# AQUACOSM-plus Cookbook

Building Bridges Between Research and Industry

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# Acronyms

BCG Boston Consulting Group

CDR Carbon Dioxide Removal

ERA European Research Area

mCDR marine Carbon Dioxide Removal

MPP Multi-purpose offshore platforms

NGO Non-Governmental Organisations

SWOT Strengths, Weaknesses, Opportunities, and Threats Analysis

TA Transnational Access – an aspect of the AQUACOSM and AQUACOSM-plus projects that facilitated access to facilities based on the condition of applicants originating from a country other than where the facility was located.

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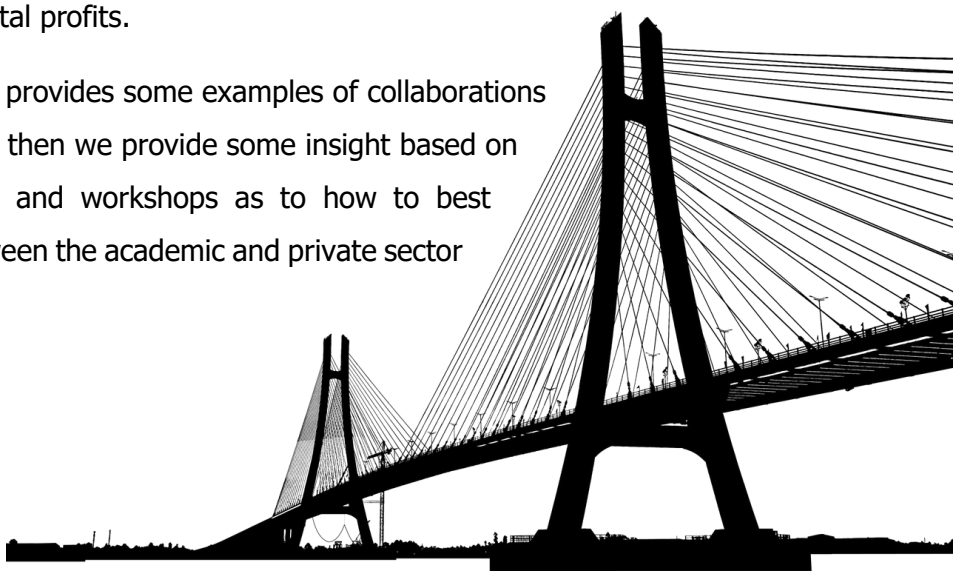
# Introduction

This "Cookbook" pulls from various streams of work undertaken within the AQUACOSM and AQUACOSM-plus projects to consider best practices for collaboration between the public and private sectors. The AQUACOSM network has great potential to offer fruitful collaborations with both the public and private sectors and we hope this Cookbook will provide some valuable and practical insight into what works, what challenges might arise, and potential solutions to those challenges.

The AQUACOSM network is made up of numerous mesocosm research facilities around Europe, providing comprehensive and diverse testing grounds, access to expertise and data, exposure to alternative applications of technologies designed for specific targets. Researchers can also facilitate the private sector in streamlining their activities and products to better align with societal policies and regulations, such as the Sustainable Development Goals, and the Grand Challenges, which could be explored for marketing to, for example, reach a wider customer basis. In turn, the private sector can help to ground truth more methods or technologies, etc. that might develop in research environments, making their impact and utility more tangible.

In many cases, one of the key challenges that have been identified is that the two communities function largely in parallel and are often unaware of how to collaborate, or even that the other exists! It is also clear, however, that though not all will have the time, resources, or motivation to foster collaborative relationships, there is significant untapped potential on both small and large scales. The practicalities of building bridges between these two communities may seem challenging, but with some adjustments, the gap may be narrowed. Making connections and considering novel developments outside of one's modus operandi can lead to small advancements, ground-breaking advancements, diversified consortia, as well as both monetary and societal profits.

First, the Cookbook provides some examples of collaborations that have occurred, then we provide some insight based on interviews, surveys and workshops as to how to best bridge the gap between the academic and private sector communities.



# Added Value – Why get involved?

Several points of added value have been highlighted toward industry throughout the AQUACOSM and AQUACOSM-plus projects (Fig. 7) through our various interactions with academic and private sector players, both from within the AQUACOSM community and beyond; these have been reiterated and further articulated here. On the grand scale, collaborations joining academia and industry do foster knowledge exchange and broadening of perspectives, but they also are gateways to more applied applications and goals beyond fundamental research, bringing additional opportunities for interesting research. Applied approaches to scientific questions are also more likely to respond to present real-world challenges immediately relevant to society. The balance of the private sector's targeted solution-oriented approach pairing with research bodies' focus on fundamental science can facilitate a better understanding of the potential role of research for key sectors of society, and how to address broader issues in a more pointed manner, including for example, regulatory issues (e.g., regarding plastics, climate change, use of chemicals, etc.). Such partnerships, especially when built into diverse consortiums also improve opportunities for R&D and accessing more diverse funding. In particular, in the context of mesocosms, it can be demonstrated how valuable they are for climate change scenarios and water quality changes.

On a more practical level, cross-sector partnerships can intensify and diversify the use of facilities and promote the use of research

**Will collaboration between the mesocosm facilities and private sector lead to more innovation? If yes, how?**

*Yes, the researcher may not be using sensors with the best specifications, for example, and we can inform them about the state of the art and provide them with the best technology.*

- Response from industry representative via survey -

**Specific examples of added value that were mentioned in workshops, interviews, and surveys:**

- Adjustment of equipment, sensors, etc. for different environments.
- Tailoring equipment to different environments
- Aim to have results from field experiment performance as close as possible to lab experiments.
- Access to a variety of sites and environmental conditions, a controlled aquatic environment, environmental expertise in the consortium
- Development of integrated measurement systems
- Potential access to broader/different customer base.
- Better ability to define problem at hand, and better understand challenges that are faced to better identify the gaps in knowledge, methodology, and technology.


