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ASTRAL

***A**ll Atlantic Ocean **S**ustainable, Profi**T**able and **R**esilient **A**quacu**L**ture*

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Lead beneficiary	BiOceanOr
Responsible	Charlotte Dupont (BIO)
Contributors	Charlotte Dupont (BIO), Pauline O'Donohoe (MI), Marie Smith (CSIR), Luis Poersch (FURG), Brett Marc Macey (UCT), Kati Michalak (SAMS)
Internal reviewers	Brett Macy (UCT), Tomás Chalde (CONICET)

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Evidence of accomplishment

(Report)

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1 Summary

This document was created as part of the H2020 All Atlantic Ocean Sustainable, Profitable and Resilient Aquaculture (ASTRAL) project. One of the specific objectives of the ASTRAL project is to develop new and improved innovative technologies, focusing on the importance of technology validation in relevant environments to ensure the developed technology meets the expected requirements of customers and farmers, performance, and functionality. The deliverable's scope and objectives include an overview of the technologies developed in ASTRAL, validation process, strengths, and the key strategies to address weaknesses and improve technology. More precisely, this deliverable describes the validation and assessment of all the technology developed in ASTRAL and deployed in ASTRAL IMTA labs, as well as recommendations for improvement and plans to implement and evaluate the improvements.

2 Introduction

2.1 ASTRAL context

Integrated multi-trophic aquaculture (IMTA) is a sustainable and efficient method of aquaculture that involves cultivating multiple species with complementary ecological roles in the same system. Technology plays a critical role in IMTA, as it enables the monitoring and control of various parameters that are essential for ensuring the health of the cultured organisms and optimal functionality of the system. Technology is essential for:

- **Monitoring Water Quality:** The success of IMTA depends on maintaining optimal water quality for each species in the IMTA. Technology can help monitor and control key parameters such as temperature, dissolved oxygen, pH, and salinity, ensuring that they are within acceptable ranges for each species.
- **Controlling Feeding Rates:** Each species in an IMTA system has different feeding requirements, and technology can help control the feeding rates for each species. This can help prevent overfeeding or underfeeding, which can lead to negative impacts on the environment and the health of the cultivated species.
- **Disease Prevention and Management:** Technology can help monitor the health of the fish by detecting pathogens and early signs of disease. This enables early intervention and treatment, which can help prevent the spread of disease and minimize declines in production and profitability.
- **Waste Management:** IMTA has been conceived to reduce waste production, which can accumulate and negatively impact the environment and the health of the fish. Technology can help manage waste by monitoring and controlling the release of waste products and recycling them as a resource.
- **Data Management and Analysis:** Technology can help collect and analyze data on various parameters such as water quality, feeding rates, and growth rates. This can provide insights into the performance of the system and help identify areas for improvement.

In summary, technology is needed in IMTA to monitor and control key parameters, prevent, and manage diseases, manage waste, and collect and analyze data. By using technology in IMTA, farmers can optimize the performance of the system and ensure sustainable and efficient aquaculture practices.

Beyond IMTA, aquaculture in general is facing significant environmental pressure due to climate change and several anthropogenic factors. Rising temperatures, changing weather patterns, and ocean acidification are affecting the health and productivity of fish and shellfish, as well as the aquatic ecosystems in which they are cultivated. Technology can play a critical role in helping aquaculture producers adapt to these environmental pressures and maintain sustainable and efficient practices. Indeed, technology can help aquaculture producers adapt to the environmental pressures of climate change by improving monitoring and control, precision feeding, genetic selection, alternative feeds, and data analytics. By using technology to optimize practices, producers can maintain sustainable, efficient, and profitable aquaculture practices, while reducing the environmental impact of the industry.

