Unlocking the potential of aquatic bioresources

Blue BIO COFUND

STRATEGIC RESEARCH AND INNOVATION AGENDA

for the Blue Bioeconomy

ABOUT BLUEBIO

BlueBio is an ERA-NET Cofund funded under Horizon 2020. The objective of the ERA-NET Cofund scheme was to develop and strengthen the coordination of national and regional research programmes. The Bioeconomy ERA-NET Cofund was created to establish a coordinated R&D funding scheme directly addressing actions envisaged within fisheries, aquaculture, seafood processing and marine biotechnologies. It started in 2018 under the BG-02-2018 Topic of the Horizon 2020 Research and Innovation Programme and consists of 30 partners from 17 countries.

BLUEBIO PARTNERS

- RCN - Research Council of Norway, Norway
- FWO - Research Foundation Flanders, Belgium
- VLAIO - Flanders Innovation and Entrepreneurship, Belgium (HERMES)
- MZO - Ministry of Science and Education, Croatia
- IFD - Innovation Fund Denmark, Denmark
- ETAG - Estonian Research Council, Estonia
- MEM - Ministry of Agriculture, Estonia
- MMM - Ministry of Agriculture and Forestry, Finland
- BLE - German Federal Office of Agriculture and Food, Germany
- BMBF - German Federal Ministry of Education and Research, Germany
- BMEL - German Federal Ministry of Food and Agriculture, Germany
- JULICH - Research Center Jülich, Germany
- VDI/VDE - Innovation + Technik GMBH, Germany
- GSRT - Ministry of Development; General Secretariat for Research and Technology, Greece
- RANNIS - Icelandic Centre for Research, Iceland
- MI - Marine Institute, Ireland
- SFI - Science Foundation Ireland, Ireland
- CNR - National Research Council, Italy
- MUR - Ministry of Education, University and Research, Italy
- IZM - Izglītības un zinātnes ministrija, Latvia
- MCST-MEYR - Council for Science and Technology, Malta
- IN - Innovation Norway, Norway
- FCT - Fundação para a Ciência e Tecnologia, Portugal
- FRCT - Regional Fund for Science and Technology of the Azores, Portugal
- UEFISCDI - Executive Unit for Higher Education, Research, Development and Innovation Funding, Romania
- CDTI - Centre for Development of Industrial Technology, Spain
- AEI - State Research Agency, Spain
- FORMAS - Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, Sweden
- VGR - Region Västra Götaland, Sweden

STRATEGIC PARTNER

- JPI Oceans: Joint Programming Initiative Healthy and Productive Seas and Oceans

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This project has received funding from the European Union's H2020 Research and Innovation Programme under grant agreement no. 817992.

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1. INTRODUCTION

Meeting the growing demand for food, sustainable energy, and freshwater, along with the imperative to address climate change and mitigate its repercussions, necessitates the responsible and full utilization of biological resources while safeguarding the long-term health of our planet. This is particularly relevant to our oceans, covering 71% of the Earth's surface.

A holistic approach, intertwining technological innovation, sustainable practices, and international cooperation is essential, not only to address these challenges but also to transform them into opportunities for advancement and sustainable development. This collective concern is embodied in initiatives like FOOD2030, led by the European Commission, which focusses on Research & Innovation for Nutrition and Food Systems, aiming to reshape food systems with sustainability, resilience, competitiveness, diversity, responsibility and performance for accessible, healthy, and sustainable food for all.

At the core of this comprehensive strategy is the Blue Economy concept, emphasizing the responsible use of oceans to create economic value while balancing economic growth with marine ecosystem conservation, fostering prosperity without compromising the environment, and contributing to the sustainable development of coastal communities.

Aquatic biomass from seas, oceans, rivers, and lakes has significant potential for ensuring future food, feed, and nutrition security. It is also recognized as a source of raw materials for high-value products like pharmaceuticals, food ingredients, chemicals, novel materials, and cosmetics, taking into account environment and climate change risks. As a low-value product, bioenergy will result as a by-product from biorefining processes, creating jobs, economic growth, and contributing to a healthier and more sustainable society. The utilization of aquatic bioresoures could, in many cases, offer climate-efficient methods of production.

The EU H2020 ERA-NET Cofund Blue Bioeconomy builds upon this foundation and pursues the goals of the Blue Bioeconomy topic BG-02-2018 in the Horizon 2020 Work Programme 2018-2020. It is a transnational partnership of Research and Innovation (R&I) funding agencies and ministries with the ambition to establish a coordinated R&D funding scheme to unlock the potential of aquatic bioresources and strengthen Europe's position in the field of the Blue Bioeconomy. Its primary objective is to generate employment, stimulate economic growth, and provide food, nutrition, identifying new and improving existing ways of bringing bio-based products and services to a global market.

2. IDENTIFYING RESEARCH AND INNOVATION NEEDS

This document presents the common Strategic Research and Innovation Agenda (SRIA) as developed over the running period of the BlueBio Cofund.

It describes the activities underpinned to identify and address the research and innovation needs and gaps in unlocking the complete potential of marine bioresources throughout the value chain. Its aim is to serve as a portfolio for ongoing and future initiatives, contributing to the EU's role in the Blue Bioeconomy and specifically for the HORIZON-COFUND "Sustainable Blue Economy Partnership" (SBEP) which has been recently initiated basing its foundations on the BlueBio Cofund (Figure 1).

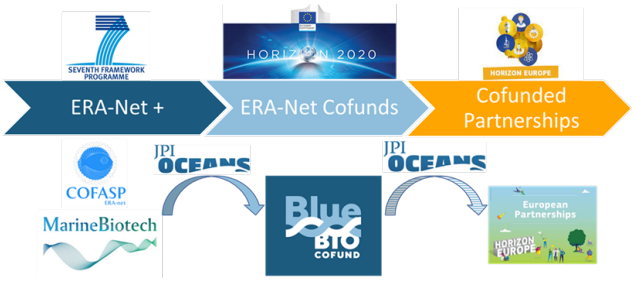


Figure 1. *BlueBio predecessors and successors.*

Leveraging networks and strategies from the previous COFASP and ERA-MBT ERA-NETs (spanning from 2013 to 2017), and JPI Oceans, the BlueBio Cofund achieved its objectives through a Cofunded call, concentrating on Blue Knowledge and technological advancements. Moreover, BlueBio extended its impact by implementing 3 additional calls, actively involving stakeholders in the development of funding initiatives, and executing various related activities to amplify the impact of cofunded projects, identify the research and innovation needs of industry and society to develop the Blue Bioeconomy further avoiding duplication, favour synergies with past and ongoing research projects, and hasten the commercialization and competitive deployment of innovative solutions.

BlueBio was expected to contribute to the ongoing implementation of EU policies, including the Bioeconomy Strategy, Circular Economy Strategy, Blue Growth Strategy, Common Fisheries Policy, Marine Strategy Framework Directive, Maritime Spatial Planning Directive, EUSAIR. It also aimed to support priorities outlined in the European Commission Staff Working Document FOOD 2030 and international initiatives such as the Atlantic Ocean Research Alliance (Figure 2).

Figure 2. *BlueBio drivers, goals, objectives, outcomes and expected Impacts as extracted from the Grant agreement.*

The initiation of the BlueBio Cofund involved creating an inventory of national research priorities and engaging with stakeholders to lay the groundwork for the development of the initial BlueBio joint call. In addition to this short-term inventory, a more comprehensive analysis of research conducted in Europe was undertaken.

More specific issues overlooked in the joint call, were pinpointed through a series of actions. This included analysing challenges encountered by the cofunded projects selected in the joint call, engaging in further dialogue with ministries and national agencies, and interacting with the partnerships of the cofunded projects.

Specific research priorities not addressed by projects funded within the joint call were incorporated into two additional calls.

Research on novel funding and private sector opportunities, analysis of interactions with projects, interviews with investors and accelerators, and a survey of projects to map commercialization needs and status led to the launch of an additional call focused solely on amplifying project reach and knowledge impact.

Specific issues concerning the improvement of Human Capacity Building (HCB), Training and Mobility (T&M) and the sharing of knowledge and research infrastructures within both the funded projects and Europe as a whole, were tackled through targeted activities, such as e-coffee meetings among funded projects, the use of questionnaires, workshops, and the organization of training courses.

A participatory Foresight exercise was conducted to identify the research needs for introducing bio-based products and services to the market and discover innovative methods of creating value from the Blue Bioeconomy over the long-term perspective (2050). This engaged representatives from key stakeholder groups in fisheries, aquaculture, food processing, and marine biotechnology from academia and industry, as well as policy and societal organizations.

3. BUILDING THE BLUEBIO COFUNDED CALLS

To unlock the potential of aquatic bioresources, BlueBio has applied a value chain approach. While traditional research in this area has focused on developing efficient ways to produce and harvest the bioresources, it is now widely acknowledged that there is a need to address research and innovation challenges, gaps, and needs throughout the entire value chain - from biomass to products and markets - in order to ensure progress towards full sustainability and to accelerate the bioeconomy.

3.1 DEVELOPING THE COFUNDED CALL

The BlueBio Cofund was built on the predecessor ERA-NETs ERA-MBT and COFASP in collaboration with JPI Oceans. A compilation and assessment of their strategies, foresights and roadmaps were used as basis for the preparations of BlueBio research in innovation priorities identifying needs and gaps along the Blue Bioeconomy values chains.

The priorities identified in the gap analysis were grouped into five areas (Figure 3):

A1 *Exploration of the aquatic environment and biological resources for improving the Blue Bioeconomy:*
biological aquatic resources consist of catches from capture fisheries, aquaculture, and of biomass such as invertebrates and microorganisms and the total aquatic gene pool, as well as products of the microbiota and the host environment.

A2 *Biomass production and processing:*
biomass production involves several processing steps from harvesting to the end-use. Long-term goals to improve processing include shortening the supply chain by integrating the processing stages, optimizing the production of feedstock, employing multi-stream bio-refining techniques etc. Possibilities for synergies across established and emerging ocean industries and land-based food, feed production and processing industries are numerous with a potential to create circular sustainable supply chains, where all biomass is fully utilized and waste is eliminated, however requiring a multi-actor approach.

A3 *Product innovation and differentiation:*
only a small fraction of aquatic biomass is presently used outside the food and feed sectors. The goal is to maximize the sustainable use of aquatic bioresources for applications in safe food, food ingredients, therapeutic compounds, medical devices and biomaterials, cosmetics and cosmeceuticals and as novel industrial materials and processes. The exploration of other market opportunities and entirely novel applications in several other sectors is also a key focus.

A4 *Market issues:*
a collective approach across the value chain, from marine biomass to market, is essential to reduce the EU's reliance on biomass imports. For European seafood producers, competing on price alone is not feasible in many market areas. Instead, the emphasis should be on delivering high-quality products that meet sustainability benchmarks, achieved by ensuring transparency, traceability, and adherence to sustainable practices.

A5 *Enabling technologies and infrastructure:*
significant progress has been made over the past decade in building a research community and infrastructure to support research and innovation for processing aquatic resources. Despite this progress, there remains an acute need to continue to build research and innovation capacity and to enhance the science and technology research infrastructure.

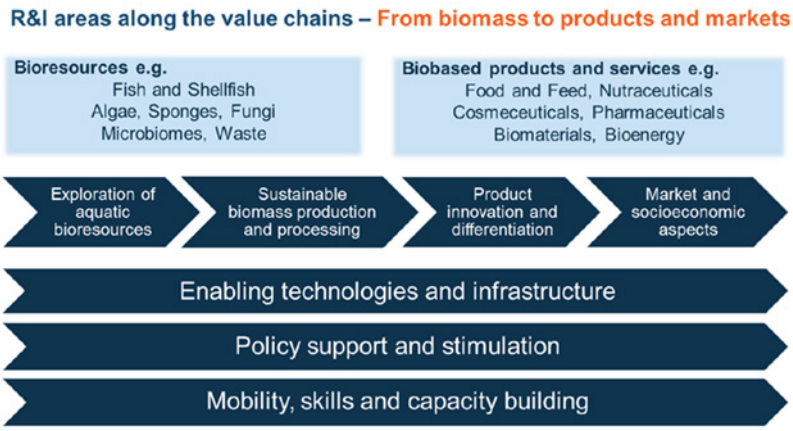


Figure 3. *BlueBio addressed research and innovation areas along the Blue Bioeconomy value chains from biomass to products and markets. The figure also shows relevant crosscutting R&I areas.*

The five areas align well with the seven elements outlined in the EU BG-02 scope, as illustrated in Table 1.