*Figure 1: Overview of Potential Incentives for Industry Collaboration with AQUACOSM-plus Network*

infrastructure to a broader user group. As noted by a researcher, "We want to utilise the mesocosms as much as possible. We want also to show how valuable mesocosms are for climate change scenarios and water quality changes.". Mesocosm facilities are documented as being effective platforms for testing new technologies and methods, such that they can be tailored to specific environments and conditions, efficiency of existing methodologies can be improved (e.g., digitising), and/or technical solutions can be developed to upgrade systems, test and/or transfer knowledge, technologies, methodologies, etc., but are underutilised. In addition, products are often developed with the goal of addressing a specific challenge, but opening up to a more diverse community of expertise can lead to identifying unanticipated alternate applications or simply better define the challenge being tackled, thereby potentially broadening the market for a particular product. This was something that was mentioned by several contacts in the process, in some cases where a single employee within a company then acts as a liaison of sorts both for networking but also for bridging the cultural research-business gap. Once an industry partner has established a positive relationship with a research body, that connection can also be leveraged to facilitate additional partnerships with other research bodies through networking and gaining credibility through those experiences, making it easier to approach further partners. Furthermore, the potential for demonstrating

an instrument in a network which is then likely to spread the word to other potential fora/customers (increased visibility) is appealing. They will also then be able to provide valuable insight into the cultural and operative differences between academic and industry environments. Furthermore, opportunities may arise for connecting with other companies (via business-to-business interactions at a mesocosm facility) with complementary expertise, methodologies, or technology.

> "*Manufacturers are always looking for places to test their equipment.*"
>
> – from interview with industry representative.

Access to data and expertise (i.e., advice, providing context for data sets, and assistance with data evaluation) from new sources and the ability to use this to further develop own tools for broader applications is also a tangible incentive for private sector companies, and if they are able to participate in ongoing projects or experiments at little or no cost, then this is an added draw. In addition, the potential benefit in accessing and comparing data from complementary instruments being used in conjunction with their own (more info, data, calibration, etc.) is of interest to industry partners, while it is useful for the test facility to gain data via their instrument (win-win partnership). Furthermore, the potential for collaboration on publications should not be disregarded, especially as the tangible impacts of research are becoming more and more essential to highlight (interest from journals, and requirements from funding bodies).

Of course, one of the key advantages would be the unanticipated outcomes of joint innovation! As one industry contact noted, "When we have close connections, we can develop to specific needs. It is beneficial to have contact with AQUACOSM or other similar networks/projects where industry can potentially provide solutions."

# Practical experiences of working with Industry

## CretaCosmos HCMR mesocosm facility collaboration with CytoBuoy b.v. (Netherlands) and Chelsea Technologies Ltd (UK).

Cytobuoy: CytoBuoy is a Dutch SME that specialises in the production of imaging pulse flow cytometers. CytoBuoy was approached directly via social media (an application scientist from CytoBuoy reacted on a Facebook post regarding an AQUACOSM TA call). After some meetings, it was agreed that a staff member would apply for TA (as an expert) and would join a mesocosm experiment. The company was interested in testing an upgraded/experimental instrument (CytoSense-C) in a low-biomass/low-abundance environment (Eastern Mediterranean) that is not available in the Netherlands. The staff member joined the mesocosm experiment for two weeks. CytoBuoy provided the data from the samples to the mesocosm providers. However, the data from the testing of the instrument (e.g., various settings/modification of analysis protocols) belongs to the company. This was an overall positive experience, with a specific advantage of HCMR personnel having benefited from training on the instrument.

*Photo: Paraskevi Pitta*

Chelsea Technologies: Chelsea Technologies is a UK-based SME specialised in marine sensors and automated-analysis instrumentation. The company was directly contacted by an AQUACOSM-plus & JERICO-S3 partner (SYKE) to participate in the RI-RI common research activities. The company applied for a TA activity through the JERICO-S3 TA scheme. The company was interested to test one of their instruments (LabSTAF) in a low-productivity environment and to compare the results with results from conventional and well-established methods. Two members of the company personnel joined the mesocosm experiment for the whole duration. Part of the data was provided to JERICO-S3, however it remains confidential (C. FRANGOULIS – HCMR). This was an overall positive experience, with all scientists that participated in the experiment having had the chance to familiarize themselves with the instrument.

## LIMNOTRON collaboration with EasyMeasure B.V, under DIGICOSM project.

EasyMeasure B.V. is a recently launched microenterprise that focuses on product development in the field of water technology and early warning systems. Under the TA project DIGICOSM, EasyMeasure B.V participated in a LIMNONTRON experiment where they used the experimental conditions to test different types of coatings on their antifouling properties. In addition, they deployed a newly developed sensor under more realistic conditions for development of new algorithms for absorbance and reflectance of particles in the water column. The TA project allowed them to do R&D on their prototypes in an experimental setting that they normally would not ha

ve access to. The remote access feature of the LIMNOTRONS allowed EasyMeasure B.V. to access the automated underwater imagery remotely, and use their time more effectively. They visited the LIMNOTRON facility 8 times for deployment and checking of their coatings and sensors. The motivation for participating in the TA was not the financial compensation for travel time and subsistence, but merely the access to the facility. A recommendation could be to foster remote access in future TA programs and focus on interactions with start-up companies that often do not have the facilities to do certain types of R&D. Interaction with the facility provider was smooth as they had a very targeted approach. They were less interested in other aspects of the experiments.

*Photo: Limnotrons (l) and scientists at work (r) in the Netherlands. Photo: NIOO-KNAW.*

TA with small company, 3edata, use the large-scale FVB-IGB Lake-Lab facilities for remote sensing quality control of products (in-situ measurements and lab).

The Transnational Access (TA) program enabled a small private enterprise from Spain, 3edata, to explore the large-scale, highly instrumented mesocosm facility LakeLab, installed in Lake Stechlin, Germany (Fig. 3) to conduct the project HIREMOT (High-resolution in-situ and surface measurements of optical lake characteristics) in close collaboration with international group of scientists and scientists at the host institution, FVB-IGB. Objectives of the project were to quantify the impact of the location of water column sampling on a parameterised bio-optical model, the optical closure of the model and the surface reflectance. Further, the project aimed to assess the performance of different methodologies for the spatially-explicit modelling of temperature, turbidity and chlorophyll using UAV (drone) multispectral, thermal imagery and spectrometer point measurements. In close collaboration with the facility access providers performing high-frequent and high-vertical resolved in-situ measurements of relevant parameters (plant pigments (chlorophyll a and temperature) at the LakeLab and additional laboratory analyses (HPLC pigments), the group deployed a range of different instruments to analyse the bio-optical properties in the water column, measured

*Photo: M. Oczipka, HTW Dresden*

This collaboration illustrates a well-performed collaboration between science and industry in the fields of aquatic ecology and remote sensing of inland waters, effectively exploring a platform with adequate dimensions for the specific task. The results from the collaboration have also been presented as a success story for the European Space Agency.

reflectance and irradiance above the water surface, and imagery from drone observation. All data measured at the LakeLab platform were relevant to intercalibrate and validate remote sensing (RS) derived data. Main achievements were the integrated approach to analyse water quality via bio-optical properties in-situ, and by remote sensing using locally installed instruments as well as drone based remote sensing. A methodology was developed for obtaining drone-based point measurements of full spectra remote Sensing Reflectance (350-800 nm). Different flight heights, fields of view, geometries and integration times were tested in the mesocosms of the LakeLab. The results showed good agreement with spectra obtained with locally installed hyperspectral devices. This collaboration illustrates a well-performed collaboration between science and industry in the fields of aquatic ecology and remote sensing of inland waters, effectively exploring a platform with adequate dimensions for the specific task. The results from the collaboration have also been presented as a success story for the European Space Agency.