2.2 Objectives of the deliverable

The purpose of the deliverable D2.10 is to provide an objective and comprehensive assessment of the effectiveness, efficiency, and reliability of the technology developed in ASTRAL for marine IMTA and beyond. This deliverable aims to identify strengths and any weaknesses or limitations in the technology's performance and provide actionable recommendations for improvement to enhance its overall performance and meet the needs of its users and stakeholders. In the context of ASTRAL, the users of the technology might be big or small IMTA producers, in land based or open water facilities. The stakeholders could be policy makers who need a clear vision of IMTA challenges. The objectives of the deliverable are the following:

- **Assess the technology's current performance:** We will provide an objective assessment of the technology's current performance based on predefined criteria, such as its reliability, efficiency, and effectiveness.
- **Identify areas for improvement:** Based on the assessment, we will identify areas where the technology could be improved to meet the needs of IMTA producers and policy makers more effectively.
- **Recommend strategies for improvement:** Actionable recommendations for improvement that can be implemented to enhance the technology's performance.
- **Implementation plan:** We will outline a plan for implementing the recommended improvements, including timelines, resource allocation, and any necessary changes to processes or systems.
- **Evaluate the impact of the improvements:** We will develop an evaluation plan to measure the impact of the recommended improvements to assess the effectiveness of the changes made to the technology.

The ultimate purpose of the deliverable is to provide guidance and recommendations to help the ASTRAL consortium make informed decisions on how to improve the performance of technology developed in the project and meet the needs of its users and stakeholders more effectively. By providing a comprehensive assessment and actionable recommendations, this deliverable can help ensure that the technology is reliable, efficient, and effective, which is critical for its long-term success.

3 ASTRAL technologies

3.1 Technology development in ASTRAL

ASTRAL project has developed a pool of technology to help IMTA to be more efficient and sustainable. These technologies are described below.

3.1.1 Biosensors

This system employs sessile bivalve molluscs (e.g., oysters and mussels) as biosensors for environmental condition monitoring. Bivalve molluscs rely on shell valve movements to control water flow across their gills and often exhibit predictable patterns of valve behaviour that can be used as the basis for monitoring water quality conditions. These animals may therefore provide early warning signals of negative changes in water conditions through recognition of non-typical variation in their behaviour patterns. ASTRAL is developing vision biosensors based on computer vision algorithms (developed by FURG) and a Micro Electro-Mechanical System (MEMS)-based accelerometer sensor to measure valve opening amplitude and activity (developed by NORCE).

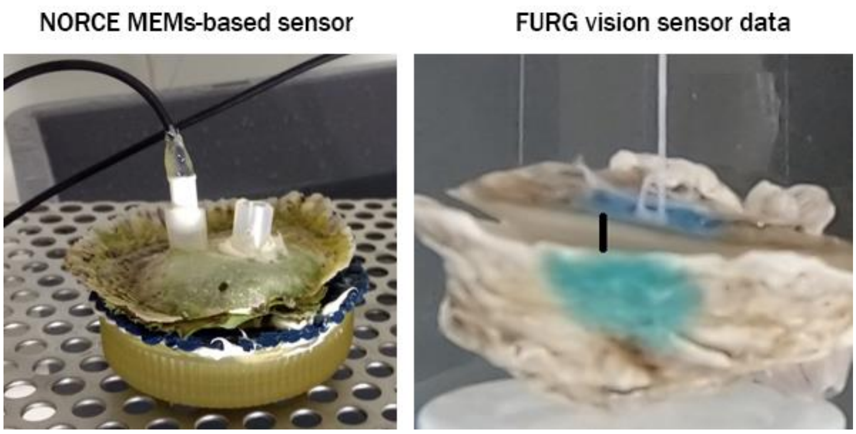

Figure 1 - Biosensors developed in ASTRAL project by NORCE (on the left) and by FURG (on the right)

3.1.2 Spectrophotometer

This solution (developed by EGM) embeds a compact MEMS-based spectrometer and uses it to get absorbance and fluorescence spectra of a sample of water processed “in the box” using an AI inference model to measure various physico-chemical parameters of the water sample. Precise parameters to measure are still under investigations as it depends on first experiments, but a target is to detect for example parameters critical for optimal functionality of an IMTA, such as dissolved oxygen, pH, salinity, ammonia, nitrite, nitrate, phosphate, turbidity, total suspended solids and chlorophyll-a. It has two modes of operation: one to get spectra in parallel with other measurements (e.g., fluorometry) from other instruments (e.g., lights at various wavelength) to calibrate the model, and another one to use the measured spectra and the inference model to provide in-situ measurements.