The purpose of BlueBio was to harmonize the research and innovation priorities of the Partners and predecessors addressing identified needs and gaps and to launch a call that responded to these recognized areas.

To achieve this goal, rather than selecting between the identified R&I needs and gaps it was agreed among all partners to keep the Cofunded call rather broad to ensure relevance and interest from partners and potential applicants in all participating Countries. Still, it was decided to condense the scope into four defined priority areas, more or less covering crosscutting and thematic needs and gaps along the value chains.

It was decided that projects should consider creating, testing, upscaling and bringing to the market new knowledge-intensive products and services derived from aquatic biomass. In general, they should consider:

- the '3R principle' of Reducing, Reusing and Recycling to achieve a circular economy;
- explore innovative, yet sustainable and climate-friendly utilisation of aquatic biomass at different trophic levels, as well as sustainable harvesting, and novel aquaculture production systems;
- targeting a range of products (food, feed, chemistry, nutraceuticals, cosmetics, etc.) in existing or new markets.

Projects that solely focussed on a segment of the value chain were requested to specify the particular part of the value chain under focus and to consider impact and consequences of new methods or products within a broader value chain perspective.

Potential list of topics from the gap analysis Gaps mentioned in BG-02-call	1. Exploitation of the aquatic environment and biological resources for improving the Blue Bioeconomy	2. Biomass production and processing	3. Product innovation and differentiation	4. Market issues	5. Enabling technologies and infrastructure
1. developing innovative uses of underutilised and waste material from fisheries and aquaculture to achieve zero waste;	X	X	X	X	
2. using biotechnology and ICT to develop smart, efficient, traceable food systems;		X	X	X	X
3. create synergies between aquaculture and fisheries (genetic assessment and digitalisation);	X	X			X
4. unlock the potential of microbiomes to support growth in aquaculture, fisheries, and food processing and biotechnology; apply the latest developments in ICT (IoT, machine learning, big data) to the Blue Bioeconomy;	X	X			X
5. creating predective tools to improve the identification and targeting of biodiversity "hot-spots" in the oceans (omics based technologies);	X				X
6. exploring synergies with land-based production in areas such as food and feed production and processing, biorefining, bioenergy, biomaterials, chemicals and nutrients and maximise the use of aquatic bioresources in terrestrial value chains;			X	X	X
7. improving aquaculture and wild harvesting of stocks by support for the creation of innovative feeds, improved brood stocks, by introducing new species, defining stock baselines, and assessing stocks and by encouraging the adoption of novel production technologies	X	X			

Table 1. *The five priority areas identified from the gap analysis and gaps highlighted in the EU BG-08-2018-2019 call.*

The thematic scope of the call was described as four different priority areas (PA):

- PA1: Exploring new bioresources - it included innovative use of waste, underutilised material, algae and invertebrates for biorefinery processes, supportive use of microbiomes, identification of biodiversity hotspots and new species.
- PA2: Exploring improvements in fisheries and aquaculture – it included innovative feeds, improved brood stock, biosecurity and stock assessments.
- PA3: Exploring synergies across sectors – it included synergies between aquaculture and fisheries as well as with land-based productions.
- PA4: Exploring biotechnology and ICT – it included use for smart, efficient and traceable production and the use of IoT, machine learning and big data.

In total, 83 pre-proposals were received and ended up funding 19 projects (Table 2; Figure 4). The majority of applications came in PA1 and PA2. There was a decreasing number of applications down the line of priority areas, that was even more distinct after the evaluation process. Fifty percent of the pre-proposals and two-thirds of the funded projects were linked to PA1, while 6% applications in PA4 ended up as no funded project. It could seem that the more cross-cutting a priority area was described, the more difficult and/or less interesting it was for applicants to prepare applications that received funding.

	PA1	PA2	PA3	PA4	Total
Pre-proposals received	41	24	13	5	83
Projects selected for funding	12	6	1	0	19

Table 2. *Number of proposals received and the number of funded applications in the BlueBio cofunded call.*

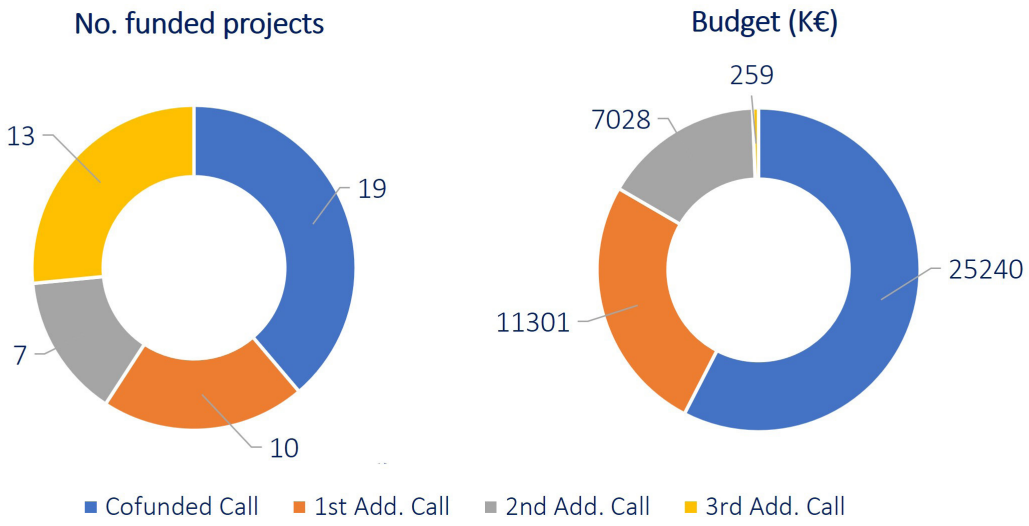


Figure 4. *Number of projects funded under the BlueBio Cofunded call and each Additional call with the total budget in thousands of EUR allocated to each call.*

Recommendation

- Establishing a clear plan and vision for consecutive calls allows to identify and address all the gaps and needs along the value chain, facilitate effective dialogue with the national funders, potential applicants and stakeholders, and increase the quality and relevance of the proposals. Building on prior efforts ensures stability for applicants and a clearer path to achieve long term strategic goals.

3.2 MAKING DEMANDS TO ENSURE IMPACT

There were a number of aspects that were included in the call to ensure impact from the projects. These included Human Capacity Building, industry partner inclusion, and expectations on increase in Technology Readiness Level.

HUMAN CAPACITY BUILDING INCLUSION

Human Capacity Building (HCB) was not initially described explicitly in the scope for the Cofunded call. However, recommendations for inclusion of HCB activities within the projects were provided to the project coordinators during the application process, and issues relating to HCB were communicated and followed up throughout the duration of the projects (see Section 2.4.5). Specifically, guidelines for proposers regarding HCB and Training Activities were produced and delivered by the BlueBio Consortium.

INDUSTRY PARTNER INCLUSION

Industry involvement was mandatory to ensure an applied perspective and industry relevance. Using new methods and technologies may require multidisciplinary approaches where the development of toolboxes and enabling technologies may be an integrated part.

INCREASE IN TECHNOLOGY READINESS LEVEL (TRL)

Project proposals with TRL up to 7 were accepted provided the funding agencies in question could fund them. Projects should propose advancements in TRL levels during their lifetime.

Recommendation

- If there are drivers that are believed to be essential for the impact of the funded projects, they must be included in the call text and followed up on while monitoring the projects.

3.3 DEVELOPING THE CALL TOPICS FOR THE 1ST & 2ND ADDITIONAL CALLS

A value chain overview of funded projects from the Cofunded call was conducted by the Value Chain Supervisors (VCS) and demonstrated gaps in three value chain areas (Figure 5). The analyses of research project database supported the need for more projects and hence knowledge in these areas.

Recognising the risk of less interest and fewer proposals from applicants in areas with few or no projects in the Cofunded call, it was still agreed among the funding partners to launch additional calls within these areas to follow up on the value chain approach (Figure 5).

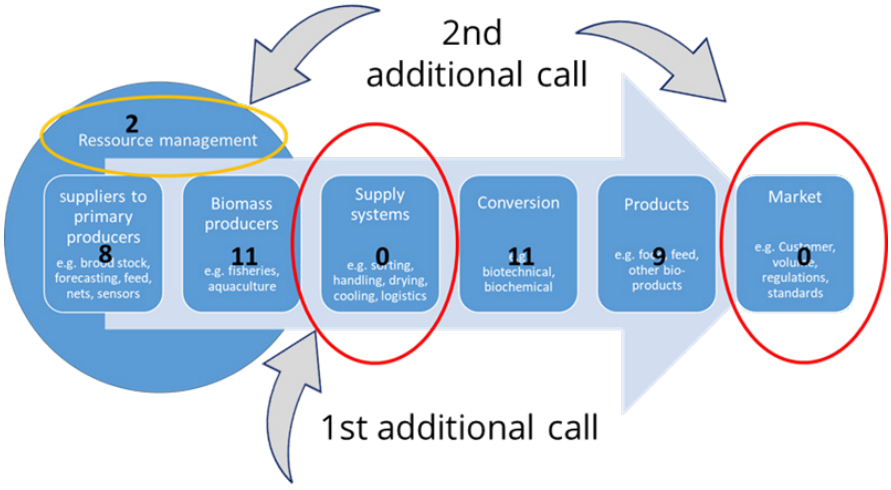


Figure 5. *Value chain overview of funded projects within the cofunded call. The numbers indicate the number of projects funded in that link in the value chain. Three areas with zero or only two projects were identified and provided the basis for the subsequent additional calls.*

For the 1st Additional call, the decision was made to concentrate on supply systems. Accordingly, the call featured only one priority area *"Advancing the supply systems in the BLUE BIOECONOMY value"*. It specifically targeted projects that facilitated the transfer (such as logistics, preservation, and transportation) of bioresources from harvest (catch or production) to processing, ensuring aspects like traceability, quality, sustainability, and the necessary quantity or pre-processing of the bioresources for conversion into marketable products.

To determine the call scope of the 2nd Additional call, a survey was sent to all BlueBio funding organisations to establish participation, financial commitment, additional activities, priorities and potential topics. The decision for call scope circled around the other two value chain gaps identified from the value chain analyses of the cofunded call projects, also considering the R&I gaps described in the BlueBio Grant Agreement and the national priorities. The scope was described as: *"Advancing Resource Management, Market and Socioeconomic aspects in the Blue Bioeconomy Value Chains".*

About Resource Management, the call aimed to facilitate research and innovation to underpin sustainable and circular management and use of natural resources. This encompassed an integrated food systems approach to ensure ecosystem integrity and resilience. Regarding the Market, acceptability, trust, transparency, and innovation uptake by citizens are crucial for developing the Blue Bioeconomy sector. To achieve this goal, the production and consumption of safe and healthy food and bio-based products (food and nutrition security) are vital. Three subtopics were described:

A. *Sustainable exploration of the aquatic environment and biological resources;*
B. *Sustainable and resilient biomass production and processing;*
C. *Traceability and regulatory constraints.*

Available funding and number of Countries were lower for the Additional calls than for the Cofunded call, due to a number of compounding factors. The most significant reason was the lack of co-funding from the European and H2020, the second one was the diversion of funding in response to the COVID 19 pandemic after March 2020, and commitments to the incoming Horizon Europe Partnerships. In addition, the narrower call scopes naturally suited fewer partner's priorities. Consequently, the number of funded projects was lower, but the targeted calls enabled BlueBio to fill the gaps and fund projects along the whole value chain.

The 1st Additional call was launched in June 2020 and received 17 pre-proposals, out of which 10 projects were funded. The 2nd Additional call was launched in June 2021 and received 20 pre-proposals out of which 7 projects were funded.

Recommendation

- Identifying gaps after the first call, enabled more precise and focused call scopes for the additional calls. It was more challenging to engage funders, but it increased the impact of BlueBio on challenging topics.

3.4 NOVEL FUNDING METHODS AND THE 3RD ADDITIONAL CALL

One of the scopes of BlueBio was to identify potential novel funding mechanisms. Combined with a reduction in national commitment in the Additional calls, which is quite common for ERA-NET initiatives, BlueBio partners were asked to suggest potential novel funding arrangements that could be undertaken to enhance the Blue Bioeconomy portfolio of cofunded projects. It was noted that not all partners would have been in a position to fund these types of initiatives and instead could only provide resources to the traditional R&I calls.