## Mesocosm sites in Türkiye, collaboration with SME

*Photo:Üniversiteler Mahallesi, Dumlupınar Bulvarı No:1, 06800 Çankaya/Ankara © ORTA DOĞU TEKNİK ÜNİVERSİTESİ ANKARA KAMPUSU*

METU established collaboration for two mesocosm sites in Türkiye with a small company that was helping to install a heating system with a cheaper and more practical system (not through the Transnational Access program as it was a domestic collaboration). The first company was found through the electrical-electronical engineering department of METU. The company is very well established with medium-scale profit margins. When they were approached, METU's needs and problems were explained, which the company was positive toward, as they saw them as a testing ground for some of their developments. METU and two people from the company formed a team for design, set-

up and trial stages of the heating of the mesocosms that are in the water attached to a platform. There was a mutual collaboration, knowledge, and experience transfer between the teams. The data were recorded onto an SD card in the main control and on the data transfer box of the established system. Simultaneously, it was being transferred to the company's server, allowing access to the data and enabling real-time data visualization through computer and phone applications. The system itself was a first-time for the company yet it underscored companies' already established technologies (i.e., IoT, Evolved.city). The company saw the mesocosm as a test ground as they have a large project with the government. They do not charge as much but as scientists we provide them with an opportunity to test, which was a win-win situation. Our second experience was with a small-scale start-up company to establish a control system for our second mesocosms system. The Arduino-based controller system was specifically designed for the mesocosm systems integrating heating control and online sensor measurements against a control mesocosm and adjusting accordingly. Furthermore, the same company developed an online sensor-integrated controller system. All these activities were done at a relatively cheaper price as the firms were also testing their know-how.

The company saw the mesocosm as a test ground as they have a large project with the government. They do not charge as much but as scientists we provide them with an opportunity to test, which was a **win-win situation**.

## MEK mesocosm facility, NORCE collaboration with various industry partners

NORCE MEK has extensive experience with industry partners in experimental work over many years. This includes companies producing pharmaceuticals or antifouling paint, oil and gas and aquaculture. More recently MEK has been contacted by start-ups that offer ocean-based carbon credits. A lot of MEK's work is dedicated to environmental impacts, so ecotoxicological exposure experiments are routinely carried out, but also simple testing of materials and for example determining the release of microplastics or leachates into the environment. Both can take place in the lab or in the field. The collaboration can be either in a publicly funded project with industry partners, or as contract work. MEK currently also has a publicly funded project that is targeting commercialisation of a

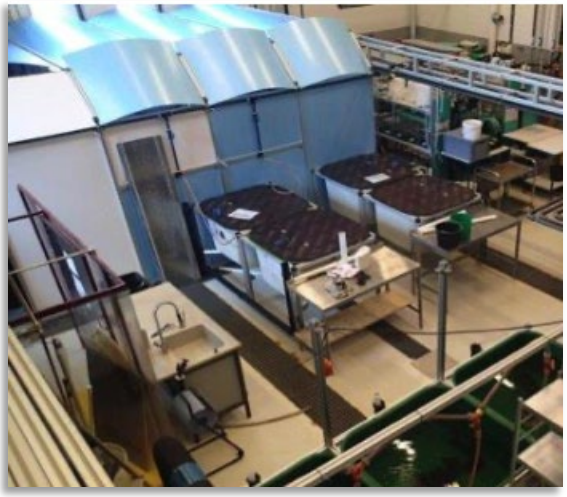


*Photo: NORCE*

sensor package that has been developed by researchers in the group. Over the years, collaboration has been generally positive, but there are a few challenges. In joint research projects, publishing rights and NDAs (non-disclosure agreements) need to be negotiated beforehand but are then generally unproblematic; in contract work, this can be more challenging. As for the publishing, we have seen both – industrial partners being unhappy with published results, but also some not being happy that results could not be published in a peer reviewed paper in the economic frame of the project.

## Finnish Environment Institute

FEI is a government institute under the Ministry of Environment that focusses on finding solutions to environmental problems. Their experience with private partnerships using their mesocosm system (12 300L tanks) is from some years ago when it was not used so much as a mesocosm with many different species, but rather to cultivate biomass (microalgae for lipids), with a large company in the refining business that was interested in biodiesel. They then built up the system more to facilitate this activity. FEI had a positive experience in that this was a source of funding and allowed them to expand/improve the infrastructure and expand more into applied research. However, there were some challenges regarding establishment of an NDA and differing views on publishing results. They did get a patent out of the activity, which was a goal of the industry partner, and FEI is a joint author on the patent. No scientific paper was published at the time. Now that the patent is public, a paper would be possible, but is not likely to be followed up on.

*Photo: Incubator for small-scale bottle experiments with adjustable light and temperature. Credit: Katri Kuuppo*

## Lake Bolmen Research Station that is directly integrated with industry

*Photo: 1Bolmen Research Station*

Lake Bolmen is the 12th largest lake in Sweden and an important water reservoir for the south-west of Skåne county. At present the lake supplies about 550 000 citizens with drinking water. In the near future Laholm and Halmstad Water Company (LBVA) also plan to utilize the water supply to serve the citizens of Laholm and Halmstad using water from Lake Bolmen. The main research focus carried out at Bolmen Research Station (Fig. 4) are in the fields of limnology, hydrology, environmental monitoring, ecosystems, and education. Activities/projects at the station vary from long-term monitoring of water quality and quantity, climate change and land-use effects on the aquatic ecosystem to support research and a manifold of projects within its boundaries. The Bolmen Research Station infrastructure is owned by the Southern Sweden Water Supply Ltd (Sydvatten AB), a drinking water producer owned by 17 municipalities in south-west of the county of Skåne (Fig. 5). Sydvatten, along with VA Syd and NSVA make up Sweden Water Research (SWR), a joint research and development company. Together with the owners, they focus on water quality, digital transformation and circular economy. SWR conducts research and development in sustainable water services to the benefit of its owners. They collaborate with industry, universities, cities, and municipalities.

