Interreg Atlantic Area

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Joint R&D&I Program

3 Biotechnology Platforms

D1.1 WP1

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Content

2 Joint R&D&I Programs

3 Joint R&D&I Programs

Introduction

MARINNONET's Joint R&D&I Programs are strategic documents aimed at compelling the collective expertise and resources of its network partners to address key challenges and opportunities in the Blue Biotechnology sector in the 8 Atlantic Area (AA) regions involved in MARINNONET (Galicia ES, Basque Country ES, Canary Islands ES, No rte and Centro PT, Bretagne FR, and N&W and Southern IE).

Considering the characteristics of the Blue Biotech sector of these regions, and their respective R&D&I strengths, MARINNONET will focus on 3 Marine Biotechnology Platforms (BP):

- BP1 **- Innovations for an efficient, sustainable, and resilient aquaculture**
- BP2 **- Omic and observation technologies for preserving marine biodiversity and restoring ocean health.**
- BP3 **- Marine-derived products for industrial applications**

This document details the Joint program of each of the 3 BPs. The Joint R&D&I Programs serve as a comprehensive framework for guiding research, development, and innovation (R&D&I) actions within the project, ensuring a cohesive and strategic approach toward achieving impactful outcomes. Secondly, the programs are tailored to align with European and international policies, ensuring compliance and relevance within the broader strategic landscape of the marine blue biotech sector. Additionally, the dynamic nature of these documents allows for continuous adaptation to the evolving context, designed to be updated annually, incorporating the portfolio of ideas and market-driven challenges that arise in the Blue Biotech Innovation (B2I) workshops, ensuring responsiveness to emerging challenges and opportunities as well as ongoing relevance and effectiveness. Furthermore, the Joint Programs facilitate collaboration and coordination with other relevant projects, fostering synergies and maximizing the collective impact of MARINNONET's initiatives. Ultimately, these Joint Programs play a pivotal role in establishing strategic collaboration agreements and actions, fostering innovation, and driving sustainable growth within the Marine Biotechnology sector.

1. **Joint R&D&I Program**: Innovations for an efficient, sustainable, and resilient aquaculture

1.1. State-of-the-art BP1 and alignment with the European and international current policies in the Marine Biotechnology area

Aquaculture made a significant contribution to global aquatic animal production in 2020, reaching a remarkable 49.2%. Sustainable development in aquaculture is crucial to meet the rising demand for aquatic foods. The Blue Transformation initiative emphasizes sustainable expansion and enhancement of aquaculture, necessitating comprehensive and adaptable approaches. These approaches must acknowledge the intricate dynamics within agrifood systems and advocate for multi-stakeholder interventions. Leveraging existing and emerging knowledge, tools, and practices is essential to ensure the role of aquatic food systems in global food security and nutrition is maximized. Predictions suggest a 15% increase in aquatic food production by 2030, primarily through sustainable aquaculture intensification and expansion. However, such growth must not compromise aquatic ecosystem health, pollution prevention, biodiversity protection, or social equity. The goals of Blue Transformation include promoting the adoption of sustainable aquaculture practices, integrating aquaculture into development strategies and food policies, expanding production to meet demand while enhancing inclusive livelihoods, and enhancing capacities to develop and adopt innovative technologies and management practices. Overcoming fundamental barriers in aquaculture production systems, governance, investment, innovation, and capacity building is paramount. Technical innovations, especially in genetic breeding programs, feeds, biosecurity, and disease control, are crucial for improved aquaculture systems, alongside coherent policies, and incentives along the value chain. Key areas for innovative aquaculture practices include aquafeeds and feeding, digitalization, and the promotion of environmentally friendly practices. Implementing these solutions requires adequate capacity, skills, training, research, and partnerships, leveraging advancements in information and communications technology and improved access to mobile applications and platforms. Biotechnology Platform 1 is instrumental in advancing knowledge in farmed organism physiology, nutrition, genetics, breeding, and disease control, benefiting both fishing and shellfish aquaculture activities.

This platform is aligned with the European and international current policies in the Marine Biotechnology area, as well as with the evolution of the Political, Economic, Social, and Technological context and its relevant forces. This includes:

1. European Union Horizon Europe research framework program, in the "Pillar II Global Challenges and European Industrial Competitiveness" section, in cluster 6 food, bioeconomy, natural resources, agriculture, and environment. Research and innovation activities under cluster 6 contribute to the objectives of:
    - the European Green Deal related to the Biodiversity Strategy to 2030
    - the Farm to Fork Strategy: our food, our health, our planet, our future.
    - the European Climate Pact
    - initiatives under sustainable industry and eliminating pollution

- a long-term vision for rural areas.

2. European Union Council policies through:
   - Sustainable oceans, sustainable blue economy, and the Atlantic Ocean articulated through Blue integrated territorial investment (I.T.I Azul)
   - Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030
   - Priority 2 of the Operational Program of the European Maritime and Fisheries Fund (EMFF), which promotes sustainable aquaculture.
3. The Regional Smart Specialization Strategy (S3) within the European Union is the challenge that aims to position the food sector based on the use of marine resources, especially in fisheries and aquaculture, as detailed in S3 regional strategies.

4. United Nations Sustainable Development Goals:
   - SDG2: End hunger, achieve food security and improve nutrition,
   - SDG12: Ensure sustainable consumption and production patterns
   - SDG14: Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

1.2. Situation of BP1 in regions of the Atlantic area involved in the proposal: main topics undertaken

This section provides an overview of the current state of BP1 across various regions within the Atlantic area that are part of the project. It highlights the key themes and initiatives being pursued in these regions, underscoring their strategic importance and the collaborative efforts aimed at harnessing BP1's potential for economic and environmental benefits.

ES-Galicia

- Development and validation of ingredients for sustainable aquafeeds.
- Feeding evaluation and control in aquaculture fish species.
- Improving nutritional profiles
- Tools for assessment of growth and metabolism.
- Improving fish culture techniques
- Improving reproduction in fish culture
- Multitrophic aquaculture
- Green aquaculture: reduced carbon footprint.
- Breeding and genetics of aquaculture species.
- Cultivation methodologies and phenotyping and genetic/genomic approaches
- Development of tool kits for welfare assessment in fish.
- Improvement of biotechnological processes involved in disease prevention and diagnosis in fish and mollusks.
- Environmental health assessment of the implementation of aquaculture production in nature.

ES-Basque Country

- Regional strategic plan of aquaculture 2014-2030
- Important industry of seafood processing, products of seafood hydrolysates.
- University spin-off company for microalgal cultivation incubators.
- Start-up company based on university algal strains for production of algal products for agriculture and feed solutions

ES-Canary Islands

- Commercial production of seabream and seabass in cages
- Pilot scale production of abalone (*Haliotis tuberculata* coccinea)
- Pilot and semi-industrial production and transformation of microalgae and macroalgae
- Research projects on the development possibilities of new species in aquaculture
- Development of Integrated Multi-Trophic Aquaculture (IMTA) approaches at pilot plant scale
- IAT Bioasis: High Tech Platform Hub for entrepreneurs' technological projects in aquaculture and biotechnology
- Projects and transference on Aquaponics and Circular Economy, including valorization of waste by-products
- Projects on sustainability and environment related to aquaculture activities
- Projects for Global Change mitigation through algal aquaculture
- Project development and possibilities associated with the "test site" at PLOCAN (Oceanic Platform of the Canary Islands). Relationships between marine renewable energies and aquaculture.