In addition to these suggestions from BlueBio partners, broader funding opportunities were explored including smart specialisation, ICT Agri-Food and CHIST-ERA challenge funding tool, the EIC programme, BlueInvest, and others.

Following the completion of this analysis and discussions both with BlueBio Cofund partners and project coordinators at e-coffee meetings, a novel funding call focusing on increasing impact for the funded projects was developed. This small-scale, short-term funding invited the funded consortia to propose projects under the following topics:

- *Dissemination of research and results;*
- *Training, exchange and capacity building;*
- *Business and commercialisation preparation;*
- *Mapping of relevant policy landscape;*
- *Barriers to commercialisation pathway.*

Under this call, launched in November 2022, 13 projects out of 19 submitted proposals were selected to amplify project reach and knowledge impact. Supporting BlueBio funded projects through this type of call enabled them to carry out complementary studies and activities that had not been foreseen in the initial proposal.

Recommendation

- Precision funding can be impactful when the calls are developed with deep understanding of the projects. An opportunity for complementary funding can increase the impact of an already funded project.

4. BEST PRACTICES

4.1 VALUE CHAIN APPROACH

BlueBio focused on establishing a sustainable and competitive Blue Bioeconomy in Europe facilitating the transition of bio-based products and services from the laboratory to production scale, while prioritizing the "food first" principle to create safe, nutritious, and valuable bio-products and services. However, this transition requires that the system must be transformed, and changes need to be made across the entire value chain.

Funded research and innovation must align with customer preferences, processing technologies, and available species to effectively contribute to this transformative process.

Considering aquatic biomass from fishing and aquaculture a versatile resource to establish a circular economy, BlueBio encouraged exploring alternative uses for by-products, employing a broader value chain approach based on the '3R principle' to develop valuable bioresource-based products, services and markets while taking into account the potential consequences of new methods or products.

Therefore, the projects funded under BlueBio had to incorporate a value chain approach and to include at least one partner from industry. The inclusion of industry partners underlined the value chain approach, as it was even clearer how the product or process from a project was one of multiple links in the value chain and strengthened the technical application and economic feasibility of the outcomes of a project.

To further support and assess this value chain approach, BlueBio appointed four Value Chain Supervisors (VCS): one on harvesting; one on cultivation; one on market and innovation and differentiation; and one on enabling technologies.

The VCS also had the tasks of being in contact with BlueBio funded projects to create synergies and collaboration, identifying value chain funding gaps after the Cofunded call as basis for defining the call topics for Additional calls, and preparing the upcoming foresight process.

This approach proved to be effective as it enabled to cover all the nodes in the value chain in terms of funded projects as well as to address the specific needs identified by the VCS throughout the entire process, from production to market.

Recommendation

- An overarching strategic focus must be followed up with concrete actions in call scope and call design, and human resources devoted specifically to this.

4.2 CREATING CONNECTIVITY AND SYNERGY BETWEEN PROJECTS

Special effort has been dedicated by the BlueBio Cofund to create connectivity and synergies among the cofunded projects. The fundamental idea was to reduce duplication, enable exchange and sharing of knowledge and technology between the funded projects to become acquainted with one another.

Connectivity and synergy were facilitated through kick-off meetings for the projects in each call, along with thematic online meetings dedicated to projects within each call or addressing specific issues relevant to a selected number of projects. Engaging in discussions among projects in smaller groups was considered to be highly relevant for several reasons:

1. Efficient Resource Utilization: by bringing together projects that may have common goals, technologies, or resources, they can explore optimization strategies such as sharing samples or divide tasks. This helps prevent duplication of efforts and maximizes the efficient use of the project resources.

2. Cross-Pollination of Ideas: when projects from similar domains or teams but with slightly different expertise come together, there is an opportunity for the cross-pollination of ideas. This can lead to innovative solutions and new approaches that may not have been discovered otherwise.

3. Risk Mitigation: by sharing of information about methods or approaches, projects can help identify potential risks and challenges early in the process. This proactive approach enables teams to address issues before they become critical and can help mitigate project risks.

Overall, eight initial meetings (four for the Cofunded call, one for 1st and 2nd Additional calls and two for the 3rd Additional call) and five topical e-coffee meetings were organized (Table 3).

The online meeting places proved to be highly effective as resulted in new and direct collaboration between projects, outputs from one project served as inputs for another, exchange of students or researchers between projects, joint organization of training sessions and courses, collaborative writing of project applications, coordinated analysis or calibration conducted jointly. The online format enabled a greater participation from the Work Package leaders of the projects, both because of the reduced time investment and no travel costs.

2020 December	e-coffee for Cofunded call projects - the projects were sorted into four thematic groups
2021 May	e-coffee on microbiomes
2021 September	e-coffee on algae joint with ERA-NET SUSFOOD2
2022 April	e-coffee on Human Capacity Building
2022 June	e-coffee for 1st Additional call projects
2022 October	e-coffee on commercialisation support
2023 June	e-coffee for 2nd Additional call projects
2023 November	e-coffee for 3rd Additional call projects - the projects were sorted into two thematic groups
2024 March/April	e-coffee on LCA

Table 3. *Overview of the 13 e-coffee meetings organized to support the funded projects throughout the lifespan of the BlueBio ERA-NET Cofund.*

Recommendation

- Creating online meeting spaces for projects leads to measurable and tangible knowledge exchange and synergies between projects, with engagement reaching further than the project coordinator.

4.3 ANALYSIS OF RESEARCH PROJECTS

To assess the existing knowledge supporting the advancement of future research initiatives at national, regional, and EU levels in Fisheries, Aquaculture, Seafood Processing, and Marine Biotechnology, an extensive database was constructed.

This database includes 3,788 relevant research projects funded by EU Member States and associated countries, the European Commission, and other international organizations spanning the years 2003-2021. Its foundation originates from the repository of research projects developed within the COFASP ERA-NET framework.

Information was gathered from various sources, encompassing international and national repositories, archives of research institutes, and responses to questionnaires distributed to individual researchers.

The analysis of this compiled information provided insights into the primary research themes targeted by EU research and the corresponding funding allocations, and enabled the compilation of a list of research topics requiring further exploration in the short to medium terms.

The dissemination of the database occurred through a dedicated WebGIS application accessible on the BlueBio website and through the publication of an open access datapaper and related Figshare repository. Furthermore, the data have been integrated into the, so called, Mission Ocean Ecosystem established within the Mission "Restore our Ocean and Waters by 2030", one of the five missions launched by the European Commission as a major contributor to the European Green Deal, the UN Decade of Ocean Science and the Sustainable Development Goals. In particular, the data have been incorporated in the WaveLinks platform developed by the EU Mission "Restore our ocean and waters by 2030" CSA PREP4BLUE.

Recommendation

- To avoid duplication and address the R&I gaps and needs, funders must have an overview of already funded projects. There must be overlap between initiatives to ensure the continuation of infrastructures that enables this overview.

4.4 COMMERCIALISATION SUPPORT AND FACTSHEETS

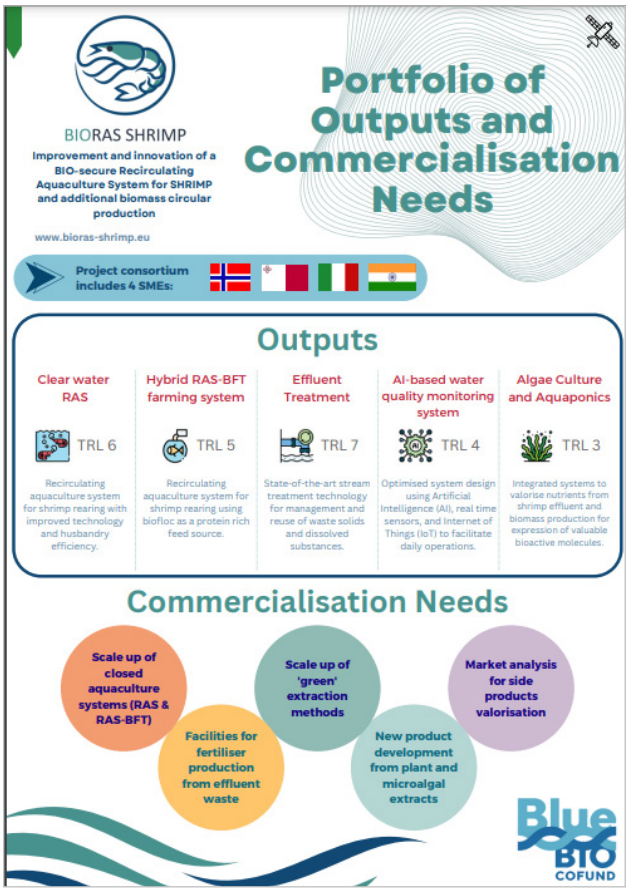
One of the objectives in BlueBio was to devise new calls for research-driven innovative activities that contribute to Europe's bioeconomy. To accomplish this, BlueBio calls were introduced to support novelty and value creation from aquatic bioresources at all stages. The funded projects were structured to increase the Technology Readiness Level (TRL) of their activities over the course of the project lifetime.

The mandatory inclusion of at least one industry partner has accelerated the advancement in TRL and promoted market-oriented co-creation in the funded projects. The outcomes of each project were distinctly applicable to industry or the market, fostering enhanced communication between academia and the industry.

To explore further how to maximise impact for funded projects, a support initiative was launched consisting of a number of different elements including research on novel funding & private sector opportunities, analysis of interactions with feedback from projects (e-coffees, mid-term reports), interviews with investors, accelerators etc., survey of projects to map commercialisation needs and status, a commercialisation support event and one-to-one support meetings, commercialisation factsheets, and a novel funding call (see Section 3.4).

The commercialisation support event was organised online for all project coordinators and industry partners from all three calls to inform projects of opportunities (funding and support) and to facilitate discussions on what support was needed, and how to increase impact and market readiness. Projects with higher TRL outputs were contacted for follow up in one-to-one meetings to provide bespoke support.

In addition, commercialisation factsheets were developed for each project to include information on enterprise partners, outputs, TRL and commercialisation needs. These factsheets were then made available and actively shared with the investment community and other relevant stakeholders. They can be consulted on the BlueBio website *(bluebioeconomy.eu)*.



Recommendation

- Mandating inclusion of industry partners and a TRL increase in the projects ensures relevance to the industry and value chain and emphasizes market-oriented development.

4.5 HUMAN CAPACITY BUILDING IN THE PROJECTS AND IN THE ERA-NET

Another objective of the BlueBio project was to contribute to enhancing the professional skills and competencies of individuals working in the context of the Blue Bioeconomy by promoting Human Capacity Building (HCB) Training and Mobility (T&M) initiatives within the R&D projects funded by BlueBio.

This goal was pursued through an integrated approach comprising two lines of action:

1. Supporting the implementation of HCB activities within the funded projects;
2. Organizing specific training courses on the Blue Bioeconomy in response to the training needs identified by projects funded under the BlueBio calls.

The first line of action encompassed providing specific guidelines for organizing T&M activities within the funded projects, along with their monitoring and evaluation through an online questionnaire. This questionnaire was also utilized to gather the opinion of project coordinators regarding the most effective tools for maximizing the impact of HCB initiatives embedded into their work plans.

Further discussion on HCB was encouraged within the context of a dedicated HCB e-coffee meeting, conducted online in April 2022 (Table 3). This meeting facilitated dialogue and laid the groundwork for organizing specialized training activities on the Blue Bioeconomy, which would be available to the broader scientific community.

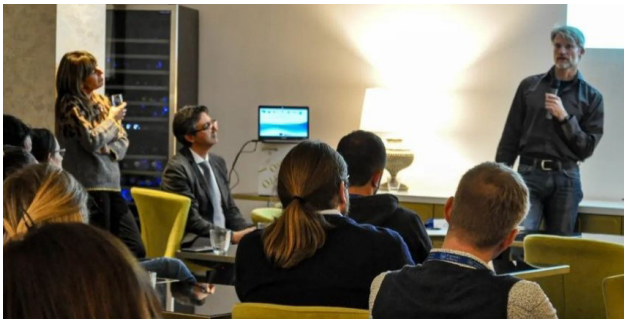
The second line of action, strictly linked to the first one, facilitated the organization of three advanced training courses:

- The 1st advanced training course, entitled "Integrated advanced training course on Blue Biotechnologies, Aquatic products and Blue Bioeconomy", was held online on 15-19 March 2021 in collaboration with the BlueMed CSA.
- The 2nd specialized training, entitled "Blue Bio-refinery technologies: from research to the industry with applications on products and biomaterials from algal biomass and side streams of fisheries and aquaculture", was held on 15-18 January 2023 at the University of Foggia (Italy) with the patronage of the ESMB.
- The 3rd and final advanced training course, entitled "Resilient Blue Bio-refinery technologies: innovative solutions to valorise fishery side streams", was hosted by the IBA-NTNU at Ålesund (Norway) on 24-26 October 2023.

