3rd International Workshop
3D underwater mapping from above and below
8-11 July 2025 - TU Wien

Underwater optical metrology for precision monitoring of marine habitats: the MANATEE project

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MANATEE
Monitoring and mApping of mariNe hAbitat with inTegrated gEomatics technologiEs)

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NEXT STEPS

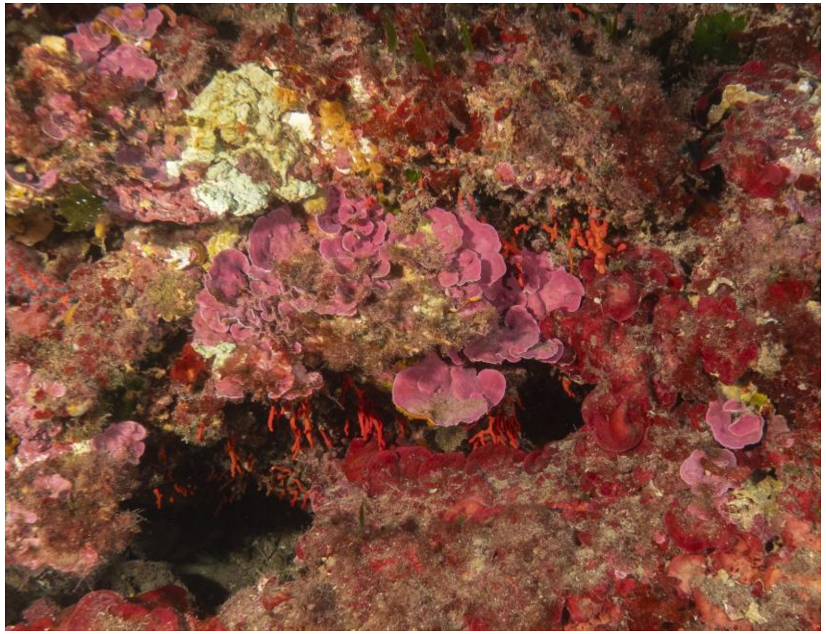
INTRODUCTION

Marine habitat monitoring

EU (MSFD 2008/56/CE) and national (for Italy D.Lgs. 190/2010) directives enforces marine habitat monitoring to evaluate the impact of climate change as anthropogenic global warming increases.

Marine habitat monitoring

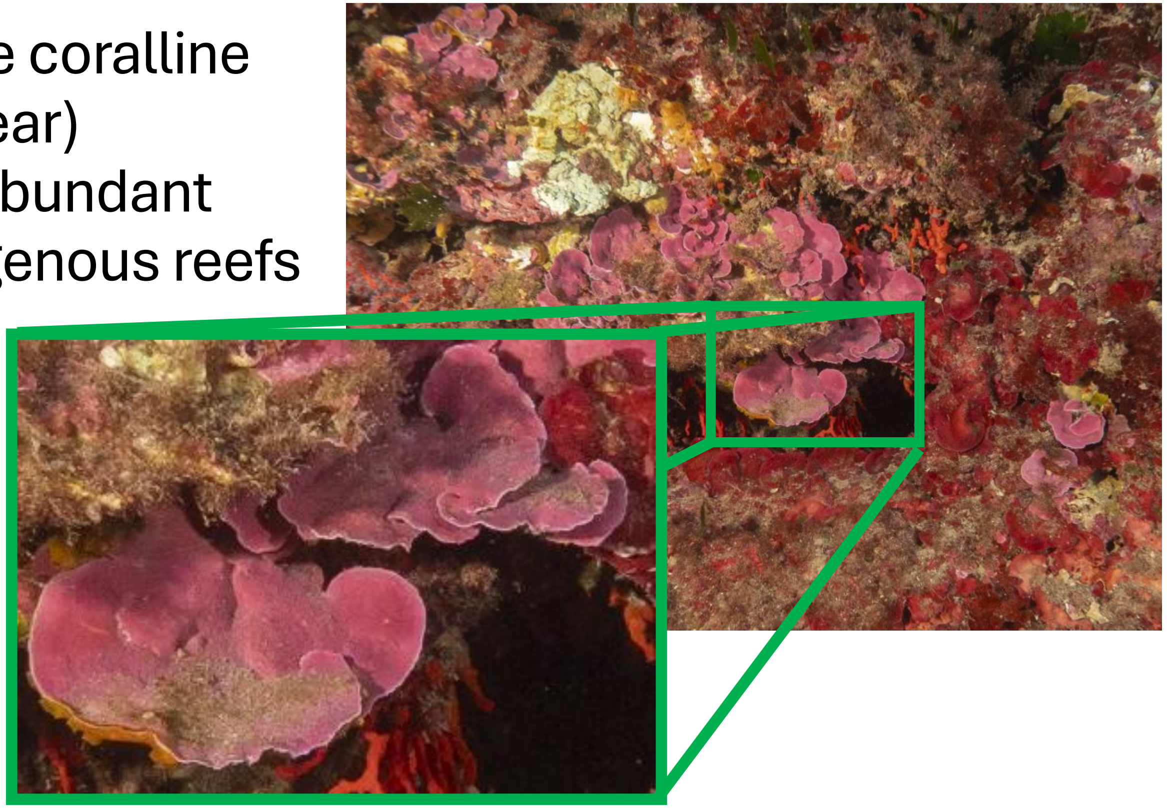
Classified in the European Red List of Habitats, there are coralligenous reefs.



Marine habitat monitoring

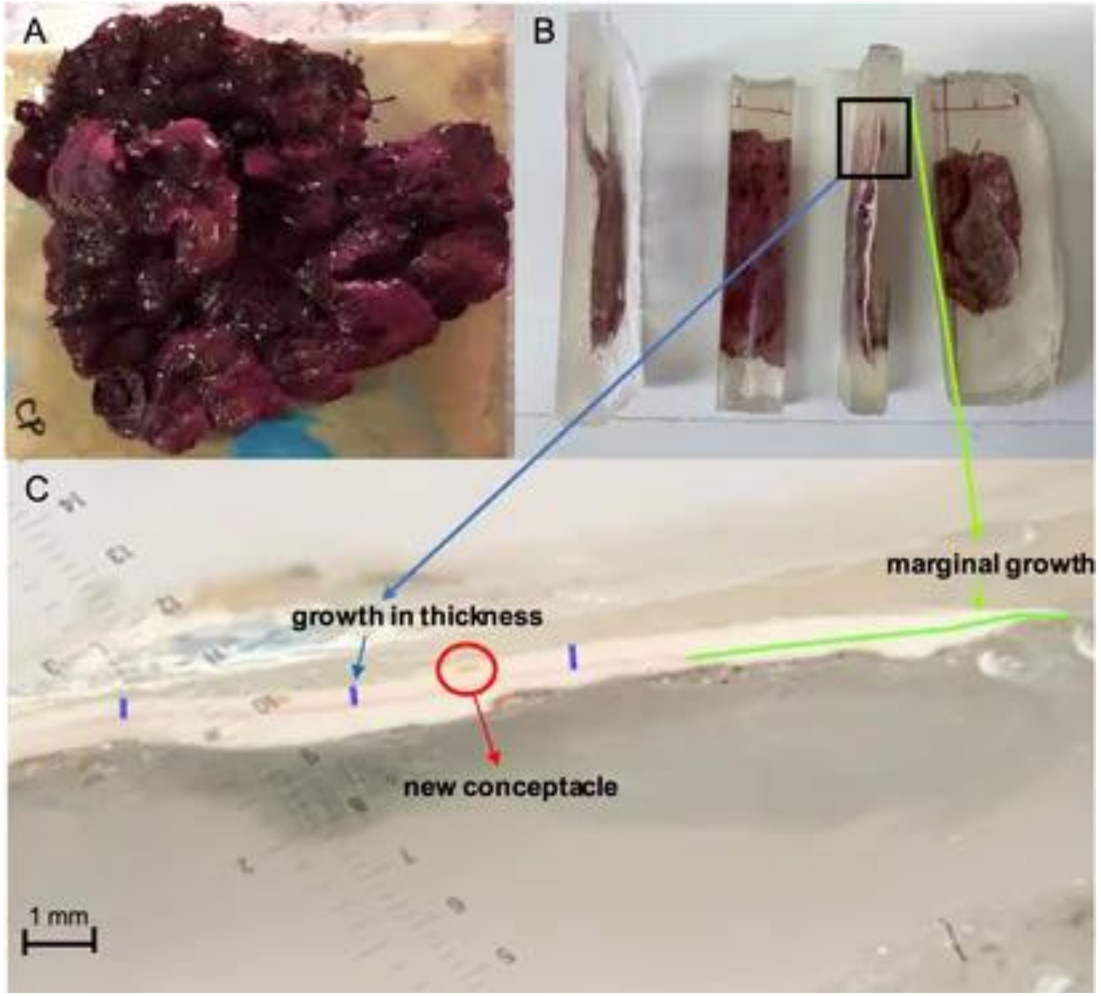
Classified in the European Red List of Habitats, there are coralligenous reefs.

