Underwater hyperspectral imagery for *Posidonia Oceanica* mapping: challenges and preliminary results from POSEIDON Project

Valeria Longhi[1], Nives Grasso[2], Paolo Felice Maschio[2], Fabio Menna[3], Arianna Pansini[3], Andrea Maria Lingua[2], Filiberto Chiabrando[4], Erica Nocerino[5], Giulia Ceccherelli[3], Sabrina Rossi[6]

[1] Interuniversity Department of Regional and Urban Studies and Planning (DIST), Politecnico di Torino, Italy – valeria.longhi@polito.it
[2] Department of Environment, Land and Infrastructure Engineering (DIATI), Politecnico di Torino, Italy – (nives.grasso, andrea.lingua, paolo.maschio)@polito.it
[3] Department of Chemical, Physical, Mathematical and Natural Sciences, University of Sassari, Italy – (fmenna, apansini, cecche@uniss.it)
[4] Department of Architecture and Design (DAD) Politecnico di Torino, Italy – filiberto.chiabrando@polito.it
[5] Department of Humanities and Social Sciences, University of Sassari, Italy - enocerino@uniss.it; [6] Biru srl, Italy - rossi@culuccia.org

ABSTRACT

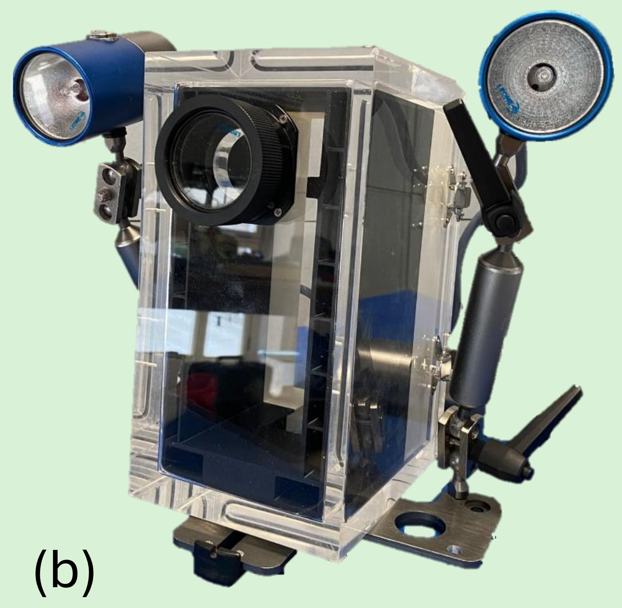
Posidonia oceanica (PO) meadows are important ecosystems in the Mediterranean, supporting biodiversity and ecosystem services, yet they face increasing threats due to anthropogenic pressures and climate change. To address these challenges, the POSEIDON project aims to develop ultra-high-resolution (UHR) and beyond ultra-high-resolution (BUHR) mapping methods for PO monitoring. This study focuses on **underwater hyperspectral imagery (UHI)** as a tool to complement and support the standard monitoring protocols established by ISPRA. Data were collected along the northern coast of Sardinia, with hyperspectral acquisitions performed both underwater, at depths of 5–15 meters, and out of the water, over collected samples, using a Senop Rikola hyperspectral camera. The study faced several challenges, including image blurring due to the movement of seagrass and light absorption by water, which limits the effectiveness of infrared bands. Despite these difficulties, the preliminary tests provided valuable insights into the system's limitations and suggested improvements for future data acquisition. This poster outlines the methodology, presents initial results, and discusses strategies to enhance underwater hyperspectral data quality for future monitoring efforts.

METHODOLOGY

1. The design and building of the UHI

The UHI (Underwater Hyperspectral Imagery) system consists of a **Rikola Senop hyperspectral camera**, showed in Figure (a). It has a spectral range of 500-900 nm, a spectral resolution of 1 nm, and captures images with a resolution of 1010 x 1010 pixels. The system is housed in a custom-designed waterproof case with a flat port (b) that accommodates the camera and its power supply. Additionally, it includes a 3-halogen-lamp lighting system (b), a tripod, and calibration targets (c).