The training courses were open for all participants, but the topics were especially relevant for the BlueBio projects, and the lecturers were in large part BlueBio project coordinators. There was a preference for applicants who were part of BlueBio projects, which lead to the training courses also functioning as networking platforms. The topics chosen for the training courses were based on discussions and input from the funded projects.

Finally, a specific session on Human Capacity Building was organized in the framework of the BlueBio Joint Evaluation Event meeting (Lisbon, 6-7 June 2023). Specifically, the session was dedicated to the 10 projects selected within the 1st BlueBio Additional call, with the aim of fostering discussion among participants on the main issues and best practices to be implemented for enhancing HCB in support of their projects and, more broadly, of the Blue Bioeconomy sector.

The starting point of the session was the findings from an online survey involving coordinators of all projects funded by the Cofunded call and the 1st Additional call. This survey aimed to pinpoint the most significant themes for supporting the Blue Bioeconomy. The identified themes were *Microalgae biotechnology, Fisheries and Aquaculture side streams*, Food quality and safety, Market & Policy. Participants were split into two groups, each asked to suggest at least one topic for each of the four themes. In the second part of the exercise, they were prompted to vote for up to three topics, rating them from 1 (less important) to 3 (more important).



Recommendation

- Mandating, monitoring, and supporting the implementation of HCB and T&M activities within projects effectively contributes to increasing professional skills and competencies. Including HCB activities as KPI in the evaluation process makes them a focal point for the projects, but there is a need to follow up on the project's activities as they develop and to adjust to their needs. Dialogue with project coordinators helps identify topics and best practices for future initiatives.

4.6 FOLLOW-UP AND MONITORING OF PROJECTS

A methodology was developed to establish a monitoring and evaluation framework, along with Key Performance Indicators (KPI) listed in Table 4. This was aimed at assessing the alignment of the projected activities outlined in the proposals with the projects' performance in key project objectives.

The indicators incorporated both national and Horizon 2020 (H2020) criteria to prevent duplications and streamline the framework's usability across all administrative levels. BlueBio partners' experiences from analogous processes, as well as insights from monitoring and evaluating COFASP and ERA-MBT ERA-NETs, along with information from ERA-LEARN and other pertinent activities, were utilized. Guidelines for project reporting and monitoring were formulated and disseminated to all funded projects along with simple reporting templates.

The follow-up and evaluation of project implementation under the Cofunded and Additional calls were performed through Mid-Term and Final Progress Reports submitted by project coordinators and related evaluation meetings (Mid-Term and Final Evaluation Meetings).

The funded projects were designed to undergo assessment through questionnaires distributed to all parties involved not only upon project completion but also two years after the projects have been concluded.

The reports were reviewed by selected members of the Call Evaluation Panel having expertise in the field of the funded projects.

Monitoring and evaluation were performed according to the following criteria (Table 4):

1. Work performed and results achieved within the project in terms of:
   - Scientific and technological progress;
   - Collaboration, coordination and mobility;
   - Impact and knowledge output;
   - BlueBio call topic(s) addressed by the project;
   - Transnational added value of the project.

2. Deliverables:
   - Consortium meetings;
   - Stakeholder engagement;
   - Socio-economic impact statement;
   - Knowledge output transfer;
   - Publications and other outputs (i.e. patents, licences, policy-oriented briefs, etc.).

Upon the conclusion of BlueBio, the project portfolio, encompassing all Additional call projects, will transfer to JPI Oceans which will assume responsibility for communication, monitoring, and final meetings.

Create, test, upscale and bringing to the market new knowledge-intensive products and services derived from aquatic biomass	Provide consumers and policy with knowledge needed to make informed decisions	Increase the efficient and sustainable use of by-products	Contribute to improving the professional skills and competences of those working and being trained to work within the Blue Bioeconomy	Contribute to policy making in research, innovation and technology
No. functional foods/ingredients, nutraceuticals, fine chemicals, enzymes, and other biomaterials derived from marine organisms	No. industrial partners involved	No. new products / services	No. trainings	No. stakeholders informed / involved
No. biological indicators	No, participation at brokerage events		No. researchers participating in training	
No. new jobs created	No. marine technology transfer		No. researchers involved in mobility	
No. SMEs involved				
TRL at start and end				

Table 4. *List of KPIs identified for projects' evaluation.*

Recommendation

- A monitoring and evaluation framework should assess the projects' performance in key project objectives so their impact is clear. Mid- and end-term meetings function as a forum for dialogue and knowledge exchange within the projects and between different projects.

4.7 RESPONSIBLE RESEARCH AND INNOVATION (RRI)

Research, innovation and technologies have the power to transform society. This gives science an important social responsibility. Responsible Research and Innovation offers techniques, tools, and frameworks for thinking about issues of social responsibility and assessing how to deal with research, innovation and technological developments that lead to societal changes and new products in the markets. RRI prompts the consideration of critical questions regarding the kinds of futures that should be shaped by science, technology, and innovation in the world.

For this reason, an independent ethics advisor was appointed at the start of BlueBio, and followed up all funded projects from the beginning to the end. The consistency of one ethics advisor, created stability and a trustworthy presence.

RRI issues had to be addressed and described in all project applications. To further educate projects on how to deal with these aspects an introduction and learning platform on how to develop and implement good RRI practices were provided during the kick-off-meetings of all calls. An open online seminar on RRI was also organised along with the kick-off-meeting for the Cofunded call.

All projects were assessed relative to ethical issues and followed up where needed by the independent ethics advisor.

Recommendation

- It is essential for all actors in the research ecosystem to work together seamlessly, ensuring that the results of funded projects provide the greatest possible benefit to society. The RRI methodology represents a sound approach for achieving this goal. An independent ethics advisor can monitor project's RRI efforts and enable a stable and predictable environment for ethics assessments.

4.8 FORWARD-LOOKING ACTIVITIES

The forward-looking activities focused on mapping research and innovation needs, especially the multi-disciplinary and multi stakeholder challenge of setting up new bio-based value chains. A five-tiered Foresight approach (Figure 6) was proposed to further understand research and innovation gaps that could underpin the development of joint research programs in the value chain and future proof the Blue Bioeconomy value chains.

Figure 6. *Steps towards the SRIA (from the BlueBio SKIA).*

Diverse groups of stakeholders were included in the Foresight, representing the quadruple helix "policy, research, society and industry" to ensure a complete research agenda.

The foresight exercise, developed in cooperation with the European Fisheries and Aquaculture Research Organisation (EFARO), was implemented through three workshops in the period May – November 2022. It combined the Foresight methodology with the use of scenarios and built on analyses and Strategic Knowledge and Innovation Agendas (SKIAs) in the marine value chain domain such as: JPI Oceans Strategy Framework 2021-2025, Sustainable Blue Economy Strategy (2021), Sustainable Blue Economy Partnership (SBEP) SRIA (2021), BANOS SRIA (2021), European Green Deal (2019), EATIP SRIA (2017), ERA-MBT Roadmap (2016), 4th SCAR Foresight Exercise (2015), COFASP Foresight (2014).

The time horizon was set at 2050 to break free from current developments and be open to a diverse range of potential futures.

In the first phase, the focus was on reviewing available information, examining and delineating the system designated for analysis, and identifying its subsystems (Figure 7), along with the variables or trends that mainly influence these subsystems, commonly known as "drivers". In this case, the overarching system under scrutiny was the Blue Bioeconomy.

In the second phase, the desirable and undesirable 'futures' explored during phase 1 were fine-tuned, resulting in robust Blue Bioeconomy Value Chain scenarios. For each of those scenarios participants determined which science and innovation should be implemented. Hence, under all scenarios, aspects and topics of research and innovation were established. Confronting the system with the selected scenarios resulted in 4 possible future 'states' of the Blue Bioeconomy System representing 4 pictures (possible future Worlds) of what the future may look like.

During the third and final phase the list of research and innovation needs for each world were fine-tuned and finalized. Based on these four lists, the participants were asked to identify the recurring research needs between the four different worlds.

The Foresight exercise resulted in a Strategic Knowledge and Innovation Agenda (SKIA) that was published in spring 2023. A set of visuals was also developed and used to disseminate the SKIA both in social media, print and in popular science and industry magazines (Eurofish Aug/Sept 2023).

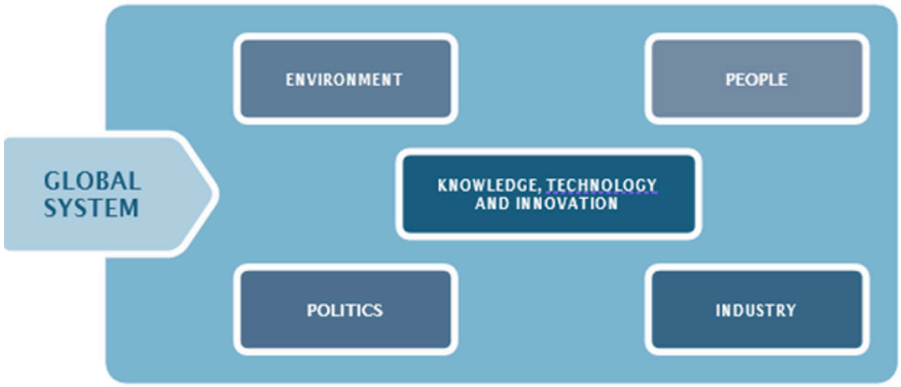


Figure 7. *The defined Blue Bioeconomy system, with sub-systems (from the BlueBio SKIA).*

Recommendation

- The financial and human resources available through BlueBio, plus the network and connectedness of the funding partners and funded projects, made a full foresight process possible, resulting in a lasting legacy in the form of a SKIA.

5. NEEDS FOR THE FUTURE BLUE BIOECONOMY

5.1 THE RESEARCH PRIORITIES IDENTIFIED IN THE FORESIGHT EXERCISE

The research needs of the four worlds were organised into six priority areas: Ecosystem balance, Societal balance, Climate Change, Technological Innovation, Value Chain Development and Science for Society.

ECOSYSTEM BALANCE

Natural systems face pressure from growing populations and human activities. Ensuring food security while maintaining the health of aquatic ecosystems is crucial and requires striking a delicate balance and adjusting to changes in nature. Developing, testing, and deploying real-time measurement sensors is essential. Understanding factors such as carbon sequestration is still key to deliver necessary services.

Fully understanding the blue biosphere; the structure and organisms:

- Map the aquatic microbiome and its connectivity in variation in time and space. Microorganisms in the ocean are crucial for ecosystem services e.g., carbon sequestration. Understanding microbiomes in coastal or confined systems can reveal more about their roles in ecosystems and potential services that can be further enhanced, like denitrification or disease control.
- Improve the understanding of how microbiomes within and across aquatic regions interact and impact each other.
- Further understanding of food web interactions.
- Understanding the Deep Ocean and the interactions between deep sea and top layers, coastal systems and atmosphere.

Identifying ecological tipping points to maintain ecosystem services:

The prerequisite for intensifying utilisation of biomass and ecosystem services from the blue biosphere is to ensure the systems can regenerate at the same rate of their utilisation. Natural variability can change the regenerative capability of ecosystems.

- Identify the tipping points where utilisation exceeds the capacity and key triggers of change to avoid systemic changes or collapse of systems.

Understanding the effects of ecosystem manipulation (Digital Twin):

Utilizing new technologies such as AI and advanced sensor technology is essential for continually updating Digital Twins and prediction models for a deeper understanding of aquatic ecosystems' functioning. Human impact on the ecosystems requires detailed knowledge of physical, chemical and biological processes including their interactions, along with understanding the physiological boundaries of organisms.

- Develop common standards for data collection, handling and sharing, e.g. through standardisation of methods, calibrations and metadata.
- Improve capacities for the prediction of the future state of ocean health.

Understanding Blue/Green relation and land/sea interactions:

The blue biosphere - the ocean and other aquatic systems – is not a separate island but is interconnected and interacts with the terrestrial systems and the atmosphere. To understand this relationship, it is necessary to develop:

- Better knowledge (data, modelling) on how, and to what extent the health of the aquatic systems is influenced by the other systems and their use and finding measures to minimize negative impacts.
- Developing methods to sustainably reconcile various uses (spatial/temporal) in a way that balances environmental, social, and economic factors, as represented in Marine Spatial Planning (MSP).

