Brussels, 12 May 2023

COST 070/23

DECISION

Subject: Memorandum of Understanding for the implementation of the COST Action “Enhancing knowledge of BIOmolecular solutions for the well-being of European AQUAculture sector” (BIOAQUA) CA22160

The COST Member Countries will find attached the Memorandum of Understanding for the COST Action Enhancing knowledge of BIOmolecular solutions for the well-being of European AQUAculture sector approved by the Committee of Senior Officials through written procedure on 12 May 2023.

MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA22160
ENHANCING KNOWLEDGE OF BIOMOLECULAR SOLUTIONS FOR THE WELL-BEING OF EUROPEAN AQUACULTURE SECTOR (BIOAQUA)

The COST Members through the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action, referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any document amending or replacing them.

The main aim and objective of the Action is to drive a paradigm shift in disease management to incorporate environmentally-friendly protocols into fish farms. The objective is that research provides pioneering technology to target an integral approach to biosecurity towards better health management, animal welfare, precise pathogen removal, and less environmental impact. This will be achieved through the specific objectives detailed in the Technical Annex.

The present MoU enters into force on the date of the approval of the COST Action by the CSO.

OVERVIEW

Summary
A growing interest in the development of new technologies to foster the sustainability of aquaculture sector has arisen over the past decade, seeking alternative scientific and technical tools for fish-farm production. In order to assess the current status, our action aims at exploring the potential of biomolecular solutions for the well-being of European aquaculture sector, proposing an innovative conceptual pathway for veterinary applications, tracking systems, diagnosis or biosafety. For that purpose, the Action proposes to establish an innovative and dynamic European network connecting scientists, aquaculture industry and stakeholders to optimize information exchange, develop a joint research agenda, explore new advance research lines and enhance the co-production among researchers and other industry and societal actors. Among the different activities and outcomes, the action will promote the visit to different aquaculture facilities and the development of an interactive website for knowledge exchange. Overall, the action will contribute to improve fish welfare and reduce costs related to critical circumstances (blooms, diseases, overuse of antimicrobials...).

Areas of Expertise Relevant for the Action	**Keywords**
● Industrial biotechnology: Sustainability ● Agriculture, Forestry, and Fisheries: Aquaculture, fisheries ● Economics and business: Management of Technology and Innovation	● biomolecular solutions ● sustainable aquaculture ● high-performance experimental workshops and training schools ● community building in a new R&I area

Specific Objectives
To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

Research Coordination
● Coordination of information seeking, identification, collection and/or data curation. BIOAQUA aims to generate a Data Lake around biomolecular solutions for the wellbeing of European aquaculture sector. Annual reports will be generated to supervise the data generated in the surveys, workshops, and research-enabling experiments.
● Coordination of experimentation & testing. BIOAQUA will conduct a series of activities which include High-Performance Workshops, tests, webinars, surveys. At least 2 workshops will be carried out on an annual basis. Coordination activities will support experimentation & testing activities during the entire action, with annual and mid-term milestones.
● Development of knowledge in relation to disruptive/implementable paradigms for fish health management and fish welfare. BIOAQUA will develop and support a series of scientific papers and research agendas. At least 5 papers will be developed jointly.
● Accelerating R&D and the conversion of technology into solutions. BIOAQUA will support at least 3 patent families. Expected outputs will be delivered by the end of the Action.
● Disseminating results to stakeholders in actionable ways. BIOAQUA will support training activities aimed at fish farmers, policymakers, and tech providers (start-ups): 40 webinars, 1 podcast channel, 1 videogame and 15 masterclasses are foreseen during the entire action.

Capacity Building

● Foster knowledge exchange and develop a Joint Research Agenda around the topic of biomolecular solutions for the well-being of European aquaculture sector. The result will be documented in the planned BIOAQUA book, cowritten and edited by the Action Members based on the “High-Performance Workshops” carried out during the Action.
● Efficient bridging of separate fields of science and other value-chain stakeholders. BIOAQUA will implement an innovation-driven perspective to achieve breakthroughs that require an interdisciplinary approach. Policymakers and industrial engagement will be supported. “High Performance Workshops” and other activities will be carried out during the Action.
● Acting as stakeholder platform. BIOAQUA aims to generate a trans-national practice community in sustainable biomolecular solutions for fish disease treatment. Engagement and collaboration with stakeholders will be sustained during the entire duration of the Action.
● Leverage learning. Effective pedagogic techniques will be implemented towards the generation of further knowledge and the market uptake of results: 40 webinars, 1 podcast channel, 1 videogame and 15 masterclasses are foreseen during the entire action.

TECHNICAL ANNEX

1. S&T EXCELLENCE

1.1. SOUNDNESS OF THE CHALLENGE

1.1.1. DESCRIPTION OF THE STATE OF THE ART

Aquaculture is called to play a major role to ensure future food and nutrition security for a growing global population.[1] It is the fastest growing food production system in the world and is expected to continue to be so in the coming decade.[2] In 2030, aquaculture is expected to account for over 70% of the fish humans consume, and will represent 30% of total protein income (from current 16%).[3] This is especially relevant in developing countries, where fish is the main source of proteins.[4]Furthermore, aquaculture has the potential to become one cornerstone for the preservation of oceanic biodiversity, with 2/3 of world's water ecosystems already overexploited.[5]

To meet these challenges, global large-scale farming is needed. However, intensive farming models and climate change are driving to an **increase in disease outbreaks**, impacting fish health, production, the environment, and the economy of the industry. In 2019, the FAO estimated 40% of global capacity –64 million tonnes– was lost due to emerging diseases, already causing direct annual losses >€5.5 billion, and considered a primary constraint to the growth of many aquaculture species, severely impeding socio-economic development in many countries.[6] Despite this**, the number of tools available for disease control in aquaculture is still limited**.

Furthermore, badly managed intensive aquaculture can create local unemployment, negatively affect habitats, and raises concerns around food safety either related to pollution or due to current abuse in the use of antibiotics.[7] Within this context, competition, regulation and demands from society are increasing, and it has become mandatory to ensure food and nutrition security.

Finally, the contamination of water for human consumption in inland fish farms, the organic enrichment of water column (mainly produced by feed surpluses, decomposition of dead fish or over fertilization) or the introduction of exotic species are also main risks the sector needs to face, since all of them could lead to fish farmers' bankruptcy.[8] **However, the lack of preventive tools is still a major issue**.

How are fish diseases treated today?

