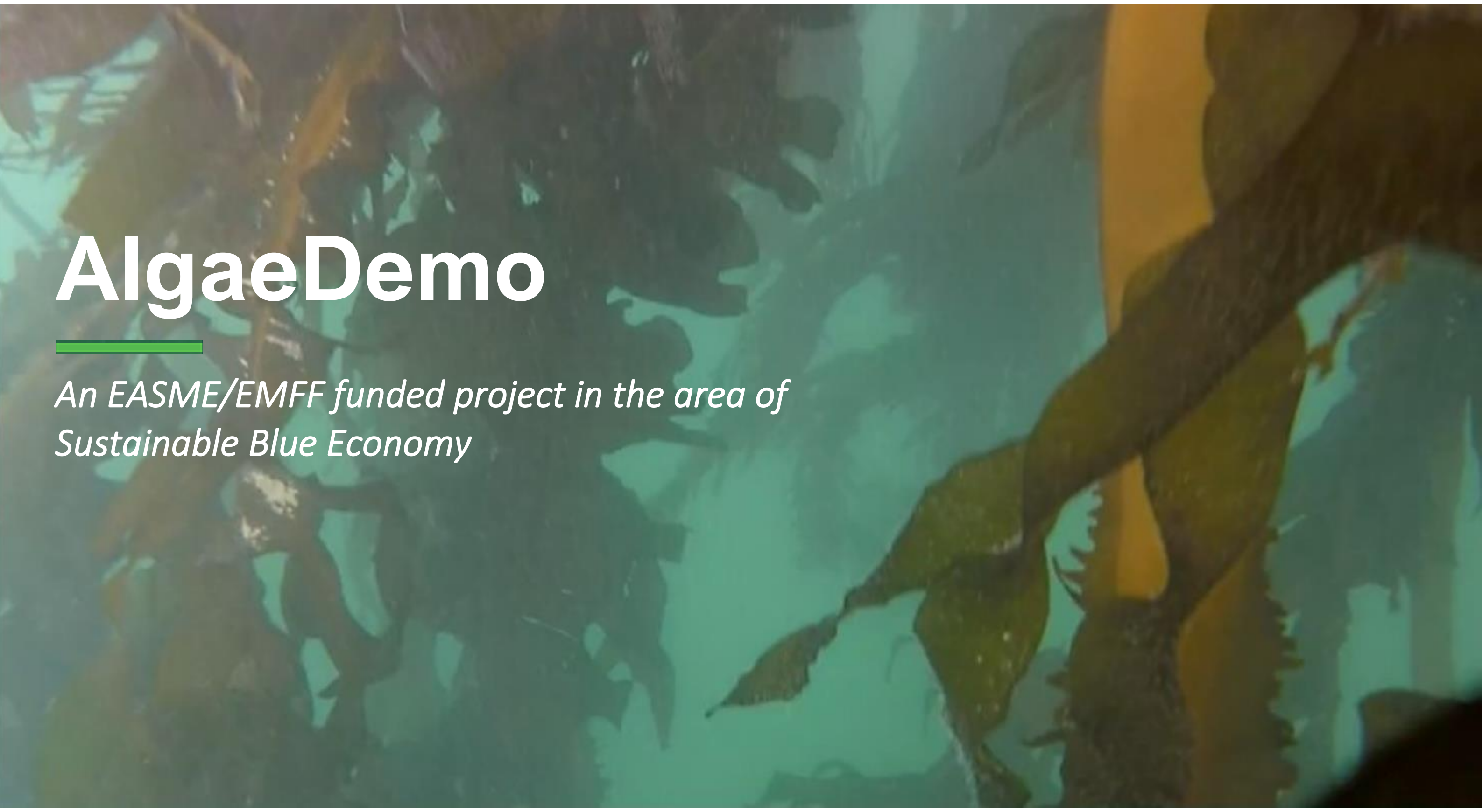
FACTSHEET

Factsheet on autonomous underwater monitoring of seaweed farms

Key findings from the AlgaeDemo project

https://www.algaedemo.eu/

AlgaeDemo is an EASME/EMFF funded project in the area of Sustainable Blue Economy. AlgaeDemo will demonstrate the advanced, mechanised cultivation and harvesting of seaweeds at the 1-2 ha scale in the Eastern Scheldt, including remote monitoring with AUVs and accurate determination of the environmental bioremediation capacity of such seaweed cultivation fields.