How to use Nature Based Solutions (NbS) in new ways of usage/ production of resources whilst restoring the ecosystem?

- Need to improve the bridge between environmental observations, controlled experiments, data science and predictive modelling to create a deep and validated understanding of system interventions, the use of ecosystem services while ensuring robust ecosystems. This raises the question of minimal human impact as baseline for ecological restoration.

SOCIETAL BALANCE

This research area explores the relationship between society and a sustainable Blue Bioeconomy. Responsible development within this sector relies on public trust, understanding, and acceptance of innovations, including novel foods, by all stakeholders and society, that is essential for implementing technologies effectively and advancing aquaculture and other Blue Bio industries in Europe and beyond. It is also crucial for enabling effective and socially legitimate regulation of production methods and the multiple uses of aquatic space, including the allocation of new production areas. The questions to address are:

- What is the optimal allocation of space and resources between distinct users and uses, taking both ecological and societal concerns into consideration?
- How can MSP techniques, management, and regulations be developed and implemented?
  - What are the potential effects of new management systems, e.g. MSP, on fisheries and other relevant stakeholder groups?
  - How can management schemes be developed to be adaptive, and how can existing management systems, such as regulations on genetics and MSP, be redefined?
- How can socially legitimate and trustworthy regulations, including monitoring systems, be developed?
- How can understanding of consumer preferences be improved to develop new markets/demands or reintroduce traditional markets?
- How can effective incentives, such as subsidies and taxes, be designed to promote sustainable consumption while avoiding imbalances?
- What is the potential recreational value of ecosystems and the effect of nature on human health? How can aquatic ecosystems be effectively managed to leverage them as a competitive advantage for Europe?
- Ecological compensation: needs, shortcomings, possibilities, means, regulation/incentives.

CLIMATE CHANGE

The anticipated climate change in the coming decades will impact on the aquatic ecosystems. Direct impacts include shifts in temperature and sea levels, while the melting of ice caps will indirectly alter ocean salinity gradients and may affect currents. Extreme weather events are expected to alter river flows, impacting lakes and coastal regions. In order to understand and mitigate these effects there is a need to:

- Develop prediction models taking climate change into account. Carbon capture will alter the physical boundaries for life in aquatic environments, affecting organisms' ability to thrive. Significant changes in carbon capture may trigger regime shifts, fundamentally altering the composition and structure of ecosystems and changing the ecosystem services we rely on.

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- Understand climate change impact on the socio-ecological system (e.g., fish stocks, aquaculture). Changes in the ecosystem and its services provision will impact the social system. For instance, fish stock distribution may change, thus impacting fisheries, resulting in different local and regional socioeconomic impacts.

- Identify adaptation and mitigation of climate change impact:
  - Develop strategies to mitigate negative human impact on the (blue) biosphere at every scale, e.g. carbon sequestration, pollution control and remediation, and methane conversion.
  - Finding measures to ensure the functioning of the aquatic ecosystems (resilience and adaptation) and the ecosystem services under the climate change.
  - How can the negative impacts on aquatic systems be mitigated?
  - How can aquatic systems assist in mitigating climate change and its impacts?

TECHNOLOGICAL INNOVATION

Development of monitoring of ecosystems, aquaculture production and resource extraction activities using remote sensors and Artificial Intelligence/ Machine Learning

- Improve intelligent monitoring of ecosystems to establish forecast systems enabling dynamic knowledge-based management of:
  - Marine spatial planning.
  - Countermeasures to adverse events.
  - Early warning systems and automatic operation of aquaculture platforms.
  - Aquaculture production optimisation.
  - Safer and efficient marine logistics.
  - Efficient and sustainable fisheries and harvesting.

Genetic engineering

- Ethical application of genetic engineering as an alternative to traditional selective breeding to achieve:
  - More sustainable production e.g., sterile production organisms.
  - New biofilters working at ambient temperatures allowing optimized production.
  - Reduced environmental impact.
  - Product with optimized traits such as composition e.g. Omega-3 fatty acids.
  - Resistance against disease.
  - Optimized production at ambient temperature.
  - Reduced extraction of marine resources for feed production.
  - Improved animal welfare e.g., organisms less susceptible to stress.

How to use carbon capture to produce food, feed and non-degradable deposition forms

Cultivating photoautotrophic and chemoautotrophic organisms to capture carbon for biomass and energy carrier production.

- Improve deep sea bioprospecting to find new organisms, genes and enzymes.
- Develop more efficient reactors.
- Develop efficient technologies for large-scale capture of atmospheric CO2.
- Use of side streams as nutrients for photoautotrophic and heterotrophic organisms.
- Responsible environmental engineering to increase carbon sequestration and system carrying capacity.

To develop alternatives to antibiotics and hazardous chemicals

- Development of new probiotics and functional feed.
- Development of new vaccines and other prophylactic measures.
- Development of less industrialized production systems – e.g., organic production.
- Development of new antimicrobial substances less prone to resistance development.

Development of recirculation systems for aquaculture on land and at sea

- Further development of closed sea water-based production recirculation systems.
- Development of new biofilters operating at ambient temperatures to optimize production.
- Development of alternatives to biological nitrification.
- Improved commercial exploitation of biofilter biomass.
- "Closed loop" approaches for fully automated production.

Detoxification of feed/food resources

- Develop innovative detoxification processes and tools that do not compromise product quality.
- Develop more efficient systems for continuously monitoring levels of toxic substances.
- Better understanding and standardization of toxicity threshold values in feed and final products.

Improvement of animal welfare and health

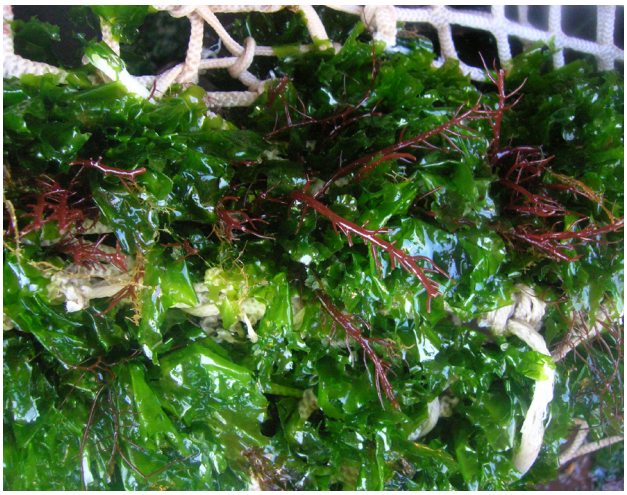
- Develop more efficient production systems allowing reduced organism density.
- Develop more animal friendly production systems with reduced stress.
- Develop new vaccines and other prophylactic approaches to prevent infectious diseases.
- Develop better vaccine concepts with less side effects e.g., oral vaccines.
- Develop novel treatment concepts to manage infections without relying on antibiotics, e.g. Phage therapy.
- Develop more efficient prevention and treatment towards parasite infestation.
- Increase knowledge on the biology of production organisms.
- Enhanced prediction and prevention of adverse environmental impacts on production.
- Development of non-invasive methods to monitor animal welfare.
- Improved systems for Individual monitoring and treatment.
- Develop system for humane killing of capture fish.

VALUE CHAIN DEVELOPMENT

How to make production cycles circular?
How to optimize side streams and minimize waste?

Every process generates side streams (e.g., by-products of fisheries and aquaculture processing, by-catch, effluents of aquaculture containing N and P, fish manure, dead fish) that should be utilized as resources for other products, such as food, feed, chemicals, materials, soil enhancers, and energy, adhering to the waste hierarchy, in order to eliminate waste entirely.

- Optimize the valorization of side streams using a biorefinery approach.
- Re-use N and P for cultivation purposes (aquaculture and agriculture), including the development of nature-based solutions, e.g. carbon capture solutions.
- Reduce or replace the use of plastics and other materials in fisheries and aquaculture with novel materials.



To implement full value chain traceability

Full-chain traceability is traceability from brood stock to adult fish in aquaculture, location of fishing grounds, origin of fish meal, supply chain, processing. Traceability is necessary to demonstrate the production processes and hence demonstrate e.g., sustainability and product quality.

- Need for reliable and trustworthy traceability systems for consumers, authorities, and companies.
- Demonstrate sustainability through traceability methods.
- Demonstrate sustainability of processes and products.

Generating a sustainable value chain ecosystem, co-existing value chains, and understanding Blue/Green relation and land/sea interactions of production systems

The competition for space, both on land and at sea, particularly in coastal areas where different maritime activities coexist, along with the need to optimize side streams from agriculture for use in aquaculture or fisheries, and vice versa, can generate more efficient agricultural and aquaculture systems, thereby enhancing land-sea interaction.

- Optimise the use of the ocean space for food production (fisheries, aquaculture), energy production, tourism considering a multi-use approach.
- Optimise the interaction between land-based and ocean-based production systems to increase sustainability and production efficiency.

Identifying new species for food production robustness (e.g., risk reduction and production efficiency) considering low and multi trophic aquaculture; developing novel foods and sustainable healthy/functional food/food supplements

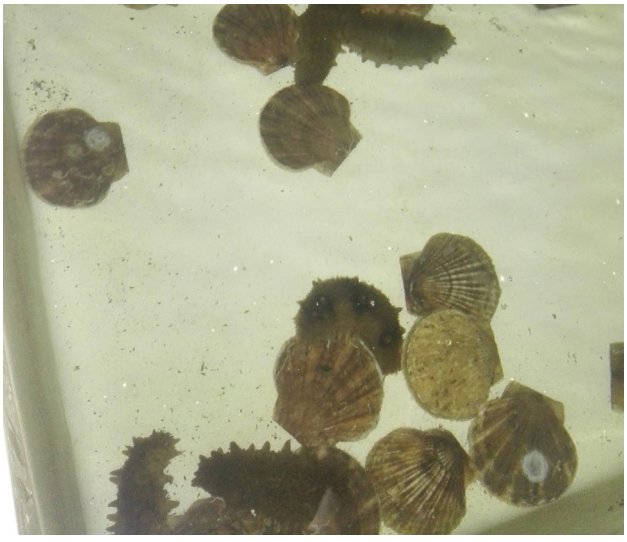
Expanding the variety and quantity of species utilized, along with aquatic products, will unlock the potential of aquatic bio-resources for healthy and functional food products and ingredients and enhance the resilience of the aquaculture system. Introducing lower trophic species can boost biomass production efficiency.

- Need to identify the best suited species for aquaculture and fisheries and to understand how to deal with the ecosystem consequences of harvesting or cultivation.
- New species, including microbiomes, will pave the way for new, healthier, and more functional products through processing, while also generating new side streams.
- How can bioprospecting reveal the opportunities of new products?

SCIENCE FOR SOCIETY

Social balance pertains equilibrium within society and its relationship with the environment, while science for society concerns the utilization and integration of scientific knowledge by society. Research in the Blue Bioeconomy should include mechanisms to facilitate the effective uptake of findings by industry and society. This encompasses enhancing education, empowering individuals, bolstering capacity, and fostering ocean literacy in Europe and worldwide. This field advocates for the integration of science into decision-making processes, emphasizing transdisciplinary research with stakeholders and capacity building to optimize the use of science in policymaking and management systems (science for policy). To accomplish this objective, it is essential to address the following issues:

- How to foresee and address unintended adverse and beneficial effects of new technologies/new interventions in systems (natural and social), e.g. example responsible use of biotechnology, genetic engineering.
- How to develop a good relation between education, fundamental research, applied research and technology, and end-users, e.g. development of new foods, use of low-trophic aquatic food.
- How properly train researchers to effectively communicate their results in an understandable and transparent manner, as well as to interact efficiently with policymakers, other stakeholders, and the public.
- How to enable the engagement and active contribution of stakeholders into the development and implementation of the Blue Bio research agenda and programmes.
- How to enable the uptake of citizen science data into Blue Bioeconomy research and innovation.
- How to implement ecosystem-based management to optimize ecosystem services, including production.
- How to operationalize the One Health concept (interaction between human, animal, and environmental health) to enhance food safety, promote animal welfare, prevent global health crises such as pandemics, and facilitate increased production from aquaculture.



Recommendation

- The research needs of the BLUE BIOECONOMY are in the areas of: Ecosystem balance, Societal balance, Climate Change, Technological Innovation, Value Chain Development and Science for Society.