Lithophyllum (*L.*) *stictiforme* is a crustose coralline algae (CCA), slow-growing (a few mm/year) calcareous red algae is one of the most abundant habitat-building in Mediterranean coralligenous reefs



Marine habitat monitoring

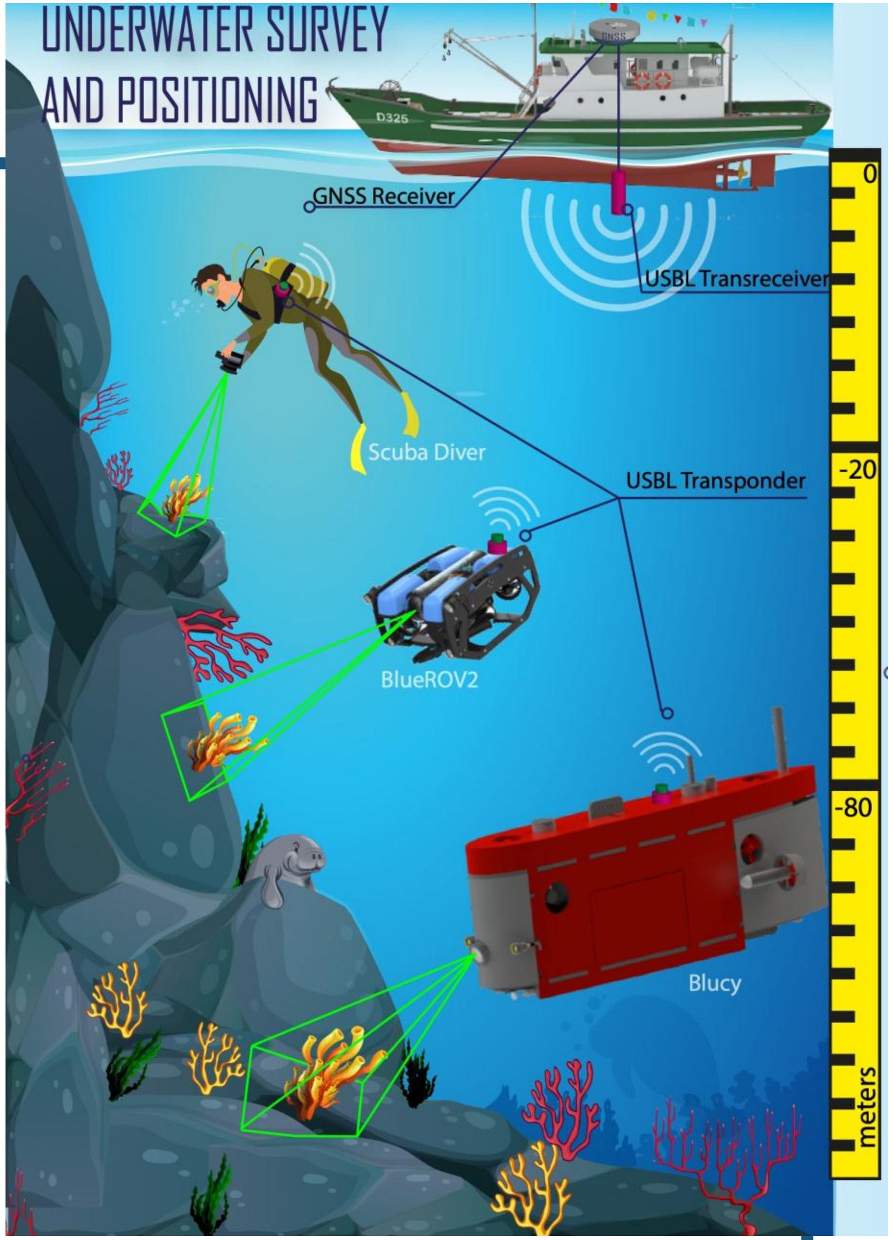
L. stictiforme was recently studied for the first time in the field to assess the effects of temperature variations on mortality, growth employing destructive sampling methods



From Pinna et al., 2022:
https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2022.930750/full

The MANATEE project

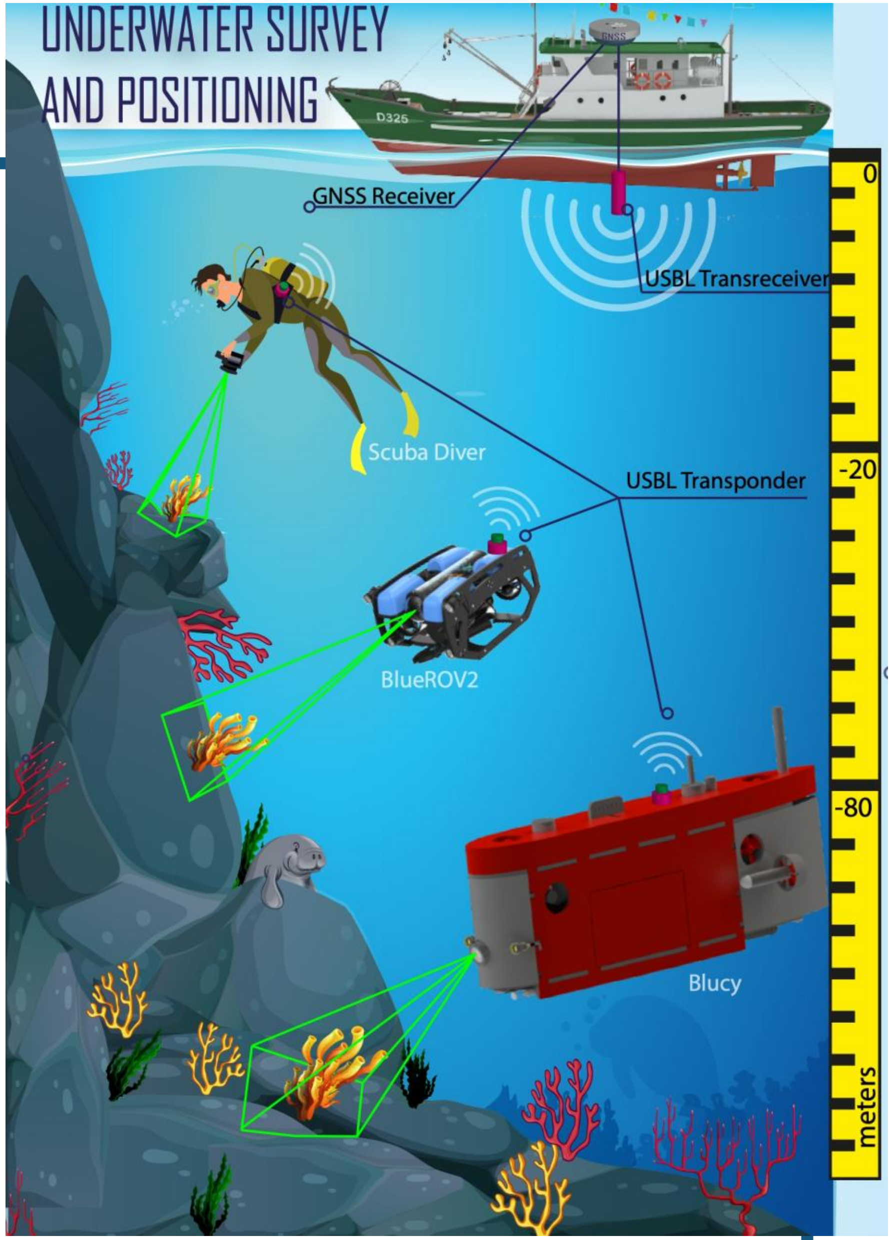
Monitoring and mApping of mariNe hAbitat with inTegrated gEomatics technologiEs – MANATEE: to enable scalable, high-resolution, and non-invasive procedures in support of monitoring practices of vulnerable marine ecosystems.



The MANATEE project

Monitoring and mApping of mariNe hAbitat with inTegrated gEomatics technologiEs – MANATEE: to enable scalable, high-resolution, and non-invasive procedures in support of monitoring practices of vulnerable marine ecosystems.

It involves three complementary platforms, ideally targeting a specific depth range but tested on a common experiment within the project framework.



