3D UNDERWATER MAPPING FROM ABOVE AND BELOW

3RD INTERNATIONAL WORKSHOP

Underwater Mapping in Shallow Coastal Waters Using MBES and Photogrammetry: Applications in Archaeology and Marine Habitat Monitoring

Dr. Sašo Poglajen

Sirio d.o.o.

Koper, Slovenia

saso@sirio.si

Dr. Mojca Poklar

University of Primorska

Koper, Slovenia

mojca.poklar@fhs.upr.si

Introduction & Objectives

Context: Why underwater mapping?

To aid in documentation and preservation of archaeological sites.

To monitor the extends of seagrass meadows.

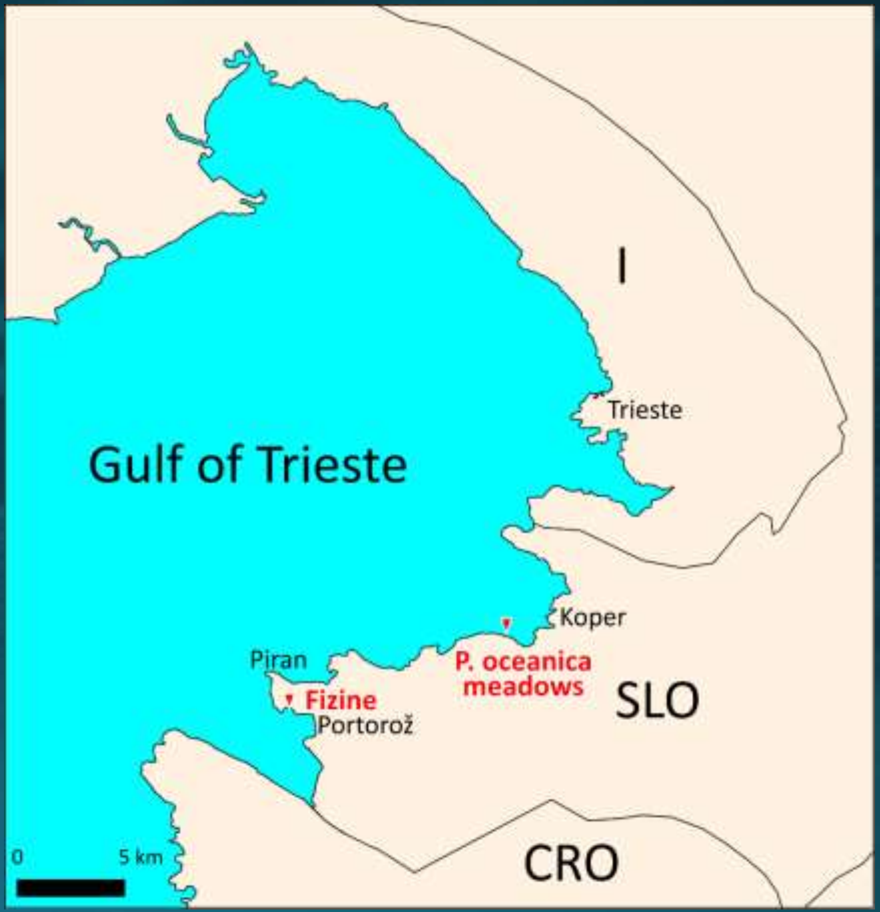
Two case studies:

1. Habitat mapping: *Posidonia oceanica* seagrass meadows near Koper
2. Archaeological site documentation: Roman underwater site Fizine

Objectives:

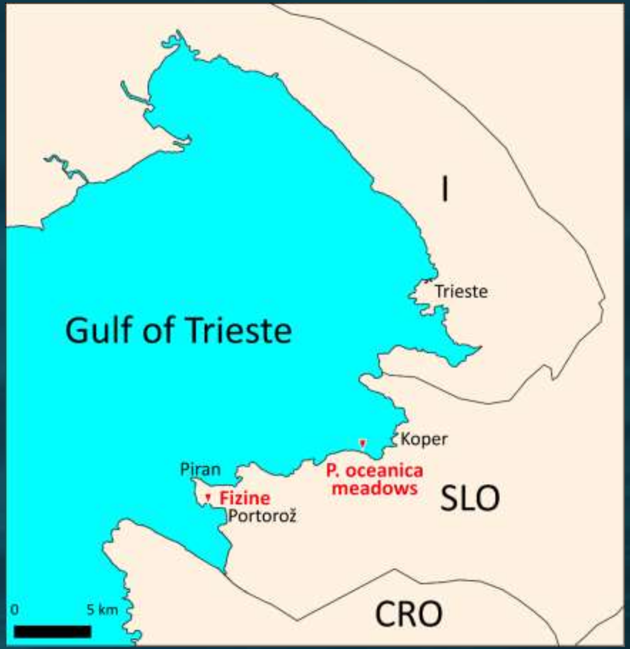
Habitat mapping: Complement bathymetry with orthomosaic

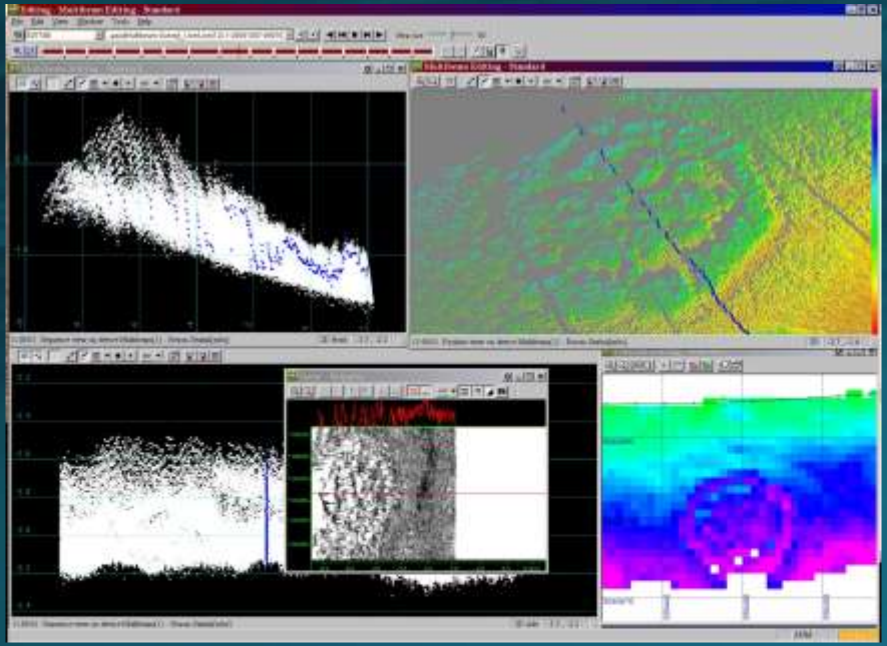
Archaeology: Increase the resolutin of DTM