5.2 IDENTIFIED NEEDS FOR SKILLS AND CAPACITY BUILDING

Even though the project proposals were required to clearly document and describe T&M actions, there was a noticeable lack of recognition of the role that training activities play in advancing the Blue Bioeconomy sector.

Insights from online questionnaires, the e-coffee meeting, and additional discussions with project coordinators during T&M monitoring indicated that the main obstacle to the implementation of HCB initiatives was the absence of specifically allocated funds for T&M within the project budget.

Consequently, the BlueBio consortium decided to set up specialized training courses as an additional approach to enhance HCB within the Blue Bioeconomy field, and by including HCB activities in the call scope of the 3rd Additional call. This strategy was consistent with feedback obtained from project coordinators, who were instrumental in identifying the most pressing training needs.

Additionally, the development of HCB activities within the projects was significantly impacted by the COVID19 pandemic. In-person initiatives were partially compensated by the organization of online workshops and courses, but it was a significant barrier especially for exchange.

Feedback obtained through online questionnaires, the dedicated e-coffee meeting, and further dialogue with project coordinators at the HCB session, held during the BlueBio Joint Evaluation Event in Lisbon (6-7 June 2023), facilitated the identification of key themes crucial for enhancing the professional skills and competencies of those working or being trained in the field of the Blue Bioeconomy.

The most relevant training needs were categorized into four broad themes: Microalgae Biotechnology, Market & Policy, Food Quality and Safety, and Fisheries and Aquaculture Side-Streams. The main topics along with some tools that were identified for each theme are listed here.

Microalgae biotechnology

- (Bio)refining – Extraction/product separation.
- Harvesting.
- Functional and sensory properties of microalgae biomass as food ingredients.

Fisheries and aquaculture side-streams

- Workshops on improving the utilization of side streams.
- How to upgrade from feed to food applications.
- Training course on how to perform LCA/LCC on side streamvalorization.

Food quality and safety

- Training – Use of new/strange/processed products in different foods;
- Policies – Political strategies to enhance social acceptance and regulatory frameworks.

Market & Policy

- Filling gaps between land-based and water-based markets (in a wider perspective);
- Streamlining new products through regulation (e.g., novel food regulation);
- Communication to/with policy makers;
- Cost-benefit analysis.

Recommendation

- Needs for skills and capacity building must be addressed both on project level and consortium level, to ensure maximum effect, and there must be a continuous exchange between the projects and the consortium to ensure the best fit on topic and format.

6. BLUEBIO AND THE EUROPEAN BLUE BIOECONOMY

6.1 STRATEGIC POSITIONING OF BLUEBIO IN THE EU CONTEXT

The BlueBio Cofund, operational between 2018 and 2024, worked within a broad range of European programs, supporting and aligning with the objectives of various EU initiatives. These include the EU Blue Bioeconomy Strategy, focusing on understanding and preserving marine ecosystems, and the EU Biodiversity Strategy for 2030, emphasizing aquatic biodiversity. It resonated with the Farm to Fork Strategy's sustainable food system goals, the Zero Pollution Action Plan's environmental protection agenda, and the EU Strategy for Plastics, promoting circular economy principles. The Cofund's priorities also intersected with JPI Ocean's and SCAR's research focus, as well as the Horizon Europe Partnership Sustainable Blue Economy (SBEP)'s emphasis on a climate-neutral Blue Economy.

Additionally, it aligned with EIT Raw Materials-KIC and Biodiversa+ approach to raw materials and biodiversity innovation, and the objectives of the Safe and Sustainable Food System Partnership and the Partnership for a Circular Bio-based Europe Joint Undertaking. This synergy enhanced Europe's approach to sustainable marine management and bioeconomy development.

The BlueBio Cofund, alongside the EU's diverse marine strategies, including the Marine Strategy Framework Directive (MSFD) and the Blue Bioeconomy concept, presented a unified front in advancing sustainable marine management. These initiatives, ranging from biodiversity preservation, sustainable food systems, circular economy, to reducing environmental impacts, align with Europe's commitment to achieving Good Environmental Status in marine waters.

Emphasizing interdisciplinary collaboration and strategic foresight, they collectively address the challenges of climate change, sustainable resource use, and environmental protection.

The integration of these efforts underscores Europe's dedicated approach to ensuring the health, resilience, and sustainable future of its marine ecosystems and communities, highlighting the importance of comprehensive research and policy alignment in marine conservation and bioeconomy development.

To illustrate how different programs and initiatives address common issues, Table 5 shows the relationship between research priorities identified by the BlueBio Foresight and those highlighted by SCAR, JPI Oceans, the Blue Bioeconomy Strategy and the SBEP as well as such priorities have been implemented within the BlueBio network.

In the portfolio analysis of the EU Mission "Restore our ocean and waters by 2030", published in May 2023, DG RTD highlights the success of BlueBio in funding projects that support the Mission objective of blue Economy – carbon-neutral and circular fisheries and aquaculture. In the report, 25 of the 30 BlueBio projects studied are found to support the Mission, a significant contribution. As the valorisation of waste and side-streams is the cornerstone of fully circular aquaculture and algae production, the BlueBio impact on Europe is clear.

Several of the above listed priorities have been already addressed or are currently addressed by a certain number of research projects funded in the framework of EU and national programmes. For instance, Table 6 lists examples of projects dealing with a few selected topics: Microbiome, Climate change, Nature based Solutions and Marine Spatial Planning over the years 2013-2023 as extracted by the BlueBio research project database and the Portfolio Analysis EU Mission "Restore our Ocean and Waters by 2030" released in May 2023 by DG RTD B4, which explicitly mention the BlueBio Cofund and its funded projects in section 9 "Carbon Neutral and circular fisheries and aquaculture".

BlueBio priorities	SCAR	JPI Oceans	EU Bioeconomy Strategy	SBEP	Addressed by BlueBio
BLUE BALANCE					
Understanding structure and functioning of the blue biosphere		✓	✓	✓	
Identifying ecological tipping points to maintain ecosystem services		✓			
Understanding the effects of human impact on the ecosystem	✓	✓		✓	
Understanding land/sea interactions	✓	✓			
Nature-based Solutions for restoration, mitigation and production purposes		✓		✓	✓
SOCIETAL BALANCE					
Optimize coastal and maritime planning and management		✓	✓	✓	
Developing socially legitimate and trustworthy regulations	✓	✓		✓	
Understanding consumer preferences to develop new markets or reintroduce traditional ones	✓			✓	
Promote sustainable consumption	✓	✓	✓	✓	
Assessing the potential recreational value of ecosystems		✓	✓	✓	
Ecological compensation					
CLIMATE CHANGE					
Understanding and modelling direct and indirect effects on the ecological and social system		✓		✓	
Strategies to mitigate negative human impacts on the blue biosphere at every scale	✓	✓		✓	✓
TECHNOLOGICAL INNOVATION					
Develop monitoring systems using remote sensors and AI/ML for Aquaculture production optimisation, safer and efficient marine logistics, and efficient and sustainable fisheries and harvesting.		✓		✓	✓
Genetic engineering to optimize aquaculture production and enhance its sustainability				✓	
Use of carbon capture to produce food, feed and non-degradable deposition forms	✓	✓	✓	✓	
Finding alternatives to antimicrobials in aquaculture	✓				
Further development of recirculating aquaculture systems	✓	✓		✓	✓
Monitoring levels of toxic substances and standardization of toxicity thresholds in feed and seafood					✓
Ensuring animal health and welfare	✓			✓	
VALUE CHAIN DEVELOPMENT					
Optimize the use of side streams from aquaculture and fishery industries	✓	✓	✓	✓	✓
Reduce the use of plastics in fisheries and aquaculture by novel materials	✓	✓	✓	✓	✓
Implement full-chain traceability	✓	✓	✓	✓	✓
Optimise the interaction between land- and ocean-based production	✓	✓	✓		✓
Multi-use of ocean space for food production (fisheries, aquaculture), energy production, tourism	✓	✓	✓	✓	
New species for food production and provision of novel, healthy and functional food/feed products and ingredients	✓	✓	✓	✓	✓
Development of low- and multi-trophic aquaculture	✓			✓	✓
SCIENCE FOR SOCIETY					
Promote research uptake in society and industry and interlinkage between science and decision-making improving education, empowering people, building capacity and ocean literacy	✓		✓	✓	✓

Table 5. *Research priorities identified by the BlueBio Foresight exercise, the 5th SCAR Foresight Exercise (2020), the JPI Oceans Strategy framework 2021-2025, the EU Bioeconomy Strategy Progress Report (2022), and the SBEP Draft Strategic Agenda (2021) along with the issues targeted by BlueBio calls and funded projects.*

Theme	Acronym	Project title	Running period	Funding programme
Microbiome	MARBLES	Marine Biodiversity as Sustainable Resource of Disease-Suppressive Microbes and Bioprotectants for Aquaculture and Crop Diseases	2021-26	H2020
	CIRCLES	Controlling mIcRobiomes CircuLations for bEtter food Systems	2018-23	H2020
	AquaHealth	Microalgae Microbiomes - A natural source for the prevention and treatment of diseases in aquaculture	2020-22	BlueBio 1st call
	META-MINE	Mining the microbiomes from marine wood-digesting bivalves for novel lignocellulose depolymerizing enzymes	2018-20	ERA-MBT Call 2016
	KiGuMi	Biotechnological potential of the Antarctic Krill gut microbiome	2020-23	National
Climate change	FutureMARES	Climate Change and Future Marine Ecosystem Services and Biodiversity	2020-24	H2020
	ClimeFish	Co-creating a decision support framework to ensure sustainable fish production in Europe under climate change	2016-20	H2020
	CERES	Climate change and European aquatic RESources	2016-20	H2020
	CACHE	Calcium in a changing environment	2013-17	FP7
	PREFACE	Enhancing prediction of tropical Atlantic climate and its impacts	2013-17	FP7
	LOST	Impact of Climate-driven habitat LOss in Norwegian fjords on ecosystem STructure and functional ecology of cartilaginous fishes	2021-25	National
MSP	MUSICA	Multiple-use-of Space for Island Clean Autonomy	2020-24	H2020
	MedCoast4BG	Med Coasts for Blue Growth	2018-20	H2020
	Capacity4MSP	Strengthening the capacity of MSP stakeholders and decision makers	2019-22	Interreg V
	Baltic SCOPE	Towards coherence and cross-border solutions in Baltic Maritime Spatial Plans	2015-17	EUSBSR
	ECOAST	New methodologies for an ecosystem approach to spatial and temporal management of fisheries and aquaculture in coastal areas	2016-19	COFASP Call 2015
NbS	RESTORESEAS	Marine Forests of animals, plants and algae: nature-based tools to protect and restore biodiversity	2022-25	BiodivERsA+ 2020-2021
	MPA4Sustainability	Enhancing MPAs' role in restoring biodiversity while maintaining access to ecosystem services	2021-24	BiodivERsA+ 2020-2021
	COCKLES	Cooperation for restoring cockle shell fisheries and its ecosystem services in the Atlantic area	2017-20	Interreg V
	Baltic Blue Growth	Initiation of full-scale mussel farming in the Baltic Sea	2016-19	Interreg V
	MARHES	Marine habitats restoration in a climate change-impaired Mediterranean Sea	2020-23	National

Table 6. *Examples of research projects aimed to enhance knowledge on Microbiome, forecast and monitor the effects of Climate change, implement MSP, and develop NbS to restore marine ecosystem and their services.*

6.2 IMPACT OF THE BLUEBIO COFUND

The BlueBio Cofund was expressly designed to make an impact on a number of issues, from creating new products and services, increasing the efficiency of by-products, improving professional skills, informing consumers and working on policy, all under the umbrella of the UN Sustainable Development Goals.

A number of actions were established to ensure and maximize the impact of BlueBio, some of which have been widely described in the previous sections.

LEVERAGING NATIONAL FUNDS AND ESTABLISHING A COORDINATED R&D FUNDING SCHEME

A total of 30 funding organisations launched four R&I calls, the last one supporting already funded BlueBio projects to amplify their reach and knowledge impact. In total, BlueBio funded 49 projects, committing an overall budget of €37.8 million of national funds. This budget was supplemented with an additional €6 million from the European Commission for the Cofunded call. Each partner contributed to the funding of at least one project (Table 7).

