is considered of high priority to those who select them. This latter observation could also indicate a lack of awareness of the importance of that ES to those stakeholders that did not select it (Rey-Valette et al., 2017).

It was finally decided to use only the indicator *Sum of ranking scores* to define the ranking position of each ES and outline the priorities (Table 5). It follows that the top 5 ES are *Coastal protection, Biodiversity, Renewable offshore energy, Navigation surface* and *Nursery & habitat maintenance.* To complete the top 10, there is *Climate regulation, Sand & other minerals*, *Wild aquatic animals*, *Mediation of wastes* and *Farmed aquatic animals.* Based on these results, it is fair to conclude that, overall, the stakeholders prioritize mostly the provisioning services (with a higher preference for abiotic provisioning) and the regulating & maintenance services, meanwhile the cultural services were considered less important.

Biodiversity as an ES on itself generated some discussion and controversy among stakeholders as well as experts (see section 8) and, as stated previously, it is not considered an ES *per se* in the CICES classification due to its intermediary nature in underpinning the biotic ES. However, given the ranking results indicated high perceived importance of this supporting ES by many stakeholders, it must be carefully considered under SUMES and is further discussed in section 8.

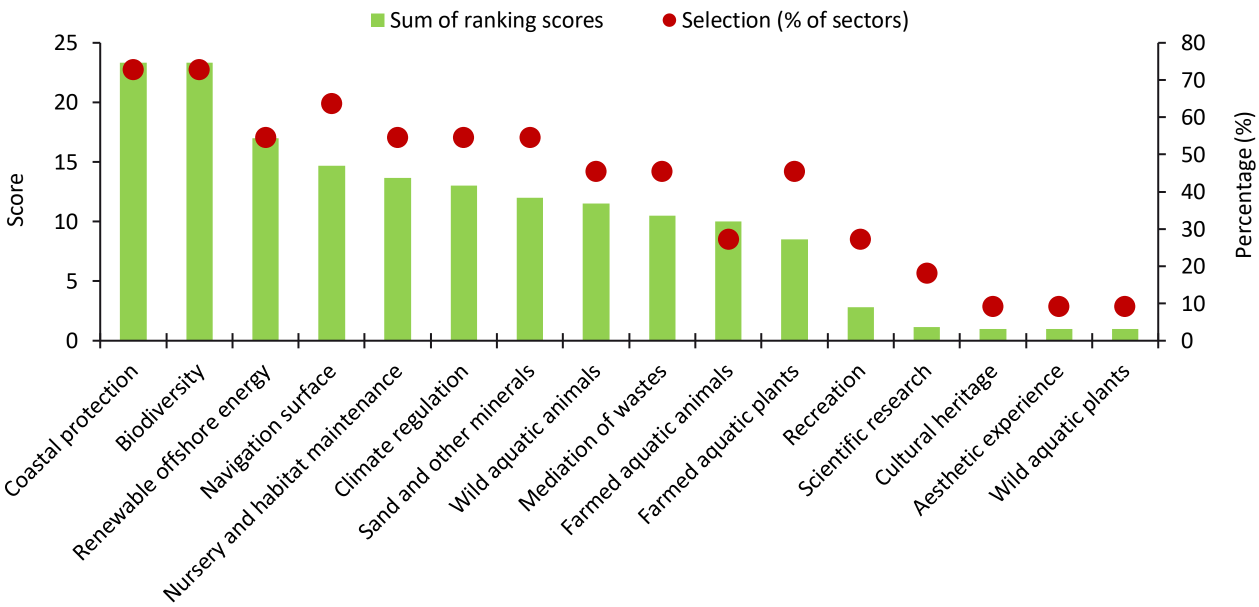

Figure 7: ES ranking scores and selection frequency.

Table 5: ES ranking.

