1. Project Information

Proposal reference number[1]	JS3_CALL_1_REF_4032_S1100-Bio
Project Acronym (ID)[2]	S1100-Bio
Title of the project[3]	ANB Sensors S Series: Long term Biofouling Deployment
Host Research Infrastructure[4]	OBSEA underwater observatory (UPC)
Starting date - End date[5]	20/09/2021 – 24/10/22
Name of Principal Investigator[6] **Home Laboratory** **Address** **E-mail address** **Telephone**	Dr. Nathan Lawrence ANB Sensors 6 Old Farm Business Centre, Toft, CB23 2RF, UK nlawrence@anbsensors.com 01223 263545

2. Project objectives[7] (250 words max.)

ANB Sensors was trialling its S1100 with a TRL of 8/9. Previous prototypes of the sensor have been tested on short deployments at SYKE through Jerico S3 funding. The key objectives for the Jerico-Next project in collaboration with UPC were to:

1. Deploy the S1100 on a coastal observing station at 20m depth for 3-4 months.
2. Deploy a second S1100 alongside the first to provide inter validation between the two sensors.
3. Provide feedback on the sensors ease of use, ease of deployment and data retieval features.
4. Evaluate the performance of the S1100 over a prolonged period of time, observing seasonal changes in weather and biodiversity.
5. Study the biofouling resistance of the sensor.
6. Validate the sensors response against independent measurements in real time deployment.
7. Allow ANB Sensors to understand the issues associated with oceanography and sensor deployment for other analytes – providing scope for future collaborations.

[1] Reference number assigned to the proposal by the TA-Office.

[2] User-project identifier used in the proposal.

[3] Title of the approved proposal. The length cannot exceed 255 characters

[4] Name of the installation/infrastructure accessed with this project. If more than one installations/infrastructures are used by the same project, please list them in the box.

[5] Specify starting and end date of the project (including eventual preparatory phase before the access).

[6] Fill in with the full contact of the Principal Investigator (user group leader).

[7] Write the short-term, medium and long-term objectives of the project. Use no more than 250 words.

3. Main achievements and difficulties encountered (250 words max.)[8]

One of the main achievements was proving the performance of the S1100 in a lab, as well as the verification from the end user that the sensor was indeed easy-to-use. Maintenance of the transducer was carried out successfully and in-situ underwater, realising the goal of this sensor being the preferable option for long term deployments as it doesn't need to be recovered for maintenance. Finally, although the body of the sensor was covered in bio growth by the end of the 8 week deployment, the transducer surface was clean, proving the biofouling resistance claim of the sensor.

The main difficulty encountered was the ability of the sensor to perform for a longer time, due to the deployment issues highlighted. Although the interferences between the sensors connected to the same power supply was a big obstacle, the power isolation board developed by ANB overcame this issue. The leakage of the sensors was a big adversity too but provided very useful information for the next design.

4. Dissemination of the results[9]

Utilizing the data and results gathered throughout this Jerico S3 project, in conjunction with our *in-situ* lab-based research, an academic peer-reviewed article detailing the measurement technique and the performance of the sensor in seasonal changes in weather and biodiversity will be published. In addition, the data will be communicated through conference/meeting presentations in order to demonstrate the validity of our system, and for the public, through social media like Twitter. Finally, the results and data will be gathered to procure intellectual property on the technologies directly resulting from this research project.

5. Technical and Scientific preliminary Outcomes (2 pages max.)[10]

The experimentation for this project was conducted in the OBSEA underwater observatory in Barcelona, Spain, in collaboration with Universitat Politecnica de Catalunya (UPC).

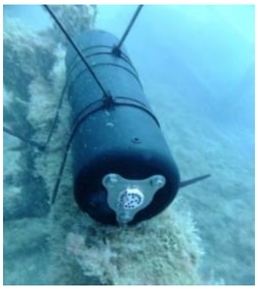
[8] Describe briefly the main achievements obtained and possible impacts, as well as possible difficulties encountered during the execution of the project. Use no more than 250 words.

[9] Describe any plan you have to disseminate and publish the results resulting from work carried out under the Transnational Access activity in JERICO -S3: scientific articles, books - or part of them -, patents, as well as reports and communication to scientific conferences, meetings and workshops. Highlight peer-reviewed publications. **Note that any publications resulting from work carried out under the JERICO -S3 TA activity must acknowledge the support of the European Commission – H2020 Framework Programme, JERICO -S3 under grant agreement No. 871153.**

[10] Describe in detail results and main findings of your experiment at the present stage.

The sensors were first tested in the lab at UPC to ensure a good performance before deployment. The tests were performed in a bucket with seawater and were powered simulating the OBSEA connection, which was a 12V power supply connecting the two sensors. It was seen that testing two sensors in the same tank with the same power supply induced noise in the response due to electrical interferences between the sensors. This effect was confirmed by testing those two sensors using the same power supply but in different tanks, which resulted in a correct behaviour, demonstrating the performance of the sensors themselves, and highlighting the electrical interferences issue when testing more than one system in the same tank.