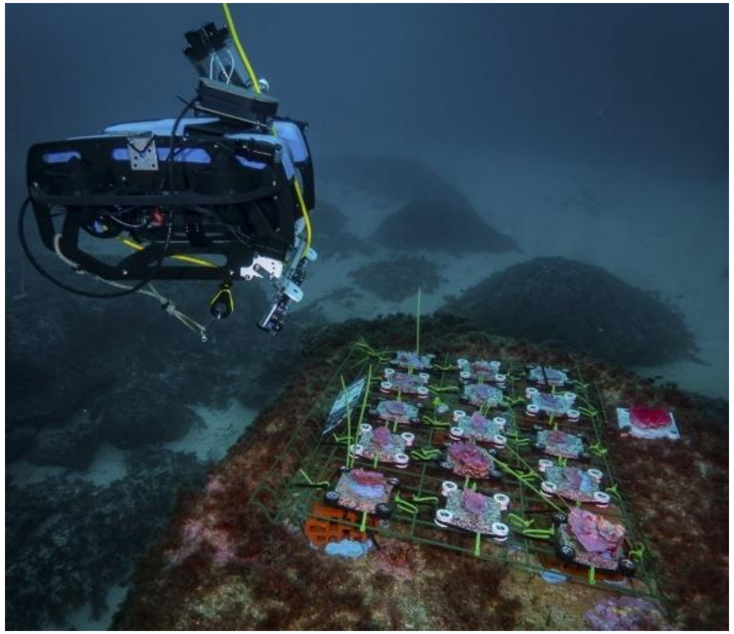
The VIP-FROG

An integrated photogrammetry system for divers the VIP (visual inertial pressure)-FROG guides a diver in the execution of a photogrammetric survey via vSLAM:

Customized BlueROV2

In addition to standard equipment, our is fitted with:

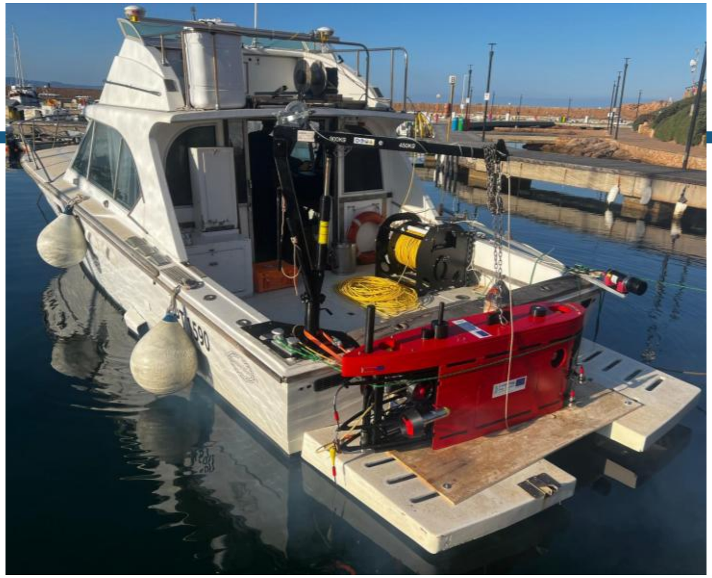
- A GoPro Hero 11 stereo cam system, synchronised via a smartphone-controlled remote system;
- A 20 MP global shutter Sony IMX541 camera with with a 12mm focal length lens managed by a Raspberry Pi enclosed in a custom-designed underwater housing



Blucy

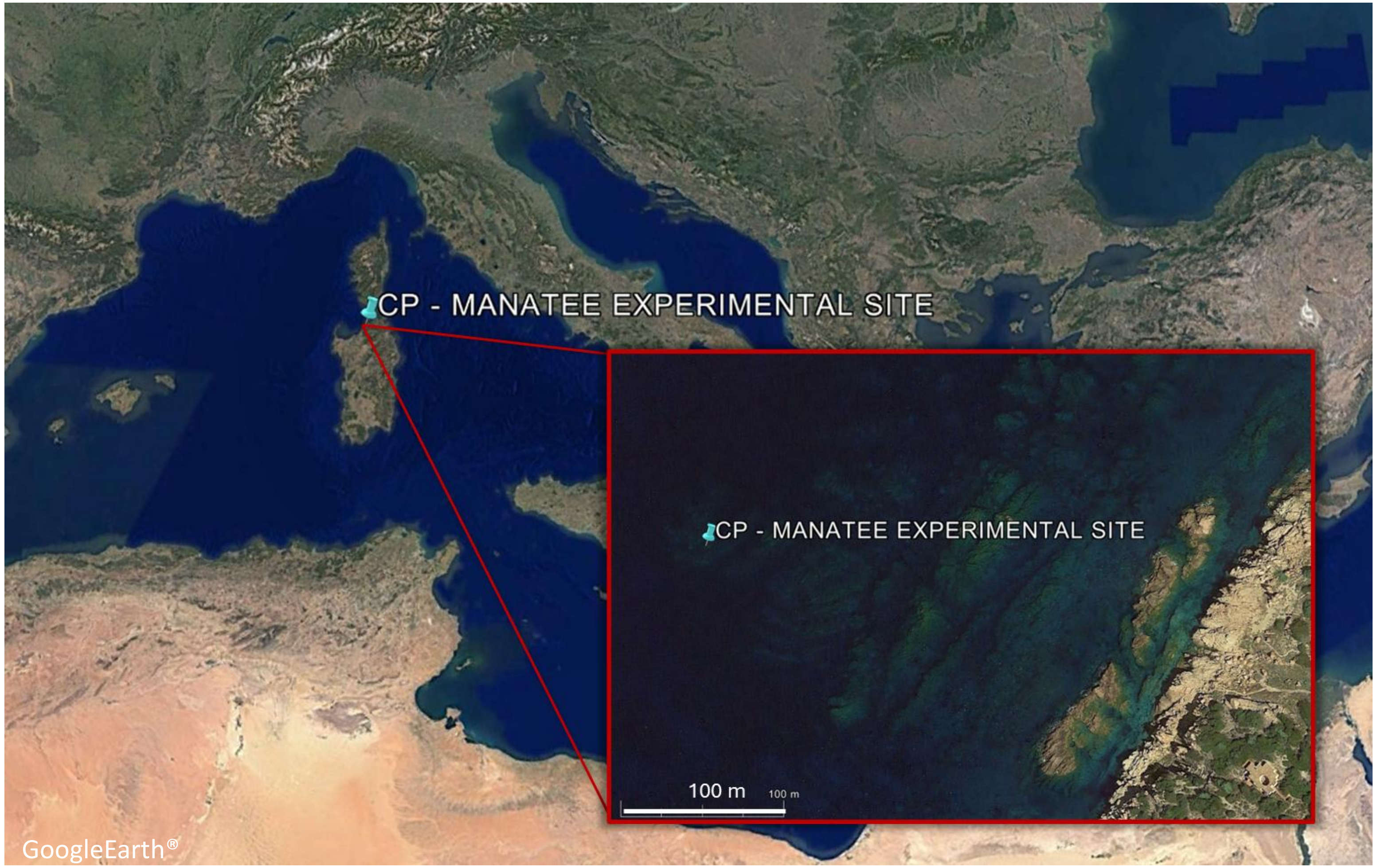
An observation-class UUV developed within SUSHI DROP (SUstainable fiSHeries wIth DROnes data Processing) project, Blucy integrates:

- GNSS-aided inertial unit
- fibre-optic gyroscope
- Doppler velocity log (DVL)
- Ultra-Short Baseline (USBL)
- downward-facing altimeter (single-beam sonar)
- mini CTD probe (conductivity, temperature, depth)
- forward-facing PilotCam provides live HD
- multibeam echosounder (MBES)
- downward-looking BottomCam (Nikon Z6 mirrorless with 24 mm lens)