Several strategies are used for prevention and control of fish diseases. Even though last-stage disease control is mainly achieved using antibiotics, these methods present drawbacks.[9] Firstly, few are licensed in Europe for use in food fish and generally only as an oral administration formulation. Furthermore, antibiotics are expensive, and their efficacy is decreasing due to appearance of antimicrobial resistance. For this reason, disease prevention needs a more sustainable approach.[10] Within this context, biosecurity programs include all kind of measures needed to exclude pathogens from facilities and to

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[1] Food and Agriculture Organization of the United Nations (FAO) and the International Food Policy Research Institute.
[2] *Fish to 2030: Prospects for Fisheries and Aquaculture*, Agriculture and Environemntal Services Discussion Paper, No.3, World Bank Report Number, 83177-GLB, 2013.
[3] "Fish to 2030: The Role and Opportunity for Aquaculture," Mimako Kobayashi et al., *Aquaculture Economics & Management,* 19:3, 2015. 282-300. DOI: 10.1080/13657305.2015.994240
[4] "Improving Productivity and Environmental Performance of Aquaculture", Waite, R. et al., Working Paper, *Creating a Sustainable Food Future,* Washington, DC: World Resources Institute, 2014.
[5] *Blue Frontiers: Managing the Environmental Costs of Aquaculture.* Hall, S.J., A. Delaporte, M. J. Phillips, M. Beveridge and M. O'Keefe. The World Fish Center, 2011.
[6] "The Sunken Billions: The Economic Justification for Fisheries Reform", Arnason, R., K. Kelleher, and R. Willmann, Washington, DC: World Bank, 2009.
[7] "Food safety impacts of antimicrobial use and their residues in aquaculture", Public Health Reviews, 2018.
[8] *Fish to 2030: Prospects for Fisheries and Aquaculture*, Agriculture and Environemntal Services Discussion Paper, No.3, World Bank Report Number, 83177-GLB, 2013.
[9] "Aspects of excessive antibiotic consumption and environmental influences correlated with the occurrence of resistance to antimicrobial agents," Simona Bungau et al., *Current Opinion in Environmental Science & Health,* Volume 19, 2021.
[10] "Biological Approaches for Disease Control in Aquaculture: Advantages, Limitations and Challenges," Tania Pérez-Sánchez, Brenda Mora-Sánchez, José Luis Balcázar, Trends in Microbiology,Volume 26, Issue 11, 2018.

limit diffusion in case of an outbreak. Fish immunity can be boosted by immunostimulants, prebiotics and probiotics, which have the capacity to strengthen fish immune system and make it more capable of reacting to pathogens.[11] In addition, vaccines can be used to elicit acquired immunity against a pathogen for preventing outbreaks. However, these measures also have weaknesses: i) few immunostimulants are licensed and available at an affordable price to be used in an aquaculture facility, and their efficacy is still being investigated, ii) few vaccines are licensed in Europe to be used in fish and are not available for all diseases concerning farmers. Besides, antibiotics and immune system boosters are administered through oral, injection, or immersion methods, which also have important drawbacks: i) injections are invasive techniques with important disadvantages (fish stressor, feed intake reduction, fish death risk and time-consuming), ii) immersion techniques (fish are dipped in a concentrate solution of antibiotics) are labour-intensive and costly (need to separate tanks and specialized equipment and environmentally harmful), and iii) feed oral administration may not give a uniform protection, requires large dosages, and could derive in environmental impact.

And how is fish disease detected today?

There is a large variety of ubiquitous pathogens (virus, bacteria, and parasites) in aquatic environments that affect fish welfare, causing disease outbreaks in fish farms that can highly undermine profitability and economic development.[12] Besides, changes in water quality or environmental conditions can aggravate disease situation, making fish more susceptible to infection through immune suppression.[13] At present, fish farmers detect a possible disease at its onset considering different behavioural (e.g., rubbing on the bottom) and physical signs (such as swollen bellies). They also monitor feeding (appetite) and water parameters in their facilities (T, pH, etc.). In many cases, fish farmers need support from a trained pathologist, who can diagnose a disease in a specific laboratory applying the most common diagnostic techniques such as bacteriology, virology, or immunological methods (western blotting, immunofluorescence, or ELISA) as well as molecular methods (polymerase chain reaction). For that, fish farmers need to take a sample of clinically affected individuals, preferably live fish, and send them to the laboratory as soon as possible. Commonly, microbiology and histopathology analysis may take between 2 to 14 days, which can be excessive time to manage outbreaks. Meanwhile, and before receiving the diagnose, fish farmers usually attempt to prevent losses feeding animals with medicated feed to control infections, which are commercially prepared and are 30% more expensive that regular feed. Current protocols are time consuming and expensive in the long term.

A variety of tests (antibody-based, molecular, DNA-based) have been developed in the last 15 years to detect bacterial and viral fish pathogens, although tests have also recently been reported for parasites and fungal agents.[14] However, their impact over fish quality and safety is hindered because they are: • Disease (certain virus, bacteria, or parasite) and/or species specific (e.g., just for trout), so their potential for direct use by farmers is limited.

- Invasive (even those that do not require dissection need, in example, samples of gills)[15].
- Some are tailored for research and policy authorities, so farmers cannot be active stakeholders[16].

Trying to address at least part of these limitations, ELISA kits were developed 10 years ago aiming at making possible field tests. Today, serological techniques have declined in use since the developments in molecular biology. **It is hoped that developments would enhance the applicability of molecular methods to field use thereby enabling both rapid and accurate diagnoses, which would facilitate the instigation of meaningful disease control strategies[17].** Relevant attempts have been conducted recently, but they are based on genome sequencing, and therefore require fish dissection (death).

The water management and fish diseases diagnostic and treatment fields require further efforts, because the need for comprehensive tools capable of assisting fish farmers in taking better ecofriendly decisions remains uncovered. We estimate this could bring to save 80% of actual fishfarm losses, a sector in which the EU can remain leader in science, technology, and production.

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[11] "Sustainable aquaculture requires environmental-friendly treatment strategies for fish diseases," T. Lieke et al., Reviews in Aquaculture, 12, 2020.
[12] Sustainable aquaculture requires environmental-friendly treatment strategies for fish diseases," T. Lieke et al., Reviews in Aquaculture, 12, 2020.
[13] "The stress response in fish — mechanisms, effects and measurement". Wiley-Blackwell, Oxford, 2007.
[14] Maintenance of Fish Health in Aquaculture: Review of Epidemiological Approaches for Prevention and Control of Infectious Disease of Fish (hindawi.com)
[15] "Scientists develop disease detection without dissection", Fish Farmer Expert News, 2018
[16] "Detecting infection before fish get sick", Fish Farmer Expert News, 2018.
[17] "Methods for the diagnosis of bacterial fish diseases", Springer, Mar Life Sci Technol, 2019.

Biomolecular solutions bring great potential, and it is an intensely active research area

New biomolecular tools for disease control are on demand for Health Management Programmes within animal production systems. Innovative biotechnological interventions can contribute to overcoming challenges for aquaculture in terms of rapid disease diagnosis capable of supporting suitable measures for preventive control of disease outbreaks. Molecular techniques have been increasingly employed to diagnose fish disease, as they are potentially faster and more sensitive than traditional culture, serology and histology methods. They also have a wide scope of application in fish disease diagnosis, which can be used as a routine tool for rapid diagnosis of fish pathogens.[18]

For example, enzymes generated by natural recruitment and protein engineering have greatly contributed to various sets of applications.[19] However, their insufficient stability requires further research to prevent bottlenecks in achieving their potential impact. Emerging advances of protein engineering strategies for enzyme stabilization open new horizons to explore as rapidly as possible[20], and creating synergies with concurrent advances in other technological fields can accelerate momentum to meet the needs from aquaculture.