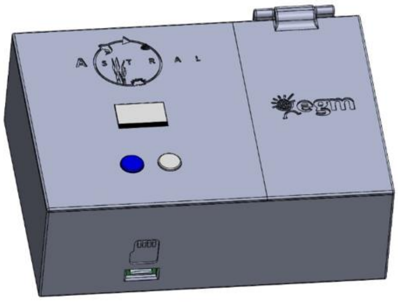

Figure 2 - Design of the spectrophotometer sensor developed by EGM

3.1.3 Low-cost IoT kit for water monitoring

The Low-cost IoT kit (LCIK, developed by Bioceanor) is an energy-autonomous device that allows the connection of several sensors that already exist in the market to monitor water quality in real time, like temperature, oxygen, pH, turbidity, or salinity. The innovative part relies on the modularity of the device, to meet the IMTA farmer's needs. It can use communication modules chosen by users including long range, low energy radio communications (e.g., LoRa) or 3G and iridium communication. It is very important to be able to choose the best communication strategy, to adapt to the particularities of the deployment site. It can also store data in case of communication outage. The Low-cost IoT kit will send its data to the AIDAP (see 3.1.6), so the data can be visualised easily by the users.

Figure 3 - The Low Cost IoT Kit developed by Bioceanor

3.1.4 Microplastic /Phytoplancton monitoring

The sensor, developed by LEITAT, is an optical device capable of inspecting a continuous flow of water to look for microscopically sized polymer particles (i.e. microplastics) and differentiate them from other natural particles that might be present in the analyzed water. The technology addresses some of the issues and limitations of current commercial alternatives, such as low flow rate or high cost, by combining fast off-the-shelf industrial cameras, tunable optics, image processing and deep learning models. In this section, the concept and design of the ASTRAL microplastic sensor together with the current state of the prototype development are presented.

The ASTRAL microplastic sensor prototype is managed internally by a microcontroller which is responsible for controlling and properly synchronizing the different elements of the device: the pump, the illumination (i.e. white and UV LEDs), the focusing of the tuneable lens, the acquisition and processing of the signal generated by the particle detection block and the triggering of the camera.

Interaction with the user is carried out by a Graphical User Interface (GUI) running on a computer (PC or embedded system such as NVIDIA Jetson). Through this GUI, the user can purge the circuit, clean it, start/stop pumping the water sample for analysis, adjust some acquisition or detection parameters visualize results, etc.

After opening the GUI, the camera is automatically configured via software so that is ready to receive hardware triggers from the microcontroller. Next, the user switches on the water pump, the system starts to grab images when a passing particle is detected. Those images are sent to the memory computer for their latter processing and saving. The number of grabbed images (N) and the delay with respect to the instant of detection of particle are parameters that can be varied and optimized according to the nature of the sample. When all the sample volume has been transferred from the sample container to the reservoir, the pump is switched off automatically, images are processed, and results of microplastic detection are presented trough the GUI and sent to the AIDAP.

The user must then internally clean the fluidic circuit to avoid accumulation of debris by means of proper cleaning fluids (e.g. ethanol and DI water) and leave the device ready for the next use. The system allows manual control of the pump for such procedure as well as for the circuit purging that should be done before pouring the water sample at the very beginning of the process in case air bubbles are observed.

Figure 4 - The Microplastic / Phytoplancton monitoring device, developed by LEITAT

3.1.5 AI-vision sensor

ASTRAL AI vision technologies bring a fresh approach to day-to-day tasks of animal biomass and phytoplankton monitoring in aquaculture. The ASTRAL AI vision technologies build upon the state-of-the-art developments from cross-discipline research to deliver technological aids in optimising IMTA aquaculture production at a reduced impact on the environment and on the stress of the organisms. The approach brings artificial intelligence, specifically deep learning models, to lower the investment risks in IMTA aquaculture. The technology offers affordable yet reliable monitoring solutions for in-land and off-shore deployments under a wide variety of farming requirements such as intensive aquaculture, biofloc-based and recirculating systems.