FR-Bretagne

- Fish growth performance and health
- Develop species knowledge (choice and production cycle)
- Manage emissions and inputs
- Establish integrated multi-trophic aquaculture
- Introduce alternative, plant- and invertebrate-based feed
- Seaweed life cycles, interaction with environment and management
- Development in sea urchins

IE- Northern & Western

- Developing cultivation techniques that support biodiversity
- Applying circular economy principles in the aquaculture sector
- Multitrophic aquaculture
- Development of seaweed culture
- Fish and mollusk health

PT-Norte

- Development and validation of ingredients for sustainable aquafeeds.
- Improving nutritional profiles

- Tools for assessment of growth and metabolism.
- Improving fish culture techniques
- Welfare assessment in fish.
- Immunological responses in fish culture
- Breeding and genetics of aquaculture species.
- Seafood safety and processing
- Fish and mollusk health
- Multitrophic aquaculture

1.3. Knowledge and experience of the project partners in the Marine Biotechnology R&D&I field

This section highlights the extensive expertise of the project partners in the Blue Biotechnology R&D&I. It summarizes their diverse backgrounds and contributions, demonstrating their ability to drive advancements and achieve the project's goals.

UVIGO (ES-Galicia)

- Development and validation of ingredients for sustainable aquafeeds.
- Feeding evaluation and control in aquaculture fish species.
- Genetic selection for traits of interest in marine mussel aquaculture and canning industry.
- Screening of potential probiotic marine bacteria for bivalve resilience to global warming effects (e.g. heatwaves, low oxygen levels, and water acidification) in aquaculture
- Improvement of biotechnological processes involved in disease prevention and diagnosis in fish and mollusks.
- Development of tool kits for welfare assessment in fish

IEO-Vigo (ES-Galicia)

- Improving nutritional profiles
- Tools for assessment of growth and metabolism.
- Improving fish culture techniques
- Improving reproduction in fish culture
- Multitrophic aquaculture
- Green aquaculture: reduced carbon footprint.
- Breeding and genetics of aquaculture species.
- Cultivation methodologies and phenotyping and genetic/genomic approaches
- Welfare assessment

UPV/EHU (ES-Basque country)

- Histopathology, fish and shellfish health
- Fish reproduction

- Basque Microalgae Culture Collection
- Embryo-tests (fish, mollusks, sea urchins)

ULPGC (ES-Canary Islands)

- Algae biotechnology: cultivation of macro- and microalgae from the test tube to the semi-industrial scale
- Biodiversity conservation
- Spanish Bank of Algae Culture Collection: bioprospection and genetic resources
- Sustainable aquaculture: nutrition, genetics, pathology, quality, economics, new species
- Integrated Multi-Trophic Aquaculture
- Biomedical applications of marine metabolites
- Cosmetic and cosmeceuticals, nutraceuticals, food products
- New materials
- Global change mitigation considering biological processes

SU-SBR (FR-Bretagne)

- Seaweed life cycles, interaction with environment and management
- Development in sea urchin

NUIG (IE- Northern & Western)

- Water and waste management
- Seaweed aquaculture and biotechnology

1.4. Enriching the BP Programs: Aligning with Blue Biotech Challenges and Opportunities identified in the participative actions

This section outlines the approach of continuously reviewing and updating the BP programs to ensure they align with the latest insights from participative workshops and market-driven R&D&i activities, as conducted in our project. In the co-creation workshop activities, namely the Blue Biotech Innovation workshops, were aimed to include different actors and members from the quadruple helix. By incorporating these findings, these BP programs will be adapted to effectively address the emerging needs, challenges, and opportunities within the Blue Biotech ecosystem. This dynamic framework aims to foster an environment of innovation, ensuring that the sector can rapidly respond to new developments and maintain a competitive edge.

Six different workshops where hosted the first year: ES-Galicia, ES-Basque Country, ES-Canary Islands, PT-Portugal, FR-France and IE-Ireland. The challenges and opportunities identified in the sessions will be linked if possible. The findings will be discussed by regions in each thematic priority and later discussed in a more general level.

Findings of the first set of Blue Biotech Innovation Workshops (2024)

ES-Galicia

Challenges	Linked Opportunities
Optimization of resources and creation of synergies between actors	Collaboration between Galicia and Northern Portugal using existing funding programs.
Lack of understanding of lower-level trophic networks	Expansion of the number of lower trophic species cultured and multitrophic aquaculture.
Reproduction and genetic improvement of species.	Culture of new species.
Development and updating of low-cost technologies across various sectors	Utilization of existing technologies for developing new technologies (i.e. zootechnical assessment, welfare monitoring, environmental monitoring, etc.)
Lack of early detection of pathogens and methods to ensure assessment of animal welfare	Development of technologies for detecting, monitoring, and ensuring animal welfare, including the use of pre/probiotics.
Low financing opportunities for companies and SMEs	Funding and collaborative project development with companies through R&D programs.
Raising awareness and improving social acceptance of aquaculture	Enhancement of social acceptance and dissemination efforts to improve consumer perception.
Monitoring and observation of the environmental impact of aquaculture practices	Environmental impact observation and mitigation, especially for offshore facilities.
Development of alternative ingredients for aquafeeds	Positioning Galicia as a primary source of aquaculture ingredients.
Lack of transparency and knowledge transfer between academia and businesses.	
	Revalorization of invasive species, including algae and animals.
	Adoption of sustainable certifications such as the ASC (Aquaculture Stewardship Council) label.

ES-Basque Country

Challenges	Linked Opportunities
Need of institutional support to build a Basque aquaculture sector and reverese societal negative perceptions	European Farm to Fork strategy, new aquaculture approcahes, new species, international collaborations of the R+D sector, valorisation of byrpoducts of aquaculture sector (biomaterials, bioplastics, biocomposites)
Crosstalk between the aquaculture and fisheries sectors	Win-win situations locally and transregionally through cross-beneficial technology transfer activities
Development of a sustainable aquaculture based on new fish species of low trophic level, including the production of feed for them	New vital cycles and domestication of species of commercial and “traditional” interest and species of low carbon footprint, best adapted to local conditions
Animal reproduction based on quality. Selection of breeders based on biological traits	Molecular evaluation of oocyte and sperm quality

Development of hatcheries for different bivalve species (spat production)	Aquaculture based on selected strains
Aquaculture for habitat restoration	Mollusc aquaculture to rebuild lost ecosystems
New and non-contaminating culture conditions for animals (household, feed, water quality…)	Identification of nitrificant bacteria for RAS production systems and probiotics for fish feed
Microalgae production: scale up	Applications for new sources of biomass, applications in bioremediation, CO2 fixation (blue carbon), bioproducts
Macroalgae production systems and protocols	European Farm to Fork strategy, health, valorisation as food ingredient
Training and education	Need for socioeconomic development of maritime regions with opportunitiues creating better and more specialised jobs

ES-Canary Islands

Challenges	Linked Opportunities
Increase value of waste by-products	To enlarge networks of marine bioresources providers
Increase value of waste by-products	Development of new products under the circular economy concept
Improvement of enzymatic techiques to modify feed promising components	Development of enrichment feeds for Artemia through specific exo-scheleton links
Financing for improvement of techniques and methodologies	Characterization and selection of bioactives from marine invertebrates and cyanobacteria
Improvement of treatments and increase inmunity	Health and society improvement
Technology improvement for the detection of alterations affecting productivity	Use of platforms for the observation and control of critical parameters in cultures
Implementation of RAS technologies in tanks at semi-industrial scale	Sinergies and collaborative actions for aquaculture and blu biotechnology
Sensors for Aquaculture 4.0	Sinergies and collaborative actions for aquaculture and blue biotechnology
Regulations and administrative issues	Education and communication actions/links between stakeholders and administration units
Regulations and administrative issues	Clarification of protocols for administrative procedures (pipeline)
Monitoring of environmental conditions and impact of infectious diseases	Improvement of monitoring techniques
Sustainable materials optimization to avoid negative impacts on the environment	Characterization and selection of bioactives from marine invertebrates and cyanobacteria
Research and development of antimicrobial recoverings for cultivation systems reducing infections	Innovative materials decreasing biofilms formation and for the design of photobioreactors for probiotic production
Identification of value chains in blue biotechnology	New species domestication
Formation in the blue biotechnology area	New programs and institutions
Discovering of new marine products for food	Marine products safety