Mathematical modelling of proteins, nucleic acids, membranes, and small organic molecules have been applied to study problems such as protein folding, enzymatic mechanisms, ligand binding/unbinding, membrane insertion mechanisms and others.[21] Despite years of developments, further refinement, expansion, standardization, and validation is still expected in the future. Transferability to a wide range of biomolecular systems and 'convergence' among different modelling approaches will continue to be relevant research issues to address, for example, the dramatic increase in size and timespan of biomolecular simulations. Scientists studying chemical and biological systems, from small molecules to huge viruses, routinely combine computer simulations and experimental information to determine or predict structures, energies, kinetics, mechanisms, and functions of these systems[22].

1.1.2. DESCRIPTION OF THE CHALLENGE (MAIN AIM)

BIOAQUA aims to transform the future of aquaculture **driving a paradigm shift in disease management practices** that will offer unique opportunities of incorporating environmentally friendly protocols to fish farms. The objective is **that research gets to provide the industry with pioneering technology**, able to target an integral approach to biosecurity. This will translate into better health management, improved animal welfare, more precise pathogen removal and reduced transfer of pathogen charge to the environment, and less environmental impact from this production system.

The research questions addressed by this Action are:

- **Developing biomolecular solutions for the prevention of disease**, evolving from current reactive models which only detect disease when it is visible to the farmer, and still require even more time to determine the specific disease affecting the fish.
- **Developing environmental-friendly and safe treatments based on biomolecular solutions**, escaping from the over-use of polluting chemicals and antibiotics.
- **Increasing the understanding around fish welfare** which could facilitate the previous two research questions, avoid invasive tests or dissections, and prevent fish suffering.
- **Assuring sustainable yet profitable management for aquaculture**, considering innovationpull processes (instead of purely technology-push approaches) to take into consideration from very early stages restrictions, needs and requirement from a primary production system that, on the one hand suffers from low economic margins, and on the other hand accumulates relevant knowhow when dealing with complex life systems heavily affected by climate, hydrology, and human activity.

[18] "Biotechnological tools in diagnosis and control of emerging fish and shellfish diseases," S.S. Mishra et al., in *Genomics and Biotechnological Advances in Veterinary, Poultry, and Fisheries,* Yashpal Singh Malik et al. (Eds.), Academic Press, 2020. [19] "The state-of-the-art strategies of protein engineering for enzyme stabilization", Qian Liu Guan hua, Xun Yan Feng, Biotechnology Advances, Elsevier, 2019.

[19] "The state-of-the-art strategies of protein engineering for enzyme stabilization", Qian Liu Guan hua, Xun Yan Feng, Biotechnology Advances, Elsevier, 2019

[20] "The state-of-the-art strategies of protein engineering for enzyme stabilization", Qian Liu Guan hua, Xun Yan Feng, Biotechnology Advances, Elsevier, 2019.

[21] "Biomolecular Modeling Thrives in The Age Of Technology", Tamar Schlick & Stephanie Portillo-Ledesma, Nature Computational Sceince, 2021.

[22] "Biomolecular Modeling Thrives in The Age Of Technology", Tamar Schlick & Stephanie Portillo-Ledesma, Nature Computational Sceince, 2021.

- **Accelerating R&I cycles** to meet on time the urgent challenges from the aquaculture sector described in section 1.1.1, for research areas in which long development cycles are the standard (in example, given their long-term cooperation with the pharmaceutical sector).

1.2. PROGRESS BEYOND THE STATE-OF-THE-ART

1.2.1. APPROACH TO THE CHALLENGE AND PROGRESS BEYOND THE STATE OF THE ART

The following table aligns the research questions addressed by the Action with the main progress beyond the start each of them can bring to the fulfilment of the Action's aim.

Research question from BIOAQUA	Progress beyond the state of the art
Developing biomolecular solutions for the prevention of disease	Based on the scientific works being carried out and the outstanding results being obtained so far by some of the Members involved in the Action, the idea is to allow a change of paradigm by shifting from diagnosis of disease in fish to the continuous detection of pathogens in water (**from fish diagnosis to water prophylaxis**, beyond vaccines, including detection of biomolecules in aqueous solutions, coordination actions for health management, and implementation of quality protocols). For this purpose, **research around new and advanced proteins and biomolecular biosensors and rapid "layman" field prediagnostic tools** will be leveraged.
Developing environmental-friendly and safe treatments based on biomolecular solutions	The focus here is related to the environmental-health-cost efficiency of the solutions. For this purpose, research around **new molecular engineering methodologies** will be leveraged, **or disruptive combinations of existing methods**. The environmental-friendliness and cost efficiency will be analysed from the LCA and LCC perspective.
Increasing the understanding around fish welfare	Fish are the most phylogenetically ancient vertebrates and the most varied group in terms of genetic and morphological diversity. Hence, the considerations about fish welfare and the physiological bases for such welfare have been adopted always later than higher vertebrates and it has been more difficult to generalize protocols and methodologies. In recent years there has been a greater social sensitivity in terms of fish welfare, which has been reflected in an increasingly protective legislation of fish, whether they are for aquarium trade, production, or research. This social defendant has been associated to a change in the growing scientific perspective and research regarding animal welfare. The development of different indicators for evaluating the status of the fish has resulted in a quantifiable set of parameters, either individually or for a given population. But questions arise regarding welfare[23]: When and how the fish start to experience stress and pain? Are stress and pain experiences in mature fish applicable to the earliest stages of development? How is stress affected by each disease (multi-disease screening potential) and vice versa? Can diagnosis or treatments (direct or indirect) affect fish stress and, therefore, create other health risks?... **Answering these questions requires different disciplines to interact and exchange knowledge and data and doing it together would increase the RRI dimension of the two research questions above**.
Assuring sustainable yet profitable management for aquaculture	Despite the great potential impact over fish farm yields and interactions with the environment, aquaculture is being a relatively slow adopter of technology, and only the beginning has been addressed so far. Two main reasons explain this situation: 1. In the experience of some of the Action's members, most times efforts are considered technology-push processes not fully understanding the day-today concerns of fish farmers. 2. Fish farms are systems where the complexity of individual fishes' life vs big groups which are under water, environment and climate, regulation, society, advanced technologies, and economics converge. Lacking to consider all these perspectives hinders the potential adoption of emerging technologies that could really help addressing in an outstanding way the challenges faced by aquaculture. **In order for research to reach its potential impact, unique interactions amongst all relevant stakeholders are to be implemented at two main levels: 1)** Assuring

[23] "About Welfare and Stress In The Early Stages Of Fish", Juan Ramos*, Joan Carles Balasch And Lluis Tort, Frontier Veterinary Science, 2021.

	that they meet and work together (this Action engages as Members researchers in biomolecular chemistry and mathematical modelling, fish veterinary medicine, fish farming, environmental toxicology, regulation, training and innovation management, and interactive activities are planned to work with farmers, policy-makers and start-ups), **2)** Designing specific methodologies for reaching efficiency in having these "different worlds" (very heterogeneous group) work together.
Accelerating R&I cycles	On the one hand, BIOAQUA will **pave the way for creating a fish and quality of water Data Lake** to support a more diverse set of data and analytic use cases. Data continues to grow more diverse and more distributed —as do the sources of data and points of data consumption. At the same time, analytical needs and operational uses of data are proliferating across science and industry. Stakeholders' needs call for a modern data management infrastructure that supports flexibility, diversity of data needs and connectedness. It needs to be defined and managed jointly by participants, also working with researchers in ICT to address data interoperability and quality. On the other hand, unique cross fertilization of expertise and **highly effective training methodologies** need to be optimized to accelerate knowledge spread-out and innovation uptake, as well as to **generate greater understanding on how to evolve or adapt technologies to be converted into highly usable and top priority solutions for aquaculture** given its current rapidly changing dynamics. Some Action Members are very active into these fields in Social Sciences and Pedagogy, and their interaction with scientists in Natural Sciences and researchers in technology development will bring valuable contributions to the fulfilment of BIOAQUA's aim and objectives.