MATERIAL AND METHODS

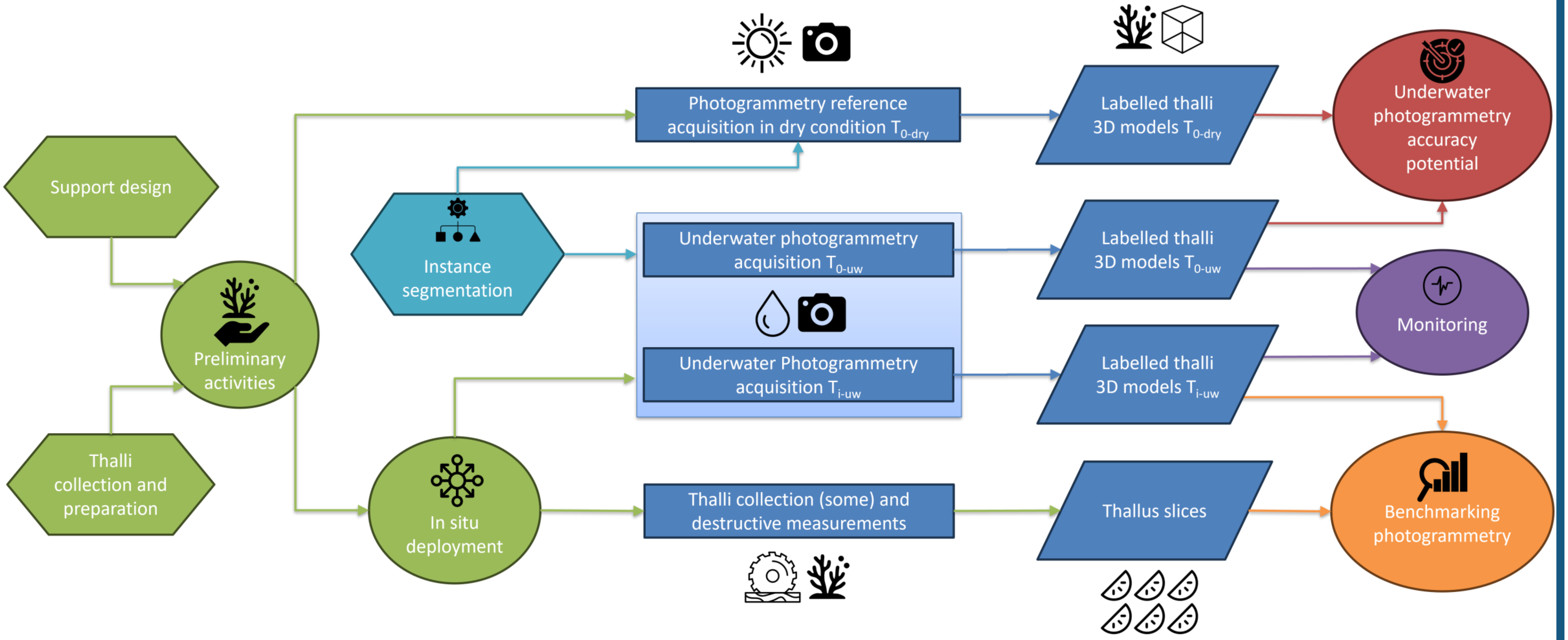
The experimental site



The experimental site

The coralligenous formation of the study area spans depths of 15 to 40 m and is mainly built up by massive calcareous structures dominated by red CCAs

The experimental design



Preliminary activities

30 thalli of *L. stictiforme* were collected from the wall in the experimental site by SCUBA divers.

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30 thalli of *L. stictiforme* were collected from the wall in the experimental site by SCUBA divers.

They were subsequently immersed in a solution of Alizarine, a red stain used to highlight the growth of their calcareous structures over time.

Preliminary activities

Each thallus was fixed on granite tiles, specifically designed for the experiment, and equipped with four coded photogrammetric targets.

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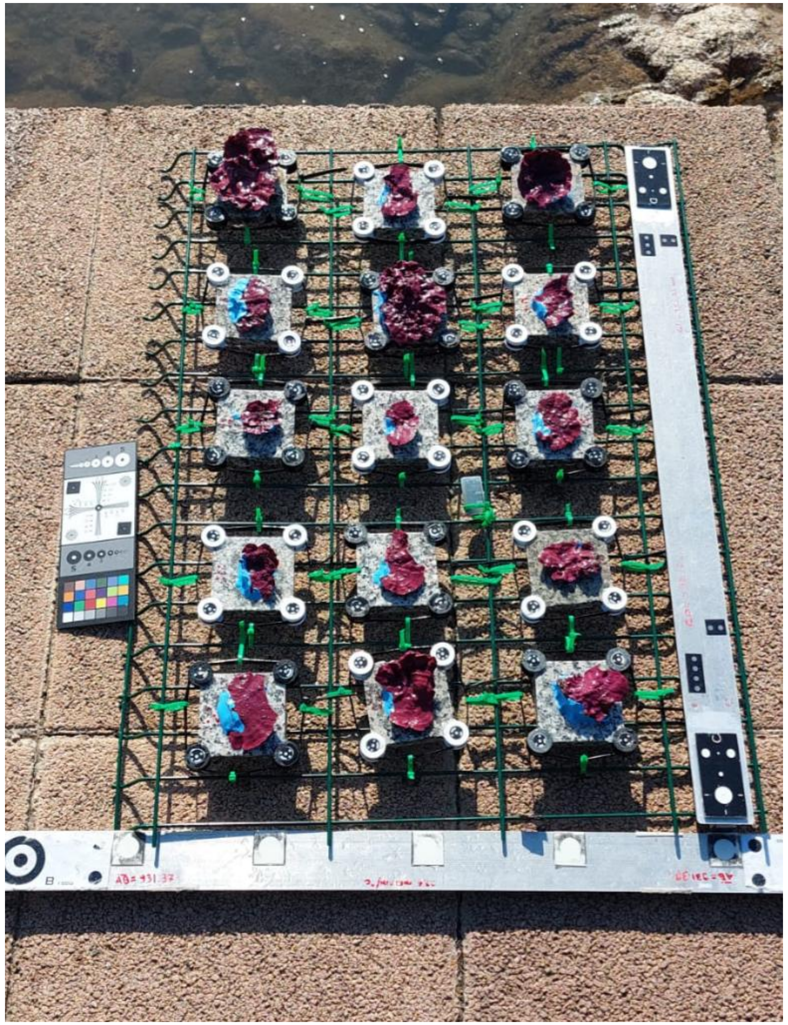
Each thallus was fixed on granite tiles, specifically designed for the experiment, and equipped with four coded photogrammetric targets.

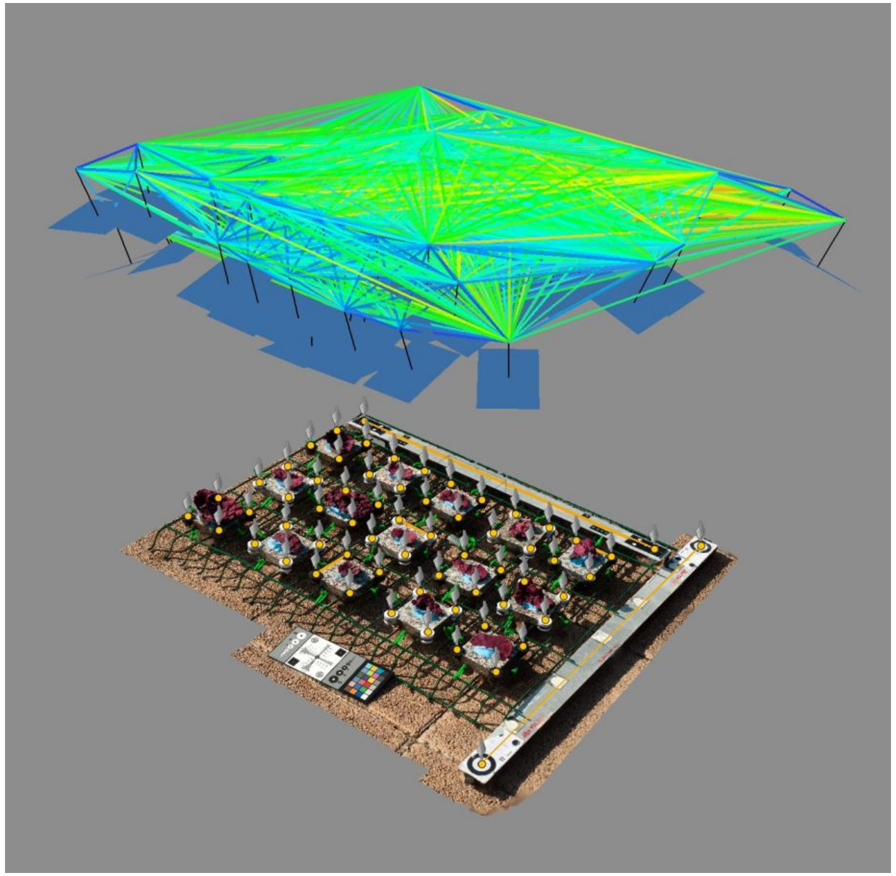
The tiles were secured on two electro-welded nets that were then anchored on ad-hoc placed pillars to a depth of about 38 meters on the seabed.