Figure 5 - AI vision sensor developed by FURG and Bioceanor for shrimp (on the left) and urchin (on the right)

3.1.6 AI Data Analytics Platform (AIDAP)

AIDAP is an open cloud-based platform aiming to make the analytics of IMTA data accessible and easy. The platform will provide important features such as prediction of physico-chemical parameters, alerting, user annotations, historical and real-time data visualizations. This is enabled by a software platform that collects data from heterogeneous sources (e.g., Low Cost Iot Kit sensors, APIs, user provided), efficiently store the data, host predictive models, and provide dashboards for visualization. The platform will offer to third party to use the ASTRAL available data information but also to input their data to use the ASTRAL AI-based predictive models, therefore in an approach Intelligence-as-a-Service (IaaS).

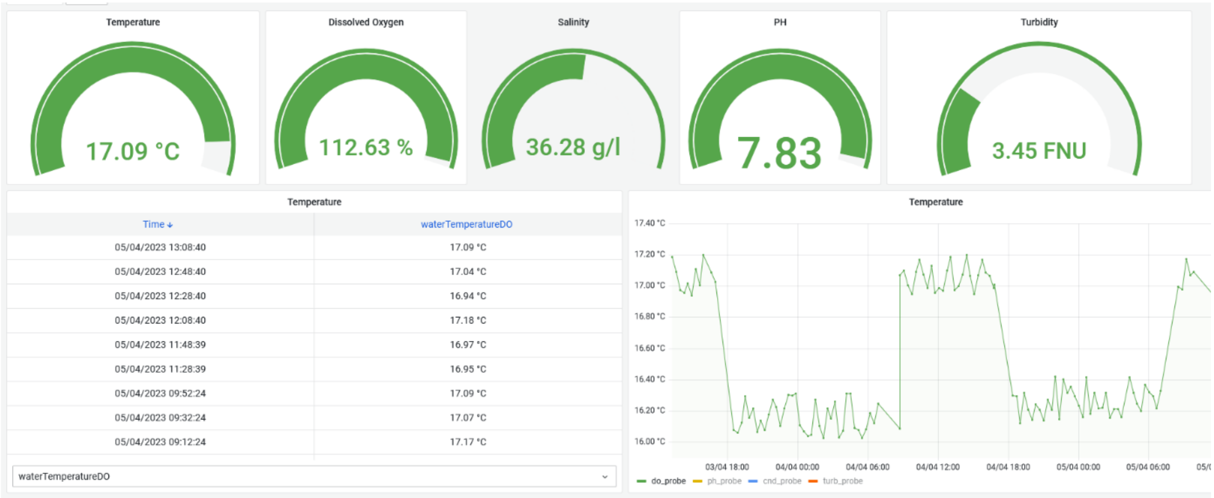

Figure 6 - Screenshot of a dashboard of AIDAP (developed by EGM and Bioceanor) showing real time values of water quality data from the LCIK

3.2 The deployment of the technology in IMTA Labs

To test the technology in real environment, it was deployed in 4 different IMTA Labs:

- MI (Ireland) - Open-water system.
  - LCIK
  - Spectrophotometer
  - MPS Phyto-imaging sensor
- SAMS (Scotland) - Open-water system.
  - LCIK
- Viking Aquaculture (Buffeljags Abalone) (South Africa) - Land-based pump ashore system.
  - LCIK
  - AIDAP
- FURG (Brazil) - Biofloc system.
  - Biosensors

Figure 7 - Pictures of the deployment of some technology in IMTA labs. On the left, Biosensors in Brazilian IMTA lab and on the right, LCIK in South African IMTA lab

The validation and assessment processes is described in the following parts of the deliverables, and will focus only on the deployed technology in the IMTA labs.

4 Technology validation

4.1 Definition and importance

Technology validation is the process of verifying that a technology product or service meets the specified requirements and performs its intended functions accurately and reliably. It involves testing the technology under various conditions and scenarios in the relevant environments to ensure that it operates as expected and delivers the desired outcomes.