Study Areas Overview: Posidonia meadows

Posidonia meadows area





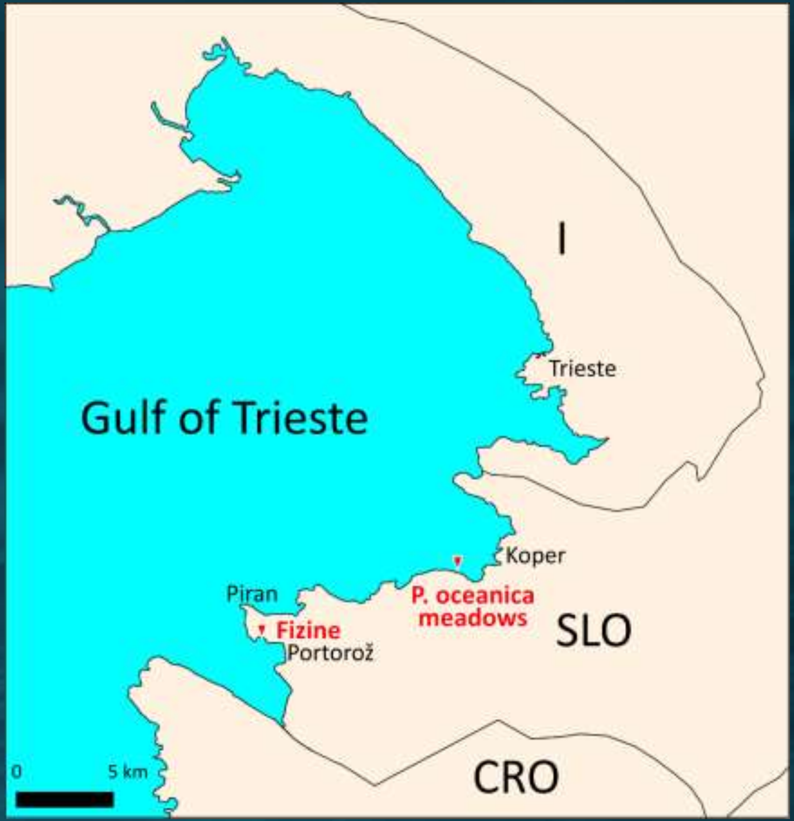
MBES data from 2006

ASV

Underwater orthomosaic from 2016

Study Areas Overview: Fizine site

Rectangular structures of the site visible on aerial image



Roman fish-farming ponds (*piscina vivaria*).

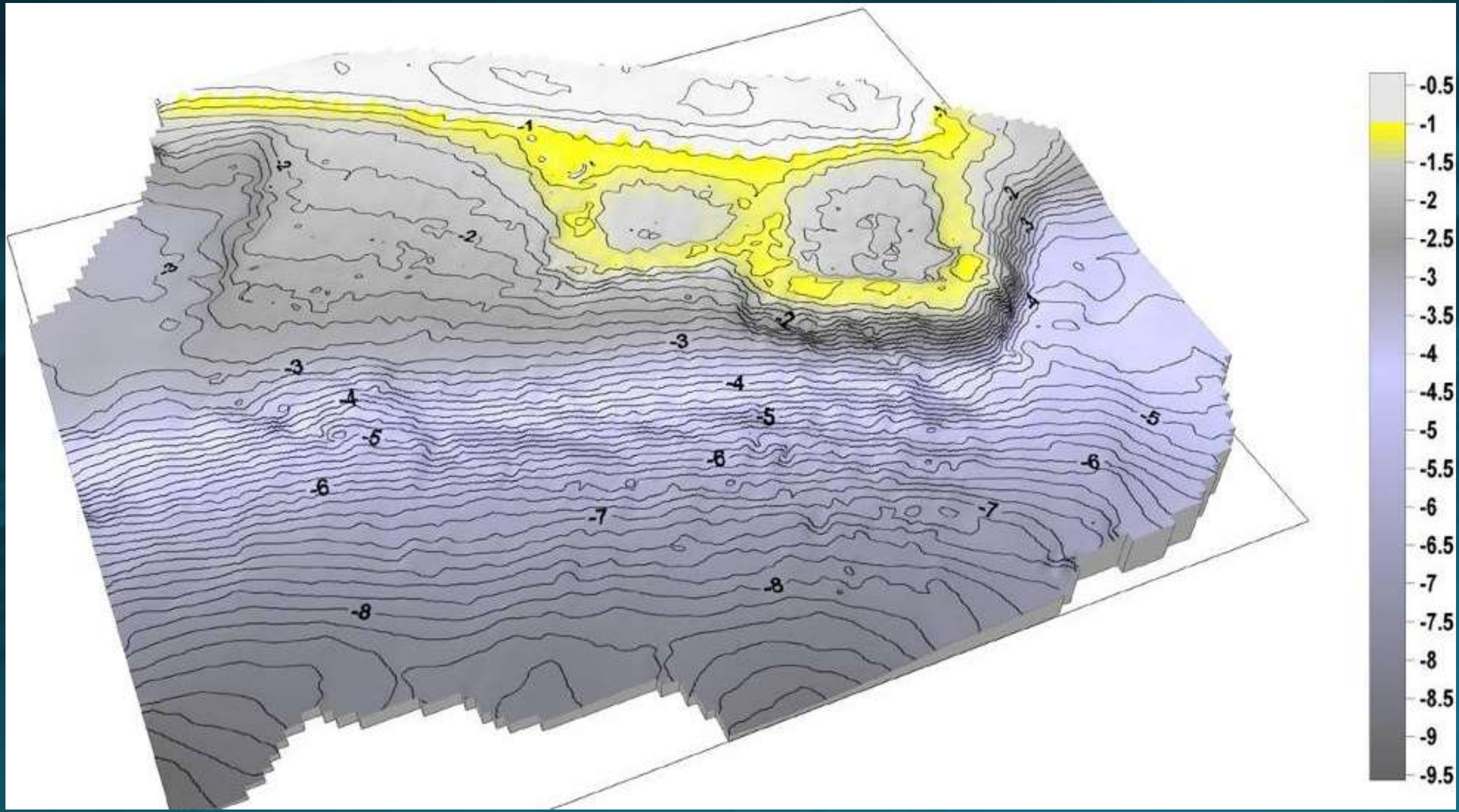
from 1st cent. BC to 5th cent. AD.