PT-Portugal

Challenges	Linked Opportunities
Monitor and predictive tools to anticipate no-go zone for bivalve	Food production, new species value chain

Add value to residues (solids, waste and process waters) resulting from canning industry	Circular economy and green deal Market studies, learn and replicate
New species domesticated for aquaculture (eg. add value to mackerel)	Aquaculture positioning, sustainable and competitive aquaculture, cultivation of les exploited species
Explore rapid, nondestructive systems and tools fostering detection of parasites and separation of polychaetes hosted by bivalves	Food security, aquaculture, EU is one of the main markets for bivalves, From farm to Fork, Green Deal, EU Aquaculture Assistance Mechanism, Funding schemes
Shelf-life extension strategies before go to consumers	Microbial food spoilage, food safety, new value chains, bio-based solutions
Machine learning for prediction of waste production: organic and inorganic residuesfostering treatment and recycling-upcycling	EU decarbonization stategy Green Deal, Digital tools. databases
New formulations and bioactives ingredients for feed (alternative to fish based)	Biorefineries, use of fish-byproducts, managing marine resources sustainability
Cod fish survival, new solutions to deliver oral antibiotics	Domestication of species, global market
Minimize parasite infections in aquariums	Tourism promotion
Scale up lab experience in microalgae production	Potential of algae for the EU's Blue Bioeconomy, addressing key challenges, such as food security and climate change mitigation. New PBR production methods to scale Connection with stakeholders, proof of concept programmes
Macroalgae: species and activities - academia and industry lack knowledge from each other	Join projects for funding, open innovation
Conducting tests and scientific confirmation	Promote knowledge dissemination, Blue Demo Network platforms and funding
From research to startups, scaleup and demonstrations	Research transfer and opportunities improving TRL, Promote knowledge dissemination, Blue Demo Network platforms and funding
Market, regulatory and legal challenges	Waste Management, Life Cycle Assessment, and Biobased-materials
Optimizing Cultivation Practices and Expanding Market/Product Development	Health and sustainability
Diatoms research and valorization: Efficient and cost-effective cultivation of diatom frustules: validate the long-term health benefits in cultured shrimp and economic viability of bioactive compound encapsulation and delivery in aquaculture.	Enhancing shrimp health by efficiently delivering bioactive compounds encapsulated in natural microcapsules, to reduce dependency, dosage and frequency of administration of chemicals (drugs). Scaling up production of diatom microalgae biosilica frustules for commercial use, as an economical and sustainable alternative to other drug delivery methods (e.g., directly into the water, injectables) or microcapsules with

	properties less suitable for drug delivery in aquaculture (e.g., alginate).
Use of surplus macroalgae biomass from IMTA and RAS for fertilizers production; Toxicological tests of new products and compounds; antibioufouling test	Sustainable carbon cycles; Potential of IMTA aquaculture for the EU's Blue Bioeconomy, addressing key challenges, such as food security and climate change mitigation.
Market information and Potential First Customers	Capacitation of stakeholders, Blue literacy, go-to market startegies Market studies available Consumer oriented campaigns

FR-France

Challenges	Linked Opportunities
Structuring the macroalgae industry: from natural state to cultivated	Efficient, structured aquaculture sector
Linking public and private industry: biobanking macroalgal strains	Importance of regulations
evolution of algal resources and impact of climate change	Transition policies
Facilitating the development of seaweed farming in the region and supporting the development of innovation and its economic spin-offs	Enhancing the value of marine by-products and developing active ingredients (cosmetics in particular)
Sustainability of the macroalgae supply chain	
Improving the yield of microalgae.	
Application of epigenetics in aquaculture	

IE-Ireland

Challenges	Linked Opportunities
Seaweed/Genetics: Limited genetic development to date and whether it is suitable for offshore production	Improved genetic strain selection of red and brown seaweeds
Large development of seaweed farming, licensing process requires total overhaul, need for blue biorefinery	Enhance the extraction, research opportunites and new product development micoralgae for high value products
Green aquaculture: reduced carbon footprint. - Sustainability of materials & supply chain	Integration of autonomy / AI into workboat activities Demonsrting climate benefits of electric / HDPE vs regular workboats. Demonstrating climate benefit of electric/HDPE vs regular workboats
Feed ingredients: Increased bacterial, viral and parasitic challenge as a result of climate change. New diseases or new stains of old diseases	Natural based feed ingredients show potential to address many of these health challenges. Need specific health challenge trials
Circular Bioeconomy: How to utilize by products and waste discharges from aquaculture and processing	Microalgae and bacteria show growth opportunities for new compounds and products. Need further work with

	microalgae/bacteria and identification of novel products
Welfare Assessment: How do we access fish welfare in light of increased consumer concern	Biomarker tests give assessment/account of fish welfare but require further development. Also require development of platforms that make data/results more farmer friendly
Diagnostics: Rapid environmental diagnostic testing kits to give indicative results	Detection of norovirus, loading and activity a challenge for the aquaculture industry
Seaweed/Genetics: Limited genetic development to date and whether it is suitable for offshore production	Improved genetic strain selection of red and brown seaweeds

Conclusions

Regional workshops were helpful in identifying challenges for BP1 from members of the 4 Helix. Most of them were common to the whole Atlantic area with limited specificities on regions, such as the importance of macroalgae production in Bretagne or bivalves in Galicia.

The transversal challenges identified in Atlantic area regions include:

-Develop knowledge and technology for using wastes and by-products from circular economy to enhance sustainability through new ingredients or additives for aquafeeds

-Green aquaculture for minimizing carbon footprint improving sustainability

-Develop knowledge on genetics, protocols, and production systems for macroalgae production

-Scaling-up of microalgae production

-Developing reliable, low-cost, and non-stressful methodology for assessment of fish welfare

-Improving diagnostics of pathogens through reliable, fast, and low-cost technologies

-Better knowledge on reproduction and genetics of cultured species to select strains and improve reproductive outputs

-Study of biology, genetics, reproduction, population dynamics and ecology of putative new species to be cultured, especially from low-trophic level

Discussion in the regional workshops also provided many **opportunities for development of innovation in the blue biotechnology** sector allowing to tackle most of the challenges. These include:

-The Close cooperation of actors involved (4 Helix) allowing to develop innovative solutions of real transfer to society through more concerned and sustainable aquaculture

-Positive European regulatory frame through different programs and strategies like European Farm to fork strategy, and green deal actions resulting in plenty of opportunities to get funding for cooperative proposals

-Increased concern of regional authorities in development of trans-regional cooperation programs including aquaculture
-Society demands on a greener, more sustainable aquaculture including more potentially procedures technologies like IMTA
-Society concerns on animal welfare pushing on development of technologies for assessment
-Available knowledge to develop new technologies suitable for monitoring, and assessment of variables Important for culture
-Increased knowledge and capacity for holistic assessment of available waste and by-products suitable to be used for aquaculture practices, especially for aquafeeds
-Increased importance of aquaculture in food security