(a)


(b)

(c)

2. Data acquisition

UNDERWATER

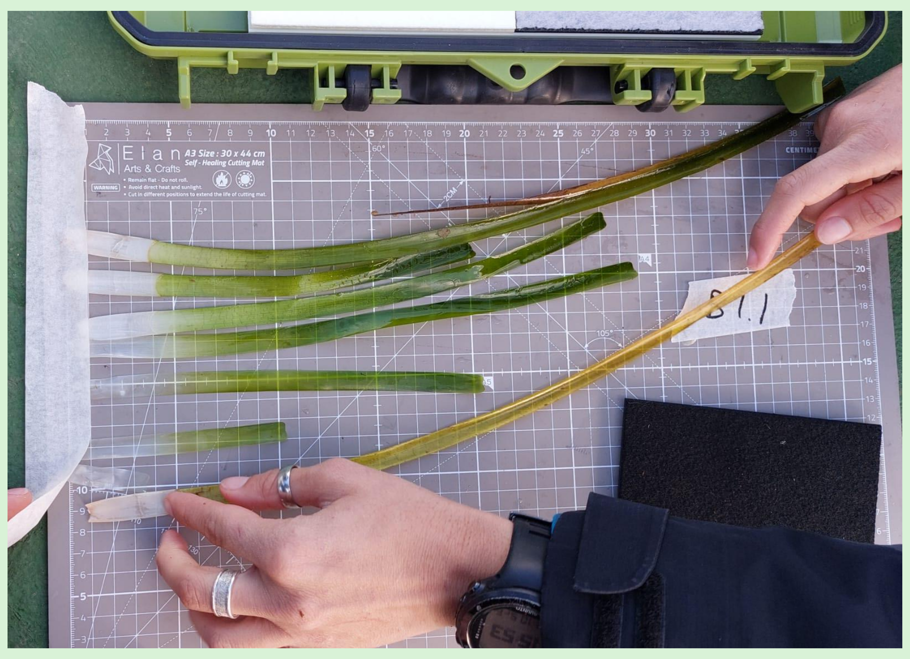
The camera has a fixed-focus lens set at the hyperfocal distance and sharp images start at 50 cm distance of camera-object, where the GSD is 0.20 mm/pixel and the footprint is 24 x 24 cm^2. The final acquisition set up used was at 15m of depth, as for ISPRA traditional PO monitoring, acquiring at least 3 quadrats 40x40cm along a transect of 20x5m.

The camera is used in standalone mode, i.e. selecting in advance the acquisition settings, such as an integration time of 100 ms and a spectral sequence covering the full spectrum with a step size of 13 nm and a narrow full-width half maximum (FWHM).

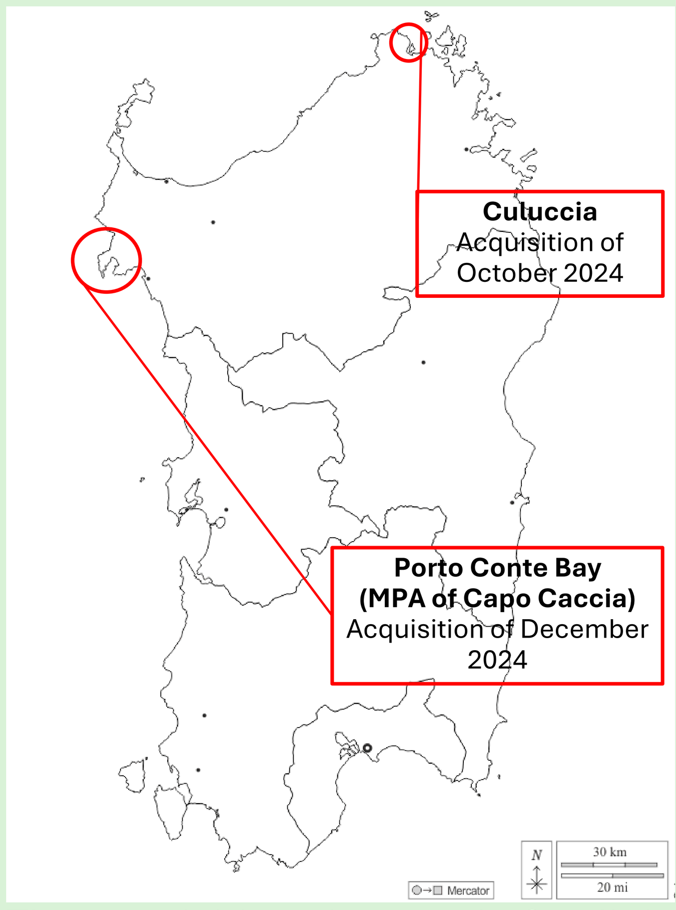
Underwater acquisition took place in October in Culuccia and in December 2024 in Porto Conte.