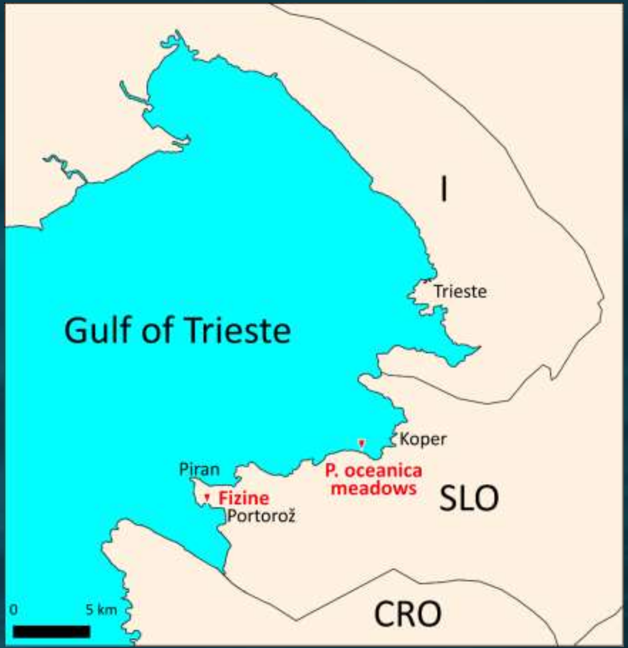
Size: approx. 80 m x 50 m

Depth: 0.5 m to 5 m

Mapping work: 2004 - 2008

Study Areas Overview: Fizine site



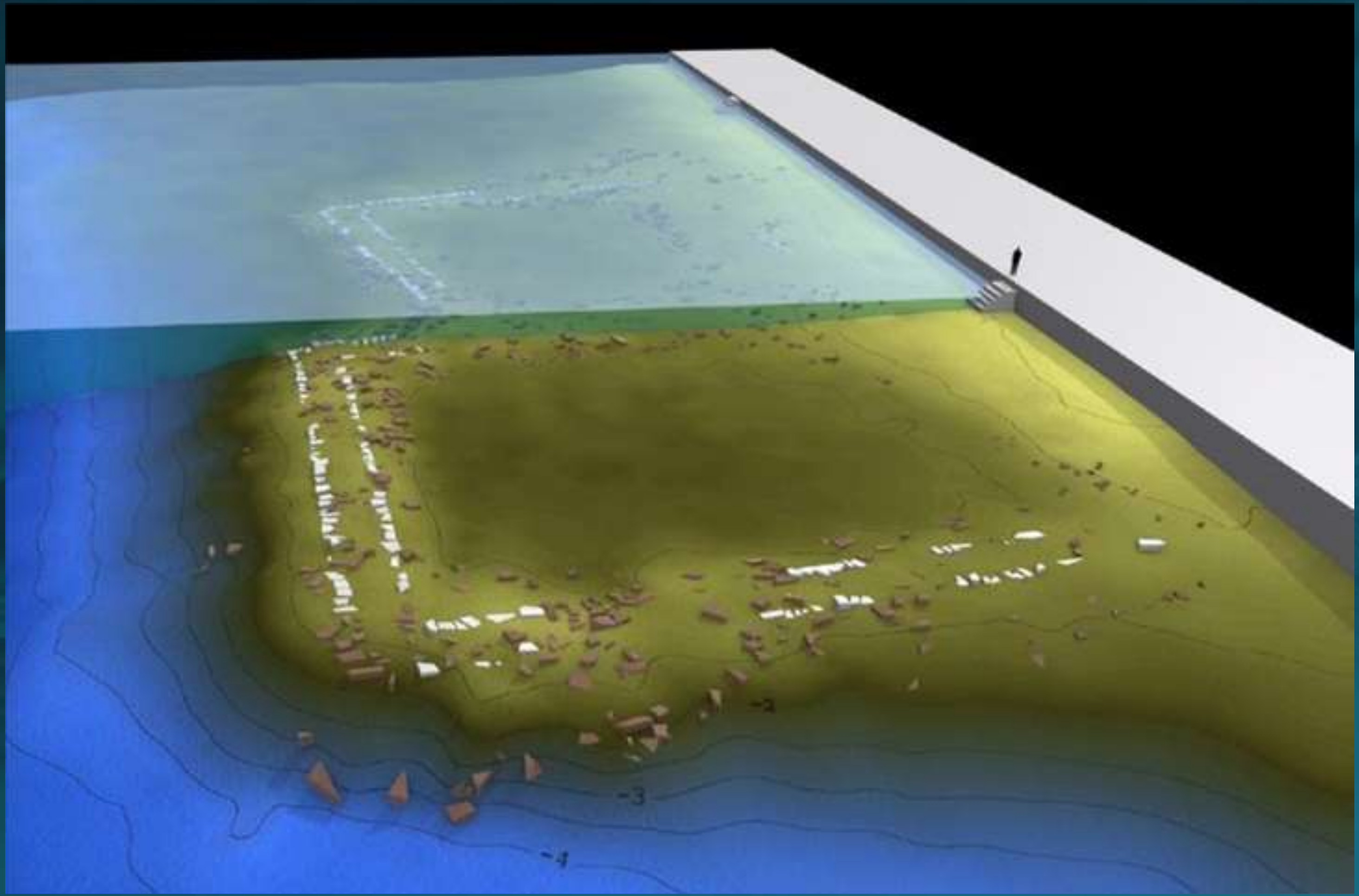


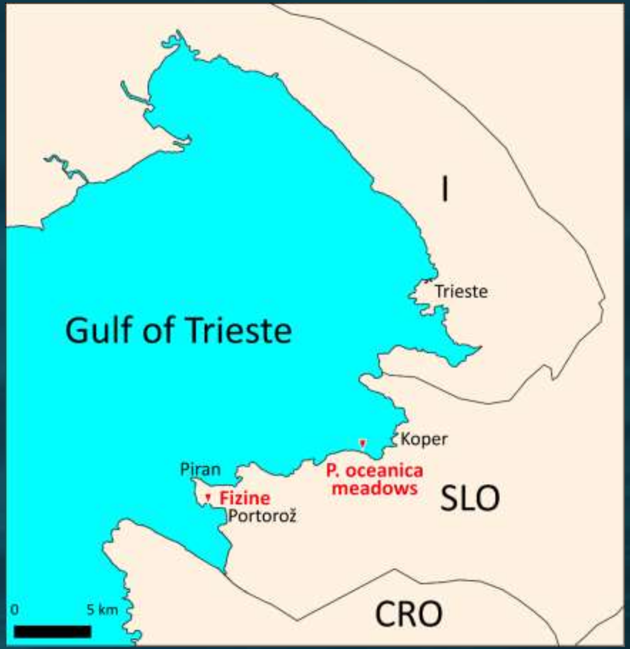
SBES survey from 2004.