INTERNATIONAL PARTICIPATION

International participation was envisaged and actively sought, e.g., with funding organisations in Argentina, Brazil, Canada and South Africa. No non-European partners were in a position to join the Bluebio calls largely because of the timing of funding commitments and the systems of collaboration between H2020 and non-associated countries.

COOPERATION WITH INDUSTRY AND UPSCALING BIO-BASED PRODUCTS AND PROCESSES TO THE MARKET

Making the involvement of industrial partners within the project consortia and the increase in Technology Readiness Level (TRL) mandatory for all projects has proven to be an effective strategy to foster cooperation between research and industry, as well as to ensure progress towards market applications.

All funded projects included between 1 to 5 companies, encompassing large, medium, and small enterprises, with an average of 2.4 companies per project.

	COUNTRY	Belgium		Croatia	Denmark	Estonia		Finland	Germany		Greece	Ireland		Island	Italy	Latvia	Malta	Norway		Portugal		Romania	Spain		Sweden		Total funding per project (€)
CALL	PROJECT ACRONYM / FUNDER	FWO	VLAIO	MZO	IFD	ETAG	MEM	MMM	VDI/VDE	BMEL	GRST	MI	SFI	RANNIS	MUR	IZM	MCST	RCN	IN	FCT	FRCT	UEFISCDI	AEI	CDTI	FORMAS	VGR	
CC	ImprovAFish				X							X	X					X	X						X		1,683,915
CC	SNAP					X			X						X			X	X						X		1,575,000
CC	MARIKAT				X						X			X											X		1,307,000
CC	MINERVA											X	X	X												X	1,096,700
CC	PlastiSea				X													X					X		X		1,454,000
CC	RASbiome	X			X													X									1,088,000
CC	DIGIRAS							X	X	X	X							X	X	X							1,679,397
CC	BlueCC	X							X						X			X	X	X					X		1,891,000
CC	SuReMetS								X			X	X					X	X								1,601,317
CC	CASEAWA								X						X								X				507,000
CC	BIOSHELL																	X		X		X					838,000
CC	BIOZOOSTAIN				X									X	X								X				847,000
CC	AquaHealth				X				X									X									1,927,000
CC	InEVal								X	X		X	X		X			X	X					X			1,467,234
CC	BESTBROOD										X				X			X					X	X			1,343,006
CC	AquaTech4Feed									X	X	X	X		X		X						X				1,275,970
CC	AquaHeal3D				X													X					X		X		1,009,960
CC	MedSpon								X		X				X												759,000
CC	SIDESTREAM								X						X			X		X			X				1,896,000
AC1	SuMaFood										X							X				X		X			1,340,000
AC1	TACO ALGAE				X	X								X		X		X									1,153,000
AC1	BlueBioChain	X			X						X			X			X										1,157,000
AC1	QualiSea		X											X				X	X								1,152,000
AC1	MuMiFaST			X	X							X						X									1,191,000
AC1	SMARTCHAIN				X									X				X	X								1,300,000
AC1	MARIGREEN				X						X							X				X					1,397,000
AC1	PROFIJS				X									X			X										1,251,000
AC1	Microalgae in IT					X								X						X							370,000
AC1	TraceMyFish				X						X			X				X									990,000
AC2	BlueGreenFeed				X	X	X							X				X									1,200,000
AC2	BIVALVI											X			X			X									872,000
AC2	ImPrESsIVE					X	X					X			X			X									1,084,000
AC2	Seasoil			X	X	X	X					X						X									1,250,000
AC2	BIORAS_SHRIMP														X		X	X									937,200
AC2	RightFish				X									X	X			X									1,143,400
AC2	EuFish_SustainableGrowth													X	X		X										541,000
AC3	DigiRAS																	X									20,000
AC3	MARIGREEN_TECB																	X									20,000
AC3	MARIKAT-BCOM													X													20,000
AC3	MINERVA_TECB											X															20,000
AC3	PlastiSea_DISS																	X									20,000
AC3	QUALISEA_DISS																	X									20,000
AC3	SeaSoilDemo																	X									20,000
AC3	SIDESTREAM																	X									20,000
AC3	SmartChain_diss																	X									20,000
AC3	Smartchain_policy													X													20,000
AC3	SoundScapes (BlueCC)																	X									20,000
AC3	SuMaFood_BCOM																	X									20,000
AC3	SUREMETS_BCOM											X															19,000

Table 7. *BlueBio R&I projects sorted by call (CC= Cofunded call, AC1-AC3= Additional calls 1-3). along with the name of funding organisations (x). Total request per project given in the last column. Dark blue cells indicate the funding organisation which did not participate in the call. Latvia was not a BlueBio partner at the time of the Cofunded call.*

The final reports of projects indicate that at least 28 products/processes are close to reaching the market. This number is likely to increase, thanks to commercialization support from BlueBio and additional funding provided to some projects through the 3rd Additional call.

COOPERATION WITH RELEVANT ORGANISATIONS, ASSOCIATIONS AND PROJECTS

The close alignment of BlueBio with JPI Oceans provided a direct channel for communication with relevant ministries, industry networks, funding organisations and decision makers. This further contributed to the alignment of R&I efforts and proved valuable to enhance the impact and visibility of BlueBio. Through the Advisory Board, contact was established with the Technology Platform EATIP and the Biobased Industry Consortium who provided input for future calls, the Foresight process and additional activities.

Additionally, the forward-looking activity undertaken by BlueBio to adapt to the evolving landscape and the initiatives succeeding the current ERA-NET Cofunds will serve as a guide to research funding organizations and new European Partnerships under Horizon Europe.

COMMUNICATION AND EXPLOITATION OF RESULTS

Effective communication of research and innovation findings to policymakers, the industry, and the public is essential for fostering informed dialogues. The dissemination of project results was a required task falling under the responsibility of the project partners. Detailed communication plans describing concrete initiatives and activities directed towards different stakeholder groups were requested and considered in the proposal evaluations.

The activities undertaken by the 19 projects funded through the Cofunded call involved organizing or participating in 18 workshops with stakeholders and coordinating 3 Citizen Science initiatives. It is worth noting that these data are still partial, as they are based only on the outcomes from the 19 projects selected in the Cofunded call. Transferring the BlueBio project portfolio to JPI Oceans after the conclusion of the BlueBio Cofund will ensure the continuation of communication and dissemination of the projects' results.

Since 2021, BlueBio external communication effort has focused on both disseminating information about calls and project selections, and on spreading the results from the Cofund to a broader audience. This included active participation at international events such as the Final Biotech HUB-meeting of ERA-NETs and European instruments (online, May 2022), the EATIP Annual General meeting (Brussels, June 2022), the European Aquaculture Society Conference 2022 (Rimini, September 2022), the OceanTraining2023 (Ghent, 9-11 January 2023), Swedish EU Presidecy Conference on Circular Bioeconomy (online, February 2023) 1st Mission Arena BANOS Lighthouse (Gothenburg session 14-16 November 2023) and Ocean Week (Brussels, March 2024), and the organization of the event "Connecting the dots for a Circular Blue Bioeconomy: From Science to Policy and Regulatory solutions" (European Parliament, Brussels, 30 January 2024), as well as the publication of articles in EuroFish Magazine and Fish Farmer Magazine.

IMPROVE THE PROFESSIONAL SKILLS AND COMPETENCES IN THE BLUE BIOECONOMY

Encouraging the implementation of Human Capacity Building activities from the project proposal stage and supporting them with meetings and training courses organized by BlueBio, as well as providing additional funds through the 3rd Additional call, has led to a noticeable advancement in the implementation of HCB within the Blue Bioeconomy sector.

Reflecting on the initiatives, it is clear that the projects themselves took the lead in organizing a variety of activities.

Notably, aside from the 3 training courses facilitated by BlueBio, that attracted participants from 8 distinct projects, the projects themselves initiated at least 3 training courses and 14 collaborations among them, further enriching the ecosystem with new partnerships.

The educational impact was marked by the active participation of around 70 PhD and Master' students, along with post-doctoral researchers, in research activities. This involvement underscores the initiatives' pivotal role in advancing academic pursuits within the BlueBio economy.

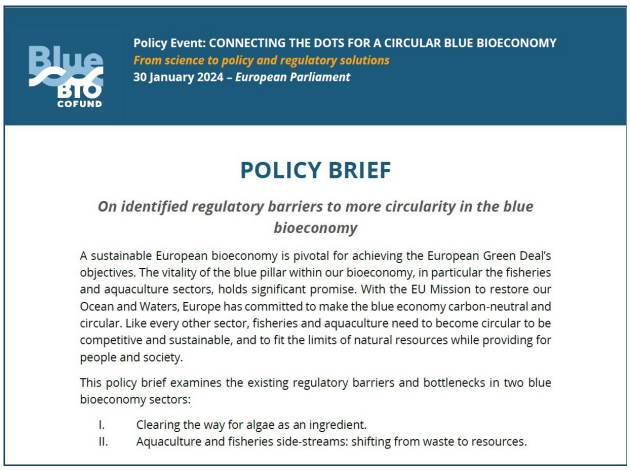
It is important to mention that, once again, these data are still incomplete, as they only reflect the outcomes from the 19 projects selected in the Cofunded call. Therefore, the anticipated final impact is expected to be more substantial.

CONTRIBUTING TO POLICYMAKING IN RESEARCH, INNOVATION, AND TECHNOLOGY

The contribution of the BlueBio Cofund to policymaking in research, innovation, and technology has primarily consisted of two actions. The first involved organizing the aforementioned event "Connecting the dots for a Circular Blue Bioeconomy: From Science to Policy and Regulatory solutions" (European Parliament, Brussels, 30 January 2024), during which a Policy Brief produced by BlueBio was presented. This brief, available on the BlueBio website (bluebioeconomy.eu) examines the existing regulatory barriers and bottlenecks in two Blue Bioeconomy sectors: I. Clearing the way for algae as an ingredient; II. Aquaculture and fisheries side-streams: shifting from waste to resources. The event was organised after many projects highlighted the regulatory barriers to market uptake of their new products and solutions at the end-term evaluations. The availability of funds after a lack of in-person events during the COVID-19 pandemic, created an opportunity for more direct policy influence.

The second action consisted of providing contributions to the SCAR Fisheries and Aquaculture Committee. Since 2020, BlueBio has been present at the SCAR FISH meetings, giving updates on activities and receiving input from the SCAR FISH members. This also created a more direct link to DG RTD, DG MARE and other stakeholders in Europe.

In addition, a few funded projects produced white papers and influenced policy processes both on national and European level.



Policy Event: CONNECTING THE DOTS FOR A CIRCULAR BLUE BIOECONOMY
From science to policy and regulatory solutions
30 January 2024 – *European Parliament*