Other examples of collaborating partners include municipalities, fishing associations, hydro power companies, forest companies and agencies (Fig. 6). Collaboration occurs through a number of regular meeting for a (annual partner meetings, where sharing information

about the work and results at the station is an important part of the development of the station and future projects/activities; Board meetings with the Lagan Water Council, where information about water related issues and challenges can be shared and discussed, and the council is often involved as a partner to research projects; Regular meetings in SWR, where ongoing and future research projects are discussed and decided and with the Research & Development department at Sydvatten). Collaboration also occurs through specific research projects and/or monitoring projects, as well as presentations for organizations, municipalities, industry in water related subjects and the work at the station. The Station also participates in events like Lake Bolmen Day, World Water Day, Sweden Water Research Day, local Forest Days etc. for industry, organisations, stakeholders and general public.

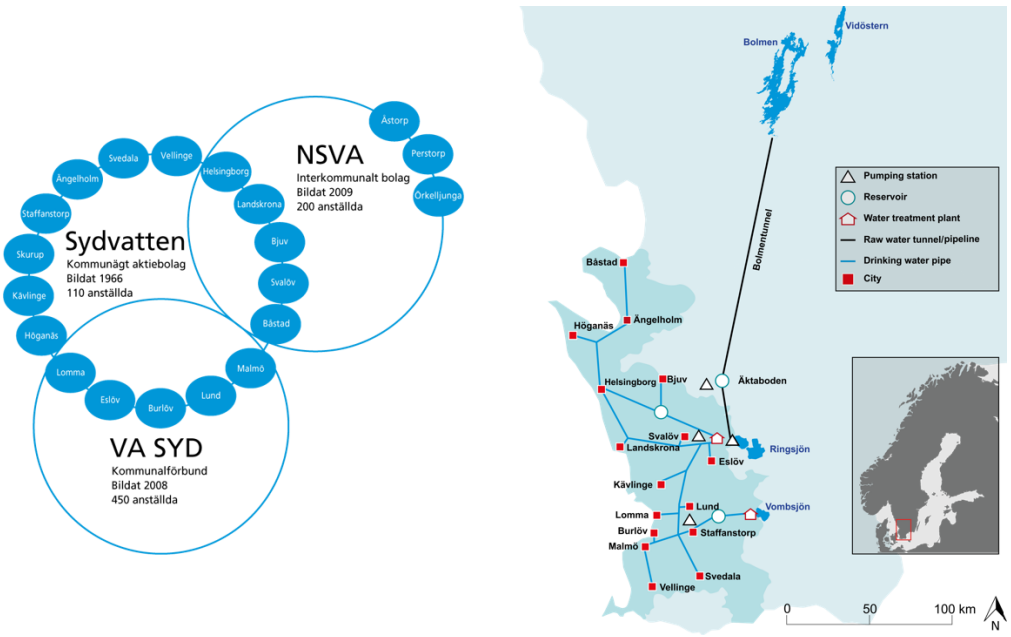



*Figure 2: Bolmen Research Station Affiliations. Left: The 3 water companies in Skåne and the connection between them through the municipalities. Right: Sydvatten drinking water system with Lake Bolmen, Lake Vomb and Lake Ringsjön (reserve) and its water plants.*

*Figure 3: Bolmen Research Station Partnerships*

## Cambridge Environmental Assessments (CEA) Collaboration with Various

CEA is an environmental consultancy providing regulatory support to global companies in chemical registration. For example, CEA regularly conducts mesocosm studies to investigate the impact of a pesticide for product registration in the EU (to GLP). It has a large mesocosm facility, comprised of outside lentic freshwater model ecosystems which can be used to perform studies that help to answer the grand challenges as well as expertise in regulatory processes for higher tier testing in the lab and field, statistical analysis and taxonomy. CEA would like academic partners to use its facilities and expertise to design and perform studies to allow them to be at the forefront of research innovation in ecotoxicology, however, better engagement is needed to facilitate this.

Much of the basic research at the facility has been conducted by industrial partners, but many users have been switching between industry and academia (for instance for research on pesticides). CEA specialises in the chemical arena, especially in higher-tier chemical risk assessment for commercial and governmental organisations, which includes running a mesocosm facility to investigate the effects of toxicants, primarily pesticides, on aquatic ecosystems (non-vertebrates only). Compared to other areas in the chemical sector, we have built long-standing collaborations between industry, academia, and regulators, which have been particularly facilitated by the Society of Environmental Toxicology and Chemistry (global, non-profit, professional organisation). As a result, there is less of a barrier to overcome for research collaborations.

*Photo: Established flat bottomed mesocosms (Credit: Cambridge Environmental Assessments)*

## Umeå – work and data management with SME

In Umeå – work with SME – in WP4.3, work with primary data share, put into a web portal, can approach Umeå for how this works. Collaboration which has been occurring with AQUACOSM-plus.

Development of a web application, "primary data shell" to foster harmonized data collection and archiving by researchers at Umeå University and information technology (IT) engineers at the small enterprise Dpend.

A web application named "primary data shell" was developed in AQUACOSM-plus to foster harmonized data collection and archiving. Researchers at Umeå University collaborated with information technology (IT) engineers at the small enterprise Dpend AB in Umeå, Sweden. The application was named "shell" to emphasize that it could be docked with an existing data repository and make efficient use of already made investments in data archiving.

The task was organised to use an interactive and inclusive approach (i.e., agile) to foster an expedient design of the shell, promoting adoption as a prime data collection tool by the researchers. Adoption is heavily dependent on confidence in that the data is managed without introducing errors, intellectual property rights ensured, and re-use of data facilitated. Direct archiving of data in a relational database should foster efficient re-use of data across experiments with a minimum of need to move and compile data in temporary databases.

The application of agile collaboration in development of the primary data-shell was based on previous experience at Umeå University and development of the dBotnia database for long-term ecological time series (i.e., environmental monitoring funded). This database has been operational during the past 20 years.The collaboration with Dpend worked smoothly due to the short decision chains and personal connections early created. Work meetings at least monthly have been held during the progress of the task, and more frequently on demand prior to e.g., reporting. An obstacle encountered was staffing of the task by the SME. A key staff member with previous experience of development of dBotnia unfortunately decided to change to another company early during the project. Dpend transferred some of the competence but failed to recruit new staff leading to less time allocated to the task. This was partly due to high competition of IT-engineer competence in the area and further compromised by the Covid-pandemic.