DTM at 2 m resolution.

General morphology of the site.

Study Areas Overview: Fizine site

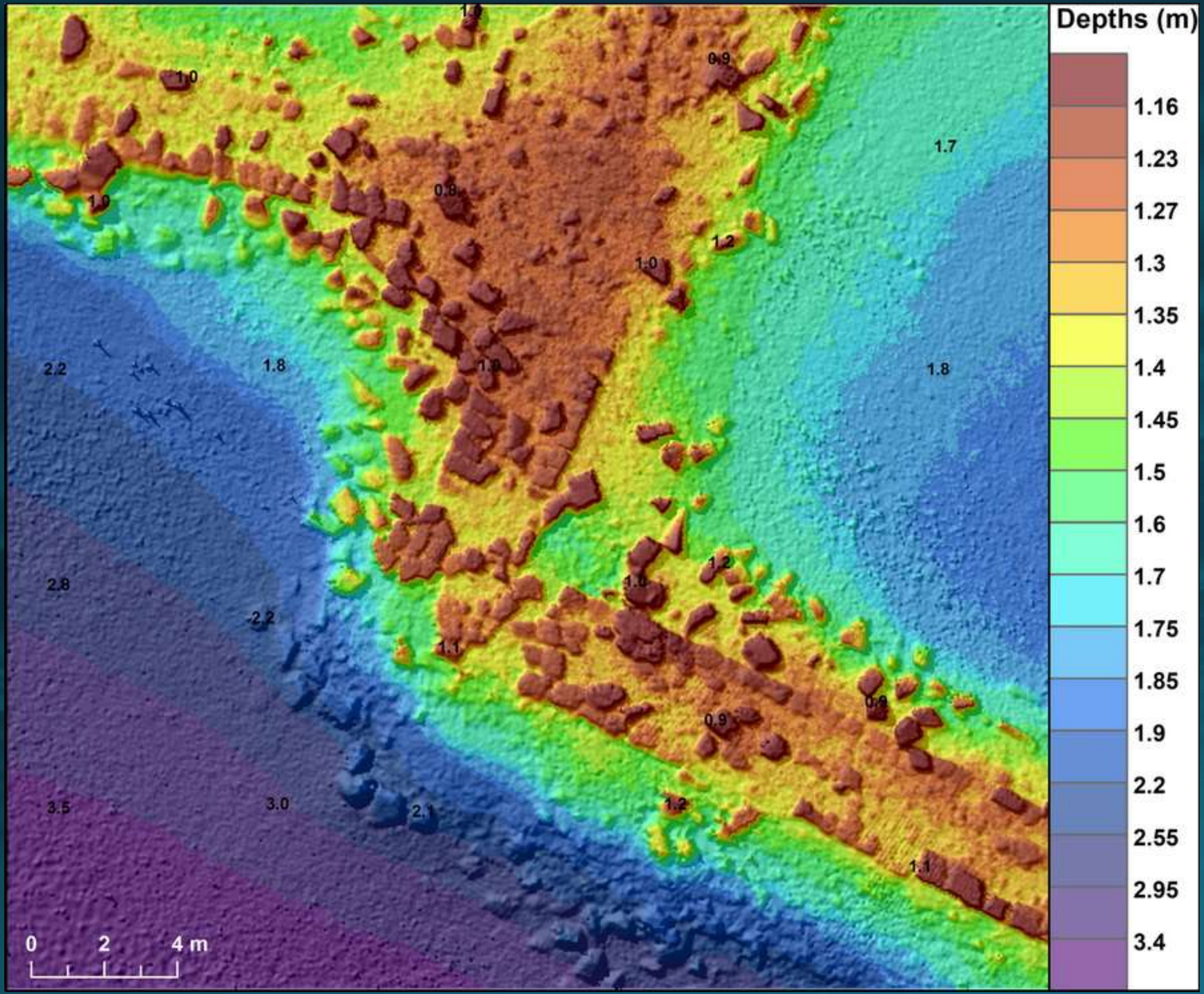




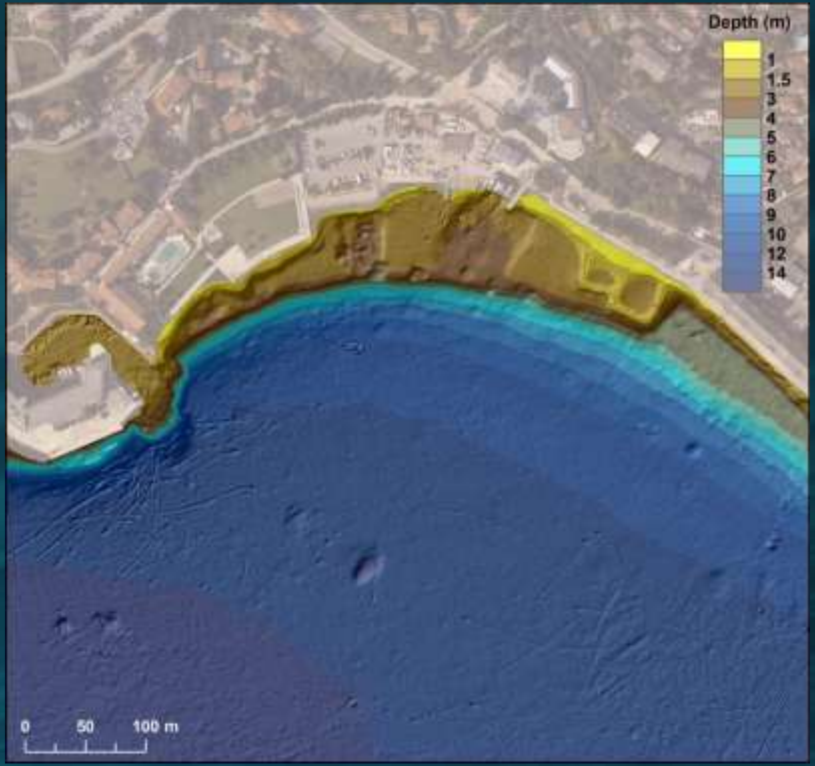
SBES survey was folowed by total station survey of individual stone bloks.