2. **Joint R&D&I Program**: Omic and OBSERVATION technologies for preserving marine biodiversity and restoring ocean health

2.1. State-of-the-art BP2 and alignment with the European and international current policies in the Marine Biotechnology area

Our growing societies depend on healthy ocean ecosystems for economic prosperity and societal well-being. We depend on marine bioresources that supply high-quality food, pharmaceuticals, nutraceuticals, and other products and materials, coastal protection and recreation, CO2 fixation, and O2 production. Besides, but also beyond, their exploitability the services provided by marine ecosystems are so relevant that Governments recognize the need to understand marine biodiversity periodically monitoring its status under anthropogenic stress and in a global changing scenario to better implement conservation and sustainable development targets. It includes evaluating progress towards the Biodiversity Targets of the new Global Biodiversity Framework of the Convention on Biological Diversity (CBD) and several of the U.N. Sustainable Development Goals (SDGs, mainly SDGs 2 and 14). Such targets are monitored through the global assessments of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the UN World Ocean Assessment.

The EU has established a series of legislative instruments related to the protection of biodiversity in general and marine biodiversity, in particular, to protect the resources that make marine-related socio-economic activities possible, ensuring planet and human health.

The EU Water Framework Directive (WFD, 2000/60/EC) and the Marine Strategy Framework Directive (MSFD) both require EU Member States to take the necessary measures to achieve a good coastal and oceanic environmental status. The MSFD came into force in June 2008 (2008/56/EC) and it was transposed into each member's state national legislation by mid-2010. The MFSD () in its 1st Descriptor defines Good Environmental Status regarding biological diversity. This means that any further loss of diversity should be prevented, restoring any deteriorated attributes of biodiversity are restored so the use of the marine environment is sustainable. Ensuring this requires observation and monitoring of three main ecological levels: species, habitats, and ecosystems. Its implementation is linked to other environmental policies tackling pollution from various sources (e.g. WFD, Habitats Directive, Birds Directive, quality of Shellfish waters), the Common Fisheries Policy, or the EU regulation on Invasive Alien Species. All countries in the European Union also need to take care of the discharges from land to sea following international conventions, such as OSPAR in the Atlantic area).

For MSFD, 11 descriptors have been defined to monitor the environmental status of the oceans. Different countries, centrally or regionally as in the case of Spain, establish different monitoring approaches, always with a component on biodiversity assessment, normally

based on traditional methods aiming at specific taxa. The COM DEC 2017/848/EU sets the specifications and standardized methods for monitoring and assessment.

1) non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems
2) Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.
3) Human-induced eutrophication is minimized (losses in biodiversity, ecosystem degradation, harmful algae blooms, and oxygen deficiency in bottom waters).
4) Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded, and benthic ecosystems are not adversely affected.
5) Concentrations of contaminants are at levels not giving rise to pollution effects.
6) Contaminants in fish and other seafood for human consumption do not exceed levels established by legislation.
7) The introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

Another element considered in the monitoring of biodiversity is related to the surveillance of invasive species in the ecosystems of European member states, following national regulations in place and Regulation (EU) No 1143/2014 of the European Parliament and the Council (22 October 2014) in trying to avoid their introduction and spread.

2.2. Situation of BP2 in regions of the Atlantic area involved in the proposal: main topics undertaken

This section provides an overview of the current state of BP2 across various regions within the Atlantic area that are part of the project. It highlights the key themes and initiatives being pursued in these regions, underscoring their strategic importance and the collaborative efforts aimed at harnessing BP2's potential for economic and environmental benefits.

ES-Galicia

- Chemical and biological analyses of water bodies according to the European WFD, MFD, and baths directive as regulated by the Galician autonomous region.
- Analysis of algal blooms and levels of fecal bacteria in drinking waters, and aquaculture areas according to national legislation and following regionally approved protocols.
- Analysis of diseases in and around aquaculture facilities.
- Monitoring of invasive species by the autonomous region according to the Natural Heritage and Biodiversity National Law 42/2007 and European regulation n° 1143/2014 of the Parliament and the Council.

ES-Basque Country

- Chemical and biological analyses of water bodies according to the European WFD, MFD, and baths directive as regulated by the Basque Autonomous region.
- Monitoring of the environmental impact of the effluents of wastewater treatment plants (water authority) and other industrial effluents.
- Analysis of algal blooms and levels of fecal bacteria in drinking waters, and aquaculture areas according to national legislation following regionally approved protocols.
- Monitoring of invasive species by the autonomous region according to the Natural Heritage and Biodiversity National Law 42/2007 and European regulation n° 1143/2014 of the Parliament and the Council.

ES-Canary Islands

- Chemical and biological analyses of water bodies according to the European WFD, MFD, and baths directive as regulated by the autonomous region of the Canary Islands.
- Analysis of algal blooms and levels of fecal bacteria in drinking waters, and aquaculture areas according to national legislation following regionally approved protocols.
- Analysis of diseases in and around aquaculture facilities.
- Monitoring of invasive species by the autonomous region according to the Natural Heritage and Biodiversity National Law 42/2007 and European regulation n° 1143/2014 of the Parliament and the Council.

FR-Bretagne

- Chemical and biological analyses of water bodies according to the European WFD, MFD, and baths directive as regulated by the French Republic.
- Analysis of algal blooms and levels of fecal bacteria in drinking waters, and aquaculture areas according to national legislation following regionally approved protocols.
- Analysis of diseases in and around aquaculture facilities.
- Monitoring of invasive species according to the European regulation n° 1143/2014 of the Parliament and the Council.

IE- Northern & Western

- Chemical and biological analyses of water bodies according to the European WFD, MFD, and baths directive as regulated by the Government of the Republic of Ireland.
- Analysis of algal blooms and levels of fecal bacteria in drinking waters, and aquaculture areas according to national legislation following regionally approved protocols.
- Analysis of diseases in and around aquaculture facilities.
- Monitoring of invasive species according to the European regulation n° 1143/2014 of the Parliament and the Council.

PT-Norte

- Chemical and biological analyses of water bodies according to the European WFD, MFD, and baths directive as regulated by the Government of the Republic of Portugal.
- Analysis of algal blooms and levels of fecal bacteria in drinking waters, and aquaculture areas according to national legislation following regionally approved protocols.
- Analysis of diseases in and around aquaculture facilities.
- Monitoring of invasive species according to the European regulation n° 1143/2014 of the Parliament and the Council.

2.3. Knowledge and experience of the project partners in the Marine Biotechnology R&D&I field

This section highlights the extensive expertise of the project partners in the Blue Biotechnology R&D&I. It summarizes their diverse backgrounds and contributions, demonstrating their ability to drive advancements and achieve the project's goals.