Challenge of underwater monitoring

Storms and collisions with boats can disrupt seaweed growth or even damage farm infrastructure. Routine monitoring of seaweed and farm structural integrity improves the lifespan of assets and allows for better crop growth prediction. At present-day, these monitoring activities are expensive as they require the presence of skilled personnel and divers operating from a support vessel. In particular offshore, the operational cost are a key limiting factor in realizing cost-effective operations. Recent advances in the field of Autonomous Underwater Vehicles (AUV) technology has created the opportunity to improve cost-efficiency, safety and sustainability of offshore seaweed cultivation. While AUVs are already an essential tool used in ocean exploration and for subsea search operations, there has been little research on their value for seaweed farm monitoring. Furthermore, the challenging environmental conditions underwater (poor visibility, high currents, no radio communication and no GPS) provide a significant challenge for AUVs. Within the AlgaeDemo project, TNO has assessed the value of AUVs as a tool to support seaweed farm operations. This fact sheet outlines opportunities and challenges in operating AUVs to support the monitoring of seaweed farms. A way forward to overcome the identified challenges is proposed.

Approach

To understand the value of AUVs for seaweed farm monitoring, two experimental campaigns took place within the AlgaeDemo project at the shallow water of the Eastern Scheldt, an estuary (Schelphoek) in the south-west of the Netherlands. The first campaign took place prior to the construction of the seaweed farm and was aimed at assessing the value of AUVs for site evaluation and mapping of the environment. The second campaign took place prior to harvesting of the winter crop in the installed farm and was aimed at assessing the ability of AUVs to evaluate the seaweed growth and farm structural integrity.

An important scoping of the project was the focus on “low to mid end” small sized (2 person portable) vehicles, as high-end solutions where considered to not provide a cost-effective alternative to diver and vessel based operations. Two types of underwater vehicles used in the test: a cylinder shaped AUV (LAUV model by OceanScan) and a Remotely Operated Vehicle (ROV) (BlueROV2 model by Blue Robotics). The AUV was equipped with a Side Scan Sonar (SSS) to map the seabed and seaweed lines. Both vehicles had optical sensors and a subsea navigation solution to determine the location of the vehicles underwater. The usage of two distinct vehicle types allowed for an effective benchmark. Various tests were conducted to evaluate the ability of the vehicles to coop with the challenging underwater conditions encountered in the seaweed farm (currents, limited visibility, floating biological material, lack of radio communication and GPS).

Results

To offer an effective alternative to diver and vessel based operations, an AUV must be able to safely and efficiently carry out the tasks provided by the operator for a sufficient range of environmental conditions (e.g. currents and sea-state). The AlgaeDemo project evaluated the ability of AUVs to carry out underwater monitoring of the seaweed and seaweed farm structural integrity.

AUV experiments

Prior to the seaweed farm installation, the SSS of the AUV provided an acoustic backscatter map of the Eastern Scheldt. This map showed bathymetric landmarks originating from the previous seaweed farm and a large heterogeneity of the seabed suggesting the presence of different types of marine habitat. In addition, this survey provided data on the actual water depth and water properties (temperature, turbidity and conductivity). The shallow water conditions (4-7 m at high tide) at the Schelphoek limited the AUV to high tide operational windows to avoid collision with the seabed. The visibility at the days of the test was too low (max ~1.5 m) to acquire useful images of the seabed with the camera of the AUV. A smaller sized AUV or improved vehicle control capabilities would allow for navigation closer to the seabed at the cost of reduced endurance/ thruster power (smaller sized AUV) or increased cost (improved navigation and vehicle control hardware)

After the farm installation, the AUV was able to safely follow a set of pre-defined waypoints parallel to the seaweed farm. This allowed the usage of the SSS to provide qualitative insights on the integrity (condition) of the farm ropes as well as the localisation of lost seaweed and debris on the seabed in between the lines. A quantitative assessment of the seaweed volume on the lines was not possible with the SSS and would require a multibeam sonar aimed at the seaweed. Furthermore, the drift of the seaweed farm rope system (caused by wind and tidal currents) combined with dead reckoning of the AUV while sailing underwater did not allow for safe deployment of the AUV in between the seaweed lines. Though these limitations reduced the operation efficiency of the AUV in the Schelphoek estuary, they are less stringent for seaweed farms in deeper water, where the AUV can sail below the lines. For safe navigation in between tightly spaced seaweed lines, an improved navigation accuracy is needed. In particular the availability of a reliable start position using GPS and knowledge on the location of the seaweed lines is critical to avoid entanglement. Alternatively also a relative object navigation approach could be used, where the AUV would sail parallel to the seaweed lines based on a range estimate provided by a sonar.