Data sets were merged into 3D model of the site.

Study Areas Overview: Fizine site



MBES DTM at 10 cm



In 2007 we did extensive MBES survey of entire bay so also Fizine site was included. Data provided first high resolution DTM of the site.

Tools of the trade

Acoustic survey with shallow water MBES system

Underwater imaging with GoPro from surface vessel

Aerial imaging with UAV

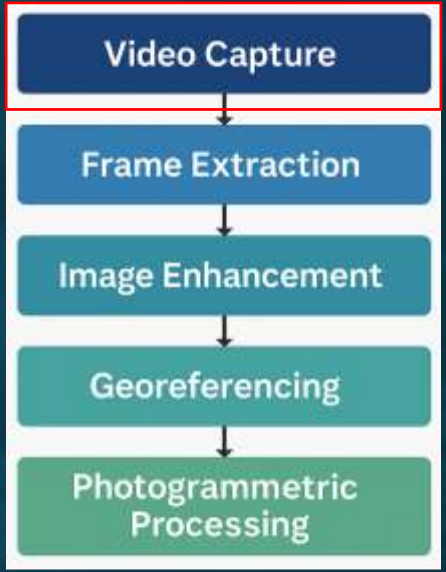
Vessel for habitat mapping:
MBES Reson Seabat 8125
5 camera rig on flexible pole

Vessel for archaeological mapping:
MBES R2 Sonic 2022
3 camera rig on rigid pole

GoPro Hero 6 Black
Video: 2.7 k @29.97 fps

DJI Air 2s
1″ CMOS sensor (20 MP)
Image size: 5472 x 3648

Underwater photogrammetry workflow



3 or 5 GoPro cameras mounted on horizontal pole

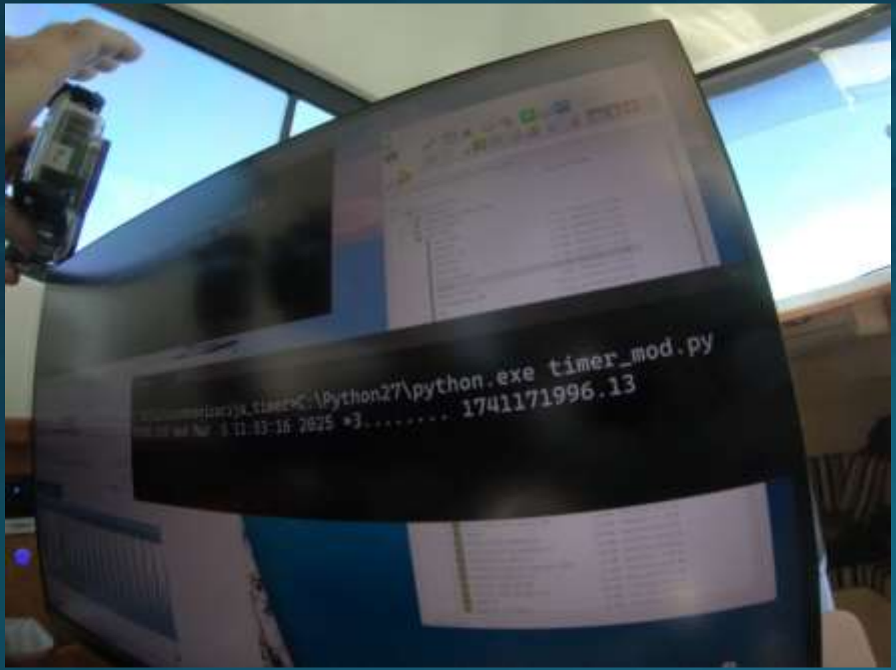
Recording 2.7k video @29.97 fps

Altitude above seabed: 1 m – 3 m

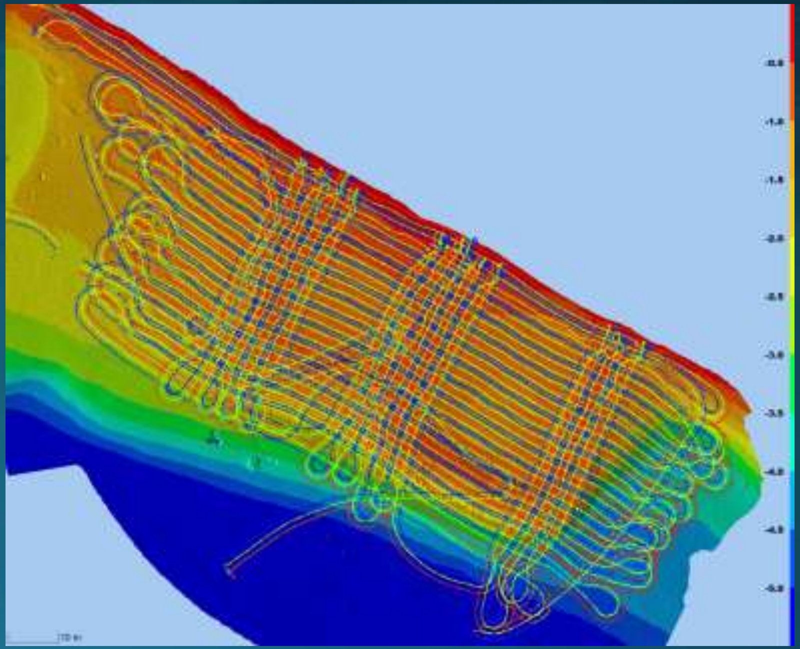
GNSS RTK positions and attitude data

Sailing speed up to 2 knots

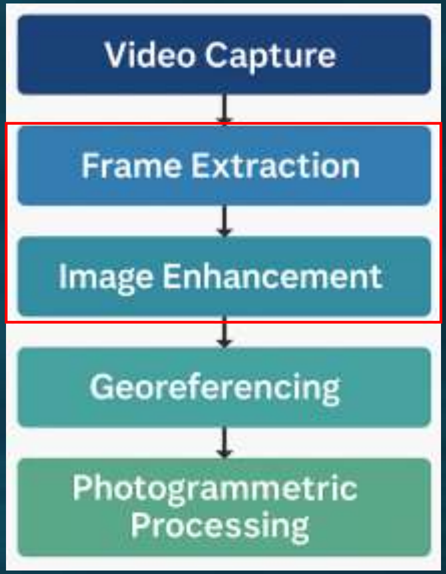
Video recording starts and ends with capturing the Ansi / Unix time