BIOAQUA focuses in leveraging cooperation for a **European-dimension, data-based, and innovation-oriented research in diverge biomolecular solutions showing high potential impact over the sustainability of aquaculture** and its potential to address global hunger, socio-economic stability in poorer regions, and preservation of the biodiversity of aquatic life.

For this, the Action plans to use some innovative approaches.

- **Creating multidisciplinary / multi-stakeholder Working Groups (WGs) in charge of coordinating research in line with the Action's defined aim and focuses:**

  WG 1 "Biomolecular solutions for water prophylaxis and biosafety", with particular focus into new proteins and biomolecular biomarkers.

  WG 2 "Biomolecular solutions as alternative methods and tools for fish-farm production", with particular focus in environmental-friendly and safe treatments, and new molecular engineering methodologies or disruptive combinations.

  WG 3 "Fish welfare" will be a horizontal WG focused in developing an integral perspective of the potential impact over fish derived from the solutions explored in WGs 1 and 2 (disease, stress, growth, feeding, behaviour, etc.)

  WG 4 "Sustainability insights" will focus on an in-depth analysis of the drivers and barriers in relation to the sustainability of aquaculture and the potential adoption of the solutions explored in WGs 1 and 2. This will include regulation aspects and proposing an innovative conceptual pathway for veterinary applications and fish tracking systems. It will also be a horizontal WG to all previous WGs described.

  WG 5 "Informed creativity", is a complementary WG that will focus on the context of R&I management, including the technological, sectorial, territorial, policy-oriented, and social dimensions potentially impacting research and uptake of results.

- **Organising "High-Performance Workshops" amongst the members of the network and beyond.** During the first year of the Action, the topics developed for the workshops will address stakeholders independently, in order to maintain a good practice policy that prevents conflicting interests. Furthermore, the Action is open to its members proposing new topics to be developed during the following periods. As an outcome from this activity, **a book titled "Biomolecular Solutions for the Well-Being of European Aquaculture Sector" will be published,** as well as related papers for **joint research publications.**

PURPOSE	Sharing of knowledge and perspectives for improving research and accelerating uptake of results.

WORKSHOP TOPICS (Year 1)	a) *Stop losses: cost-effective emerging technologies for health management in fish farms*. Aimed to industry and fish farmers, to address the reduction of fish mortality and economic losses. Design thinking methodologies will be used to extract feedback from users. b) *Certification processes in pest management*. Aimed at policymakers and certification agencies, to address certification methodologies and standards.
OVERALL DESCRIPTION	If conducted remotely: 4-morning sessions / workshop. If conducted physical: 2 or 3-days workshop. In any case, a strong focus will be given to boosting knowledge, alliances, and results. With the participation of members of the network + inviting other relevant stakeholders and researchers. These workshops will take place at least once a year.
WORKSOP DYNAMICS	The following structure is planned for these workshops, although changes could be implemented during the project to adjust to lessons-learnt and increase consensus-building: 1. PART 1: Scholars and senior members of the network will work together in certain experimentations related to BIOAQUA's research focus, in general, and the selected thematic areas for each particular WG. The purpose will be to test the ideas, knowledge, and concepts generated by the WGs, as well as the research results from Action members, following multi-disciplinary/multistakeholder approaches that enrich the R&D activities of all participants. Attention will be paid to make these tests measurable, through the compilation of KPI (tests could be experimental, but also, testing concepts with target stakeholders via in-depth surveys or focus groups organised applying Design Thinking techniques, in example). The participation of specific experts, multiple stakeholders (also from different geographic outreach), end-users and society will be expected. This part could take 1 or 2 days, and some Action Members research and experiments with different dynamics to increase the efficiency of interchange and creation of synergies during interactive events. 2. PART 2: Think-tank on the results from the experiments during Part 1; searching for advice and ideas on specific problems related to BIOAQUA's focus for a greater impact. Co-authoring of a book titled "Biomolecular solutions for the well-being of European aquaculture sector" (although this title may be adjusted during editing). Networking activities will be organised along the workshop.
EXPECTED RESULTS	The think-tank's work will continue online in between workshops, as well as the co-authoring exercise for the book. Results from the tests and conclusions from discussions will be compiled, documented, and properly stored. Emerging topics will be discussed for future workshops.

- **Research enriching international tours,** mainly to visit different aquaculture facilities (while being able to interact with fish farmers), but also to visit special research facilities related to the targeted areas by the WGs (i.e., analytical or related to molecular engineering). They will be conducted biannually and engage multiple Action Members. During these tours, experimentation activities initiated at the "high-performance workshops" could be continued or scaled up.

- **Cross-training amongst members of the Action and effective training towards the target stakeholders, on issues related to the activities/results from the GWs.**

PURPOSE	Sharing of knowledge and perspectives for improving research and accelerating uptake of results.
OVERALL DESCRIPTION	Two categories of training will be implemented: 1. **Cross-training in science, technology, and fish farming practice** for Action Members to train each other in critical knowledge and capabilities, and also inviting relevant international experts and young researchers to participate in a bidirectional way. Within this category, 2 types of trainings will be differentiated: o Ordinary trainings: 1-morning trainings at least once every 3 months.

	o Extraordinary trainings or 'Training schools', focused in longer/wider scope themes or areas of interest. During these trainings, areas of R&I management will also be covered. 2. **Training towards stakeholders**, to accelerate knowledge creation and uptake of results. Adopting e-learning approaches such as MOOCs and digital masterclasses, podcasts, and gamification will be considered for different purposes (i.e., MOOCs allow for longer training programmes, podcasts open the possibility for long-term continuous training, while gamification can facilitate addressing heterogeneous stakeholders with the same training materials). One of the Action Members is an active researcher in this area, and another one is an active performer in digital training.
HOW THEY WILL BE RUN	The ordinary trainings will be, in principle, synchronous webinars during which the speaker and the participants are connected in real time, so that interaction between them and amongst participants can happen. Training schools could be organised as satellite events to the high-performance workshops, when they take place physically (i.e., 1 or 2-day course after or before). If high-performance workshops were to be kept digital, 1-week webinar programmes (just half days) will be designed.
EXPECTED RESULTS	Training calendar, programmes, and materials. At least 1 MOOC (for future professionals in Aquaculture -e.g., vets, biologists, degrees in marine sciences…), 1 podcast channel on biomolecular solutions (targeting researchers and policymakers), 30 masterclasses (targeting fish farmers and their associations), and 1 videogame (in principle targeting society, although this could be revised).