Ecosystem Service	Sum of scores	Rank
Coastal protection	23.3	**1**
Biodiversity	23.3	**1**
Renewable offshore energy	17.0	**3**
Navigation surface	14.7	**4**
Nursery and habitat maintenance	13.7	**5**
Climate regulation	13.0	**6**

Sand and other minerals	12.0	**7**
Wild aquatic animals	11.5	**8**
Mediation of wastes	10.5	**9**
Farmed aquatic animals	10.0	**10**
Farmed aquatic plants	8.5	**11**
Recreation	2.8	**12**
Scientific research	1.2	**13**
Cultural heritage	1.0	**14**
Aesthetic value	1.0	**14**
Wild aquatic plants	1.0	**14**

The ranking results (i.e. rank scores) for each sector were used as input to a hierarchical clustering algorithm and the resulting dendrogram is presented in Figure 8. By reading off only two clusters from the dendrogram, it is possible to see one cluster formed by the Aquaculture and Fisheries sectors and another formed by the remaining sectors. This indicates that Aquaculture and Fisheries prioritize a similar set of ES that is dissimilar to the set of ES prioritized by the other sectors. As the height (i.e. the distance metric between clusters/observations) decreases, a third cluster emerges away from the larger cluster, composed of the sectors Conservation and Consultancy. At a height of six, a fourth cluster is formed by the Offshore energy & communication sector and the Shipping sector, while the larger cluster is composed of Society, Shipping, Ports, Marine engineering, and Research. Note that no 'correct' number of clusters can be determined through hierarchical clustering, but a rule of thumb is to look for clusters with the longest branch heights (in this case the optimal number would be two clusters). Overall, the utility of this visualization is to provide some sense of which sectors are more likely to agree in terms of which ES to prioritize and where disagreements or conflicts might arise.

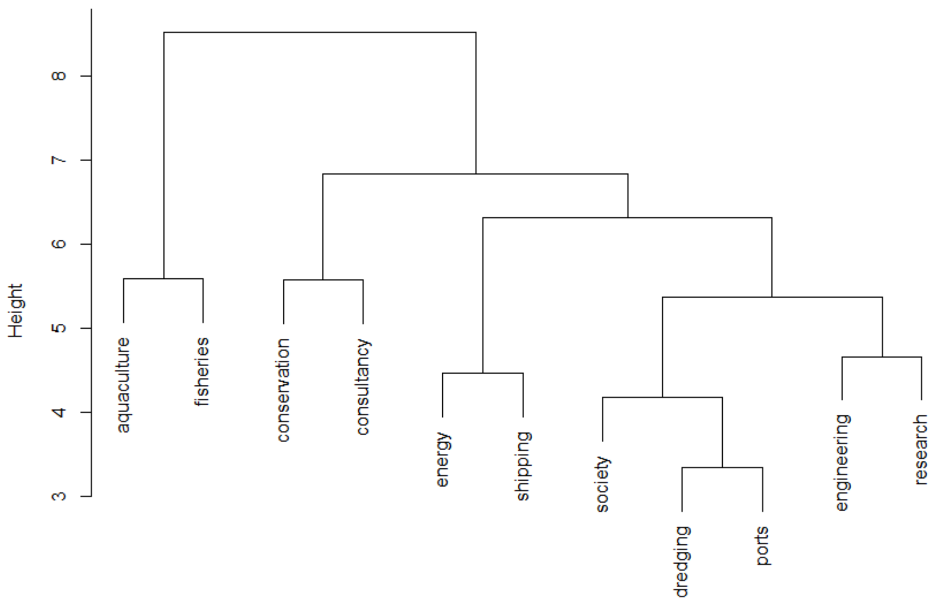

Figure 8: Hierarchical clustering dendrogram (linkage method: ward's minimum variance).

7.2. Linking ES supply and marine activities

The four breakout groups successfully created four linkage diagrams (Figure 8A-D), from which a unified diagram was created (Figure 8E), following the rules described in section 6.3. Overall, offshore wind farms (OWF) were connected to many different ES and other marine activities through a mix of negative and positive effects that must be considered when assessing the environmental and socioeconomic impacts of this activity.