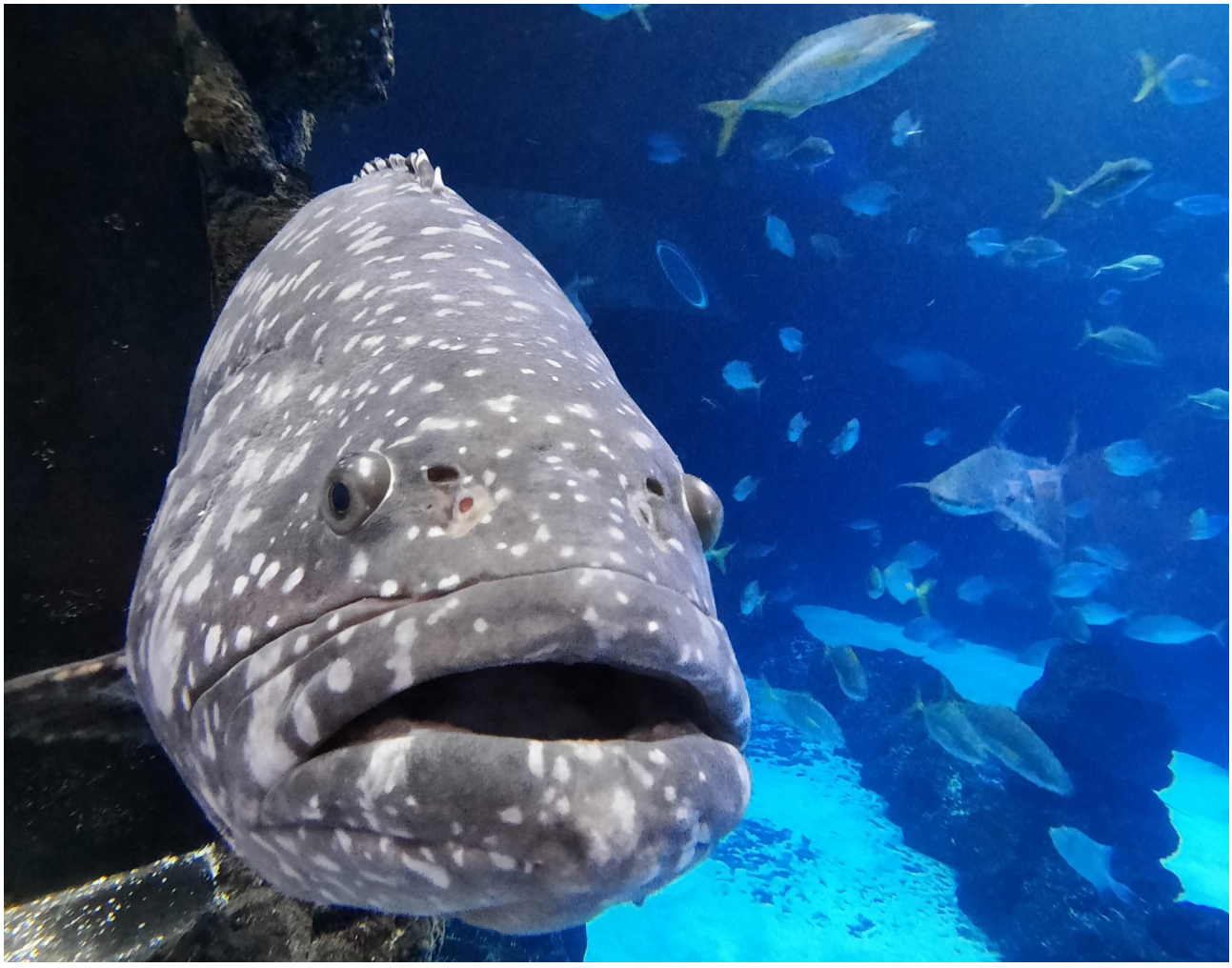
POLICY BRIEF

On identified regulatory barriers to more circularity in the blue bioeconomy

A sustainable European bioeconomy is pivotal for achieving the European Green Deal's objectives. The vitality of the blue pillar within our bioeconomy, in particular the fisheries and aquaculture sectors, holds significant promise. With the EU Mission to restore our Ocean and Waters, Europe has committed to make the blue economy carbon-neutral and circular. Like every other sector, fisheries and aquaculture need to become circular to be competitive and sustainable, and to fit the limits of natural resources while providing for people and society.

This policy brief examines the existing regulatory barriers and bottlenecks in two blue bioeconomy sectors:

I. Clearing the way for algae as an ingredient.
II. Aquaculture and fisheries side-streams: shifting from waste to resources.



7. RECOMMENDATIONS TO EUROPEAN FUNDING INSTRUMENTS AND CONSORTIA

There is a lot to be gained from having a portfolio approach when setting up and running an organisation like an ERA-NET and working systemically along multiple axes.

For the BlueBio Cofund, the axes were the Value chain, Technology Readiness Level and Human Capacity Building. To achieve a sustainable and competitive Blue Bioeconomy in Europe and improve the transfer of bio-based products and services from the laboratory to production scale, there needed to be a concerted effort along the three axes.

To ensure improvements along the whole Blue Bioeconomy Value chain, there was first a wide call for projects along the whole value chain. After the projects were funded, the gaps of funding along the Value chains were identified and the two subsequent calls only focussed on the uncovered areas (Figure 8). The mandatory inclusion of industry partners within the projects also ensured a closeness to the value chain and a relevance to industry.

It was very successful to make an overarching plan for subsequent calls after analysing the first call to provide guidance and direction for the work of the consortium. By identifying the gaps and needs along the value chain, the consortium could tailor the topics and criteria of the second and third calls to address them. This ensured that the funded projects were aligned with the strategic objectives and priorities of the BlueBio Cofund and the European Blue Bioeconomy sector. Moreover, by having a clear plan and vision for the future calls, the consortium could communicate effectively with the national funders, and potential applicants and stakeholders, and increase the quality and relevance of the proposals. The plan also facilitated the coordination and collaboration among them. It will also be valuable to get experience from the novel funding fourth call supporting communication, dissemination, commercialisation training and policy needs of the previous three calls with the aim of enhancing the impact and outcome of those projects.

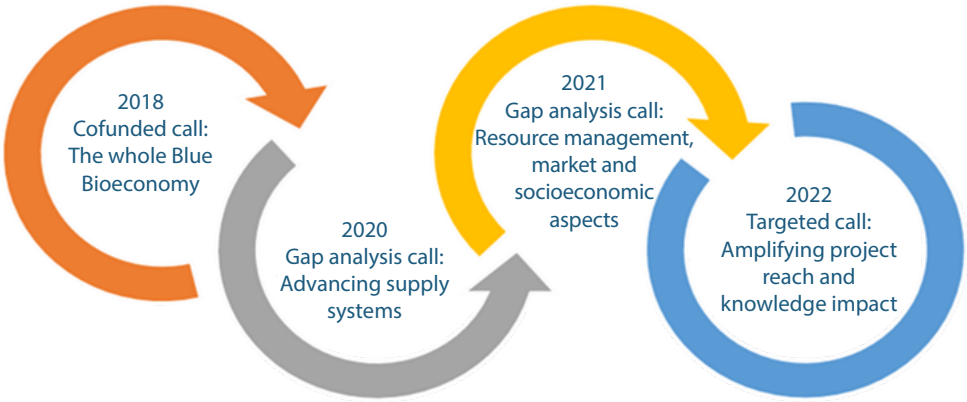


Figure 8. *The BlueBio transnational call process addressing the whole value chain.*

Making an increase in TRL mandatory for all projects, even those that commenced at the lowest level, made it a focus for every project. The expectation for an increase meant that the projects should emphasise a movement towards market applications and that the Consortium needed to support them in that effort. It became the focus both inside each project and for the Consortium as a whole. The impact of the commercialisation support is hard to measure, as the fruits will be harvested after the end of BlueBio, but the interest from both research and industry partners has been significant and there are great hopes for the future. The efforts of the Consortium were also disseminated to the research and innovation community, and the research-based industry community.

It is crucial for researchers, funders, and technology developers to remain mindful of the broader context surrounding their work. Responsible Research and Innovation prompts reflection on the desired outcomes of scientific and technological advancements. Collaboration among all stakeholders within the research ecosystem is essential to ensure that funded projects yield maximum societal benefits.

To ensure implementation of Human Capacity Building, it was mandatory in all projects and was set as Key Performance Indicator in the mid-term and final evaluation. For the most part, this translated into master and PhD students involved in the projects. However, some projects also organized exchanges, training courses, or contributed to HCB in other ways. From the interactions with the funded projects, it was clear that the projects should have allocated more funds, but also that the BlueBio Consortium could support HCB by organising high level training courses. The topics for the training courses were identified through surveys, meetings, and discussions with the projects, aiming to be most beneficial for members of the Blue Bioeconomy community. HBC was also included as a topic in the 3rd Additional call in 2022.

Identifying the availability of dedicated funds for HCB as a key issue potentially impacting the effectiveness of research in the Blue Bioeconomy sector, this focus could be considered a model approach for future initiatives.

Having the flexibility in a consortium to interact with the funded projects and adjust the planned activities has been invaluable. Facilitating meeting places between the funders and the projects, the funded projects within one call and between calls, and projects funded within and outside the BlueBio Consortium, has been a well of information and ideas and an essential sounding Advisory board to guide the development of the Consortium.

RECOMMENDATIONS FROM BLUEBIO

BUILDING THE COFUNDED CALLS

- Establishing a clear plan and vision for consecutive calls for: identifying and addressing all gaps and needs along the value chain; facilitating dialogue with national funders, potential applicants and stakeholders; increasing quality and relevance of the proposals.
  Building on prior efforts ensures stability for applicants and a clearer path to achieve long term strategic goals.
- Identifying gaps after the initial call enables more precise and focused scopes in subsequent calls. It was more challenging to engage funders, but it increased the impact of BlueBio on challenging topics.
- Drivers (e.g., HCB and industry partner inclusion, increase in TRL) that are believed to be essential for the impact of the funded projects must be included in the call text and followed up on while monitoring the projects.
- Complementary precision funding can increase the impact of already funded project. Targeted calls must be developed with deep understanding of the projects.

BEST PRACTICES FOR MAXIMIZING THE IMPACT OF COFUNDED PROJECTS AND OF THE COFUND

- ***Value chain approach***

  An overarching strategic focus must be followed up with concrete actions in call scope and call design, and human resources devoted specifically to this.
- ***Creating connectivity and synergy between projects***

  Creating online meeting spaces for projects leads to measurable and tangible knowledge exchange and synergies between projects, with engagement reaching further than the project coordinator.
- ***Analysis of past and ongoing research projects***

  Having an overview of already funded projects enables funders to avoid duplication and address the gaps and needs in Research and Innovation (R&I).
  There must be time overlapping between initiatives to ensure the continuation of infrastructures that enables this overview.
- ***Commercialisation support and factsheets***

  Mandating inclusion of industry partners and a TRL increase in the projects ensures relevance to the industry and value chain and emphasizes market-oriented development.
- ***Human Capacity Building (HCB) and Training and Mobility (T&M) in the projects and in the ERA-NET***

  Mandating, monitoring, and supporting implementation of HCB activities within projects contributes to increasing professional skills and competencies.
  Including HCB activities as KPI in the evaluation process makes them a focal point for the projects. Monitoring project activities and adjusting to evolving needs is essential.
  Dialogue with project coordinators helps identify topics and best practices for future initiatives.
- ***Follow-up and monitoring of projects***

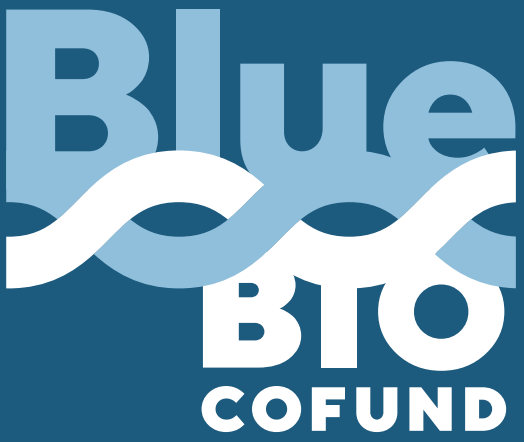
  A monitoring and evaluation framework should assess the projects' performance in key project objectives so their impact is clear.
  Mid- and end-term meetings function as a forum for dialogue and knowledge exchange within the projects and between different projects.
- ***Responsible Research and Innovation (RRI)***

  All players in research must collaborate smoothly to maximize the societal benefits of funded projects.
  The RRI methodology is key to achieving this goal. An independent ethics advisor can oversee RRI efforts in projects, ensuring a consistent and predictable ethics assessment environment.
- ***Forward-looking activities***

  The resources from BlueBio, along with the network of funding partners and projects, enabled a comprehensive foresight process, leading to a lasting legacy in the form of a Strategic Knowledge and Innovation Agenda (SKIA).

ANNEX 1. GLOSSARY

AI	Artificial Intelligence
BlueMed CSA	BlueMed Coordination and Support Action
COFASP	Cooperation in Fisheries, Aquaculture and Seafood Processing ERA-NET
EATIP	European Aquaculture Technology and Innovation Platform
EC	European Commission
EFARO	European Fisheries and Aquaculture Organisation
ESMB	European Society of Marine Biotechnology
ERA-MBT	Marine Biotechnology ERA-NET
EUSAIR	EU Strategy for the Adriatic-Ionian Region
EUSBSR	European Union Strategy for the Baltic Sea Region
GES	Geography, Environment, and Sustainability
HCB	Human Capacity Building
KPI	Key Performance Indicators
IBA	Department of Biological Sciences
ML	Machine Learning
MPA	Marine Spatial Planning
NbS	Nature based Solutions
NTNU	Norwegian University of Science and Technology
RAS	Recirculating Aquaculture System
R&D	Research and Development
R&I	Research and Innovation
RRI	Responsible Research and Innovation
SBEP	Sustainable Blue Economy Partnership
SCAR	EU Standing Committee on Agriculture Research
SDG	Sustainable Development Goals
SKIA	Strategic Knowledge and Innovation Agenda
SRIA	Strategic Research and Innovation Agenda
T&M	Training and Mobility
TRL	Technology Readiness Level
UN	United Nations



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 817992.