The reference survey ($T_{0\text{-}dry}$)

The grids with the thalli were measured in dry conditions with a DSLR Nikon D700 equipped with a 50 mm lens:

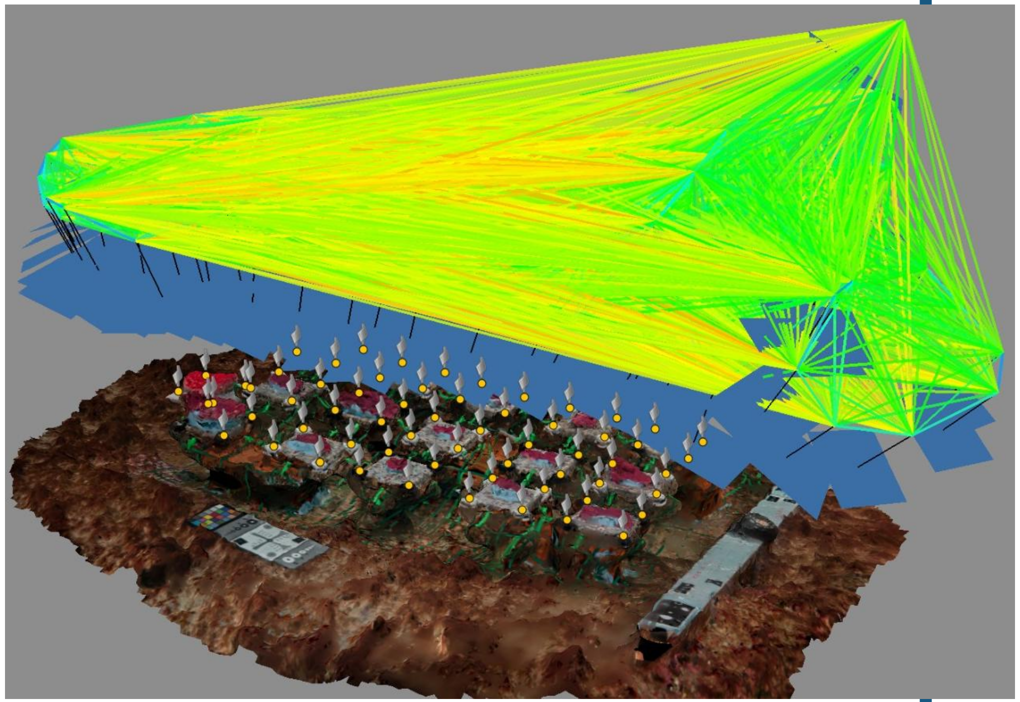
- 100 oblique and nadir-looking photos
- GSD better than 0.15 mm
- 10 x known lengths on two 1 m long scale bars
- 1 x colour checker
- RMS reprojection error = 0.5 pixel (>0.1 pixel on the targets)
- LME better than 0.1 mm
- Resolution mesh model ≈ 0.25 mm



Underwater photogrammetric survey ($T_{0\text{-}UW}$)

The grids with the thalli were measured underwater an Olympus OM-D E-M1 II MFT 20MP mirrorless camera with an Olympus 9-18mm lens:

- 200 oblique and nadir-looking photos
- GSD better than 0.2 mm
- 10 x known lengths on two 1 m long scale bars
- 1 x colour checker
- RMS reprojection error = 1.5 pixel (>0.5 pixel on the targets)
- LME better than 0.25 mm
- Resolution mesh model ≈ 0.5 mm



Underwater photogrammetric surveys ($T_{1\text{-}UW}$)

After about two weeks, two underwater surveys were carried out at 24-hour intervals, referred to as $T_{1.1\text{-}uw}$ and $T_{1.2\text{-}uw}$.

The second survey was executed after the micro-ROV inadvertently impacted one of the grids during its movement.

- GSD better than 0.2 mm
- RMS reprojection error = 2 pixel (>0.7 pixel on the targets)
- LME better than 0.25 mm

Instance segmentation of *L. stictiforme* thalli

Via Roboflow, we manually labelled about 200 *L. stictiforme* thallus instances in 20 images extracted from the $T_{1.1\text{-uw}}$ dataset.
After augmentation to increase the diversity and size of our training dataset, the labelled images were split into the canonical train (42 images), validation (4 images), and test (2 images) sets.

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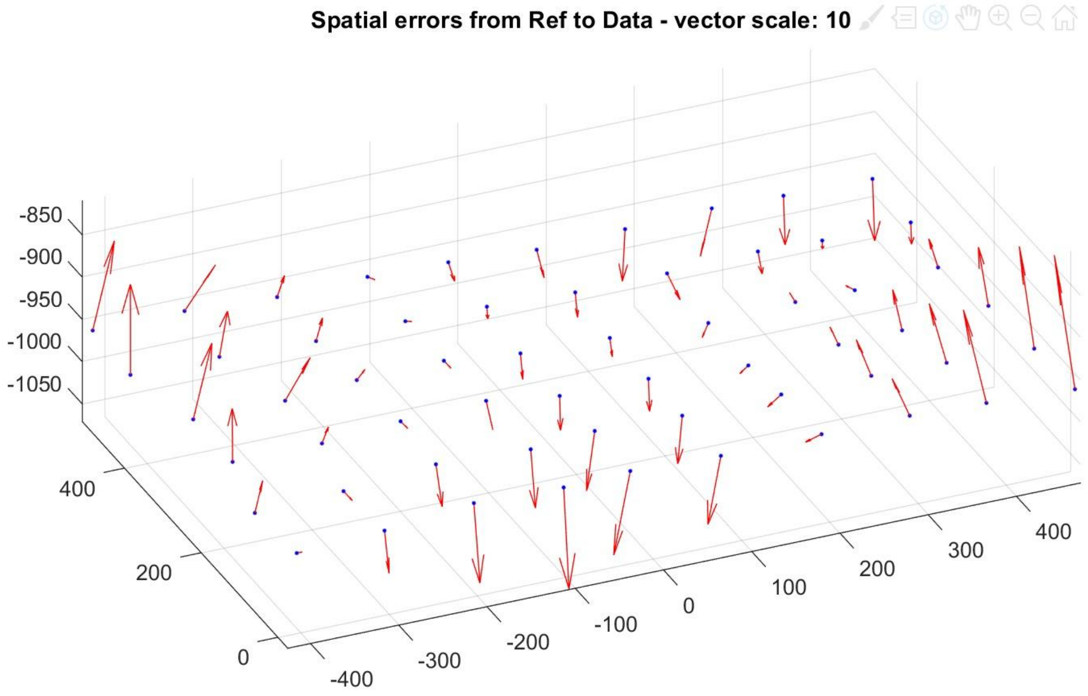
A custom model based on YOLOv8 was trained, providing a mean average precision mAP50-95 of 0.83 and a recall of 0.94

RESULTS

Underwater photogrammetry accuracy assessment $T_{0\text{-}UW}$ vs $T_{0\text{-}dry}$

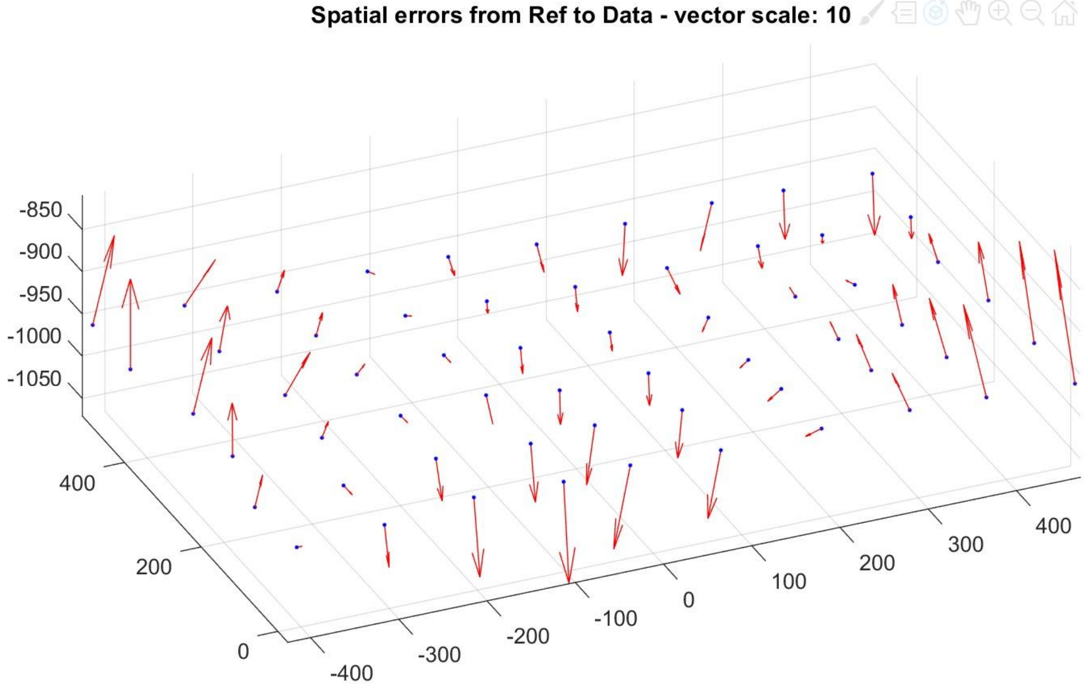
Residuals of the DOF Helmert rigid transformation estimated on 60 targets (no scale factor)



Underwater photogrammetry accuracy assessment $T_{0\text{-}UW}$ vs $T_{0\text{-}dry}$