A reliable acoustic communication link was established between the acoustic modem deployed from the RHIB and the AUV. For larger scale operations within a seaweed field, the seaweed may block this direct line of sight and hence limit human operator to monitor and intervene with the AUV operation. The usage of a lower bandwidth, but more robust communication protocol, may be desirable to ensure connectivity at all times.

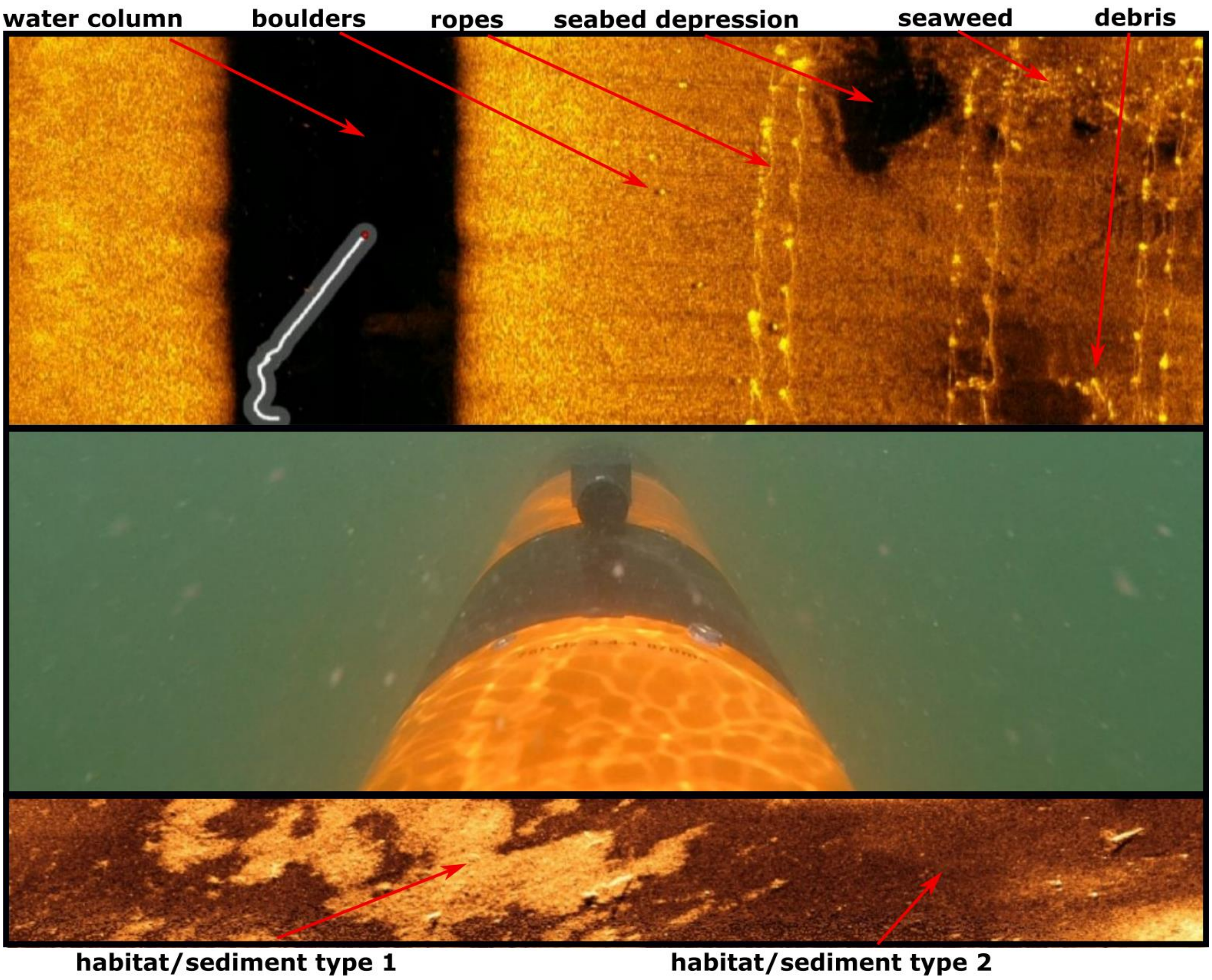


Figure 1 (Top) Acoustic side-scan sonar image indicating boulders, seaweed and debris on the seabed and seaweed ropes in the water column via high acoustic amplitudes (bright colors). Dark colors indicate areas with no or very little acoustic energy returning to the sonar as for the water column below the sonar and a depression on the seabed. (Middle) AUV travelling through the murky water. (Bottom) Acoustic image showing a heterogeneous seabed with two different habitat/sediment regions.