The importance of technology validation cannot be overstated, especially in today's technology-driven world where businesses and individuals rely heavily on technology to carry out their operations and activities. Here are some reasons why technology validation is crucial:

- **Ensuring Quality and Reliability:** Technology validation ensures that a product or service performs the intended function(s) and meets the required quality and reliability standards. This helps to build customer confidence and trust, which are critical to the success of any technology product or service.
- **Mitigating Risk:** Validating technology helps to identify and mitigate potential risks associated with its use. By testing the technology under different scenarios and conditions in the indented environment, potential flaws, and vulnerabilities can be detected and addressed before they become a problem.
- **Compliance:** Many industries and government regulations require technology products and services to meet specific standards and regulations. By validating technology, businesses can ensure they are in compliance with these requirements.
- **Cost Savings:** Validating technology can help to prevent costly errors and mistakes that can arise from using faulty or unreliable technology. This, in turn, can help to save money and resources in the long run.

Overall, technology validation is critical for ensuring that technology products and services are reliable, efficient, and effective, and meet the expectations of users and customers. By validating technology, businesses can improve their reputation, reduce risk, and increase customer satisfaction, which are all essential for long-term success.

4.2 Methods and tools used for validation

The validation process was conducted *in situ* in the four IMTA labs, when the technology was deployed. IMTA lab managers were asked to evaluate the usage of the technology in the context of the day-to-day operations of the IMTA labs.

Interviews were conducted and questionnaires were completed by each lab (managers, partners or operators) to gather information about the validation of the technology.

IMTA labs where asks to rate their overall user experience from very poor to very good.

The questions were the following:

1. How would you rate your overall user experience?
2. How satisfied were you with the technology?
3. How easy was it to use the technology?
4. How much does it correspond to your needs?
5. Would you recommend the technology to others?

IMTA labs were also asked to describe the eventual problems encountered, to give recommendations for improvement and evaluate their willingness to pay for the technology.

4.3 Results of the validation process

4.3.1 Biosensors

Biosensors were evaluated by Brazilian IMTA lab. The validation was complicated because of bad electrical contact issues, and some animals were stuck in the bottom of the cage.

A second unit is in preparation for validation in the South African IMTA lab.

The validation process is still ongoing for the Biosensors.

4.3.2 Spectrophotometer

The spectrophotometer was tested and validated at the Irish IMTA lab. The technology was considered easy to use and accurate, with a good user manual. However, there were some issues with the light stability.

4.3.3 Low cost IoT Kit (LCIK)

For South African IMTA lab, the low cost IoT kit was considered a good and reliable product, that gathers the data in real time and sends it to the cloud. Even if they were some troubleshooting to be done first, the latest version of the LCIK deployed at the lab seems to be stable.

On the contrary, for Scottish and Irish IMTA labs, the low cost IoT kit could not be tested because it was inappropriate for offshore deployment. The casing was impossible to fix on the facilities and the sensors connectors was not placed in a good place to support strong wind. Thus, the validation of the LCIK failed in these 2 labs.

In Brazil, the LCIK with LoraWAN version has only been tested in laboratory but not in real IMTA environment yet.

4.3.4 Microplastic / Phyto imaging sensor

The phyto-imaging sensor was tested at Irish IMTA lab. The device was evaluated as easy to set up and easy to use. However, it was difficult to eliminate all bubbles entirely. It was also difficult to evaluate how much water to put through the device. Some bugs were detected like blurred images, not-waterproof, water leaks, physical buttons and false positives. Validation is still ongoing with a new validation period in June 2023.

4.3.5 AI Data Analytics Platform (AIDAP)

The AIDAP has been tested with the low cost IoT kits deployed at the various IMTA labs. Because some LCIKs could be validated at the time of writing this report, the AIDAP was only tested by South African IMTA lab. Their evaluation of the product was good, although some problem of logging had occurred. The AIDAP seems to be very useful, but not completely stable yet. Sometimes the website hosting the visualisation platform is unavailable. Also, some inaccuracy of the measurement seems to be displayed online.

In conclusion, the technology of AIDAP has been validated, with some improvement to be made.