- **Organising bi-annual "Dissemination events"** to present the results from the Action and draft joint exploitation plans around results. The form of these events will be determined during the Action, considering the competitive landscape around the organisation of networking activities, which is showing symptoms of saturation. The idea is to organise sharp, short events allowing to raise awareness and interest in the results from the Action, and facilitate uptake of knowledge, methodologies and processes worked into by BIOAQUA members. They will also be a good opportunity to work into creating alliances and outlining plans for the future sustainability of results. For this purpose, during the Dissemination events foreseen, advocacy and awareness will be reinforced on research and innovation issues among policymakers, research leaders, researchers, entrepreneurs, and sectorial & civil associations, considered very valuable for the creation of impact from this Action. The Action will also aim at reinforcing this purpose with the participation of BIOAQUA members in high level forums on Science, Technology, and Innovation. Finally, within these events, it will be considered to run structured short courses, seminars, and work sessions in the process of developing a strategy for the proactive engagement of different stakeholders.

1.2.2. OBJECTIVES

1.2.2.1. Research Coordination Objectives

BIOAQUA focuses in leveraging cooperation for a European-dimension, data-based, and innovation oriented research in diverge / last-generation biomolecular solutions showing high potential impact over the sustainability of aquaculture and its potential to address global hunger, socio-economic stability in poorer regions, and preservation of the biodiversity of aquatic life.

Within this context, the research coordination objectives of BIOAQUA are:

RCO 1 **Coordination of information seeking, identification, collection and/or data curation.** **[S]:** BIOAQUA aims to generate a Data Lake around biomolecular solutions for the wellbeing of European aquaculture sector. **[M]:** Annual reports will be generated to supervise the data generated in the surveys, workshops, and research-enabling experiments. **[A];[R]**: Tasks developed under WG3 and WG4 will serve as a powerful axis driving this objective, which encompasses and will make accessible all data generated by the action. **[T]:** The Data Lake will be updated periodically and revised annually (Y1-Y4).

RCO 2 **Coordination of experimentation & testing. [S]** BIOAQUA will conduct a series of activities which include High-Performance Workshops, tests, webinars, surveys. **[M]** At least 2 workshops will be carried out on an annual basis. **[A];[R]**: Initial topics have been proposed and agreed among Action Members (see Section 1.2.1), however, BIOAQUA is open to discussing and/or adding new topics, when considered relevant by the Action Members. **[T]:** Coordination activities will support experimentation & testing activities during the entire action, with annual and mid-term milestones.

RCO 3 **Development of knowledge in relation to disruptive/implementable paradigms for fish health management and fish welfare. [S]:** BIOAQUA will develop and support a series of scientific papers and research agendas. **[M]:** At least 5 papers will be developed jointly. **[A];[R]:** The development of new knowledge will be based on the proven scientific ability of the Action's Members. **[T]:** Even though actions towards this objective will run during the entire Action, the main milestones regarding scientific output will be monitored biannually after the Action's mid-term.

RCO 4 **Accelerating R&D and the conversion of technology into solutions. [S]; [M]:** BIOAQUA will support at least 3 patent families. **[A];[R]:** The conversion of technology into solutions will be based on the proven scientific and R&D managerial abilities of the members of the Action. **[T]:** Expected outputs will be delivered by the end of the Action.

RCO 5 **Disseminating results to stakeholders in actionable ways. [S]:** BIOAQUA will support training activities aimed at fish farmers, policymakers, and tech providers (start-ups). **[M]:** 40 webinars, 1 podcast channel, 1 videogame and 15 masterclasses are foreseen during the entire action. **[A];[R]:** Actively involving and engaging stakeholders in BIOAQUA's activities is key in both generating and disseminating the Action's results. **[T]:** Expected outputs will be delivered during the entire Action, starting on Month 6.

1.2.2.2. Capacity-building Objectives

CBO 1 **Foster knowledge exchange and develop a Joint Research Agenda around the topic of biomolecular solutions for the well-being of European aquaculture sector. [S]; [M]:** The result will be documented in the planned BIOAQUA book. **[A];[R]**: The book will be cowritten and edited by the Action Members based on the "High-Performance Workshops" carried out during the Action. **[T]:** The book will be delivered by the end of the Action.

CBO 2 **Efficient bridging of separate fields of science and other value-chain stakeholders. [S]:** BIOAQUA will implement an innovation-driven perspective to achieve breakthroughs that require an interdisciplinary approach. **[M]:** Policymaker and industrial engagement will be supported through Action Members and invitations to the Action's activities. **[A];[R]**: "High Performance Workshops" and other activities carried out during the Action. **[T]:** Engagement with external stakeholders will be sustained during the entire duration of the Action.

CBO 3 **Acting as stakeholder platform. [S];[M]:** BIOAQUA aims to generate a trans-national practice community in sustainable biomolecular solutions for fish disease treatment. **[A];[R]**: The book will be co-written and edited by the Action Members based on the "High Performance Workshops" carried out during the Action. **[T]:** Engagement and collaboration with stakeholders will be sustained during the entire duration of the Action.

CBO 4 **Leverage learning. [S]:** Effective pedagogic techniques will be implemented towards the generation of further knowledge and the market uptake of results**. [M]:** 40 webinars, 1 podcast channel, 1 videogame and 15 masterclasses are foreseen during the entire action. **[A];[R]**: The book will be co-written and edited by the Action Members based on the "High-performance Workshops" carried out during the Action. **[T]:** Expected outputs will be delivered during the entire Action, starting on Month 6.

2. NETWORKING EXCELLENCE

2.1. ADDED VALUE OF NETWORKING IN S&T EXCELLENCE

2.1.1. ADDED VALUE IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

For years already, efforts at European level are carried out in relation to networking in aquaculture, at project level[24,25,26,27] and with direct institutional networks[28,29,30]. Also, the FAO contributes to this endeavour. However, many of these projects have finished already, while networking in this sector is still important today to address the greatest impacts from climate change. Additionally, there is a gap in relation to the contribution from deep science and technologies to the sector, and vice versa. BIOAQUA aims to change this and create new networking momentum engaging integral value chains.

2.2. ADDED VALUE OF NETWORKING IN IMPACT

2.2.1. SECURING THE CRITICAL MASS, EXPERTISE AND GEOGRAPHICAL BALANCE WITHIN THE COST MEMBERS AND BEYOND

BIOAQUA represents a range of countries and individuals having a high scientific and technical reputation in their fields. This Action is transnational, because **12 COST countries** have been involved, of which **58,3% are from COST Inclusiveness Target Countries (ITC)**. Out of these, 8 are EU Members, and 4 are non-EU countries. Some of the countries are worldwide leaders in fish farming (i.e., Turkey, Spain, Italy), others are main production areas (UK, Norway, Greece) or close to main production areas (Ireland, Croatia, Slovenia) (see Section 3.1.1). The Action engages **20 Members** (10 COST + 10 ITC), **of which 55% are women and 30% are Early Career Researchers (ECIs).** As described in Section 4, more ECIs will be invited to join the network during the Action's duration.