From the point of view of the stakeholders, the ES that can directly benefit from increased OWF are *Offshore renewable energy* and *Scientific research.* For example, OWF the *Scientific research* service by offering opportunities for studying e.g. the impact of offshore man-made structures in the ecosystem and the artificial reef effect that these hard structures promote (Dannheim et al., 2020; De Borger et al., 2021; Gill et al., 2020). Indirect benefits can also arise, for instance, for *Farmed aquatic animals* and *Farmed aquatic plants* because OWF areas allow for co-location with the Aquaculture sector, providing suitable space for low-trophic aquaculture to develop (e.g. seaweed and mussel aquaculture) (Abhinav, 2020; Galparsoro et al., 2020). These ES, in turn, can positively impact the ES of *Mediation of wastes,* through the nutrient filtration and extraction capacity of those low-trophic organisms (Lindahl et al., 2005; Mavraki et al., 2020), in a cascade of positive effects.

ES that can be negatively directly affected by OWF are not so evident. One could argue, as pointed out by stakeholders, that OWF can negatively affect *Sand and other minerals* by occupying sea bottom area and therefore decreasing the sand available for extraction. Direct negative effects of OWF are mostly associated with the other marine activities, as OWF concession areas become exclusion zones to most of them. One of the most obvious conflicts is with the Fisheries sector, which sees its fisheries grounds being reduced substantially, which in turn can have a cascade positive effects in ES (e.g. increase in *Wild aquatic animals* and *Nursery and habitat and maintenance*) as well due to a reduction in fishing in those areas. This could in turn have an indirect positive effect on Fisheries due to a potential spillover effect (Stelzenmüller et al., 2021).

Most highlighted links have a mixed effect associated with them. For example, the ES *Aesthetic experience* can be negatively affected by OWF due to its impact on the seascape, but the extent of this effect depends on OWF areas distance to the shore (i.e. visibility) and also depends on the sociodemographic characteristics of the person assessing the aesthetic experience provided by a seascape with OWF (Gee, 2010). *Recreation* can also be affected both ways, as opportunities for sailing or birdwatching offshore decrease because of the exclusion zone. However, other recreational opportunities can be created in collaboration with wind farm operators, such as snorkeling in proximity to wind turbines, given the increase in biodiversity. As discussed previously, OWF can benefit *Wild aquatic animals* by promoting the aggregation of important fish species around wind turbines through the artificial reef effect that increases the abundance of sessile and benthic species and, therefore, feeding opportunities for those fish (Slavik et al., 2019). On the other hand, it could have a negative effect on some species that seem to avoid OWF, which is the case of harbor porpoise during the pile-driving phase of the OWF operation (Degraer et al., 2020).

Overall, the linkage diagram represents stakeholders' understanding and knowledge of the relations between ES and marine activities in the BCS, with a focus on the OWF and is by no means a full representation of the potential links. This diagram was further complemented with ScAB inputs and information from the OWF literature (see Section 8). A follow-up workshop was also suggested by some of the stakeholders to continue developing this linkage diagram, building towards a more comprehensive illustration of those interactions within the BCS.