5 Technology assessment

The assessment process, as compared to the validation process, is a broader evaluation of the technology's performance, impact, and effectiveness. It involves evaluating the technology's overall performance against a wide range of criteria, including its ability to meet business objectives, user satisfaction, cost-effectiveness, and other factors. It is essential to assess the effectiveness and efficiency of technology for several reasons:

- **Performance:** Assessing the effectiveness and efficiency of technology ensures that it is performing as intended. By measuring the performance of technology, users can identify areas that need improvement, such as speed, accuracy, or reliability.
- **Cost-effectiveness:** Assessing the efficiency of technology helps users understand its cost-effectiveness. This includes evaluating the costs of implementing, operating, and maintaining the technology compared to the benefits it provides. By assessing the efficiency of technology, users can identify ways to reduce costs and increase profitability.
- **Innovation:** Assessing the effectiveness and efficiency of technology helps users identify areas for innovation. By understanding the limitations of existing technology, users can develop new technologies or processes that are more effective and efficient.
- **Competition:** Assessing the effectiveness and efficiency of technology helps users stay competitive. By understanding the performance of competing technologies, users can develop strategies to improve their own technology and remain competitive in the market.
- **Customer Satisfaction:** Assessing the effectiveness and efficiency of technology helps ensure customer satisfaction. By providing technology that performs as intended and is cost-effective, users can increase customer satisfaction and loyalty.

5.1 Evaluation of the technology’s effectiveness and efficiency

5.1.1 Biosensors

The validation of the biosensors has not been pushed far enough to be able to evaluate the technology’s effectiveness and efficiency yet.

5.1.2 Spectrophotometer

During the validation process, the spectrophotometer has been evaluated as corresponding enough to the needs of the IMTA labs. The labs indicated that they are willing to pay for the product when ready to be commercialised. Overall, the spectrophotometer was deemed easy to use and a professional device that is reliable enough to be recommend to other users. The spectrophotometer achieves its intended purpose; thus, we can consider that it has a good effectiveness. However, the access to data is not as quick as it needs to be, so the efficiency of the product is not optimal yet.

5.1.3 Low cost IoT Kit (LCIK)

During the validation process, the spectrophotometer has been evaluated as corresponding very much to the needs of IMTA lab, regarding South African IMTA facilities. Regarding Scottish or Irish IMTA facilities, the LCIK poorly meets the expectation of the industry. For the evaluation purposes we will then separate the LCIK in 2 categories:

- Land-based pump ashore LCIK (as evaluated in South Africa)
- Open-water LCIK (as evaluated in Scotland and Ireland).

Coastal LCIK has given satisfaction and users are ready to pay for the product and recommend it to others. The effectiveness of the product is very high as it achieves its intended objectives.
The efficiency of the product is optimal, as it operates smoothly enough and meets the expectations.
Offshore LCIK has failed to meet the expectation, and considered as irrelevant regarding the users needs. Thus the effectiveness and the efficiency of the product are very poor.

5.1.4 Phyto imaging/ Microplastic sensor

The phyto-imaging sensors corresponds well to the needs of the user. The intended objectives are met and the users are ready to buy the product and recommend the technology to others. However, due to some improvement to be made in the operation of the technology itself, the efficiency of the product is not optimal yet.

5.1.5 AI Data Analytics Platform (AIDAP)

AI Data Analytics Platform is a technology well perceived by the users and corresponding exactly to their needs and expectations. Users would buy and recommend the product. Despite some unavailability of the platform, the efficiency of the technology is good as it delivers the information nicely. The efficiency can still be optimised with some improvement of the technology.

5.1.6 Summary of all technology's effectiveness and efficiency

Technology	Effectiveness	Efficiency
Biosensors	N/A	N/A
Spectrophotometer	Fair	Fair
LCIK (coastal/inland)	Very good	Very good
LCIK (offshore)	Very poor	Very poor
Phyto-imaging sensor	Good	Fair
AIDAP	Very good	Good

5.2 Identification of the technology’s strengths and weaknesses

5.2.1 Biosensors

The validation of the biosensors has not been pushed far enough to be able to evaluate the strength and weaknesses of the technology.

5.2.2 Spectrophotometer

The spectrophotometer is easy to use, presented as a kit that has been evaluated as very professional. The kit was very well prepared with all standards for calibration. However, the displays are not optimal and the access to data difficult.

5.2.3 Low cost IoT Kit (LCIK)

For the evaluation purposes we will separate the LCIK in 2 categories:

- Land-based pump ashore LCIK (as evaluated in South Africa)
- Open-water LCIK (as evaluated in Scotland and Ireland).

