Advances in Seagrass Monitoring

Robotics, Deep Learning, and Actionable Insight

by David Hull and Tim Scott

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The invaluable contribution of seagrass meadows as critical ecosystems for marine biodiversity, carbon sequestration, and coastal protection has become increasingly studied and well documented over recent years. However, monitoring these underwater habitats has, until now, posed significant challenges and incurred substantial costs.

As an ecosystem service, the importance of seagrass meadows in providing vital ecological functions cannot be understated. They act as nurseries for marine species by providing shelter and food sources for juvenile fish, seahorses, and countless other organisms. Seagrass contributes to the purification of surrounding seawater and helps to stabilize the seabed, thereby playing an important role in reducing coastal erosion. Seagrass meadows also function as highly effective carbon sinks, sequestering carbon at rates which exceed terrestrial rainforest – a fact that has gained attention from scientists and policy-makers looking toward nature-based solutions as a means of addressing climate change.

But there are obstacles. Traditional monitoring programs for these ecosystems have been heavily reliant on labour intensive and costly diver surveys and camera-based techniques, which are sporadic and often unrepeatable. Ultimately, this restricts the acquisition of widespread spatial coverage, as well as the performance of accurate resurveys to capture temporal changes in the extent of the seagrass. At a time when precious natural capital assets are exposed to a slew of environmental threats, any sparsity of evidence that might support understanding of the rate of expansion or decline in these habitats results is a significant information gap for the practitioners involved in managing them.

Low Impact, Low-cost Robotic Solutions

The good news is that recent technology advances used to observe submerged aquatic vegetation (SAV) are demonstrating significant potential to revolutionize seagrass monitoring. Leveraging the capability of surface robotic platforms and advanced data analysis techniques has shown that accurate and comprehensive spatial and temporal assessment of coverage and density is possible without harming the environment, or the commissioner's budget.

This essay examines developments in the field realized through a collaborative partnership between the University of Plymouth, recognized globally for its coastal science expertise, and HydroSurv, a U.K.-based ocean technology start-up that designs, builds, and deploys uncrewed surface vessels (USVs). Supported by funding from Innovate UK and the Department for Environment Farming & Rural Affairs, the partnership's work on seagrass projects at important meadow locations in the U.K. has highlighted a myriad of benefits possible when deploying robotics, deep learning algorithms, and cloud-based data visualization with the aim of driving effective conservation and restoration.

Central to the collaboration is the integration of an advanced sensor array onto small USVs. Since July 2021, the partners have been on a journey to configure solutions for scale commercial adoption in the field of SAV monitoring that provide a comprehensive understanding of seagrass meadows and surrounding environments.

New Developments in Payload and Data Processing

The central component of the USV's payload is a Valeport VA500 altimeter, recognized for its cutting-edge signal processing capabilities. Having engaged with the University of Plymouth's early research using acoustic ground discrimination, Valeport undertook custom modifications to the firmware on the instrument exclusively for this use-case, ensuring low noise and high-quality acoustic profiles sampling at up to 10 Hz. Designed for underwater positioning, the VA500 altimeter is typically installed on autonomous, remotely operated, or towed underwater vehicles to