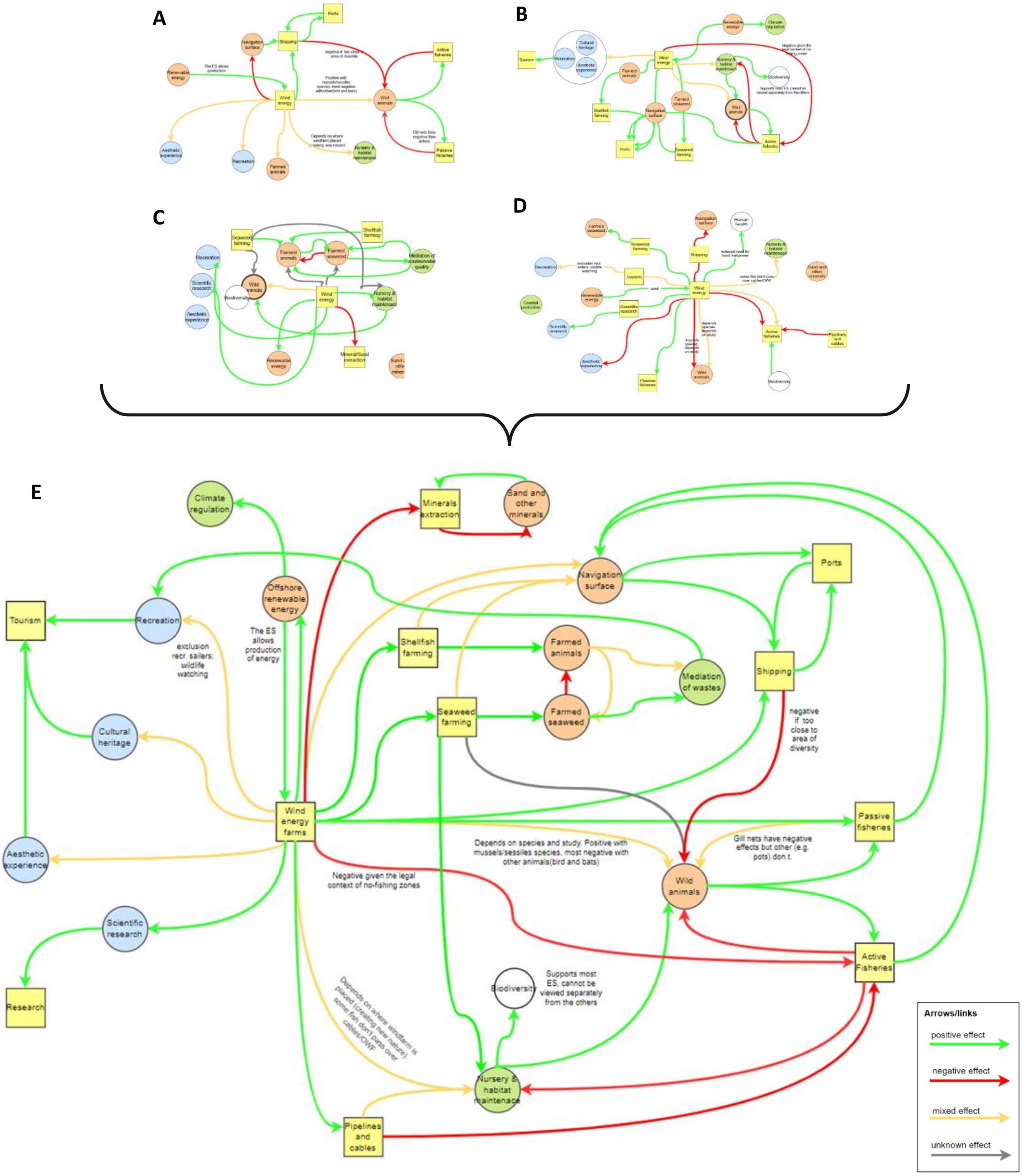

Figure 9: Linkage diagrams co-created by the breakout groups (A-D) and the resulting unified diagram (E).

8. Scientific Advisory Board consultation

On the 27th of May, a 2-hour consultation was carried out virtually with members of the ScAB with expertise on ES, virtually, namely Angel Borja (AZTI), Fiona Culhane (University of Plymouth), Gert Van Hoey (ILVO), Jan Vanaverbeke (Royal Belgian Institute of Natural Sciences) and Stephen Hynes (NUI Galway). The main goals were to present and receive feedback on the outputs from the workshop, further improve the linkage diagram and also receive inputs on the most appropriate *demand* indicators as done with the stakeholders.