Cameras trace lines



Underwater photogrammetry workflow



Frame extraction: FFmpeg tools:

Every 10-th frame (3 fps)

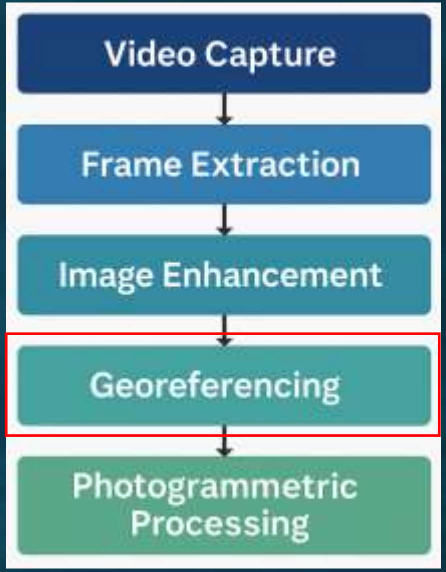
Image Enhancement:

Contrast Limited Adaptive Histogram Equalization (CLAHE), Unsharp Masking, and white balance correction.

Before

After

Underwater photogrammetry workflow



Georeferencing of frames: Spreadsheet approach

Exporting positions and attitude from navigation software (Teledyne PDS):

Ansi seconds,Time,x,y,z,heading,roll ,pitch @30 Hz

Merging frames with positions by time in spreadsheet

```
10f_230222_gp60_00035.jpgCRLF
10f_230222_gp60_00036.jpgCRLF
10f_230222_gp60_00037.jpgCRLF
10f_230222_gp60_00038.jpgCRLF
10f_230222_gp60_00039.jpgCRLF
10f_230222_gp60_00040.jpgCRLF
10f_230222_gp60_00041.jpgCRLF
10f_230222_gp60_00042.jpgCRLF
10f_230222_gp60_00043.jpgCRLF
10f_230222_gp60_00044.jpgCRLF
```

List of frames

```
1677058024.86997,22. 02. 2023 10:27:04.869,388987.13,42615.25,0.54,138.83,-1.48,-0.20,(F)Full aided mode - Settled conditionCR
1677058024.90199,22. 02. 2023 10:27:04.901,388987.14,42615.25,0.54,138.81,-1.51,-0.18,(F)Full aided mode - Settled conditionCR
1677058024.93408,22. 02. 2023 10:27:04.934,388987.14,42615.26,0.54,138.78,-1.54,-0.16,(F)Full aided mode - Settled conditionCR
1677058024.96590,22. 02. 2023 10:27:04.965,388987.14,42615.26,0.54,138.76,-1.56,-0.14,(F)Full aided mode - Settled conditionCR
1677058024.99795,22. 02. 2023 10:27:04.997,388987.14,42615.26,0.54,138.74,-1.59,-0.12,(F)Full aided mode - Settled conditionCR
1677058025.03006,22. 02. 2023 10:27:05.030,388987.14,42615.26,0.54,138.72,-1.54,-0.14,(F)Full aided mode - Settled conditionCR
1677058025.06193,22. 02. 2023 10:27:05.061,388987.15,42615.26,0.54,138.70,-1.50,-0.17,(F)Full aided mode - Settled conditionCR
1677058025.09396,22. 02. 2023 10:27:05.093,388987.15,42615.27,0.54,138.68,-1.45,-0.19,(F)Full aided mode - Settled conditionCR
1677058025.12606,22. 02. 2023 10:27:05.126,388987.15,42615.27,0.53,138.66,-1.40,-0.21,(F)Full aided mode - Settled conditionCR
1677058025.15795,22. 02. 2023 10:27:05.157,388987.15,42615.27,0.53,138.64,-1.35,-0.23,(F)Full aided mode - Settled conditionCR
```

Exported camera positions

C591 =VLOOKUP(A591;pds_export_GP60_ok!$A$1:$H$200000; 3)

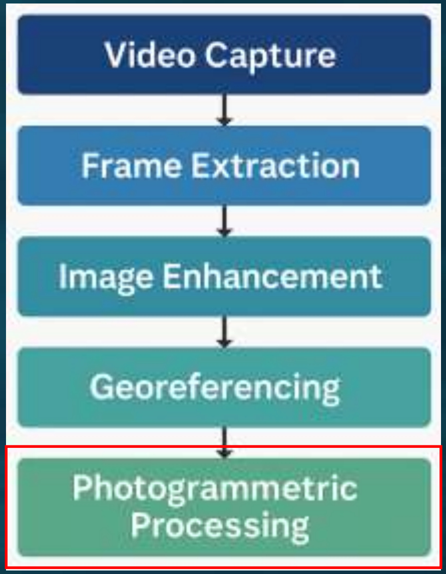
	A	B	C	D	E	F	G	H
591	1677058025	10f_230222_gp60_00623.jpg	388987.15	42615.27	0.53	138.66	-1.4	-0.21
592	1677058025	10f_230222_gp60_00624.jpg	388987.18	42615.3	0.52	138.52	-0.69	-0.52
593	1677058026	10f_230222_gp60_00625.jpg	388987.19	42615.32	0.51	138.51	-0.51	-0.69
594	1677058026	10f_230222_gp60_00626.jpg	388987.2	42615.34	0.52	138.39	-0.79	-0.6
595	1677058026	10f_230222_gp60_00627.jpg	388987.21	42615.35	0.52	138.37	-1.32	-0.75
596	1677058027	10f_230222_gp60_00628.jpg	388987.22	42615.35	0.52	138.44	-1.4	-0.71
597	1677058027	10f_230222_gp60_00629.jpg	388987.25	42615.37	0.55	138.42	-0.79	-0.15
598	1677058027	10f_230222_gp60_00630.jpg	388987.28	42615.39	0.56	138.57	-0.5	-0.06
599	1677058028	10f_230222_gp60_00631.jpg	388987.3	42615.41	0.54	138.59	0.02	-0.39
600	1677058028	10f_230222_gp60_00632.jpg	388987.31	42615.42	0.53	138.71	-0.03	-0.55
601	1677058028	10f_230222_gp60_00633.jpg	388987.32	42615.41	0.54	138.98	-0.65	-0.19
602	1677058029	10f_230222_gp60_00634.jpg	388987.34	42615.42	0.55	138.94	-0.55	0.12
603	1677058029	10f_230222_gp60_00635.jpg	388987.37	42615.44	0.56	138.68	-0.13	0.33
604	1677058029	10f_230222_gp60_00636.jpg	388987.4	42615.48	0.57	138.45	0.18	0.4
605	1677058030	10f_230222_gp60_00637.jpg	388987.41	42615.5	0.55	138.36	0.15	-0.04
606	1677058030	10f_230222_gp60_00638.jpg	388987.42	42615.53	0.52	138.32	0.21	-0.53
607	1677058030	10f_230222_gp60_00639.jpg	388987.44	42615.55	0.54	138.17	0.44	-0.27