A pilot-version of the primary data shell was anyhow developed based on collected requirements from the AQUACOSM-plus researcher community. This can be a foundation for further development of an operational primary data collection tool of mesocosm and other type of experimental science. The agile method for developing expedient data administration

tools is recommended in future projects. Small and medium sized enterprises can be important providers of development and maintenance of a fully operational primary data shell and other IT-applications.

Insight from the task can be found in the reports D4.1 "Plan for centralised data portal for mesocosm data", D4.9 "Report of centralised data portal launch and D4.16 "Report of the primary data shell status and use for open science data collection" at the AQUACOSM-plus web portal.

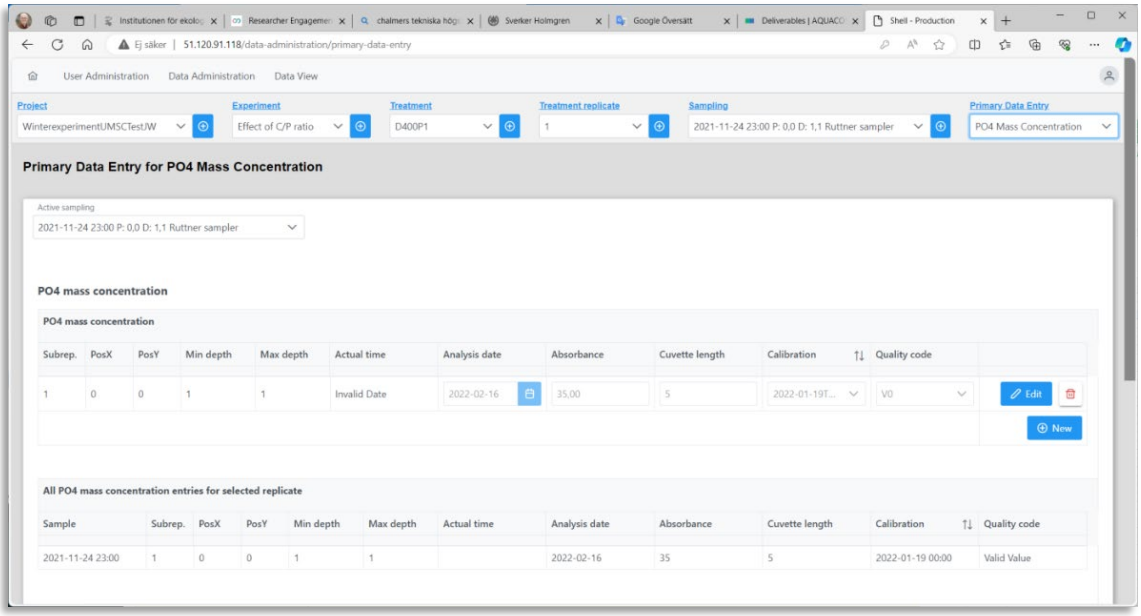



*Photo: Screen shot of the primary data shell.*

## Elaborations from experience

Many of the companies we spoke to, and this was reiterated by participants in the AQUACOSM network, indicated that they have developed a particular product or method with a specific environment or customer in mind. More comprehensive testing, calibration, etc. in a mesocosm facility has the potential to produce results that would enable a company to access a broader market.

For example, some sensors do not work well in different water types, but industry sells everywhere. Intercalibration between sensors in water related sensing, building infrastructure at different lakes and freshwater systems, or high frequency automated systems can also present a high level of uncertainty to the sensor measurements. The potential to test the calibration of sensors in different water types across the EU in mesocosms would be ideal. The potential advantage to industry is there, but what is the financial incentive or enabler for the company to actually pursue such testing?

There is also potential to provide certification of technology based on controlled testing. For example, providing a test ground for calibrating sensors could present the opportunity to have some kind of "stamp" or certification that demonstrates that they have tested the sensors in different water types. Furthermore, the value of co-development can be very attractive to a company if they are able to reliably state that they have a network of researchers working with them. Similarly, incorporating a panel of industry experts on how to execute an application in practice can be invaluable to extending the impact of publicly funded projects.

In the ecotoxicology field there is a long-standing industry collaboration, where it is not just a one-way street of academia serving industry, but also with research bodies benefiting. The collaborations between academia and industry in the frame of "mesocosm experimentation" could also be considered to provide i) new university configurations and a field for training students to meet industry needs for staff, ii) increasing industry activities thereby fostering a more thriving industry, iii) the large data sets of testing prototypes of sensors/instruments provided by industry during mesocosm experiments that can be compared/validated with the data that scientists acquired using scientifically accepted methods and instruments, and iv) supporting the use of industry sensors/instruments at the disposal of scientists via official thanks to industry in the acknowledgments of articles.

# 1. Crossing Cultures – Elements and Models of Collaboration

Though many express interest in cross-collaboration, many refer to both logistical and cultural elements that are crucial to consider. Many times, initial contact is made via individual networks and contact points, with both communities often being somewhat unaware of the other – who the players are, what they can do, what their goals are, or how to find them! In addition, there are differing mindsets, schedules, budgets, drivers, regulations, and so forth that must be acknowledged and addressed for successful collaborations to occur. This is not to say that all challenges need to be solved in order for a successful collaboration to take place, but being aware of the cultural and practical differences can go a long way to setting the stage.

## Time Scales, Schedules and Drivers

The private sector often operates on different time scales (down to quartals) from research institutes, which creates communication challenges. A research institute might have a more 9-5 mindset with longer time frames for projects and research goals, while an industry player might work in a more compressed manner with a need to see results over a shorter period. Depending on whom one is collaborating with, there must be an appreciation that private companies will often be looking for a clear path to developing a business angle (and may not engage without this), while researchers would likely be more interested in building a knowledge base and the ability to publish. The immediate business angle may be particularly true for SMEs with few employees, tight budgets, and the need to get to or expand market access. Although the TA program may provide compensation

for some of the costs to participate in an experiment, and will be a sufficient incentive for some companies, the often protracted time frame of a full experiment (weeks or even months) will not be practically doable for other industry partners. For the latter industry partner, the available TA support for travel and subsistence may be less relevant than simply quick access to an adequate testing ground, even without any TA support. Although the attraction of accessing facilities in different geographic locations with a variety of conditions is attractive in theory, the ability of small companies to physically be present for a specific period of

time compounded with the challenge of not being entirely present for their daily business responsibilities, may be insurmountable. The suggestion has been made to develop opportunities for remote access or participation, which could still greatly benefit both parties. There may also be differing expectations in terms of the data generated, where industry may be looking to get sufficient data to ensure a proof-of-concept, for example, and have expectations of a short turn around, while research bodies would be aiming for the most robust and reliable results, which may require longer testing periods. The ability of research bodies to respond quickly with sufficient resources for a particular activity may also be a challenge.