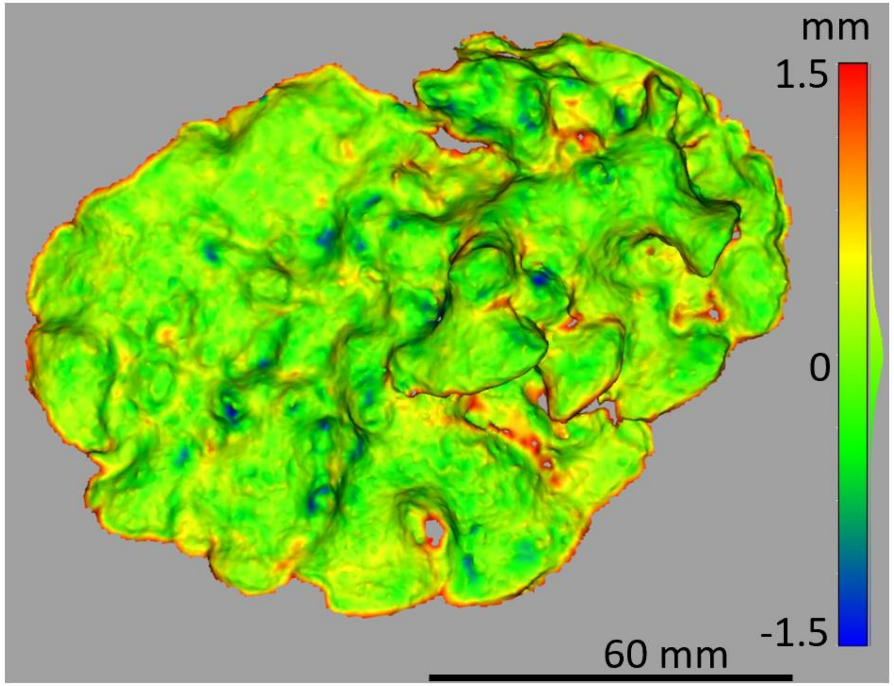
Residuals of the DOF Helmert rigid transformation estimated on 60 targets (no scale factor)

Grid deformation in the Z-direction, with a maximum deflection greater than 25 mm



Underwater photogrammetry accuracy assessment $T_{0\text{-}UW}$ vs $T_{0\text{-}dry}$

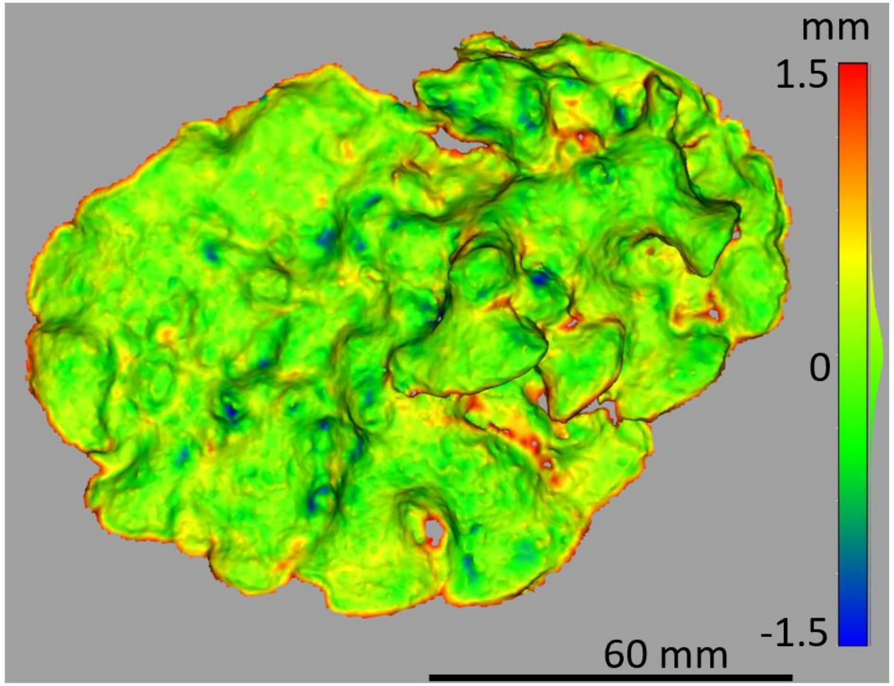
Differences in mm between the 3D mesh model of the same thallus (after ICP)



Underwater photogrammetry accuracy assessment $T_{0\text{-}UW}$ vs $T_{0\text{-}dry}$

Differences in mm between the 3D mesh model of the same thallus (after ICP)

Sub-millimetric difference:
standard deviation ≈ 0,3 mm



Set-up stability $T_{1.1\text{-}UW}$ vs $T_{0\text{-}UW}$

Residuals of the DOF Helmert rigid transformation estimated on 60 targets (no scale factor):

RMS_X = 0.2 mm, RMS_Y = 0.2 mm, RMS_Z = 0.4 mm

Set-up stability $T_{1.1\text{-}UW}$ vs $T_{0\text{-}UW}$

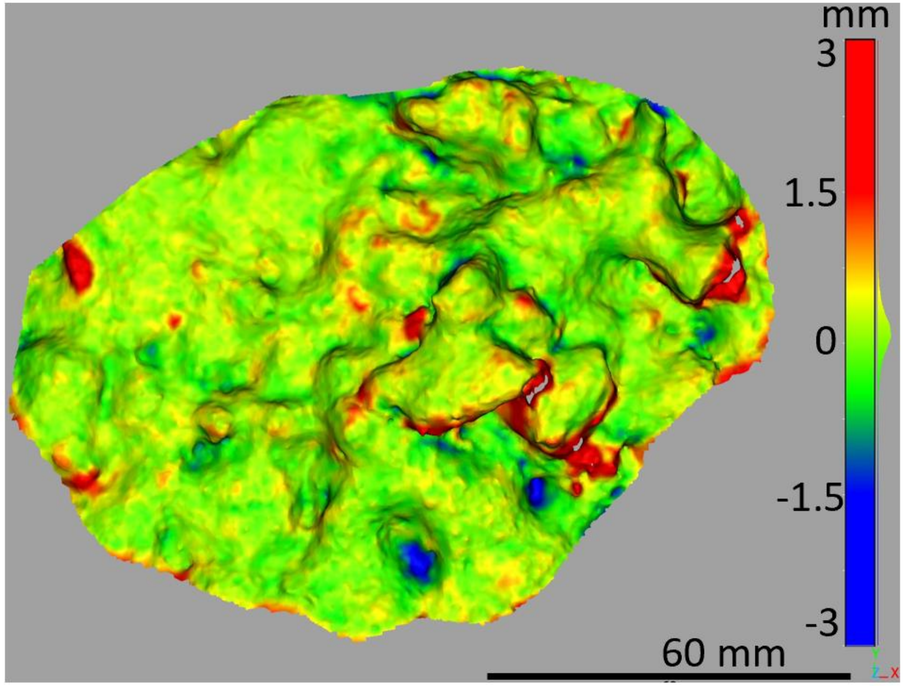
Residuals of the DOF Helmert rigid transformation estimated on 60 targets (no scale factor):

RMS_X = 0.2 mm, RMS_Y = 0.2 mm, RMS_Z = 0.4 mm

Stability of the experimental set-up!

Underwater photogrammetry reproducibility $T_{1.1\text{-}UW}$ vs $T_{0\text{-}UW}$

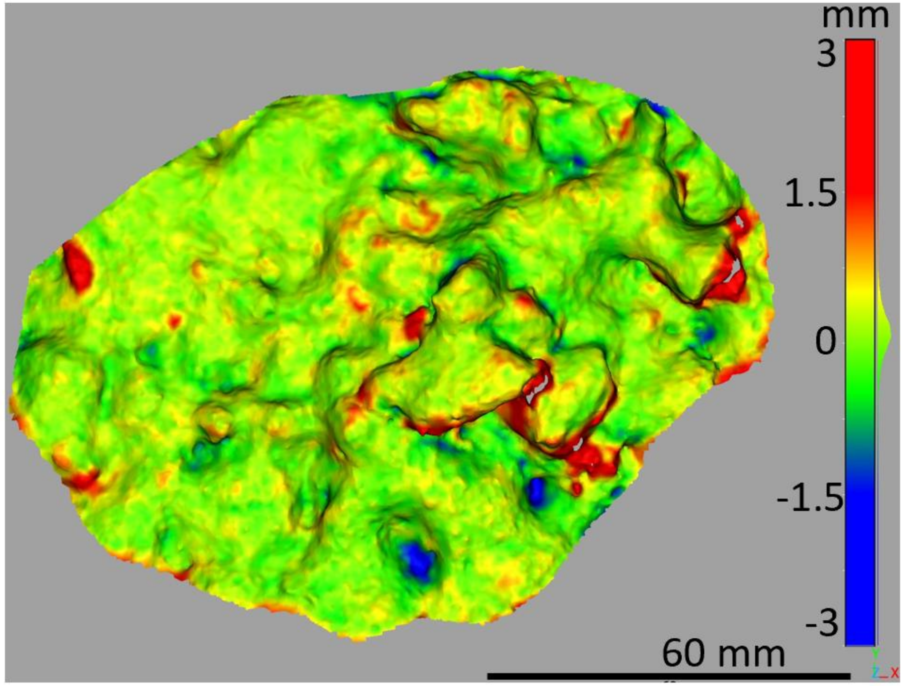
Differences in mm between the 3D mesh model of the same thallus computed on the 4 common targets (no ICP)