Coastal LCIK is very easy to use, with plug and play technology. It can be easily installed and deployed and it communicates automatically to send data in the cloud. However, there can be some problems to initiate the communications at first.

Offshore LCIK is not adapted to the type of deployment. Several problems has been encoutered:

- Condensation: internal PCBs are not independently housed.
- Mounting and attachments: no brackets available, need to drill housing to install. Pole mounting kit required to mount both solar panels and box.
- Suspension of sensors: sensors previously have been suspended by a rope and bracket to remove strain from the cable.
- Suspension of sensors: sensors are independent and will bang against each other in the water. As sensors are optical, mounting together in a pipe could interfere with readings.
- Location of glands on housing: the glands are positioned on the sides of the box, thus the rain and wind can be an issue.
- Connecting glands to housing: the sealent inevitably loses its grip on the plastic housing and the gland begins to spin.

5.2.4 Phyto imaging / microplastic sensor

The phyto-imaging sensor is very user-friendly, and the instruction manual is very informative and helpful. The equipment is very easy to set up. However, it is difficult to eliminate the bubbles entirely, when making the sampling. It is also complicated to know how much data and images is enough per sample. The ideal volume of water that should be put through the device per sample is complicated to determine.

5.2.5 AI Data Analytics Platform (AIDAP)

AIDAP is very easy to use, and the data are easy to find and to navigate through. The usage of AIDAP is intuitive and user-friendly. The platform seems a bit unstable as it can be inaccessible sometimes. Some readings seem inaccurate and needs to be sorted.

5.2.6 Summary of technology's strengths and weaknesses

Technology	Strengths	Weaknesses
Biosensors	N/A	N/A
Spectrophotometer	Easy to use Very professional kit Very well prepared kit for usage	Displays not optimal Difficult access to data
LCIK (coastal/inland)	Easy to use Plug and play Easy to install Automatic communication	First connection can fail
LCIK (offshore)	None	Condensation Mounting and attachment Suspension of sensors Location of glands Connecting glands to housing
Phyto-imaging sensor	User-friendly Easy to set up	Difficulties to eliminate bubbles Quantity of data Quantity of water
AIDAP	Easy to use Intuitive	Unstable Data inaccuracy

6 Recommendation for improvement

6.1 Strategies for addressing weakness and improving the technology

6.1.1 Biosensors

The validation of the biosensors has not been pushed far enough to be able to make recommendations for improvement.

6.1.2 Spectrophotometer

After evaluation of the technology, the users' recommendations for improvement are to upgrade the data displays, so it is more user-friendly. The data should be easier to access, ideally in real-time.

6.1.3 Low cost IoT Kit (LCIK)

For the evaluation purposes we will separate the LCIK in 2 categories:

- Land-based pump ashore LCIK (as evaluated in South Africa)
- Open-water LCIK (as evaluated in Scotland and Ireland).

Regarding the coastal/inland LCIK, no particular recommendation has been made, as there is no major identified weakness.

Regarding the offshore LCIK, there is many recommendation, as the LCIK doesn't meets at all the users expectations:

- Condensation: internal PCBs should be independently housed.
- Mounting and attachments: brackets should be made available.
- Suspension of sensors: rope should not be necessary to adapt to the sensor's weight.
- Suspension of sensors: sensors should be dependent to each other.
- Location of glands on housing: All cable glands should be positioned underneath the box. In previous experience any other location allows for water ingress from wind driven rain.
- Connecting glands to housing: use rubber o-rings for the gland and not sealant.

6.1.4 Phyto imaging /Microplastic sensor

Regarding the difficulties to evaluate how many images is required per sample, the recommendation would be to have a program to read the images, to identify the phytoplankton as part of the application.

6.1.5 AI Data Analytics Platform (AIDAP)

No particular recommendation has been identified for the AIDAP technology, except to solve the instability issue.

6.2 Implementation plan for recommended improvements

6.2.1 Biosensors

The validation of the biosensors will be continued in an another IMTA lab (South Africa).

6.2.2 Spectrophotometer

New light sources have been implemented since the first validation period, and the stability test is still an ongoing process. The design of the autonomous version is in progress and will allow to address the recommendation of a better data access. This improvement should be made before the end of Q2 2023.