In close collaboration with the private sector, unlike regular projects in pure academic arrangements, research has to be application- and user-oriented, prioritising research questions relevant to technology implementation. This includes an adaptable research framework capable of realignment and recalibration to meet the dynamic demands of the research and development sector. For aquatic scientists, one primary concern lies in understanding the influence of technology or other anthropogenic activities on aquatic ecosystems. Consequently, scientists often want to answer questions differently from those posed by private sectors. Scientists will often want to have a mechanistic understanding of the aquatic system before endorsing strategic interventions. Private entities, on the other hand, often seek thresholds for operational boundaries within specific sectors. One example, within the realm of marine Carbon Dioxide Removal (mCDR), the core aspects for a scientist are to evaluate the efficiency of marine technology to remove atmospheric $CO_2$, assess environmental safety, and develop a protocol to monitor and verify this technology. It is imperative to establish from the beginning of a project the autonomy of academia from private funding entities. This autonomy is advantageous for both parties, particularly in sensitive domains where a transparent dissemination policy is pivotal for garnering public acceptance. Past collaborations between the private and academic sectors offer valuable lessons. For instance, in the context of mCDR, academic independence, coupled with transparent engagement with the public, can significantly enhance public acceptance. However, this is true when it is clear from the beginning that academia is an independent entity that provides independent and impartial analysis and development of methods for modelling, monitoring, reporting and verifying the outcomes[1]. On the other hand, it has to be clear that scientists should provide data to policymakers but they should not be involved in the political decision of choosing one or another strategy.

[1] one example can be found here: https://www.planetarytech.com/alkalinity-addition-with-dye-tracer-in-tufts-cove-nova-scotia/

Another example of potentially opposing interests between public science and industry is development of sensor technologies. Scientists will often want to understand all the details of an instrument (how it functions, what algorithms are used for estimation of the measured variables, etc.), while for industry, most of this information is confidential since they are in competition with other industries, which can make tight collaborations between scientists and industry challenging.

Although maximising the use of mesocosm facilities is a goal, sometimes industry working with research mesocosms is not a good match. Platforms may have several different experiments running in parallel, but enterprises may ask for monopolising all the mesocosms available for their experimental set up, which may not always possible. Finally, industry partners may also need to test contaminants that would not be possible to clean out of the system afterwards, and would thus make the mesocosms unusable for future experiments.

## Bureaucracy

The bureaucracy of participating in a large publicly funded project may be challenging or impractical for some industry players, such as filling in application forms, meeting eligibility requirements, or the need for extensive reporting, etc. The Transnational Access program, for example, was inviting and worked for many, but had an element of academic review, which is perhaps not so relevant for assessing industry players. There may also be internal bureaucratic or legal challenges for research bodies to engage with industry, such as state aid rules, non-competition policies, or a lack of process to support such interactions, etc.. Exploring alternate roles for industry in projects can also help to introduce a company to a network and become the basis for future interactions. Furthermore, institutional guidelines and policies that support interactions with the private sector would go a long way to paving the road to increased and improved interactions, such as, clear pricing guidelines, contract templates, and policies on data management and sharing of rights. Even adapting institutes' mandates or guiding policies could create a more conducive environment. For example, technical universities in Sweden have the commission to interact more directly and actively with the private sector. Funded initiatives from the private sector (or research groups) where competence is needed, and personal costs are well covered (i.e., allowing recruitment), could lead to more projects with the private sector.

## Trust and Rights

Establishing trusting relationships is key in R&D and working across sectors. Sometimes a Non-Disclosure Agreement will be necessary and desirable to set in place, such that partners can interact freely. Sensitivities, especially for SMEs, over disclosing details or data, or the protecting of intellectual property rights are valid concerns that can be overcome. One should also consider that the goal may not always be to obtain a specific and concrete result from a particular interaction, but that it may lead to future interactions of a similar or broader nature, and potentially with a broader partnership. Open and free data use and publication on test results might be problematic, as well as licensed software and products, IPR, and obligations to comply with the open data policy in EU projects for example. Some types or pieces of information may not be approved for use (e.g., specific locations, key elements of a technology or method, etc.), but this just needs to be agreed upon beforehand. Building relationships of mutual trust and respect is important, so even if one signs an NDA, for example, common courtesy can be used to inform your partners before publishing any data – in fact this is a normal element of consortium agreements even when all partners are from the academic community.

## Ethics

Ethical considerations may also play a role in partnerships. Consulting firms, start-ups, geoengineering studies, as well as companies will sometimes show interest in the development of a specific topic. For this reason, many private entities are inclined to finance or collaborate in the research. This synergy can be of great value as research can be directed towards the needs and questions of the private sector. However, to maintain its credibility, scientific research in academia must maintain its independence. This means that in the case of co-funding, experimental designs must be scientifically determined by researchers and not influenced by funders, and that researchers


must have free hands in directing their research. It is common to question what private funders or philanthropic groups gain from funding academia. One strategy to maintain research freedom and shield it from private influences but at the same time gain knowledge needed by the private sectors, is to incorporate external experts into the advisory boards chosen by the project funders. This approach allows the

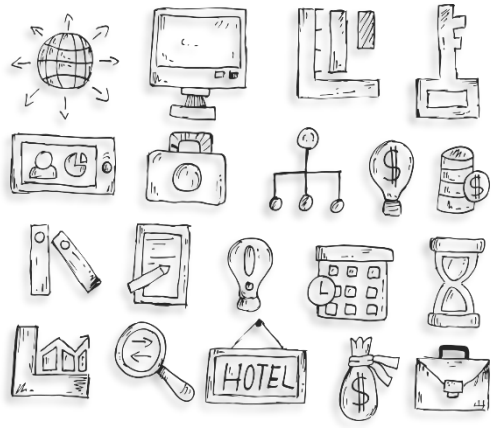
advisory board to evaluate project advancements, request adjustments to maintain research equilibrium, or realign research focus based on attained results or existing data.

### Young Researchers

Many early career researchers do not stay in science. A tighter collaboration with industry could support recruitment of more well-trained personnel in the future. Thus, a useful link could be made with industry partners, particularly in relation to training, such as via industrial PhDs where a student can spend a period of time at a host research institute and build on their work.