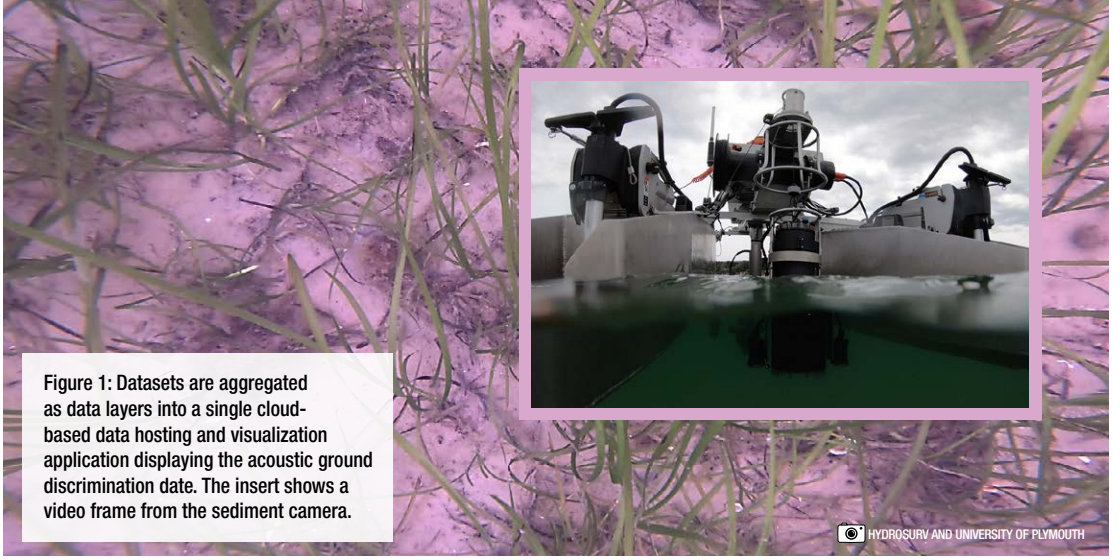

Figure 1: Datasets are aggregated as data layers into a single cloud-based data hosting and visualization application displaying the acoustic ground discrimination date. The insert shows a video frame from the sediment camera.

HYDROSURV AND UNIVERSITY OF PLYMOUTH

provide precise measurement of the altitude from the seabed. Using advanced digital signal processing techniques, the VA500 effectively filters out ambient noise and focuses on signal returns.

Operating on a frequency of 500 kHz, the VA500 altimeter emits an acoustic pulse and measures the time it takes for echoes from distant surfaces to return. By utilizing the known speed of sound in water, the sensor accurately calculates the distance based on the measured time. Now in their second year of delivering monitoring campaigns with the system, the University of Plymouth and HydroSurv teams have recently enhanced the data accuracy from this sensor by adding additional measurements from a hull mounted Valeport sound velocity sensor to improve the accuracy of the soundings.

Where the standard VA500 altimeter receives multiple signal echoes and must determine which echo corresponds to the seabed, the customized instrument used in this project provides the full echo response. Subsequently, all measured echoes, along with their strength and sharpness, are further analyzed in the processing algorithm. The University of Plymouth's SeagrassNet deep learning algorithm employs a recurrent neural network to detect and classify the presence of seagrass, and the elevation and echo strength of the seagrass canopy, enabling a determination of relative density.

In addition to the primary acoustic payload, Valeport turbidity and chlorophyll a sensors acquire other measurements requested by commissioning stakeholders to inform work site environmental characterization.

Ground Truthing and Sediment Analysis Cameras

In early summer 2023, significant new capability milestones were achieved by adding drop camera capabilities to the USV, operated using a new profiling winch and customized control system. The equipment spread included a high-resolution ground truthing camera to correlate acoustic ground discrimination datasets with high-accuracy georeferenced photographic data. In addition, a new sediment analysis camera, which lands a macro lens camera in direct contact with seabed sediments, collected datasets that were then analyzed using a digital grain size algorithm, incorporated into SeagrassNet, to classify the sediment type.

Collectively, these new datasets are then aggregated as data layers into a single cloud-based data hosting and visualization application displaying the acoustic ground discrimination data (Figure 1). This tool can be used by practitioners to determine the seagrass biomass characteristics and evaluate the carbon sequestration potential of the work site to inform conservation strategy.

When compared with traditional diver-based approaches, the accuracy and efficiency of