UVIGO (ES-Galicia)

- Biotoxins in bivalves
- Toxic algal blooms
- Diseases in aquatic organisms
- Ecotoxicology bioassays: microalgae growth, sea-urchin or bivalve embryo development tests, survival bioassays with copepods or amphipods, Microtox.
- Biodiversity surveys (phytoplankton, pelagic copepods, benthos, macroalgae, EMO-BON, ARMS-MBON)
- Biological oxygen demand in water, samples, total organic carbon, organic matter, PAHs in sediment. Presence of E. coli and/or other coliforms. Analysis of PAHs and other compounds in marine organisms

IEO-Vigo (ES-Galicia)

- Phytoplankton photobiology, chemistry of natural products (biotoxins), taxonomy and chemotaxonomy, life cycles. Contribution to the global databases of harmful algae such as HAEDAT or the IOC-UNESCO Taxonomic Reference List of Harmful Micro Algae.
- Pigments as biomarkers in the study of populations of planktonic organisms.
- Ecophysiology of bivalves to determine the impact of global change or other threats on exploited bivalve species and generate new aquaculture management tools with an ecosystem perspective

UPV/EHU (ES-Basque country)

- Cell and molecular biomarkers of stress

- Ecotoxicology bioassays: toxicity tests, growth, and developmental tests with different marine phyla, Microtox.
- Analytical chemistry of (priority substances and emerging compounds in biota, water, and sediments)
- One-Health marine observatory
- Biobanking (Biscay Bay Environmental Biospecimen Banking- https://www.ehu.eus/PIE/services-and-facilities/bbebb/)
- Basque Microalgae Culture Collection (https://www.ehu.eus/es/web/bmcc), isolation, identification, characterization, and culture
- Biodiversity surveys (phytoplankton, cyanobacteria, pelagic copepods, benthos, macroalgae, EMO-BON, ARMS-MBON)-
- High-resolution numerical models and statistical downscaling of satellite environmental data.

ULPGC (ES-Canary Islands)

- Spanish Bank of Algae, member of the European Culture Collections' Organisation (ECCO), of the WFCC and is included in the World Data Centre for Microorganisms (WFCC-MIRCEN). Accredited before the Government of Spain as the international authority for the deposit of microorganisms (Budapest Treaty).
- Maintenance of Biodiversity of microalgae and cyanobacteria.
- Polyphasic identification of isolated strains.
- Bioprospecting

SU-SBR (FR-Bretagne)

- Roscoff Culture Collection (https://roscoff-culture-collection.org/)
- Plankton diversity, description of new lineages, molecular studies uncovering cryptic species. Analysis of Interactions (symbioses…), the food chain in the kelp forest, the introduction of exotic species, and adaptation to extreme environments.
- Response to Change: physiological response of photosynthetic bacteria, calcification of organisms in response to global change.
- Modelling of larval dispersal and the permeability of genomes for gene flow.

NUIG (IE- Northern & Western)

- Chemical Monitoring (marine sediments, rocks, waters, and biological tissue) to determine elemental abundances (including rare earth elements), elemental speciation, organic compounds, and isotopic compositions

2.4. Enriching the BP Programs: Aligning with Blue Biotech Challenges and Opportunities identified in the participative actions

This section outlines the approach of continuously reviewing and updating the BP programs to ensure they align with the latest insights from participative workshops and market-driven R&D&i activities, as conducted in our project. The co-creation workshop activities, namely the Blue Biotech Innovation workshops, were aimed to include different actors and members from the quadruple helix. By incorporating these findings, these BP programs will be adapted to effectively address the emerging needs, challenges, and opportunities within the Blue Biotech ecosystem. This dynamic framework aims to foster an environment of innovation, ensuring that the sector can rapidly respond to new developments and maintain a competitive edge.

Six different workshops where hosted the first year: ES-Galicia, ES-Basque Country, ES-Canary Islands, PT-Portugal, FR-France and IE-Ireland. The challenges and opportunities identified in the sessions will be linked if possible. The findings will be discussed by regions in each thematic priority and later discussed in a more general level.

Findings of the first set of Blue Biotech Innovation Workshops (2024)

ES-Galicia

Challenges	Linked Opportunities
Characterization of port areas	Characterization of port waters and biodiversity.
Impact of port activities on marine biodiversity	Monitoring, regeneration, and restoration of port areas.
Challenges with invasive species	Monitoring of invasive species and development and standardization of related protocols.
Need for stable funding for biodiversity monitoring	Utilization of existing data and platforms for long-term environmental impact observation.
Low technological development for the revaluation of products	Revaluation of invasive species and involvement of fishermen as first line observers.
Insufficient knowledge of species omics	Enhancement of species omics knowledge to associate gene pools with the appropriate species.
Limited understanding and monitoring of marine environments	Offshore observation to explore new areas and create knowledge.
Lack of transparency and knowledge transfer	Creation of synergies among different stakeholders and groups to advance technology.
Ethical considerations related to invasive species management.	
	Inclusion of public institutions and organizations, such as port authorities, in biomonitoring efforts.

ES-Basque Country

Challenges	Linked Opportunities
Information and data flow across the sector and its stakeholders	Training oportunities and adhesion to the open science initiative
Nagoya protocol and ABS regulations in Spain	Best practice guidelines and accss to biodiversity/bioresources through ceryfied collections and biobanks
Marine biodiversity assessment is not strategic and is dependant on grant money	Make marine observation equivalent to metereology: science at the service of society. Involve all concerbed stakeholders
Biodiversity (plus associated metadata) data FAIRness	European strategy of FAIRification
Impact of climate change on coastal, estuarine and humans populations	Observation based on scientific multidisciplinar ecosystem monitoring (holistic view): One-Health approach
Impact of human activities on estuaries and harbour areas and offshore renewable energy instalations	Observation and Risk assessment based on scientific multidisciplinar (biomarkers, analytical chemistry, biodiversity, metagenomics, eDNA) ecosystem monitoring (holistic view): One-Health approach
When bioiversity is a problem for my marine device: fouling	Identification of bioresources (macroalgae, molluscs…) that fight naturally against fouling.
Monitoring and management of invasive species	Observation based on scientific multidisciplinar ecosystem monitoring (holistic view): One-Health approach
Monitoring of traits of interest in natural stocks of socioeconomically relevant bioresesources (fish stocks…) for a better management	Microscopic, cellular and molecular tools to the analysis of health status, reproductive capacity, population resilience, food webs
Detection of the presence of pathogens introduced by alocton species or aquaculture practices in the nevironment	Metabarcoding and barcoding coupled to microscopy
Presence and origin of pathogens in and around aquaculture facilities	Metabarcoding and barcoding coupled to microscopy
Exotic species, invasive species, toxic algal blooms, dangerous jellyfishes,...	Development of early warning systems
Ecosystem resources	Metagenomics coupled to functional annotation
Marine microbial diversity	Metagenomics coupled to functional annotation
Antibiotic resistance in the land sea interface	Analysis of horizontal gene transfer between antibitoci resistant bacteria associated to waste water treatment and marine microbia

ES-Canary Islands

Challenges	Linked Opportunities
Regulatory and administrative issues	Education and communication actions/links between stakeholders and administration units
Global Change	Mitigation actions
Aquaculture development	New species and procedures
The role of waste and by-products	Biorefinery / Circular Economy / Valorization
Marine biotech value chains	Identification

New products development	Industrial opportunities
Enterpreneur possibilities	Collaborative actions

PT-Portugal

Challenges	Linked Opportunities
Control and prevent of bacteria in fish (eg. *Vibrio*)	Aquaculture sustainable and safety production, conservation and environmental protection
Production of halophytes: Reduce costs in drying, methos to increase shelf lifetime, reduce cost in production fostering a fhair competition in the market New systems of infrastructures to support sultivation in saltmarshes (Portugal) Carbon capture market	Novel ingredients, market needs, novel valu chains
Machine learning to design processes for data colection and monitorization in halophyte production	Digitalization of aquaculture and monitoring systems; New functional ingredients for aquaculture
Preventive systems on the control of invasive species with ballast waters	Maritime transport, coastal environment, tourism, invasive species control
Methods to cultivate microalgae off shore	Implementing **optical system** and promotinc carbon capture
Environmental Stress Monitoring and Market Expansion	Precision Aquaculture/ Agriculture and Supply Chain Transparency
Research on diatoms: Develop reliable monitoring protocols to track the microcapsules in the aquaculture system (for example, by marking the capsules with an organic fluorescent dye). Ensure compliance with environmental regulations (both the microcapsule/drug carrier and the fluorescent marker).	Monitoring the environmental impact of large-scale diatom cultivation. Assessing the ecological benefits of reducing chemical use in shrimp aquaculture.
Access to biomass for research and proof of concept to industry, constraints on availability, season dependence, biochemical composition, regulation applied to bioresources for science and for commercial purposes	Digital platforms, uniformization on regulations and availability of information in one single point, Blue Demo Network, proof of concept programmes