In regards to the ranking of the relevant ES, some key takeaways were distilled from the discussion. The main point of discussion was whether or not to include the ES *Biodiversity* in the SUMES assessment. Scientific experts expressed conflicting opinions about this ES, similarly to the opinions expressed by the stakeholders. On the one hand, some defended its exclusion from the assessment because it is not a final ES (but instead supports/underpins the final ES). On the other hand, others referred to the possibility of considering *Biodiversity* as an ecosystem component that provides a cultural ES of *Existence value* as a way to go around the issue and include it in the assessment to meet stakeholders' expectations. It was decided that *Biodiversity* should be addressed in SUMES by providing a clear definition of *what* it means and *how* it is considered in the assessment. Given the intermediary nature of *Biodiversity* from an ES perspective (i.e. supporting service) and considering that CICES was chosen as SUMES reference classification (where supporting services are not covered, only final services are), in principle *Biodiversity* will not be quantified as an ES *per se* (but will nonetheless be considered within the structural components of the ecosystem that deliver ES and that might be impacted by human activities). For a detailed discussion on the conceptual problems with intermediary services in the context of environmental accounting and why these are not covered under CICES, see Potschin-Young et al. (2017).

Another concern was raised about the fact that the ES *Recreation* emerged as a low priority service from the workshop, which could be explained by the underrepresentation of sectors that valorize this ES (e.g. Tourism). It was therefore recommended that *Recreation* is still included in the assessments, where relevant, given its importance to the Tourism sector (Ruskule et al., 2018)

Concerning the linkage diagram, ScAB experts approved the stakeholders' unified diagram and provided additional links that in their view were missing. The latest version of the linkage diagram is displayed in Figure 10 (created with DiagrammeR package in R) after incorporating the inputs from the ScAB and additional information extracted from the recommended literature. It expands the unified workshop diagram by incorporating 8 additional links as suggested by the ScAB, in a total of 58 links.

The ScAB members were also asked, through a series of polls, which 'ES demand' indicators they recommended for each of the relevant ES, and the outcome of these polls will be presented and discussed elsewhere (Deliverable 2.4 - *Valuation of ES demand in the BCS*).