As evidenced by the different fields of knowledge of the Action's participants, BIOAQUA is a highly **interdisciplinary** network that involves experts in biomolecular biochemistry and mathematical modelling, fish veterinary medicine, fish farming, environmental toxicology, regulation, ICT, pedagogy, and innovation management. This interdisciplinary collaboration is crucial for achieving BIOAQUA's targets and will give exceptional opportunities to the participants to adopt new knowledge, jointly develop novel ideas and initiatives, and acquire understanding of the different steps necessary for the development of the knowledge economy scenario. Likewise, BIOAQUA's **transdisciplinary approach** allows different research communities, disciplines, fields, and methodologies to be bridged to achieve (and exceed, if possible) the proposed objectives. Industrial engagement is also committed through the participation of **5 companies,** which represent up to a 26,3% of the network's composition.

Beyond COST and COST ITC countries, BIOAQUA is planning to involve further participants from Near Neighbor Countries (NNC) as part of the Action, to increase its experimentation fields and scale, obtain wider visibility, open new scientific and technological horizons, and potentially bringing new joint projects or opportunities related to Technology Transference.

2.2.2. INVOLVEMENT OF STAKEHOLDERS

Dissemination of the knowledge generated by BIOAQUA will target several groups of stakeholders.

1. **Scientific community: Involvement and dissemination activities:** Dissemination aimed at the scientific community will occur through several activities: 1) The results of this Action will be published in high-impact peer-reviewed journals; 2) Action Members will attend scientific meetings and conferences to present the results; 3) A book (or, alternatively, book chapters or methodological contents) will be edited; 4) Technical reports by WG and other documents will be openly published. Beyond this approach, a complete list of European Research Foundations will be prepared to which BIOAQUA will target concrete dissemination measures: invitations to participate in dissemination events, attendance to common forums, meetings with some representatives to explain BIOAQUA results, among others.

   Involvement with the scientific community will be achieved through several activities: External researchers will be invited as speakers in different BIOAQUA activities; 2) To reach the next generation of researchers, the results of this project will also be communicated to students, for example, in specific actions focused on Early Career Investigators (ECIs), considering the subjects already managed in the master's degrees of the academic participants. BIOAQUA will keep contact with ECIs through the use of social network accounts created specifically for the Action.

[24] PANDA project - https://cordis.europa.eu/article/id/87847-networking-for-healthy-aquaculture
[25] AQUA-FLOW project - https://cordis.europa.eu/project/id/FAIR973837
[26] European Aquaculture Technology and Innovation Platform - https://eatip.eu/?page_id=29
[27] MEDAID project - http://www.medaid-h2020.eu/
[28] European Marine Research Netowrk - https://www.euromarinenetwork.eu/activities/eu-aquaculture-farmed-eu-regions
[29] European Aquaculture Society - https://es.linkedin.com/company/european-aquaculture-society
[30] EIT Food - Aquaculture

2. **Fish farmers: Involvement and dissemination activities:** Fish farmers will be addressed directly and via their associations and collaborative institutions (Digital Innovation Hubs, Living Labs, and clusters). Specific added value materials will also be prepared for them, at the level of information (videos, Success Story Brochures, and infographics) and training (masterclasses and webinars). Their peak of engagement is expected during the "High-Performance Workshops" and subsequently related activities such as the in-depth surveys. Activities during the "Research enriching international tours" will also be relevant. Finally, start-ups will be addressed via incubating and acceleration platforms, and could be invited to the "High-performance workshops" and the Training schools.
3. **Policymakers and other economic actors: Involvement and dissemination activities:** Knowledge resulting from BIOAQUA will be made available on the Action's website and sent to the EU's Officers and specific policy-making groups interested in this topic (mainly via de book to be co-authored, but also by preparing Success Story Brochures and relevant infographics). In addition, members of these groups (or other relevant experts identified during the Action) will be invited to join and participate in some of the foreseen activities.
4. **European individuals: Involvement and dissemination activities:** This project primarily aims at improving the quality of life of individuals by providing new jobs, skills, and new economic possibilities. Thus, it is important to **inform** a large portion of the public regarding the benefits of the research field of the COST Action. This will be done through the website, dissemination events, and through intensive communication on social media to promote the scientific and innovative excellence of BIOAQUA. Beyond this approach more passive approach, it is also important to **engage** with the general public, in order to contribute to the dynamism of the discussion, and to knowledge generation. E-learning approaches such as introductory MOOCs, podcasts, or gaming activities are foreseen within the multimedia training materials of the Action and are expected to raise attention and attract early talent around the targeted issues.

3. IMPACT

3.1. IMPACT TO SCIENCE, SOCIETY AND COMPETITIVENESS, AND POTENTIAL FOR INNOVATION/BREAK-THROUGHS

3.1.1. SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS (INCLUDING POTENTIAL INNOVATIONS AND/OR BREAKTHROUGHS)

Aquaculture grows faster than all the other main primary sectors in the world. The increasing demand for protein rich aqua food is urging suppliers of aquaculture products to become more efficient and productive, pushing the sales of aquaculture technology upward. Currently, South Asian regions (China, Indonesia, India, Vietnam) are major producers, followed by Egypt, Norway, Chile, Ecuador and USA.

The EU is the first and most relevant world market for aquatic products. In 2019, the EU consumed nearly 12,8 million tons of aquatic products, out of which 9,5 million tons were imported. Thus, self-sufficiency of aquatic products in the EU barely represents a 25,3%. The total European production of fish by aquaculture is estimated to be 2,570,242 tons in 2019, indicating a small increase of 7% in total production as compared to 2018. Marine cold-water species represent a 70% of the total production, while freshwater species represent a 16%, and marine Mediterranean species a 14%. Norway remains the dominant producer in Europe with up to 56% of the total supply, which mainly consists of salmon and large trout (>1.2 kg) production. Other countries that produce more than 100,000 tons annually are Turkey, United Kingdom, and Greece, followed by Spain and France. The main species produced are salmon, trout, seabream, seabass, and carp, which represent 95% of European production in 2019.[31]

Given this huge value and the need to address the climatic situation, **Precision Aquaculture Systems Markets** grow faster than aquaculture itself (up to 14%[32]) and it is expected to yield €875M profit for 2025. The rising adoption of advanced IoT, AI, and underwater technology, will help boost the demand for precision aquaculture, opening new opportunities for market growth while improving safety by minimizing the reliance on physical operations.

Important **drivers** towards uptake of BIOAQUA's outputs are:

- Increasing prevalence of diseases/emerging diseases due to Climate Change and world trade liberalization, already described in Section 1.

[31] All data from FEAP - http://www.feap.es/
[32] "Precision Aquaculture Market by System Type, Application; Offering, and Geography - Global Forecast to 2024", 2019.