FR-France

Challenges	Linked Opportunities
Restoring declining populations	Construction of reference databases for environmental DNA (e.g. non-native species, indicator species)
Commercial acceleration, access to wild bioresources to improve them	
Bioproduction of active ingredients and mechanism of action	High levels of unexplored biodiversity, strong potential for bioactive products
Analysis of plant biomass	

Impact of climate change on coastal and estuarine populations	
Identify players in the biomass value chain	need for secure macro-algae supplies and guaranteed traceability
Enhancing the value of little-described organisms and achieving large-scale cultivation at low carbon and economic cost	
Preservation and restoration of natural resources	
Taking sustainable development into account in the development of marine bioresources, marine biomimicry	

IE-Ireland

Challenges	Linked Opportunities
Biodiversity inventories. Poor baselines. Lack of information about ecosystem function. Data inconsistencies and many qualitative assumptions in relation to nature conservation impacts. Regulatory challenges.	Opportunities for real time monitoring of biodiversity in and adjacent to aquaculture facilities. Examination of ecosystem function and as well composition. This extends to alien species.
Cost -AI image processing for habitat mapping / species identification (invasive and endangered)	-Development and integration of new sensors to address particular scientific problems.

Conclusions

Analyzing the challenges and opportunities for marine biodiversity observation in the workshops carried out in the 6 focused Atlantic regions a marked transversality becomes apparent, touching aspects of the other two BPs in Marinnonet (aquaculture and marine bioproducts) but also many others relevant for the maritime sector such as fisheries, maritime transport, digitalization etc…

In general, challenges in BP2 can be grouped along three major lines:

- Administration and funding issues.

- Global challenges associated to climate change, need for safe bioresources, pollution, anthropization and new uses of the maritime space

- Technical limitations and state of the art together with constrains imposed by a research culture of data handling.

Funding challenges are mentioned in the 3 Spanish regions linked to the lack of stable and strategic funding for monitoring programs and the opportunities lie in sharing existing

information under the open science and FAIR data rules. Administration challenges relay in the flow of information between effective observation and management (restoration, invasive species, endangered species, pollution, new uses of the maritime space) and sustainable utilization regulations (Nagoya protocol and others). Opportunities lies in education, outreach, multidisciplinary, synergies between stakeholders, transregional collaboration, utilization of existing data.

Global challenges impact all regions and are common to all, although they may be seen from a regional perspective. In this respect, toxic algal blooms are important in Galicia because of the intensive mollusk aquaculture, in the Canary Islands and Basque Country because of tourism. Opportunities come from the intrinsic need for biodiversity monitoring that ask for common/validated observation protocols (new omic techniques coupled to analytical chemistry and biomarkers analysis, early warning tools, new sensors) and restoration measures (mitigation actions, blue carbon, bioremediation, regeneration, one-health approach). There is a common need also to find new bioresources providing food and biomaterial sources, maintaining the quality of the stocks already (over)exploited.

Among the technical limitations the common understanding is that there is insufficient milking of the information obtained from traditional and modern biodiversity biomonitoring programs. On the one hand, there is a lack of sharing of information, with the opportunity arising from the current wave in favor of data FAIRification. There is also a lack of functional information associated to species inventories that could be linked to sustainable bioresource utilization activities downstream. The opportunity lies in the increasing incorporation of marine research stakeholders into the mainstream of omic research.

3. **Joint R&D&I Program**: Marine-derived products for industrial applications

3.1. State-of-the-art BP3 and alignment with the European and international current policies in the Marine Biotechnology area

The marine environment is characterized by vast biodiversity, still largely unknown, with representatives from all the kingdoms, going from the small unicellular organisms such as bacteria, to the largest animals as whales. Since ancient times mankind has been looking to these marine organisms as biological resources, firstly of food, but also of a variety of compounds and materials. Indeed, the biosynthetic capabilities of Nature, including those of marine organisms, go way beyond the imagination – not to mention the technical limits – of scientists and engineers regarding chemistry and biological activities and functions. In this regard, different biopolymers have been produced, such as polysaccharides like agar, alginate, or chitosan, or proteins like collagens or enzymes, using seaweeds, crustaceans, fish, or jellyfish as raw materials. Besides, calcium carbonates and biosilicas are also identified in crustaceans, corals, sponges, and diatoms, among others. Bioactive compounds, particularly small metabolites with a myriad of biological activities, have been prospected in marine plankton and invertebrates, as they are commonly the result of specific synthetic pathways used to produce chemical weapons against predators or needed tools to withstand harsh conditions found in the Ocean. Considering the countries enrolled in the Atlantic Area Program, besides the intense R&D efforts developed by universities, institutes, and research centers of that area, several companies are exploring products based on marine origin compounds and materials, with important examples being PharmaMar (in Spain, but outside the Atlantic Area regions) that explores antitumor drugs inspired in a compound from a tunicate, namely Yondelis® (one of the first marine origin drugs in the market), and CEAMSA (in Galicia) that explores natural ingredients from seaweeds, among others. Nevertheless, the capitalization of the biotechnological potential of marine natural resources is still in its infancy, with several challenges appearing on the horizon, regarding technological, economic, and environmental perspectives, as follows:

- the establishment of effective extraction methodologies for a competent production of many identified but not yet explored molecules.
- the development of greener approaches for the extraction of marine natural products, using green solvents, reduced consumption of energy and chemicals, or generating fewer (quantities of) residues and effluents.
- the design of sustainable production methodologies, avoiding the harvest of large quantities of biomass affecting the populations and the equilibrium in the ecosystems.
- the implementation of fair access and benefits-sharing procedures.
- the creation of safe and sustainable by design (SSbD) strategies enabling the continuation of bioprospecting initiatives, under a framework of protection of marine life, in agreement with EU guidelines and the Sustainable Development Goal 14.

- the use of isolated materials or bioactive extracts in applications for different industrial areas, from proof-of-concept to prototypes, clarifying the full value chains.
- the rise of private investment to explore further successful pilots, towards new market products, processes, and services.

This Platform is aligned with the European current policies that are placing Marine Biotechnology and the use of its tools for the establishment of sustainable blue products at the forefront of investment priorities. This can be seen within Horizon Europe, namely in:

1) the Pillar II “Global Challenges and European Industrial Competitiveness", particularly in cluster 6 “Food, bioeconomy, natural resources, agriculture, and environment”, with topics on the use of marine resources for the production of valuable compounds and products, bio-based innovation supported in these resources and circular economy as a new paradigm in the horizon of new processes.
2) The mission “Healthy oceans, seas, and inland waters”, where the organization of the activities as lighthouses focused on particular water basins underlines the relevance of sustainability in the exploration of marine (biological) resources, with a clear intersection between the health of the Ocean ecosystems and the Human Health (towards the new concept of One Health being developed).