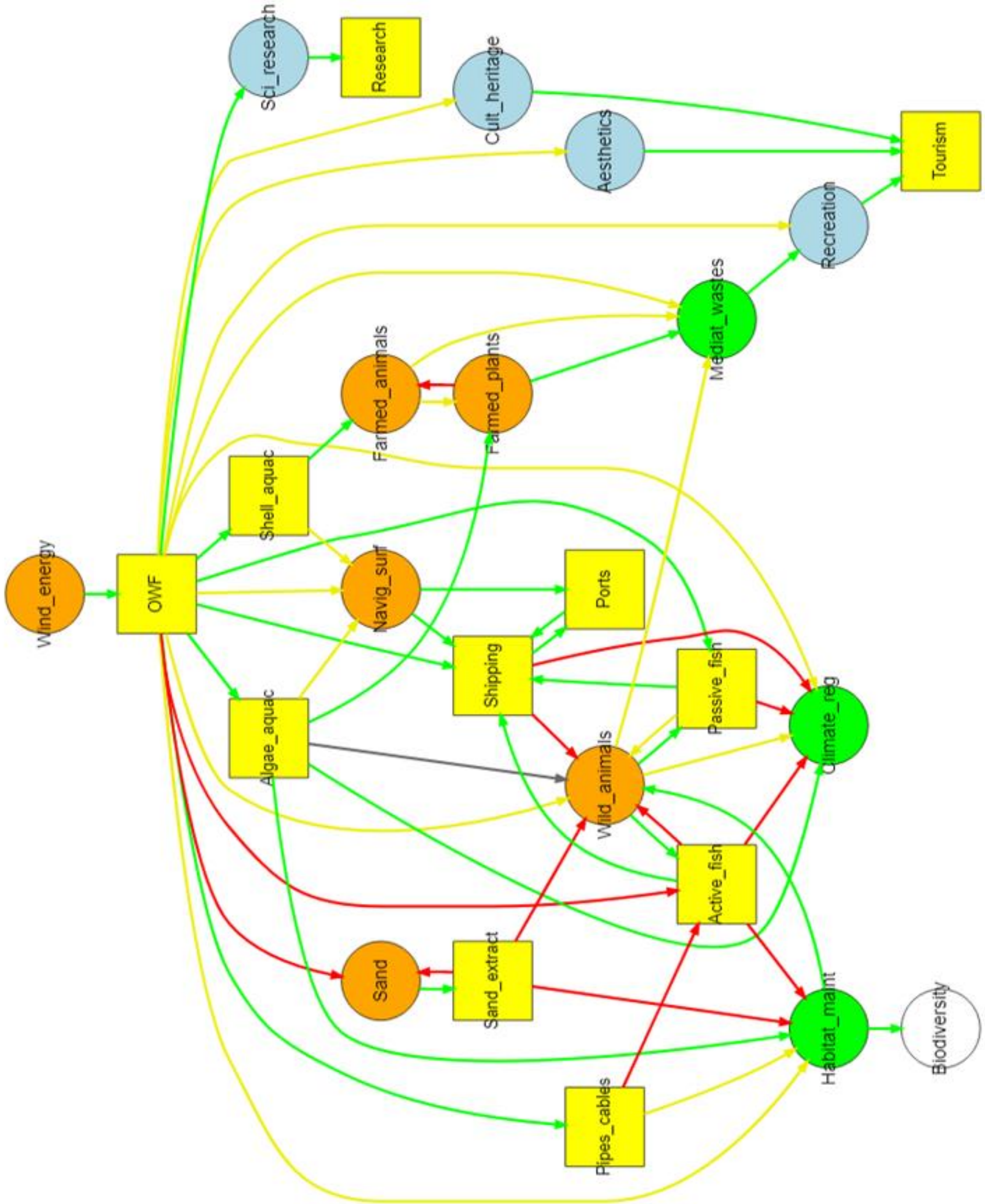

Figure 10: Linkage diagram based on the stakeholder workshop and the inputs of the Scientific Advisory Board.

9. Conclusions

A diverse group of stakeholders from the BCS, representing 11 marine-related sectors, was engaged in a virtual workshop to select and prioritize the relevant ES of the BCS for the SUMES project. The five ES of highest priority agreed upon by this stakeholder group were (excluding *Biodiversity*): *Coastal protection, Renewable offshore energy, Navigation surface, Nursery & habitat maintenance* and *Climate regulation*. Those with the lowest priority (bottom 5) were (in descending order), *Recreation, Research, Cultural heritage, Aesthetic experience* and *Wild aquatic plants*. The ES *Biodiversity* generated some controversy among the stakeholders and the ScAB in regards to its inclusion or not as an ES in the SUMES assessment, and it was decided to follow the CICES guidelines to be consistent with the classification system used in SUMES. The linkage diagram created during this work provided insights on the potential causal relationships between ES and marine activities in the BCS, first based on stakeholders' understanding of the system and complemented with experts' knowledge and information from relevant OWF literature. A special focus was given to OWF, which provides a good overview of the causal relationships worth exploring for the first SUMES case study. Regarding the demand indicators, the outcomes will be presented in a future deliverable concerning Task 2.3 (i.e. Deliverable 2.4).

Overall, this work collected useful insights from a diverse group of stakeholders representing different sectors of the BCS, about which ES they valorize the most and what is their understanding of the existing causal links between BCS-relevant ES and marine activities. The outcomes of this work will support and inform ongoing and future tasks of the SUMES project, namely Tasks 1.1, 2.3, 3.1, and 4.1.

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11.Annex

Table 6: Relevant ES from the BCS. Orange cells – Provisioning ES (biotic); green cells – Regulating & maintenance ES (biotic); blue cells – Cultural ES (biotic); red cells – Abiotic ES.