Underwater photogrammetry reproducibility $T_{1.1\text{-}UW}$ vs $T_{0\text{-}UW}$

Differences in mm between the 3D mesh model of the same thallus computed on the 4 common targets (no ICP)

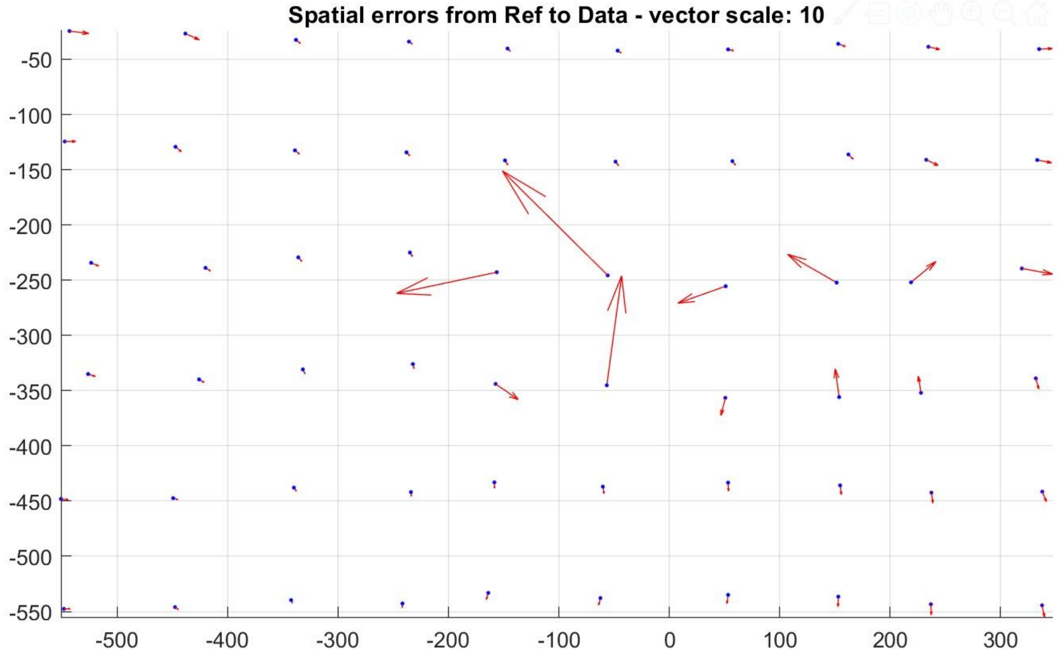
- Average difference ≈ 0.1 mm
- Standard deviation ≈ 0.45 mm



Sensitivity to global deformation
$T_{1.2\text{-}UW}$ vs $T_{1.1\text{-}UW}$

Residuals of the DOF Helmert rigid transformation estimated on 60 targets (no scale factor):

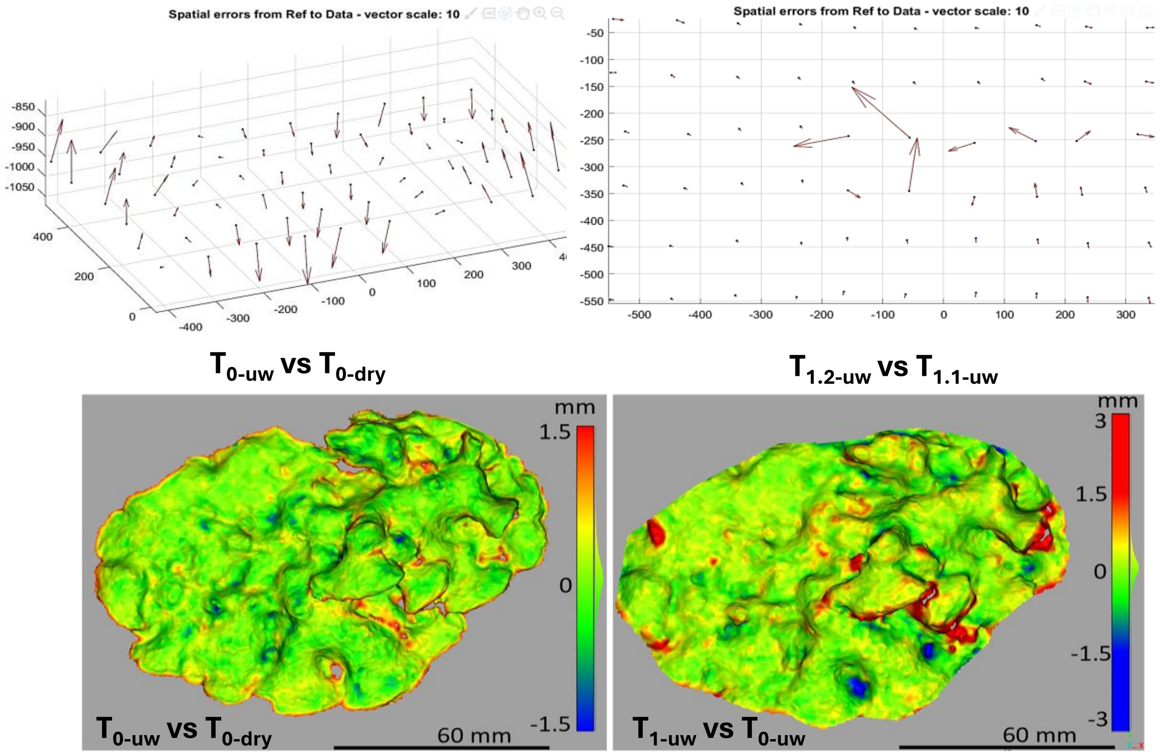
Rhe ROV's impact on the grid caused a significant shift in the X-axis and rotation in the horizontal plane of the central tile and the tiles to its right.



CONCLUSIONS

Conclusions

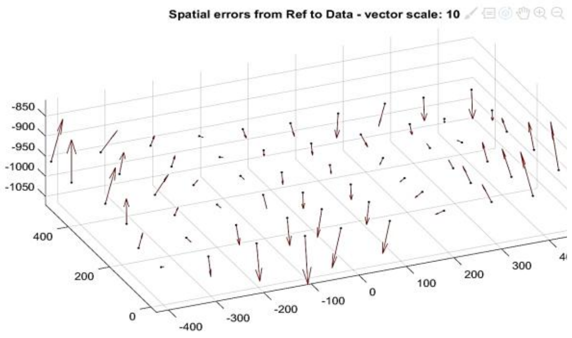
The experimental protocol confirmed the possibility of estimating changes over time in the order of millimetres.



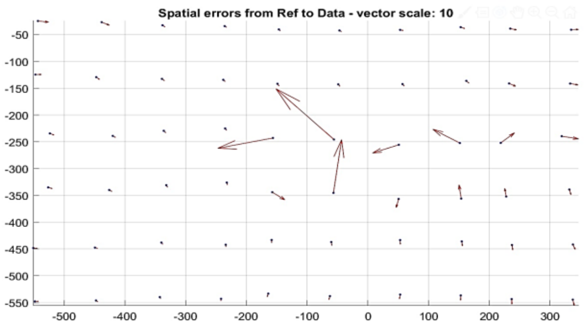
Conclusions

The experimental protocol confirmed the possibility of estimating changes over time in the order of millimetres.

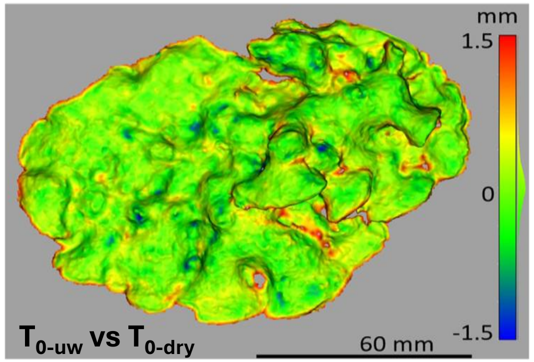
The targets confirmed their usefulness in identifying macro changes in the experimental set-up.