- Lack of fast methods for early-stage detection of disease outbreaks that would allow rapid action.
- Increased farmer awareness on the importance of innovative knowledge and advanced technology[33].
- Demand from society. Studies show consumers have a very positive perception of fish products, especially with respect to health benefits. Even though fish origin seems to be of limited importance, Southern and Northern EU countries prefer wild fish, while most of Central EU countries (landlocked) and Eastern EU countries (Poland and Romania) prefer farmed products. Young people tend to express a preference for farmed products that is higher than the EU average[34].

BIOAQUA will also contribute to several priorities of the **European Green Deal** by creating strong synergies among different target objectives:

1. Industry for a clean and circular economy:

- Achieve climate neutrality: BIOAQUA could contribute to reducing greenhouse gas emissions from aquaculture, as well as reducing water pollution levels.
- Sustainable job intensive economic activity: Private investment and jobs related to circular economy sectors.
- Sustainable product policy: Eco-farming.

2. Preserving and restoring ecosystems and biodiversity:

- Measure biodiversity: Water bodies in good ecological status (%)

3. From "Farm – to Fork": designing a fair, healthy, and environmentally friendly food system:

- Nutritious and high quality of food.
- Reduce the use of chemicals and pesticides

Aquaculture is a key component of both the Common Fisheries Policy and the Blue Growth Agenda from the EC, which identifies enhancing the competitiveness of EU aquaculture and assuring biodiversity and sustainability as main urgencies. It is also called to play a crucial role in the fulfilment of **UN's Sustainable Development Goals (SDGs).** Four goals that can be achieved by aquaculture with the support of biomolecular solutions are:

- **No Poverty (SDG #1):** The UN's primary goal is to eradicate poverty by 2030. It is a lofty ambition, but as aquaculture becomes more popular —fish farming is responsible for 80,000 jobs in the EU alone— it is easy to understand how the industry can help. According to the UN's Food and Agriculture Organization (FAO), aquaculture's contribution to the global fishing industry increased nearly seven-fold from 1970 through 2000 —and most of that production occurred on small, familymanaged fish farms in developing nations. In parts of Africa, for example, aquaculture has been essential in creating jobs and supporting the livelihood of families. As the industry expands into more nations, jobs in aquaculture will be instrumental in providing agency to individuals across the world and may ultimately help to reduce poverty worldwide.

- **Zero Hunger (SDG #2):** Studies have shown that aquaculture has the potential to produce 16.5 billion tons of fish annually. This helps feed local populations and caters to global seafood demand. Through responsible fishing methods, aquaculture reduces negative effects on oceans and marine species, while providing accessible, affordable food for all.

- **Responsible Consumption and Production (SDG #12):** BIOAQUA targets to reduce the environmental impact of aquaculture. As these methods are globally adopted by fish farms, aquaculture will consolidate as the most responsible choice for fish and seafood production.

- **Live Below Water (SDG #14):** Although the UN has set "ambitious" targets to improve aquaculture operations worldwide, fishing is at risk on a global scale due to the effects of climate change. The most obvious way aquaculture can support the UN's goals is by addressing 'Goal 14: Sustainability in the Fish and Seafood Trade and Protection of the Oceans.' Despite aquaculture has been questioned for less-than-sustainable methods, many fish farms are now open to ecological responsibility, and aquaculture has a bigger potential to become more respectful of environment than traditional fishing methods.

[33] MEDAID project - http://www.medaid-h2020.eu/
[34] The European Market Observatory for fisheries and aquaculture (EUMOFA). It is a market intelligence tool developed by the EC to increase market transparency and efficiency, analyses EU markets dynamics, and supports business decisions and policymaking.

3.2. MEASURES TO MAXIMISE IMPACT

3.2.1. KNOWLEDGE CREATION, TRANSFER OF KNOWLEDGE AND CAREER DEVELOPMENT

The contribution of BIOAQUA can be summarized into:

- **Promoting high impact research**. The main KPIs in relation to this contributions are: **1)** promoting at least 5 thesis; **2)** preparing at least 25 scientific papers (5 per WG) and participating in 10 scientific congresses or trade fairs; **4)** organising "High-performance workshops" and "Enriching international tours" (Section 1); **5)** co-authoring the book "Biomolecular solutions for the well-being of European aquaculture sector"; **6)** preparing joint research agendas for the WGs and opening their technical reports; **7)** starting the described Data Lake (Section 1); **8)** one-to-one meetings with scientific foundations and promotion of the Action's results with universities.
- **Leveraging wide and deep knowledge creation**. Main KPIs: **1)** foreseen training activities (Section 1); **2)** tests at the "High-Performance Workshops"; **3)** running as close as possible to 100 in-depth surveys related to the topics developed in the "High-Performance Workshops" (see Section 1.2.1).
- **Driving transfer of technology**. Main KPIs: **1)** supporting at least 3 patent families; **2)** training to fish farmers, policymakers, and other stakeholders in the value chain; **3)** training Action Members (and beyond) into fundamental issues of R&I management, with particular focus into the ECIs; **4)** preparing and publishing success story brochures and infographics.
- **Boosting career development**. Mainly in 3 axes: **1)** research (by training and engaging ECIs into the Action's highly promising research and industrial areas); **2)** entrepreneurship (addressing startups willing to promote solutions or detect new/promising innovation areas); **3)** fish farming (offering opportunities for sustainability and helping to retain rural population).

3.2.2. PLAN FOR DISSEMINATION AND/OR EXPLOITATION AND DIALOGUE WITH THE GENERAL PUBLIC OR POLICY

Action Members are committed to maximising the benefits from the outcomes and activities of BIOAQUA. The activities undertaken by each Action Member are related to their individual areas of expertise, and they can easily be combined to support the overall strategy of BIOAQUA. A secure Internet platform will be implemented to enable collaboration among the Action Members.

ACTIVITY	TIMING	DESCRIPTION
Accounts on social media	Year 1 (updated)	-Stimulate social discussion and the dissemination of the results of the Action, BIOAQUA will create Twitter and LinkedIn accounts.
Action's website	Year 1 (continuously updated)	-Information on the knowledge generated (summary reports, best practices, etc.). -Schedule of conferences, meetings, and other gatherings. -List of potential partners for other collaborations within Europe. -News about R&I project building and informed creativity. -Links to other websites related to BIOAQUA's research areas.
Joint events held by Action Members	Years 1-4	-High-performance workshops -Practical events at schools, colleges, businesses centres, etc. -Events towards policymakers to demonstrate and promote the Action's outcomes. -Dissemination events
Conferences, congresses, and trade fairs.	Years 1-4	-E.g., Biophysical Society (USA); FEBS Congress: From Molecules to Living Systems; European Aquaculture Society Meeting; European Association of Fish Pathologist; Aquafarm.
Training materials	Years 1-4	-Annual Training Schools will provide intensive training in emerging research topics within the organisations involved in the Action and beyond. TS will be enriched with monthly webinars.