### Micro SMEs or Single Proprietor Entities

There is currently no opportunity for people who are self-employed to enter the TA program. For example, an artist in residence was interested in participating in a TA project, but the TA regulations were too rigid (due to work insurance questions) to allow for individuals without an official affiliation. To enable such opportunities to build infrastructure networks with small industry players or individuals, by giving access to the mesocosm/research facilities and provide them with better R&D opportunities, such hurdles like insurance questions need to be addressed. For larger companies this was not an issue as they provide official company insurance and professional affiliations, making them eligible for the TA-provision. There are also regulatory impediments in place that hinder public funding reaching individuals that are self-employed.




### SME perspective

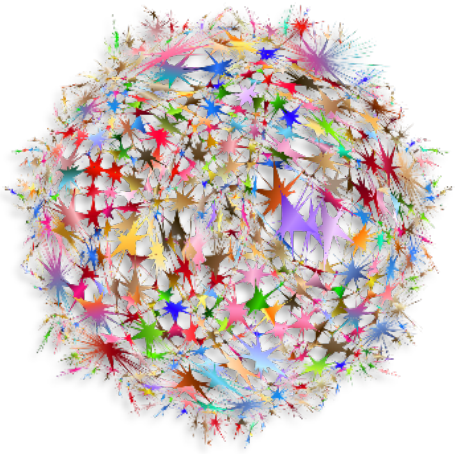
Participation in projects or programs with research bodies is beneficial both for networking purposes, testing and proof-of-concept, but also to broaden consideration of alternative applications. In some cases, it was noted that relations with academic partners was perhaps smoother than with other companies (perhaps due to competition or confidentiality issues), and also that it is sometimes easier to participate in projects as a subcontractor. It is crucial for the partnership to function such that both parties have a degree of flexibility to operate slightly outside of their comfort zones.

## Regulations

In some cases, depending on the research body, but especially those that are public entities, collaboration with the private sector can be more challenging due to rules and restrictions around competition and what could potentially be construed as favouring individual companies. Some operate through procurement processes, or commissions from authorities. State aid rules will also often limit the amount of funding that a company can receive in a project, which needs to be clearly communicated and considered. Large EU projects will also often provide some but not all of the funding upfront, while other programs function on a reimbursement financing model. This may also hinder private sector participation or engagement, especially for SMEs, which may be functioning with limited budgets.

## Communication

Sharing information on cooperation opportunities both ways can be improved, both from research communities to industry and vice versa. How do funding bodies effectively promote opportunities for the private sector? Similarly, research bodies themselves are often probably not well known to stakeholders in the industry or the private sector. Therefore, they are not aware of the possibilities and better advertisement in public media or even short videos distributed among stakeholders could promote future collaborations. Match making events were also something that was frequently suggested by contacts from both research bodies and the private sector. A plethora of information is available on research facilities, but it is not necessarily accessible or easy to navigate. Building an online tool for reviewing AQUACOSM facilities, parameters, expertise and so on, as well as a platform for posting challenges to be solved, for example, could be quite attractive to both communities. Scientific publications could also be better exploited to illustrate the added value of doing applied sciences, in that it is a service to industries but that it simultaneously provides insight into fundamental sciences.



## Contacting the Private Sector

Many contacts indicated that their cross-sector interactions began via individual and personal contacts. In some cases, social media was used as a successful contact medium, or ideas for projects were developed out of joint meetings or congresses. Almost all contacts indicated that a large gap exists even in terms of simple awareness of one another. This, along with some of the practical challenges (existing or anticipated) means that some degree of facilitation of these interactions from funders, policy and decision makers, and so on is necessary.

Large scale events that could be prime ground for matchmaking also often miss audiences since they are more often than not focussed on either academic OR private sector communities. Some specific events were noted as providing an environment for interactions and cross-pollination, such as the Society of Environmental Toxicology and Chemistry (SETAC) Conference where regulators, research and industry are brought together, and sessions require participants from all three sectors. More opportunities could be built by academics and the private sector themselves. Also, event organisers and the funders for such events could arrange side-events or create occasions for networking.

For example, based on experiences from conferences and fairs that feature companies working in the aquatic realm (e.g., manufacturers of aquatic field measurement instruments and sensors, aquaculture, etc.), it seems that the concept of mesocosms (even the term itself) is virtually unknown among many of these companies. In general, it would seem that products developed and sold by these companies could well be tested in mesocosms. Examples for instruments include, for instance, the possibility to test and optimise the performance of instruments under varying environmental conditions, and to establish detection levels under nature-like conditions etc. For aquaculture, applications could include optimisation of culture and feeding conditions, development of methods to culture species that are novel to aquaculture, testing the suitability of established aquaculture-species in environments where they have not been cultured before (including evaluation of environmental risks), and development of sustainable methods (e.g., closed system

aquaculture). Recommendations for mesocosm RIs interested in collaboration with companies should be visible at relevant conferences and fairs (e.g., own stands, pitches, etc.), to establish direct contacts with companies, and to be prepared to offer information of what can be provided, as well as to provide information on economic and other terms for collaboration. An additional recommendation is to seek contact with established research networks and infrastructures and other partnerships that already include a strong component of product development – at least within the fields of aquaculture there are already several such partnerships (e.g., in seaweed-farming). Apart from applications related directly to market products, the aforementioned fora also featured stakeholders that work on offshore wind power. This realm could provide the opportunity to provide testing of environmental risks associated with wind power, but also an opportunity to take part in work on development multi-use offshore platforms[2].

[2] As for aquaculture, there are already Horizon-projects involved in such activities, which include aquaculture and several other applications of potential interest for the mesocosm-community (see e.g., the UNITED project).

## Simplified and Targeted Communication Approaches

In our interactions with the private sector, it was highlighted to us that the reach of academic papers to this audience was limited. The time- and resource-limited culture of this sector makes shorter, snappier, and more targeted communications materials more effective. It was suggested that engagement would be more effective with the use of 1-pagers, infographics, use of social media, and brief videos, for example. LinkedIn has been noted as a platform that is more accessible, and making use of tags that are relevant to a broader audience could also be helpful. Making use of more popular style publications, such as Marine Survey, Sea Technology, or Ocean Use and Technology (see Appendix for other suggestions), or communicating via clusters (see Appendix) to spread the word of mesocosms and the facilities, services, and potentially available funding was also strongly encouraged. Furthermore, there are many events at various scales that draw broad audiences. Some are highly specialised, while others foster a cross-over of sectors, such as the Society of Environmental Toxicology and Chemistry (SETAC) Conference where it was noted that regulators, research, and industry attend, and sessions often require participants from all three sectors such that they are "forced" to interact. (See Appendix also for a list of potential recurring events of interest.)