The picture on the left shows the acquisition during the survey in Porto Conte - December 2024

OUT OF THE WATER



Also out of the water, the same spectral sequence of bands is acquired, with a shorter integration time due to more intense light conditions. The picture above was taken during the «dry» acquisition in Porto Conte.



The acquisition sites are in Sardinia, as shown in the picture above.

3. Processing and spectrum extraction

The processing workflow begins with radiometric calibration, performed using the Senop Hyperspectral Imager software. Calibration employs both a dark reference (obtained by covering the lens with a black object) and a white reference target (a MAPIR Light Gray card with 65% reflectance). Then, spectral extraction was carried out on ROIs, selected from different portions of the seagrass leaves, including green tissue, intermediate zones, and adult leaf sections. To derive a representative spectral signature, the spectra from all ROIs were averaged, and the standard deviation was calculated to assess variability across wavelengths. Finally, a Principal component analysis was used to identify the wavelengths corresponding to the factors that explain 95% of the variability of the dataset to possibly develop a targeted vegetation index.

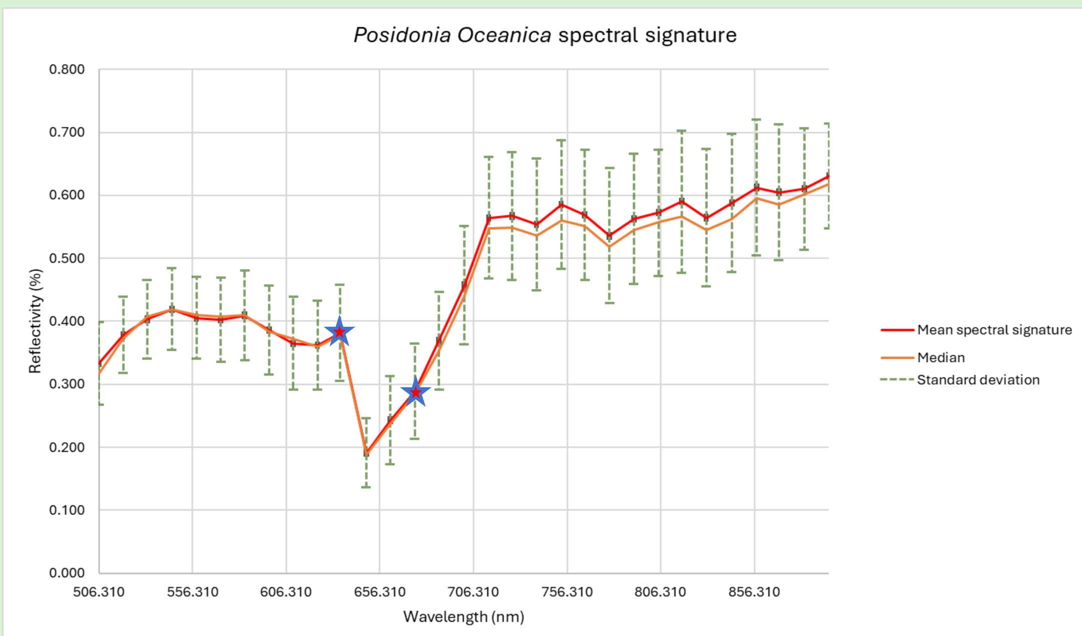
PRELIMINARY RESULTS

UNDERWATER

Underwater hypercubes posed significant challenges in this project. During our field surveys last October and December, images were blurry and dark, making processing impossible. The blurriness stemmed from the movement of seagrass in ocean currents and the long capture times of the camera.