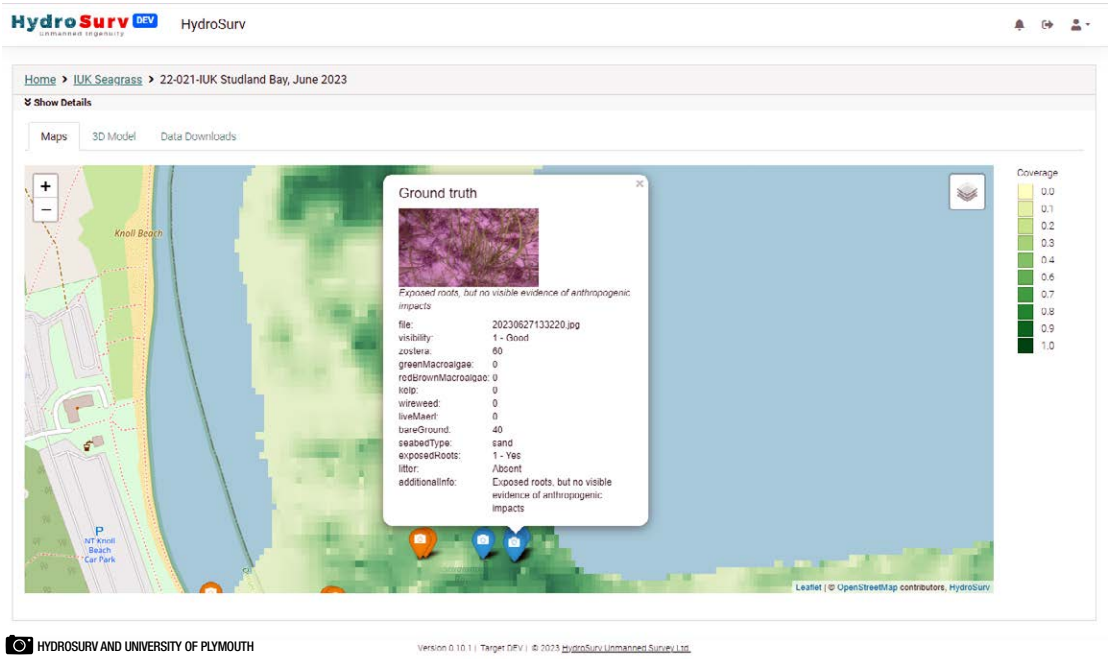

Figure 2: *EasySurv* is an award-winning geospatial data hosting and visualization application.

seagrass monitoring is significantly improved by covering larger areas. This solution facilitates the planning of protection and regeneration projects, while deployment of lightweight electric survey platforms operated from the shore enables repeatable mapping campaigns and ultimately slashes the cost and carbon intensity of the operation.

Actionable Information Delivered through the Cloud

The University of Plymouth developed data processing tools with the aim of creating a more accurate and efficient pipeline, reducing the reliance on expert data processors within the workflow. Aligned to the SeagrassNet toolchain for machine learning, streamlined data cleaning and metrics reporting, HydroSurv has made enhancements to the cloud-based application used by commissioners to visualize and interpret the processed survey data.

Originally designed for coastal process and dredge applications, *EasySurv* is an award-winning geospatial data hosting and visualization application (Figure 2). It seamlessly integrates project management, data storage, and visualization within a secure web-based platform. An important aspect of its system design is the elimination of the need for specialized GIS skills to perform basic visualization or difference modelling tasks.

EasySurv offers users the ability to create unique login credentials with varying content editing rights for creating and viewing survey data. Key stakeholders – including the Environment Agency, Natural England, Cornwall Wildlife Trust, and Cornwall Inshore Fisheries and Conservation Authority – provided positive feedback during the development phase. They particularly appreciated features like 2D heatmap comparisons between Z-axis datasets, uploaded from the outputs of the SeagrassNet application.

In the current project, additional metadata such as turbidity and chlorophyll a measurements can be displayed on the chart, alongside georeferenced content from the ground truthing cameras and sediment analysis (Figure 3). For scientists using their own interpretation tools, the original raw data is also available through the application, alongside the processed data deliverables. This ensures flexibility and accessibility for all researchers.