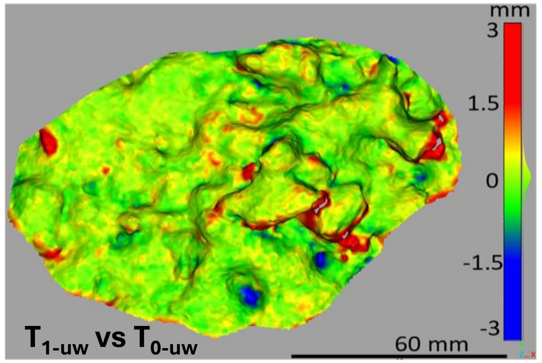


$T_{0\text{-uw}}$ vs $T_{0\text{-dry}}$



$T_{1.2\text{-uw}}$ vs $T_{1.1\text{-uw}}$



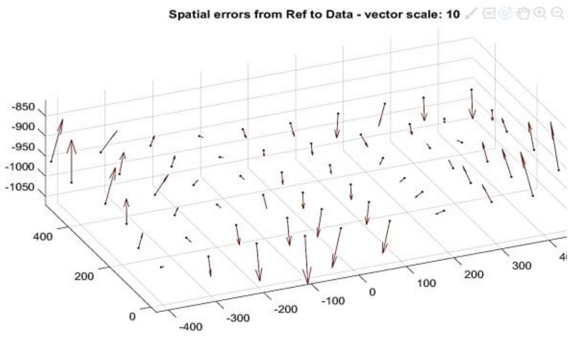


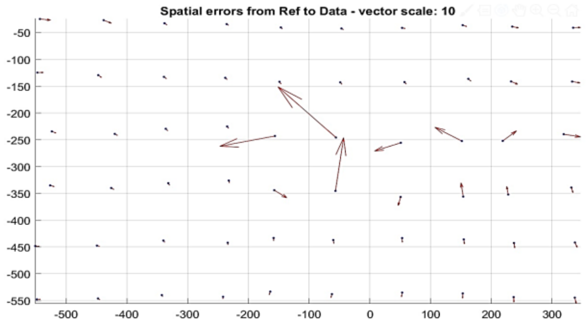
Conclusions

The experimental protocol confirmed the possibility of estimating changes over time in the order of millimetres.

The targets confirmed their usefulness in identifying macro changes in the experimental set-up.

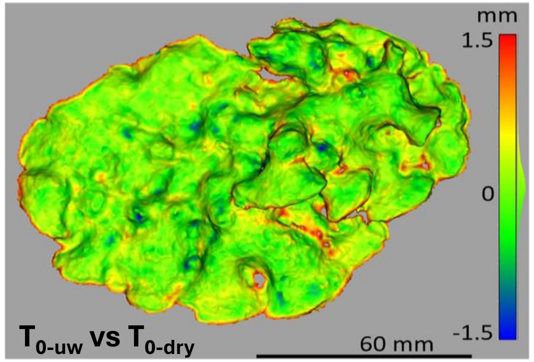
Instance segmentation proved to help segment the individual thalli.

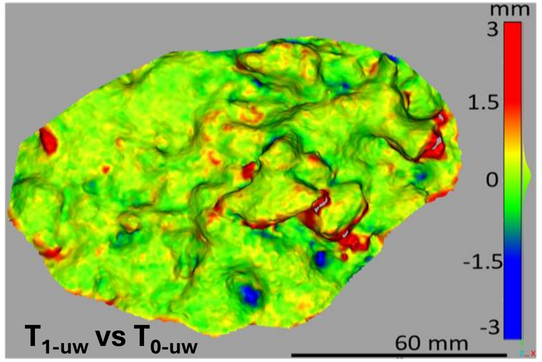




$T_{0\text{-}uw}$ vs $T_{0\text{-}dry}$

$T_{1.2\text{-}uw}$ vs $T_{1.1\text{-}uw}$





Next steps

Comparative tests between VIP-FROG, BlueROV2 and Blucy.

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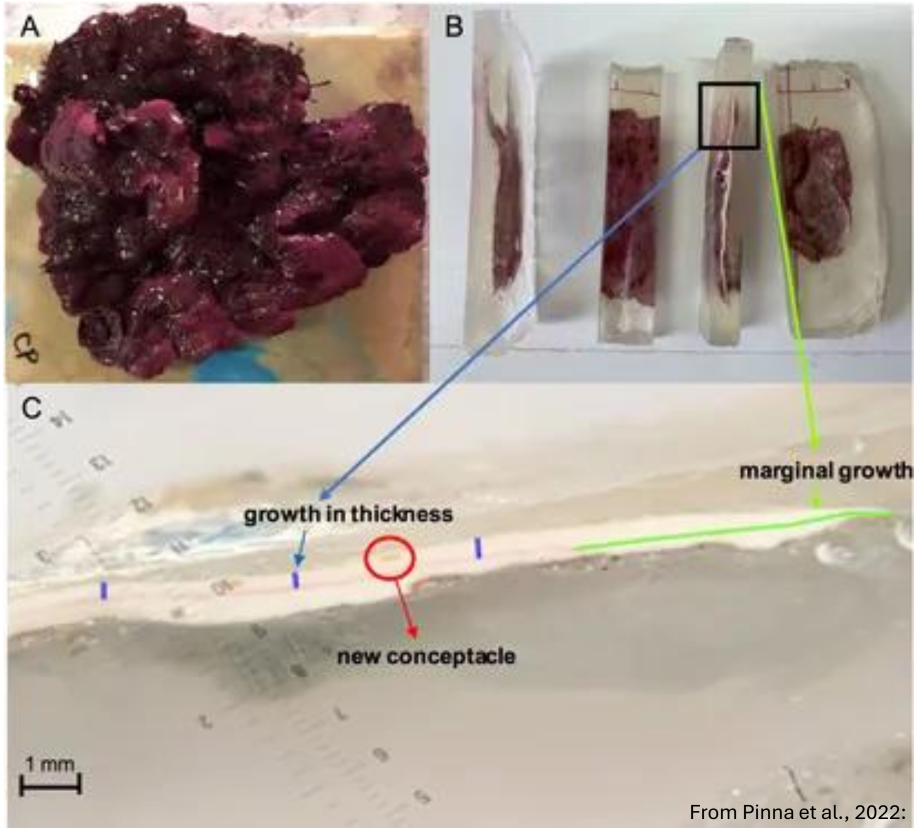
At the end of the field campaign, the thalli will be sliced to measure their growth serving as a benchmark for underwater photogrammetry estimates



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Comparative tests between VIP-FROG, BlueROV2 and Blucy.

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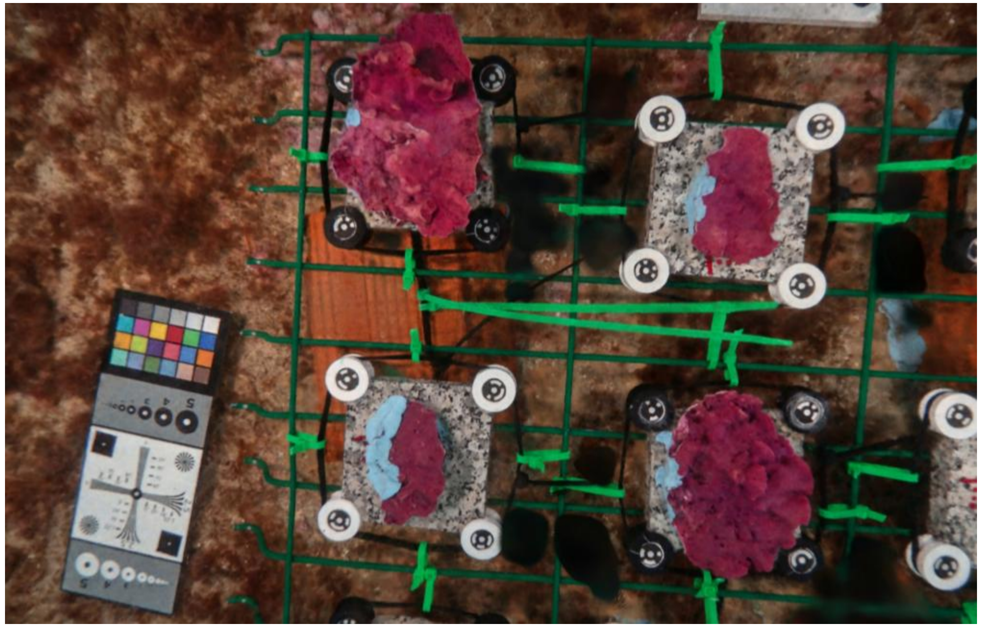
Future analyses will also focus on the colour fidelity of the photogrammetry products.



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by Woodleywonderworks

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