6.2.3 Low cost IoT Kit (LCIK)

Regarding the offshore LCIK, we are following the users recommendation and a completely new version of the LCIK, designed for offshore facilities, is under developpement. Redeployement in Scottish and Irish IMTA labs are planned for end of April 2023.

6.2.4 Phyto imaging sensor

A third version of the prototype is currently under development, and is planned to be redeployed in June 2023. In this prototype the robustness and performance will be improved. Identified bugs will be fixed, as recommended by the users. Additional features will be implemented, as a tunable lens, a touch screen, and more a functional housing.

6.2.5 AI Data Analytics Platform (AIDAP)

The next version of the platform is currently under development, with data displays improvement. However, the biggest part of AIDAP on going development is the integration of the developed algorithms for shrimp and urchin biomass detection. This integration should allow those algorithms to run automatically on the platform and let the users upload their own data. The deployment of these new features is planned for July 2023.

6.3 Evaluation plan to measure the impact of improvements

After the improvements will be made, it is important to measure the impact of the improvements and make sure that they are good enough to finally validate the technology. For that we need to set up an evaluation plan with all the technology partners. The plan will have to take in consideration the following elements:

- **Identify the metrics to be used for evaluation:** The first step is to identify the metrics that will be used to evaluate the impact of improvements.

- **Monitor and evaluate the impact:** Once the improvements have been implemented, monitor and evaluate their impact on the metrics identified in step 1. This may involve collecting data through user feedback, surveys, data analysis, or other methods.
- **Compare the results to the baseline:** Compare the results of the evaluation to the first deployment. This will provide a clear picture of the impact of the improvements on the technology system.
- **Identify areas for further improvement:** Based on the results of the evaluation, identify any areas for further improvement and implement additional changes as needed.
- **Communicate the results:** Finally, communicate the results of the evaluation to stakeholders, including users, management, and other relevant parties. This will ensure that everyone is aware of the impact of the improvements and can make informed decisions about future developments.

By following this plan, we will be able to evaluate the impact of improvements to ASTRAL technology and ensure that it is effective, efficient, and meets the needs of users.

7 Conclusion

In general, the technology developed in ASTRAL context has been well received by the IMTA users. They correspond globally to their needs and can be future commercialised products. Some of them still need to be improved to be completely efficient and effective, but the implementation plan of the recommendation is already ongoing and we are confident that all ASTRAL's technology will fit to the IMTA users' needs and expectations.

To conclude this deliverable, it is essential to remember why technology validation and improvement is important, not only in the context of any technology development, but also in the context of Integrated Multi-Trophic Aquaculture.

As IMTA continues to evolve, it is important to **develop integrated technologies** that can support the growth and success of multiple species. This includes developing technologies that can support the growth of macroalgae, finfish, shellfish, and other organisms in a single system. As IMTA systems continue to expand, it is important to **assess the impact** of these systems on the environment. This includes evaluating the sustainability of IMTA systems and the potential impact of these systems on local ecosystems and natural habitats. To ensure the success of IMTA systems, it is important to develop **monitoring technologies** that can accurately assess the performance of the system and potential impact on the species cultivated in the system. This includes developing sensors and monitoring tools that can track water quality, harmful organisms and the stress on organisms. As IMTA systems become more complex, it is important to develop **management tools** that can help farmers effectively manage their systems. This includes developing software tools that can help farmers monitor and manage their systems in real-time, and that can provide insights and recommendations for improvement. To increase efficiency and reduce labor costs, it is also important to develop **automation technologies** that can streamline the operation of IMTA systems. This includes developing technologies such as automatic feeders, water pumps, and nutrient dosing systems. As IMTA systems become more complex and capital-intensive, it is important to develop **financing tools** that can help farmers and investors finance these systems. This includes developing financial models that can accurately assess the risks and rewards of investing in IMTA systems, and that can help farmers secure financing for their projects.

Overall, the future of IMTA will depend on the continued development of technologies that can support the growth and success of multiple species in a single system. This will require ongoing innovation, investment, and collaboration between farmers, researchers, and technology providers.