ROV experiments

The manual operations and high manoeuvrability of the ROV allowed the system to operate close to the seaweed and farm infrastructure. This resulted in capturing high quality images. The acquired data could be used to assess the seaweed growth, assess the scouring around the farm foundations, identify lost seaweed, assess sediment types and characterise marine habitats. The ROV was equipped with a navigation suite that allowed the operator to track the estimated location of the ROV during operation. Though the navigation algorithms worked as expected, waves caused the antenna to fail getting a robust GPS fix. An elevated antenna was used in a follow up harbour trial which provided good performance. The analysis of these experiments showed that for a track length of 100 m, a maximum position drift of 0.45% distance travelled and a 0.17 degree heading accuracy could be obtained. Furthermore, an absolute position estimate at the surface of <30 mm was obtained using the RTK sensor. These performance specification would allow for safe autonomous navigation in between the seaweed lines and potentially also within the optical visibility range in case the location of the seaweed lines is known with high accuracy. In case of strong currents, the performance of the system is expected to degrade and intermittent GPS fixes at the surface may be needed to guarantee safe and effective optical inspection of the seaweed.

Vehicle endurance & robustness

Free floating seaweeds got entangled in both the AUV and ROV propellors during their operation in the seaweed farm. The seaweed entanglement did not lead to a full system failure, but the vehicle navigation capabilities were severely compromised and resulted in a significant power drain of the battery. Improving the self-performance evaluation capabilities and propellor seaweed resistance of AUVs are therefore recommended.

Figure 2 ROV camera footages. (Top left) Scouring around farm foundations, (top right) growing seaweed, (bottom left) lost seaweed and debris on the seabed and (bottom right) extensive field of seaweed.

Conclusion and way forward

The AlgaeDemo project has evaluated the performance of low and mid-range Autonomous & Remotely operated Underwater Vehicles for seaweed farm site characterisation, the inspection of seaweed and the assessment of the seaweed farm structural integrity. The key robotic system capabilities that determine the performance of unmanned vehicles for seaweed farm monitoring where evaluated. In summary the results show that off the shelve AUVs and ROVs already provide a useful tool for seaweed farm operators. However, in order for AUVs to be able to safely and effectively carry out more complex tasks (e.g. the visual inspection of seaweeds) the endurance, robustness, navigation and planning capabilities need to be improved. While vehicle performance could be improved by using higher-grade navigation sensors and the usage of more powerful thrusters, this would significantly increase the cost of the system and hence not provide a cost effective alternative to human centric operations. Recent advances in sensory fusion and artificial intelligence are expected to improve the subsea navigation performance of AUVs without the need of using more expensive sensors. Improved navigation capabilities combined with more intelligent planning of vehicle trajectories (using information on the seaweed farm and METOCEAN forecasts of wind, waves and currents) are expected to provide the prerequisites for safe and effective seaweed farm monitoring using AUVs.

Project Identity

Coordinator Bert Groenendaal, bert.Groenendaal@telenet.be

Communication Jaap van Hal, jaap.vanhal@tno.nl

Project Officer Estelle Coornaert, estelle.coornaert@ec.europa.eu

Technical Task lead Bas Binnerts, bas.binnerts@tno.nl

Consortium

Duration Jan 2019 – Dec 2022

Website All AlgaeDemo Fact Sheets and other publications are available at:
Algaedemo website - https://www.algaedemo.eu/

If you have any further questions and for further discussions, please contact via the contact form at

https://www.algaedemo.eu/

Co-funded by the European Maritime and Fisheries Fund

This Fact Sheet is part of the AlgaeDemo project (EASME/EMFF/2017/1.2.1.12/S1 – DEMO Project – Sustainable Blue Economy). The project has received funding from the European Maritime and Fisheries Fund.