Following these lab tests, the two sensors were deployed at OBSEA. At this time the firmware on the sensor was upgraded and tested by the staff at UPC. Excellent feedback was given on the ease of use of the sensor in terms of both the firmware configuration of the sensor prior to deployment and the low amount of handling required for the sensor to be deployed. However, on this initial deployment electrical interference cross talk was observed across the sensors. To alleviate this in the short term one of the sensors was put in sleep mode, and the second sensor ran. However, the initial impact of this electrical cross-talk meant the response of the sensor was already effected for the longer term measurements.

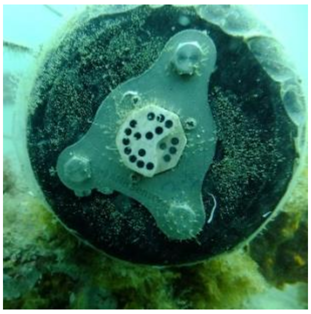


Despite the electrical cross talk meaning that the sensors response was not optimal, they were left at the OBSEA to study the impact of biofouling on the transducer head. After 4 weeks, the sensor in sleep mode was recovered, while the other one was left in the OBSEA for a longer study of the biofouling. The sensor recovered showed a white layer deposited on the head (see image on the left). This was caused by electrolysis, as the electrodes on the surface of the head are polarized to induce salt deposition, as the difference voltage between the negative pole of the power supply induced current between the OBSEA chassis (it is connected to earth) and the sensor head, producing that salt deposition on the transducer head. The second sensor was recovered from the OBSEA 4 weeks later. After a total of 8 weeks under the water, no biofouling was found. Nevertheless, as predicted from the previous sensor deployed, salt deposition was found (see image on the right) on the surface of the counter electrodes, where the current flows. These results highlighted the importance of these tests to understand the performance of the sensor under different conditions, and the urgent need of an isolation system for the sensor.

During this deployment a power isolation board was developed by ANB to avoid the electrical interferences between the sensors. In order to install the isolation boards in the sensors, they were opened by the staff from UPC. The feedback on this process was provided to ANB, the learnings of which were used for the development of the next version of the sensor. Upon opening of the sensors both sensors showed rust inside, indicating some leakage, especially where the transducer was placed.

The emergence of rust within the sensors suggests that the transducer had leaked during deployment and the poor responses were obtained in the lab due to the corrosion in the socket board produced by the leakage. After both sensors were cleaned, isolation boards were incorporated, and the transducers were replaced, both sensors showed correct measurement for pH in the lab trials. However, when downloading the data, it was seen that the SD card in one of the sensors was corrupted. The sensor was then opened to access to the SD card, and the files were removed, to ensure smooth performance. All this real field trial feedback was very useful to ANB, as it is difficult to replicate this in-house.

The sensors were then redeployed in the OBSEA, and no further electrical interferences were found between the sensors, indicating the effectiveness of the isolation boards. Unfortunately, one of the sensors showed a quick decay in the electrode's response, very possibly due to the socket board being damaged after the leakage. On the other hand, the data collected in the other sensor showed different responses between the electrodes, corroborating the heterogeneity between the electrodes after its previous issues. The transducers needed abrasion, but due to bad weather, the next diving operation, and therefore the next abrasion, was done after 6 weeks. The sensors response to biofouling in this time was very pleasing. No bio growth or salt deposits were seen on the transducer surface after 6 weeks deployment (see image), confirming the biocide formation and the effectiveness of the isolation boards. Both transducers were successfully abraded underwater, giving good responses after. This results highlights that remediation of the sensor surface can be achieved in-situ without the need to bring them to surface. However, the after abrasion the signals that the sensors measure were too large for the sensor to interpret, achieving the maximum limit set by the firmware at that time. These results were very useful to ANB to improve the firmware settings for future deployments. Furthermore, the importance of knowing when the transducer required abrasion was flagged by UPC so ANB developed a colour code firmware update instructing the end user when to perform maintenance.



After further tests, it was seen that the reference sensing part was damaged in both sensors, which in turn led to corruption of the SD card. All these issues were taken into consideration for the development of the next version of the sensor. The sensors were recovered 3 weeks later, again showing no bio growth on the transducers. They were both opened to understand why the reference system failed. Water leakage was found inside of one of them, which irreparably damaged that sensor, however, the other was still functioning, so it's transducer was replaced, checked in the lab, and deployed in the OBSEA. After showing no biofouling within 4 weeks, the communication between the OBSEA and the sensor was lost due to a problem inside the OBSEA node. The sensor was then recovered and deployed again with a battery pack for two weeks, but unfortunately the data showed inconsistences between the pH sensing electrodes, which was found to be due to a leakage in the battery cylinder, where one O-ring was compromised, so no discernible data resulted.

The data retrieval unit (DRU) provided by ANB was not used in the OBSEA deployment, but it was tested in the lab and found to suffer with some random communication issues. These observations helped ANB for the development of the new power source unit for the new version of the sensor.

In conclusion, all the tests performed allowed ANB to highlight some key issues, such as interferences between sensors, leakage, and the need for more accurate QA/QC limits after abrading the transducer underwater. None of these development issues could be unearthed in laboratory tests, so these field trials were invaluable. All the feedback gathered from UPC, positive and negative, has been vital for further sensor development.

The other big win from these tests was the positive biofouling results achieved. This differentiates ANB's sensor from all other ocean sensors and will make it the go-to sensor for long term oceanographic monitoring of pH.

ANB Sensors, 02/02/2023

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Location and date Signature of principal investigator