Industry players may use technical papers as a means to find partners, but it would be advantageous to write technical briefs. In addition, having the relevant papers available via open access platforms would allow consultants, for example, to pick up topics. There is a significant paywall for non-open academic papers which potential industry partners cannot always access. Papers can also be opened up on LinkedIn (which is a platform frequently used by industrial partners) and other social media channels.

> *"Brief summaries of scientific findings could be helpful as few in the private sector will take the time to read scientific papers. Researchers go into too many details and are not always aware of what is important for the commercialisation process."*
>
> – comment from industry representative via interview

# Data Management, Confidentiality and IPR vs Open Science

It is important to agree in the beginning of mutual projects on data properties and availability. When a philanthropic and/or private sector is involved, scientists must anyway follow international standards such as the FAIR principles for both data availability and publication. When a philanthropic organisation is involved, it is commonly requested that data be available and therefore, all research output including metadata, data (observations, model results and codes), preprints and peer-reviewed publications should be published as open access. The publication process in academia is generally quite slow with long rounds among co-authors and a long review process. In the case of philanthropic grants, this paradigm should change. It is strongly requested that data are made available as soon as possible: all research output should be available via the publication of pre-prints so that other scientists and the wider community can benefit as quickly as possible. In most cases it is requested or required to have an active data management plan that ensures that metadata is published ahead of research data to transparently show which data will be publicly available in the near future. Data publications should also always be placed in an open access chosen repository (e.g., PANGAEA) that guarantees citability via a Digital Object Identifier (DOI) and high-quality metadata. To rigorously follow the idea of Open Science it should also promote the usage of persistent identifiers for objects, authors, and affiliations (DOI, ORCID and ROR, respectively) as well as the publication of article reviews and answers to reviewers. It is very important in the topic of mCDR, for example, that not only the research financing is clear and underlined but also the eventual conflicts of interest since private sectors (like start-ups) might join the studies.

In general, conditions need to be negotiated, defined and accepted by all partners before entering into a collaboration, creating a sense of mutual trust. As researchers, we naturally prefer projects that contribute to the knowledge base by providing FAIR data access, and this is required by many public funding bodies, so it should not be problematic in joint projects with industry partners. However, there is evidence for some sensitive topics, such as the impacts of a technology, and how "negative" results should be dealt with, for example if a publication is receiving press attention. In such cases, it must be ensured that the respective researcher is fully backed by the project and their institution. For contract work where data and reports are confidential or property of the customer, publishing the data may not be possible and may create a conflict of interest for the researcher.

# 2. Summary

There may be natural challenges to bridging the gap between researchers and the private sector, ranging from those that are more practical to the forces that drive each group to the mechanisms available and utilised to connect. With environmental and socially responsible oriented regulations and social pressures affecting businesses more and more, and changes at a policy level strongly encouraging and even requiring research bodies to engage with the private sector and users of research, the interlacing of these two groups is becoming more and more significant. We have seen, and have hopefully demonstrated here, that there are numerous concrete steps that can be taken to close that gap in a meaningful manner that will have lasting effects.

# Appendix: Events, Fora, Publications to Potentially Target

## 2.1 Popular Type Publications

- Fish Farmer
- Ecosystem
- Marine Survey
- Sea Technology
- Ocean Use and Technology
- Ocean System Design
- Ocean Technology
- Ocean News & Technology
- Environment Coastal & Offshore

## 2.2 Events

- Ocean Business
- Ocean sciences meeting
- MTS IEEE Ocean conferences
- OI exhibition
- AGU
- Aquaculture Europe
- AquaNor – Norfishing
- Digital Ocean Convention
- European Climate Change Adaptation Conference ECCA
- EGU General Assembly
- Global OCEANS
- ICES Annual Science Conference
- Nor-Fishing
- Ocean Business
- Ocean science Meetings (ASLO)
- Oceanology International
- Offshore Northern Seas
- Sea Tech Week
- Society of Environmental Toxicology and Chemistry (SETAC) Conference (regulators, research, and industry together and sessions require participants from all 3 sectors so are "forced" to talk to each other)
- Symposium for European Freshwater Scientists
- West European Fish Technologists Association

## 2.3 Clusters

- ASTER - ENERGY AND ENVIRONMENT PLATFORM
- BIG TC - Italian Technology Cluster
- Bioökonomie auf Marinen Standorten (BaMS) e.V.
- Black Sea Energy Cluster
- Blue Tech Cluster Alliance
- BRIT'INOV
- Cluster ACUIPLUS
- Cluster de la Acuicultura
- CLUSTER SMART CITIES DE LA REGIÓN DE MURCIA
- CTN - Marine Technology Centre
- De Blauwe Cluster vzw
- EFSA, European Food Safety Authority (http://www.efsa.europa.eu/)
- European Strategic Cluster Partnership IN OFFSHORE RENEWABLE ENERGY, ELBE
- European Aquaculture Technology and Innovation Platform (EATIP)
- EUROTOX, Federation of European Toxicologists and European Societies of Toxicology (http://www.eurotox.com/)
- Finnish Water Forum
- Fórum Oceano - Associação da Economia do Mar (Association of Maritime Economy)
- GCE Node
- GCE Ocean
- Geokompetenzzentrum Freiberg eV
- Marine South East Ltd
- Maritime Cluster Copenhagen North
- MOVE
- NATUREEF
- NCE Aquaculture
- NCE Aquatech
- NCE Seafood Innovation Cluster
- North Sea Farmers
- NOSCA Clean Ocean
- OffshoreVäst
- Pôle Mer Bretagne Atlantique
- Pôle Mer Méditerranée - Business & Innovation Sea Cluster
- SeaMICI
- sEaNERGIA Baltic Cluster
- Skane Food Innovation Network
- SpaceWave
- STIIM Aqua Cluster
- Swedish Maritime Technology Forum
- Team Humber Marine Alliance
- The Fisheries and Blue Growth District
- The Water Cluster (Anglia Ruskin University and Opportunity Peterborough)
- TMA BlueTech (formerly The Maritime Alliance)
- WaterCampus Leeuwarden

Inform https://www.eureau.org/ (European water utility organisation) that AQUACOSM exists and invite stakeholders to contact different national representatives for mesocosm facilities for further discussions.