While the camera acquires in its different bands, PO moves: the pictures on the side are two different bands from the same hypercube. The darkness was also due to water's inherent properties, which absorb light more in infrared wavelengths than in visible light.

OUT OF THE WATER

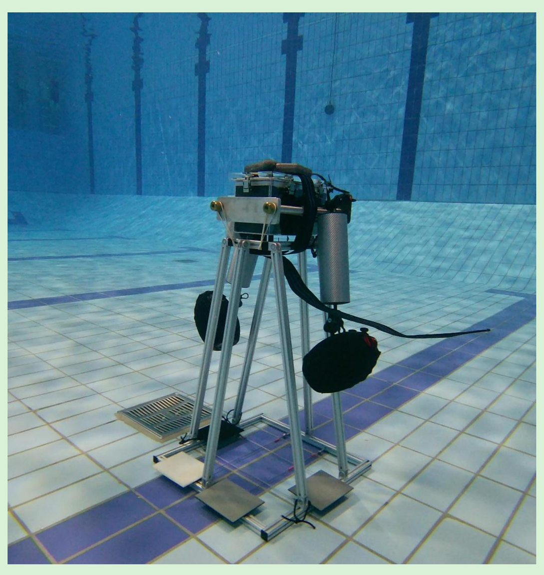


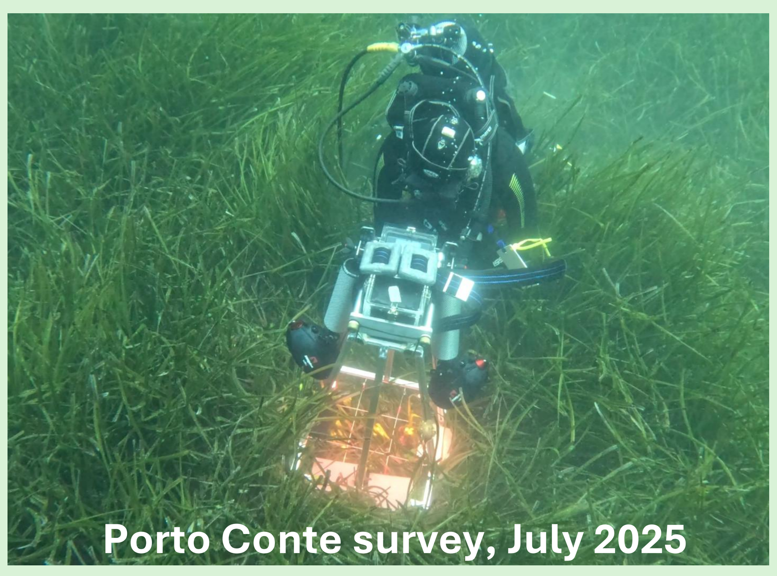
The average spectrum shows typical chlorophyll absorption features and a clear NIR plateau, similar to terrestrial vegetation.

A principal component analysis highlighted specific wavelengths, such as 687.9 and 634.8 nm, which are highlighted in the graph by a star.

FUTURE WORKS

For **underwater acquisition**, we focused on enhancing the acquisition setup. This involved creating a more stable structure and using more powerful lights. We tested the new setup first in a pool and, for the first time in the sea, last week in Porto Conte, where we successfully acquired underwater hypercubes without any blur or darkness!




Porto Conte survey, July 2025

As for the **processing**, future works include exploring image calibration in an open-source environment to allow greater control over the procedure.

As for the **analysis of the spectral signature**, the next step is to investigate the correlation between spectral indices created from these wavelengths, such as the Normalized Difference Vegetation Index (NDVI), and traditional biological indicators like fatty acids or pigments. These indicators will be analyzed using the samples collected in Porto Conte and future collection surveys.

Politecnico di Torino · Geomatics Lab · UNISS Università degli Studi di Sassari · Funded by the European Union · Ministero dell'Università e della Ricerca · Italiadomani Piano Nazionale di Ripresa e Resilienza