Other European initiatives should be also highlighted, namely the Sustainable Blue Economy Partnership, a joint effort of different funding organizations to push forward economic growth in and with the Ocean, under strict principles of sustainability and circularity.

At the international level, it should be underpinned by the alignment of this Platform with the Sustainable Development Goal 14 of the United Nations 2030 Agenda, aiming to “Conserve and sustainably use the oceans, seas and marine resources”.

3.2. Situation of BP3 in regions of the Atlantic area involved in the proposal: main topics undertaken

This section provides an overview of the current state of BP3 across various regions within the Atlantic area that are part of the project. It highlights the key themes and initiatives being pursued in these regions, underscoring their strategic importance and the collaborative efforts aimed at harnessing BP3's potential for economic and environmental benefits.

ES-Galicia

- One of the world's largest fishing ports (Vigo) and the location of many big fishing industries; one can foresee the generation of huge amounts of fish by-products, thus offering opportunities for biotechnological valorization through isolation of compounds and further application.
- research on the isolation of marine compounds and materials from fish waste, by-products, by-catches, and discards.

- research on the characterization of fish ceramics and application in different industrial sectors, including biomedicine.
- research on the production of extracts from different marine organisms and evaluation of biological activities as antioxidant, anti-bacterial, anti-fungal, anti-fouling, anti-viral, anti-inflammatory, anti-tumoral, etc.
- research on the development of devices and applications for human health and well-being
- spin-off companies of seaweed extracts

ES-Basque Country

- The Smart Specialization Strategy (S3) of the Basque Country recognizes the health sector as one of the 3 pillars of the local economy and identifies a niche of opportunity in territory and environment
- The S3 of the Euro-region New Aquitaine / Euskadi / Navarre specifically mentions Blue Biotechnology as one of its main pillars
- This BP presents a good opportunity to lay bridges between the local bioindustry and clinical medicine in the Basque Country, to explore possibilities to develop green processes for identifying biomolecules for industrial applications

ES-Canary Islands

- Research on the production of extracts from different microalgae and seaweeds and evaluation of biological activities as antioxidant, anti-bacterial, anti-fungal, anti-fouling, anti-viral, anti-inflammatory, anti-tumoral, etc.;

FR-Bretagne

- Research on the production of extracts from different marine organisms and evaluation of biological activities as antioxidant, anti-bacterial, anti-fungal, anti-fouling, anti-viral, anti-inflammatory, anti-tumoral, etc.
- Active entrepreneurial ecosystem on biotechnology, including marine resources.
- Cosmetic companies using seaweed extracts as ingredients

IE- Northern & Western

- research on the production of extracts from different marine organisms and evaluation of biological activities as antioxidant, anti-bacterial, anti-fungal, anti-fouling, anti-viral, anti-inflammatory, anti-tumoral, etc.
- research on marine ceramics; and mineralization mechanisms.
- active entrepreneurial ecosystem on biotechnology.
- biomedical companies, namely associated with USA large enterprises

PT-Norte

- Research on the production of extracts from different marine organisms and evaluation of biological activities as antioxidant, anti-bacterial, anti-fungal, anti-fouling, anti-viral, anti-inflammatory, anti-tumoral, etc.
- Research on the isolation of marine biopolymers, including under the concept of biorefinery.
- Processing of marine origin materials for the development of biomedical applications.

3.3. Knowledge and experience of the project partners in the Marine Biotechnology R&D&I field

This section highlights the extensive expertise of the project partners in the Blue Biotechnology R&D&I. It summarizes their diverse backgrounds and contributions, demonstrating their ability to drive advancements and achieve the project's goals.

UVIGO (ES-Galicia)

- Research on extracts and compounds from marine biological resources and assessment of several biological activities.
- Research on marine origin ceramics from fish, from isolation to processing for industrial application

IEO-Vigo (ES-Galicia)

- Research on the production of extracts from microalgae with potential biotechnological application, making use of the CCVIEO culture collection.

UPV/EHU (ES-Basque country)

- Characterization of local marine biodiversity and identification of target resources/species with higher potential for biotechnological exploitation.

ULPGC (ES-Canary Islands)

- Research on the production of microalgae and cyanobacteria known as sources of biologically active extracts and compounds.
- Research on the production of extracts and purification of compounds from micro- and macroalgae and assessment of several biological activities.

SU-SBR (FR-Bretagne)

- Characterization of local marine biodiversity and identification of target resources/species with higher potential for biotechnological exploitation.

- Maintenance of a very large marine microorganism culture collection with the potential for biotechnological exploitation as a source of bioactive extracts and compounds

NUIG (IE- Northern & Western)

- Research on the production of extracts from different marine organisms, namely using green methodologies and evaluation of different biological activities.
- Exploitation of bioactive extracts and compounds in cooperation with industrial players.

UMinho (PT-Norte)

- Research on the isolation and characterization of biopolymers from seaweeds, namely sulfated polysaccharides, and evaluation of their biological activities with interest for human health.
- Research on the isolation of collagen and calcium phosphates from fish by-products.
- Processing of marine origin materials as biomedical applications, namely as bio-based materials for tissue engineering and other advanced therapies

3.4. Enriching the BP Programs: Aligning with Blue Biotech Challenges and Opportunities identified in the participative actions

This section outlines the approach of continuously reviewing and updating the BP programs to ensure they align with the latest insights from participative workshops and market-driven R&D&i activities, as conducted in our project. In the co-creation workshop activities, namely the Blue Biotech Innovation workshops, were aimed to include different actors and members from the quadruple helix. By incorporating these findings, these BP programs will be adapted to effectively address the emerging needs, challenges, and opportunities within the Blue Biotech ecosystem. This dynamic framework aims to foster an environment of innovation, ensuring that the sector can rapidly respond to new developments and maintain a competitive edge.

Six different workshops where hosted the first year: ES-Galicia, ES-Basque Country, ES-Canary Islands, PT-Portugal, FR-France and IE-Ireland. The challenges and opportunities identified in the sessions will be linked if possible. The findings will be discussed by regions in each thematic priority and later discussed in a more general level.

Findings of the first set of Blue Biotech Innovation Workshops (2024)

ES-Galicia

Challenges	Linked Opportunities
Standardization and characterization of by-products	Cataloging of marine resources and potential by-products. For example, production of

	agricultural supplements from mussel shells and maybe their use in other sectors, such as construction.
Poor consumer perception of by-products revalorised	Increasing dissemination efforts to improve consumer perception.
Insufficient utilization of data from studies and experiments	Creation of databases to enhance knowledge transfer between industry and academia.
Low standardization and categorization of data	Integration of DNA techniques and classical taxonomy for comprehensive monitoring.
Limited industry involvement at larger scales to prove viability in pilot projects	Leveraging R&D funding programs requiring public-private collaboration for biotech products.
Low standardization in the use of new technologies	Utilizing new technologies, including artificial intelligence, for revaluation.
Poor knowledge transfer between industry/business and academia	Creation of databases to enhance knowledge transfer between industry and academia.
Lack of regulation of by-product use	Development of new policies and regulations to support the use and revalorization of by-products.
Bureaucratic hurdles affecting the implementation of innovative processes.	