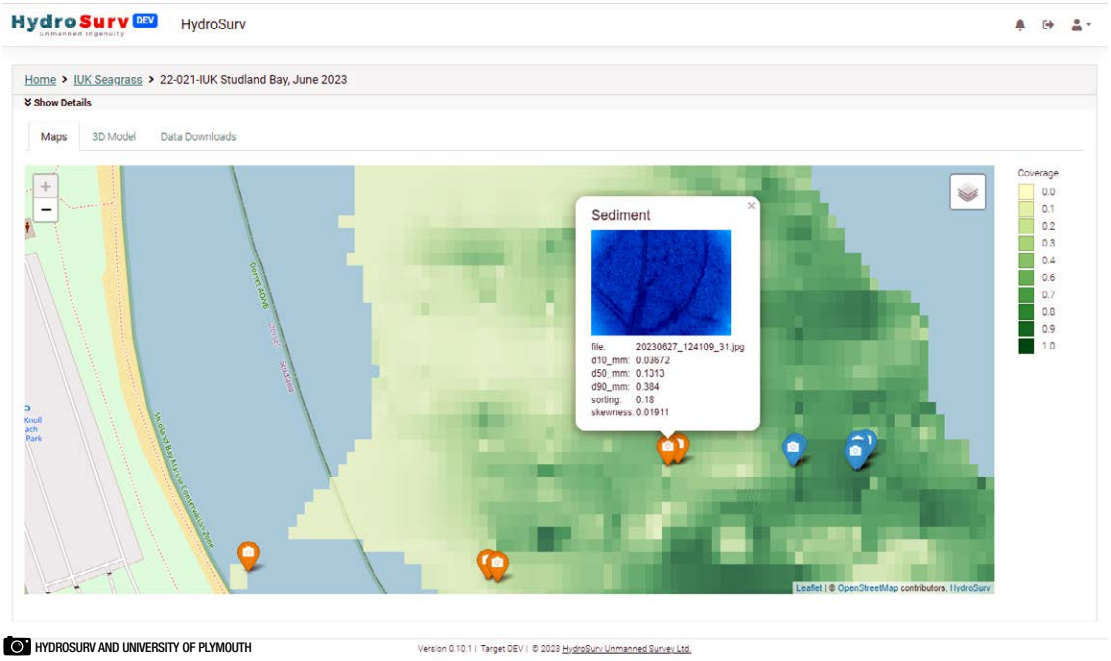

Figure 3: In *EasySurv* additional metadata can be displayed on the chart alongside georeferenced content from the ground truthing cameras and sediment analysis.

Enhancements to the Robotic Survey Platform

The ongoing work delivered by the project team has primarily focused on HydroSurv's REAV-28 USV (Figure 4). The versatile USV platform measures just 2.8 m in length and was initially developed to be easily transportable and deployable by a small survey team on remote and often resource-constrained beaches and foreshores. Designed for day work operations, the REAV-28 is equipped with twin electric outboards, allowing it to achieve speeds of up to 5 knots. Its propulsion batteries enable approximately nine hours of continuous operation.

In the second phase of development, HydroSurv dedicated significant efforts to enhancing the winch control system. This included a new automation system and a front-end application capable of precise bottom tracking and constant altitude line control for deploying the ground truthing camera. A notable addition is the sediment camera mode, which automates the process of lowering the macro lens camera into contact with the seafloor from a safe distance above the seabed.

Initial activity to validate the system's functionality was undertaken during the resurvey of work sites for the Environment Agency in July 2023, during which the team successfully deployed the new winch and camera systems. Building upon these results and extensive commissioner engagement, a prolonged period of system fielding, optimization, and resurveys that demonstrate the fidelity of the integrated survey system are now planned for the coming two years.

Roadmap to Scale Deployment

The collaboration between the University of Plymouth and HydroSurv was initiated with a well-defined, mutual vision to create a comprehensive, all-in-one solution that would empower the commissioner with easy access to seagrass habitat information. Throughout the delivery of works, the most significant validation has been the enthusiastic interest and active engagement of stakeholders responsible for the management of these natural capital assets, whose involvement served as testament to the value and relevance of the initial vision.

In the next phase of the development roadmap, the project aims to broaden the scope of

Figure 4: HydroSurv's REAV-28 uncrewed surface vessel (USV) measures 2.8 m in length and is easily transportable and deployable. It is equipped with twin electric outboards; its propulsion batteries enable approximately nine hours of continuous operation.

classification beyond seagrass habitats to include other SAV types. Additionally, the focus will shift towards addressing various critical components for scaling deployment of the technological solution. This encompasses areas such as regulatory compliance and certification of both the robotic platforms and operators involved. In parallel, efforts will be directed towards achieving tighter integration among the individual toolchains within the data acquisition and processing workflow. Ultimately, the project aims to expand deployment, not only in the United Kingdom, but also in other overseas territories to extend reach and impact.

Significant development efforts by HydroSurv and the University of Plymouth have led to successful demonstrations combining the advanced deep learning algorithms with novel practical solutions to data acquisition that enable precise assessment of seagrass distribution and density. Given the urgent requirement for viable, deployable solutions, time will play a crucial role in the next phase of the partnership's endeavours.

David Hull is the founder and CEO of HydroSurv Unmanned Survey (UK) Ltd. He is an accomplished entrepreneur working in the field of uncrewed surface vessels (USVs). In 2019, he founded HydroSurv, a research-informed provider of USV technology focused on impact-led use cases that harness the potential of surface robotic systems. Under his leadership, HydroSurv has delivered more than 50 USV projects including the design, construction, and deployment of 18 USVs for customers in the U.K., Europe, North America, and Asia Pacific regions. Currently, Mr. Hull's focus lies in developing large scale commercial pilots within the realm of natural capital assessment, asset inspection, and hydrographic survey where he is committed to driving the adoption of sustainable technologies in industrial use.

Dr. Tim Scott is an associate professor in ocean exploration at the University of Plymouth. Working within the Coastal Processes Research Group, he has more than 20 years' experience in the collection and analysis of coastal morphological, hydrodynamic, and hydrographic data. Recent research has focused on the use of autonomous platforms for coastal/marine environmental sensing.