		-Other training materials will be prepared (1 MOOC, 15 masterclasses, 1 podcast channel and 1 video game).
Press articles and media reports	Years 1-4	-Disseminated to the wider community and education organisations, the ecosystem of organisations around innovation and start-ups, and to governmental advisory bodies.
Media informative brochures and documents	Years 1-4	-Distribution to public institutions, educational organisations, research centres, business organisations and society. In addition, a website and media networks will be available for all stakeholders. It will include infographics (at least 5) and Success Stories Brochure. -Dissemination materials will be translated from English to partners' main languages (Spanish, Croatian, Italian, Polish, Turkish, etc.). Asiatic languages might be tackled.
Networks with wider European Research Area	Years 1-4	-Establish effective networking with other funded Actions, EU research projects, etc.
High-impact publications	Years 3-4	-Joint publication of results in scientific or specialised journals. -Book edition and technical reports from WGs (as described in Section 1).

Regarding the Exploitation Plan, BIOAQUA aims to build a successful and sustainable project in the field of R&I, efficiently and effectively managed towards a greater impact**.** During the Action, a viable **Plan for the Sustainability and Exploitation of Results** will be designed and implemented within WG5. The Action Members have already been working on it, defining as main element of this plan that any project outcome with some potential for exploitation or usage will be identified and characterized from a marketing perspective, and a particular full business plan will be designed for the achievement of the maximum possible impact and guaranteeing sustainability after the end of the project.

Intellectual Property Rights (IPR) will be managed along the Action's lifetime and as part of the Plan for the Sustainability and Exploitation of Results, following Open Access paradigms when possible.

4. IMPLEMENTATION

4.1. COHERENCE AND EFFECTIVENESS OF THE WORK PLAN

4.1.1. DESCRIPTION OF WORKING GROUPS, TASKS AND ACTIVITIES

The following describes the **5 WGs foreseen during BIOAQUA**:

OBJECTIVES

Networking, knowledge exchange and spread-out:

- **WG 1 "Biomolecular solutions for water prophylaxis and biosafety",** with particular focus on new proteins and biomolecular biomarkers.
- **WG 2 "Biomolecular solutions as alternative methods and tools for fish-farm production",** with focus on safe and environmentally friendly treatments, and new molecular engineering methodologies or disruptive combinations.
- **WG 3 "Fish welfare",** will focus on the potential impact over fish from the solutions explored in WGs 1 and 2. It will be a horizontal WG and, therefore, its chair will also participate in the monthly meetings of WGs 1 and 2.
- **WG 4 "Sustainability insights",** will focus on an in-depth analysis of the drivers and barriers in relation to sustainability of aquaculture and the potential adoption of the solutions explored in WGs 1 and 2. It will be horizontal to all previous WGs described, and therefore, its chair will participate in the monthly meetings of WGs 1, 2 and 3.
- **WG 5 "Informed creativity"** will offer a complementary support to all other WGs by focusing on R&I management aspects. It will include specific joint activities regarding the technological, sectorial, territorial, policy-oriented, and social dimensions potentially impacting the research, as well as the uptake of the project's results.

PURPOSE	Sharing knowledge and perspectives for improving research and accelerating the uptake of results.
OVERALL DESCRIPTION	Most WGs' activities will take place online and will be enriched with physical activities if the high-performance workshops mentioned below can be organised locally. A strong focus will be given to boosting knowledge, alliances, and results. By using the Action Member's existing networks, relevant stakeholders and researchers may be invited for specific sessions, when considered positive.
WORKING DYNAMICS	WGs will meet at least once a month. During these meetings, specific working agendas will be defined, agreed, and shared for the next month.
EXPECTED RESULTS	Joint research agenda for each WG, updated during the duration of the Action, facilitating amongst the R&D activities being carried out by each Action Member. Technical reports.

TASKS

- Organisation of monthly meetings and working agendas.
- Organisation of High-Performance Workshops and related collaboration research-enabling activities (e.g., thematic focuses, dynamics, needed stakeholders, etc.).
- Preparation of publications and active participation in the co-authoring initiatives.
- Preparation of webinars and 'training schools' (e.g., themes, contents, professors).

ACTIVITIES

- Stakeholder engagement and recruiting scholars.
- Management of research-enabling tests during high-performance workshops.
- Co-authoring
- Sharing information, data, and knowledge.
- Preparing training contents and materials and defining detailed programmes.
- Organising visits to relevant facilities, to increase the created value for participants.
- Participation in dissemination events and activities (i.e., blog or podcast).
- Explore synergies amongst other WGs.

MILESTONES

- Creation of the group: First working meeting (M1).
- Annual definition of themes for "High-Performance Workshops" and documentation of results (M3, M5, M7, M9).
- Publishing co-authored contents (annual milestone: M3, M5, M7, M9).
- Organisation of training schools and dissemination events (bi-annual milestone: M5 and M9).
- Final meeting towards sustainability of results (M9).

4.1.2. DESCRIPTION OF DELIVERABLES AND TIMEFRAME

Compiled in the following table:

Deliverable	Timeframe
Tests (data, surveys…) from "High-performance workshops." Reports on workshops and research-enabling experiments.	Annually
40 webinars	Monthly from month 6
1 podcast channel (or blog)	From month 6
5 joint papers / WG	Years 3 and 4
Joint research agendas and technical reports from WGs	Action's Mid-term & End of Action
Reports on networking and dissemination	Action's Mid-term & End of Action
4 joint R&D proposals in the area	Action's Mid-term & End of Action
BIOAQUA Data Lake	End of Action

3 patent families supported	End of Action
Success story brochures and infographics	End of Action
1 video game	End of Action
MOOC	End of Action
15 masterclasses	End of Action
BIOAQUA book (or equivalent)	End of Action

4.1.3. RISK ANALYSIS AND CONTINGENCY PLANS

The assessment of the potential risks will be done by all WG leaders (WGL) and by the Management Committee (MC). WG leaders will be committed to regular contact with the chair and monthly contact with the MC to provide updates on the progress of each WG. If any problem arises, it will be adequately assessed, and an appropriate solution will be proposed through an effective mechanism supported by a strong management structure. The following table summarises the potential risks identified, and the contingency plans associated with them:

Risk	Probability	Impact	Contingency Plan
Delays in WG activities	Low	High	Increase follow-up activities. Involve new participants in the WG.
Knowledge gaps amongst BIOAQUA Action Members	Medium	Medium	Identification of external key players and invitation to join the Action or participate as speakers to fill in gaps.
Low participation in events and co-authoring exercises by non-Action Members	Medium	Medium	Increased dissemination and communication efforts. Adapting activities to lessons-learnt along the Action's lifetime.
Difficulties in integrating multidisciplinary and multisided knowledge	Low	High	Participation from external experts will reinforce knowledge integration activities. The possibility to divide publications and results into more specific units has been considered.
Early Career Investigator (ECI) involvement is insufficient	Medium	Medium	ECIs coming from organisations outside academia could also be invited. Involvement of practitioners could be leveraged by Members.
Difficulties in gaining sustainability of results	Medium	Medium	Sustainability and business plans will be designed for specific results (i.e., book, MOOC)
Not being able to recruit	Low	Medium	Mobilize members to seek partners. Invitees to the Action's activities may be recruited if agreed. more partners

4.1.4. GANTT DIAGRAM