ES-Basque Country

Challenges	Linked Opportunities
Obtention of macromolecules for the feed industry	New marine bioresources as sources of proteins, lipids, carbohidrates, omega-3
Obtention of macromolecules for the feed and other industries	Chemical synthesis
Byproducts of fisheries industry	Ontention of macromoelcules and new biomaterials/composites
Low eficiency in the extraction of valuable composites from marine biota	Improve eficiency in the extraction of valuable composites from macroalgae and microalgae
Identification of biomaterials of interest for the market and data mining of the marine biodiversity databases for best marine opportunities to cover those needs	Functional analyses of marine metagenomes. Translate biodiversity monitoring data into information of prospective bioresources
Discovery of new biobased products	Bioprospection: culture collections, biobanks
Antifouling	New materials
New pharmaceuticals and bioactive compounds	Different functional tests for bioprospecting and screening (cell growth, cell death, anioxidant capacity, UV light isolation, moisturising capacity…)

ES-Canary Islands

Challenges	Linked Opportunities
Regulatory and administrative issues	Education and communication actions/links between stakeholders and administration units
Global Change	Mitigation actions
The role of waste and by-products	Biorefinery / Circular Economy / Valorization
Marine biotech value chains	Identification
New products development	Industrial opportunities
Enterpreneur possibilities	Collaborative actions

PT-Portugal

Challenges	Linked Opportunities
Make available the huge amount of data monitoring ocean, fish auction, fish nets	Public funding, digital opportunities Creation of databases to enhance knowledge transfer between industry and academia.
Recycle or upcycle polystyrene and other polymers coming from fish activities	Pact for plastics and marine litter, circular economy
Add value to halophytes fostering entrance in others markets rather than food; difficulty in discovering novel products and bioactives	Explore biorefinery concept and new formulations, guaranteeing competitive processes
Add value to side streams from canning industry Create new value chains	Startups with solutions for collagen production and circular economy in Europe
Difficult in access Efficient Extraction and Processing of Bioactive Compounds and Product Development	Development of Bio-based Products and pharmaceutical applications, Blue Demo Networks platform
Identification of natural sources of the bioactive compounds to be encapsulated and adapt them to different industrial applications. Overcoming technical barriers to large-scale production and commercialization of marine-derived products.	Creating high-value, more sustainable aquaculture medicines. Exploring additional industrial applications of purified diatom frustules (microcapsules) beyond aquaculture (e.g., biomedical applications).
Creation of digital platform adding value to marine based by products (FISH MATTER)	Cataloging of marine resources and potential by-products Add value to cut offs coming from fisheries, fish processing and canning industry
Identify sources of side streams, stock and preservation, establishing collaboration between industry and academia	Leveraging R&D funding programs requiring public-private collaboration for biotech products.
Scale up tech in the extraction of resources to pilot and industrial scales	Development of new policies and regulations to support new value chains Blue Demo Network platform
Connect design and marketing to the blue for consumer acceptance	Increasing dissemination efforts to improve consumer perception. Promote cooperation
Bio based materials production using microalgae, understand regulation, value of residues, how to scale from lab to market in algae to wellbeing and welfare	Development of new policies and regulations to support new value chains

FR-France

Challenges	Linked Opportunities
Observation of natural/cultivated resources according to variations in environmental conditions on a large spatial scale	

IE-Ireland

Challenges	Linked Opportunities
Transition to bio-based materials or recycled materials for vessel construction. Issues of materials selection, availability, knowledge of reproducibility, structural properties.	-Local in-house recycling of material cutoff/chips to usable material or welding filament. Local, energy efficient recycling of collected beach plastic

Value added ingredients for fisheries processors	Fisheries Processors are looking for opportunities in value-add ingredients, however are hesitant to examine processes that have high cap ex., a market that is unproven in Ireland thus far.
Processors are hesitant to deviate from existing processes and markets due to inexperience and overly complex processing methodologies.	Simplified methodologies for processing
Lack of commerciality from some projects, indicating a missing link in the supply chain.	Processors would be somewhat willing to minimally process their raw material to sell to an intermediary that further processes, which would give them a better margin on their side streams.
Unaware of the compounds or bioactive properties of raw materials, that are applicable to nutraceutical sector.	Identify additional compounds of interest in the studied biomass
Biobased materials in relation to marine have been focused on algae,	is there any prospects for other raw material sources? invertebrates
Lack of public awareness in opportunitiesw from marine bioresources	A generalized, easy to understand roadmap of biomass opportunities and case studies or examples of such to garner commercial and public awareness
Large development of seaweed farming, licensing process requires total overhaul, need for blue biorefinery	Enhance the extraction, research opportunites and new product development micoralgae for high value products
-Transition to bio-based materials or recycled materials for vessel construction. Issues of materials selection, availability, knowledge of reproducibility, structural properties.	-Local in-house recycling of material cutoff/chips to usable material or welding filament. Local, energy efficient recycling of collected beach plastic

Conclusions

In the first set of B2I workshops held across the 4 AA countries involving stakeholders of the quadruple helix, various **challenges** were identified, some of which are common to multiple regions and can be grouped within four main stages of the value chain:

- Efficiency in Extraction Processes;
- Scalability and Commercial Viability;
- Reproducibility, Standardization and Bureaucratic Constrains;
- Consumer Perception and Market Acceptance.

At the initial phase of the value chain, a main challenge is associated with limited extraction yields and high costs, as the methodologies are normally focused on the purity of compounds and not of maximization of extraction, thus resulting inefficient from that point of view. When considering the translation to industry, inefficiency means an undesired cost that needs to be tackled. In the same rational, these extraction and production methodologies, sometimes with significant complexity, are not easy to scale-up. Moreover, the limited industry involvement in this scale-up procedure, particularly at the pilot stage, adds uncertainty to the industrial feasibility of technologies, mandatory for its commercial exploitation.

When dealing with natural origin materials and compounds, batch-to-batch variability is an intrinsic characteristic that needs to be accounted. Besides, the regulations for using marine biomass, including by-products, for innovative biotechnological processes, are also unclear, adding another level of variability to the processes. This regulatory burden is not only felt upstream but also downstream, with complex bureaucratic processes affecting the development of novel marine products and their commercialization.
Finally, even after overcoming the several challenges on access to marine origin materials, the industrial production of derived applications and placing new products in the market, there is still a lack of awareness of potential customers about the potential of marine-derived by-products and some reluctance to new products, even if characterized as nature-derived, due to absence of well-established examples.

Nevertheless, in the innovation arena, challenges are not regarded as dead-ends, but as gaps that can be bridged. Indeed, the discussions held during the regional B2I workshops disclosed various **opportunities** for boosting research and innovation within the Blue Biotechnology sector, paving the way to address some of the identified challenges effectively. These co-creation workshops highlighted potential strategies and collaborative approaches that could be leveraged to overcome important challenges, including:

- **Biodiscovery from Marine Resources:**
  - Exploration of untapped marine resources can yield novel bioactive compounds and materials with diverse industrial applications.
  - Biobanks as platforms for identifying, characterizing, and preserving unique marine organisms for future research and development.
- **Development of Bio-Based Materials:**
  - Transitioning to bio-based or recycled materials, namely marine-derived biopolymers and composites, in different industries, addressing environmental concerns.
  - Implementing biorefineries toward full use of biomass, promoting circularity and zero-waste concept.
- **Collaboration for Industry Readiness:**
  - Enhancing academia/industry collaboration to a more efficient scaling up.
  - Developing market-driven products using safe and sustainable by design (SSbD) principles.
  - Data sharing to establish standardized methods aiming to improve product quality and reproducibility.
- **Commercial Acceleration and Market Integration:**
  - Clearer regulations and quality assurance processes can facilitate market entry and acceptance.

Demonstrating the feasibility and profitability of marine innovations through pilot projects can attract industry investment and speed up commercialization. There is a strong believe that successful marine-based products will trigger many more to arise.