CICES Section	CICES Division	CICES Group	CICES Class	Terminology used in the workshop	Reference
Provisioning (Biotic)	Biomass	Cultivated aquatic plants for nutrition, materials or energy	Plants cultivated by in-situ aquaculture grown for nutritional purposes	*Farmed aquatic plants for food, materials and energy*	(Causon & Gill, 2018) UNITED project(*Offshore Wind and Flat Oyster Aquaculture & Restoration in Belgium*, n.d.)
			Fibers and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials)		
			Plants cultivated by in-situ aquaculture grown as an energy source		
		Reared aquatic animals for nutrition, materials or energy	Animals reared by in-situ aquaculture for nutritional purposes	*Farmed aquatic animals for food, materials and energy*	(Causon & Gill, 2018) UNITED project (*Offshore Wind and Flat Oyster Aquaculture & Restoration in Belgium*, n.d.) EDULIS project (*Edulis: Offshore Mussel Culture in Wind Farms | BLUEGent*, n.d.)
			Fibers and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials)		
			Animals reared by in-situ aquaculture as an energy source		
		Wild animals (terrestrial and aquatic) for nutrition,	Wild animals (terrestrial and aquatic) used for nutritional purposes	*Wild aquatic animals for food, materials and energy*	(Causon & Gill, 2018) (Gill et al., 2020) (Vogel et al., 2018)

		materials or energy	Fibers and other materials from wild animals for direct use or processing (excluding genetic materials) Wild animals (terrestrial and aquatic) used as a source of energy		(Hooper et al., 2017) (Busch et al., 2011) (Papathanasopoulou et al., 2015)
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Bioremediation by microorganisms, algae, plants, and animals Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	*Mediation of wastes*	(Causon & Gill, 2018) (Volkenborn et al., 2007) (Lindahl et al., 2005) (Braeckman et al., 2010) (Vogel et al., 2018) (Hooper et al., 2017) (Papathanasopoulou et al., 2015)
	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Hydrological cycle and water flow regulation (including flood control and coastal protection)	*Coastal protection*	(*Coastbusters*, 2018) (Hooper et al., 2017)
		Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats (Including gene pool protection)	*Nursery and habitat maintenance*	(Causon & Gill, 2018) (Degraer et al., 2008) (Vogel et al., 2018) (Hooper et al., 2017)
		Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans	*Climate regulation*	(Causon & Gill, 2018) (Hooper et al., 2017)
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on the presence in the	Physical and experiential interactions with the natural environment	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions	*Recreation*	(Causon & Gill, 2018) (Gill et al., 2020) (Degraer et al., 2019) (Vogel et al., 2018) (Hooper et al., 2017)

	environmental setting		Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions		(Biest et al., 2017)
		Intellectual and representative interactions with the natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	*Scientific research*	(Vogel et al., 2018) (Hooper et al., 2017)
			Characteristics of living systems that are resonant in terms of culture or heritage	*Cultural heritage*	(Vogel et al., 2018) (Causon & Gill, 2018) (Busch et al., 2011)
			Characteristics of living systems that enable aesthetic experiences	*Aesthetic value*	(Vogel et al., 2018) (Hooper et al., 2017) (Busch et al., 2011)
Provisioning (Abiotic)	Water	Other aqueous ecosystem outputs	Other	*Surface for navigation*	(Vogel et al., 2018) (Neyts et al., 2015)
	Non-aqueous natural abiotic ecosystem outputs	Mineral substances used for nutrition, materials or energy	Mineral substances used for material purposes	*Sand and other minerals*	(Degrendele & Vandenreyken, 2017)
		Non-mineral substances or ecosystem properties used for nutrition, materials or energy	Wind energy	*Renewable offshore energy*	(Vogel et al., 2018) (Busch et al., 2011)
Regulation & Maintenance (Abiotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of waste, toxins and other nuisances by non-living processes	Mediation by other chemical or physical means (e.g. via Filtration, sequestration, storage or accumulation)	*Mediation of wastes*	(Causon & Gill, 2018) (Volkenborn et al., 2007) (Lindahl et al., 2005) (Braeckman et al., 2010) (Vogel et al., 2018) (Hooper et al., 2017) (Papathanasopoulou et al., 2015)