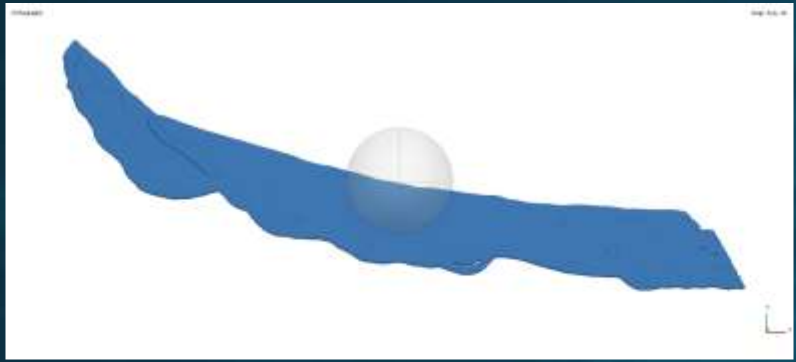
Final reference file

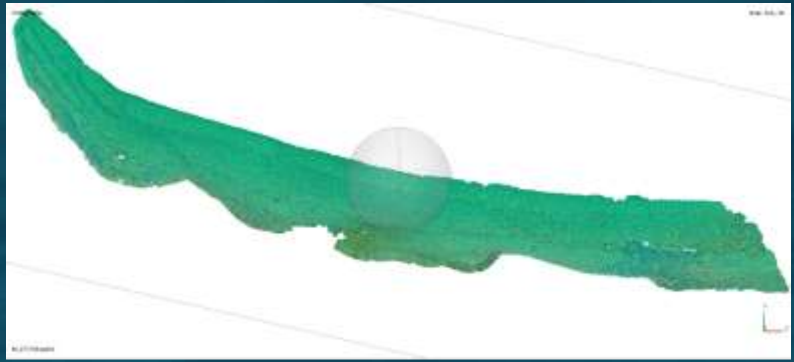
Underwater photogrammetry workflow

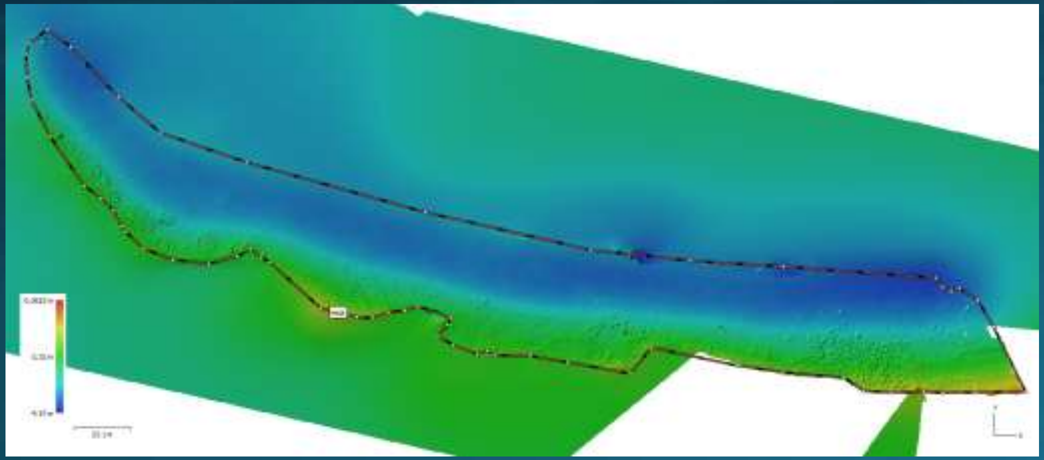
Standard processing in Agisoft Metashape:

Import images and reference, align, refine, depth maps, DTM, orthomosaik



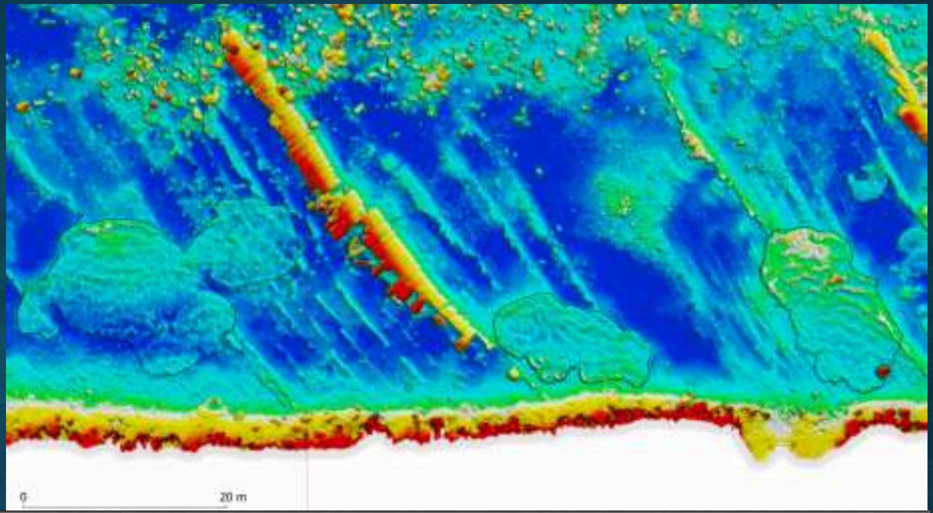


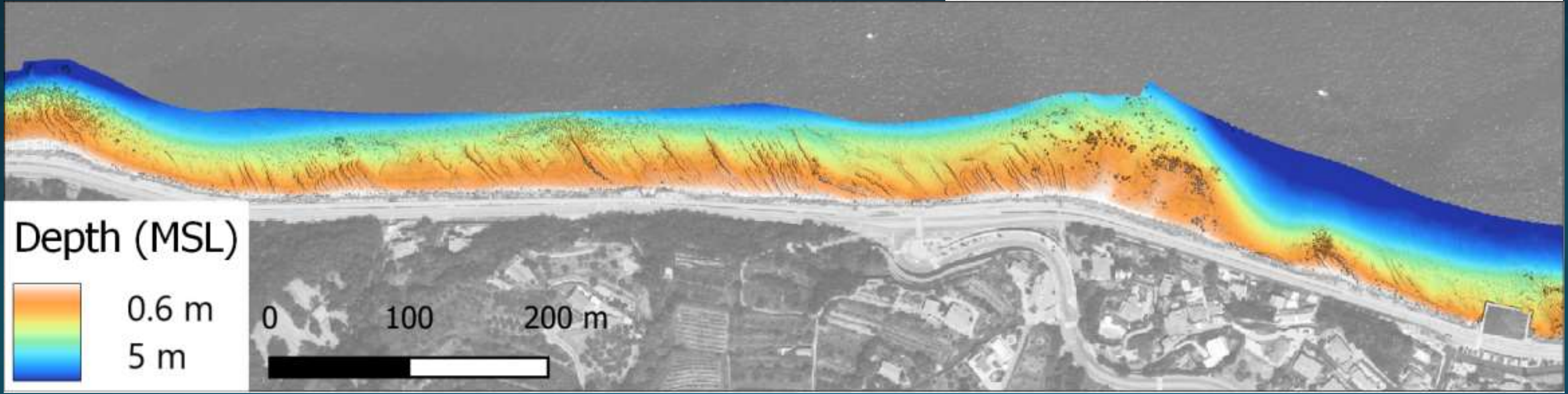




Results: Habitat Mapping

1. Extensive bathymetry of the entire study area
   Sonar point cloud resampled to 10 cm and 25 cm DTM grid
2. Underwater orthomosaics of Posidonia meadows (west and east) at 1 cm resolution
3. Aerial orthomosaic of coastal area at 1.5 cm resolution
4. Mapping of individual Posidonia features / meadows





Results: Habitat Mapping

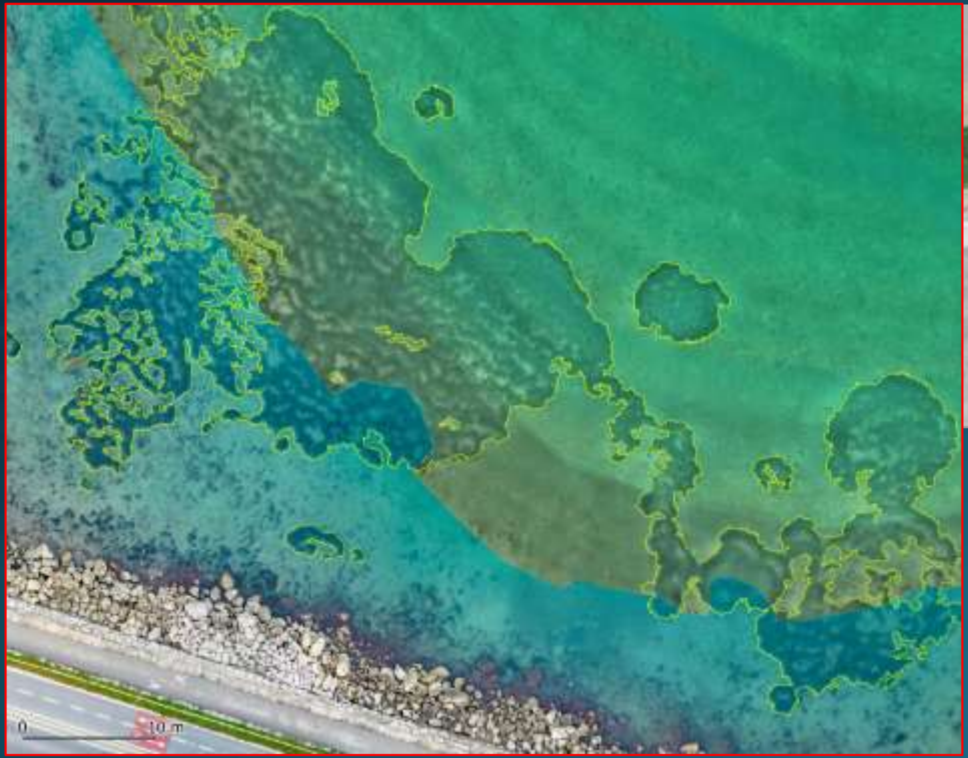
1. Extensive bathymetry of the entire study area

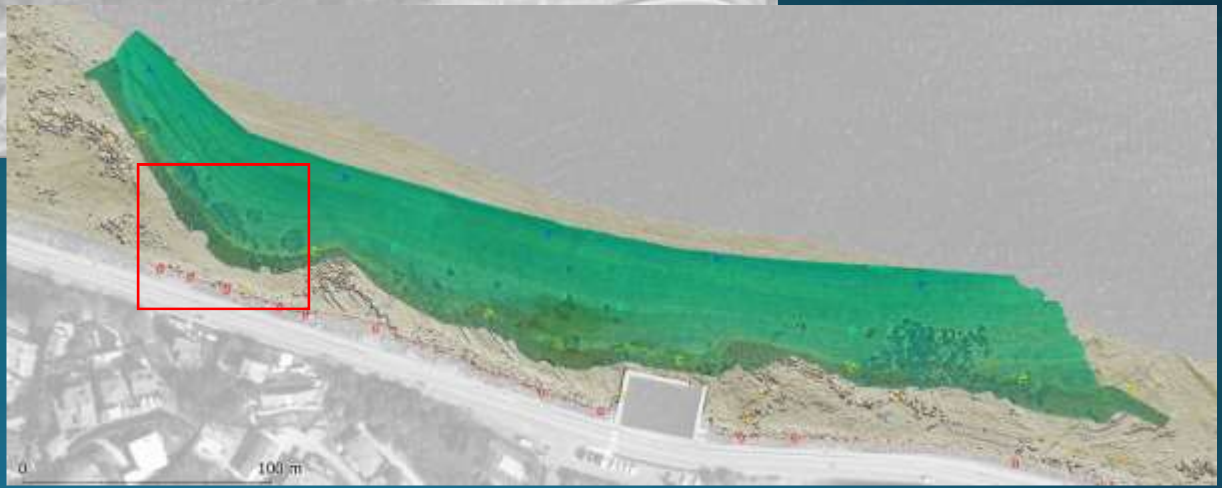
    Sonar point cloud resampled to 10 cm and 25 cm DTM grid

2. Underwater orthomosaics of Posidonia meadows (west and east) at 1 cm resolution

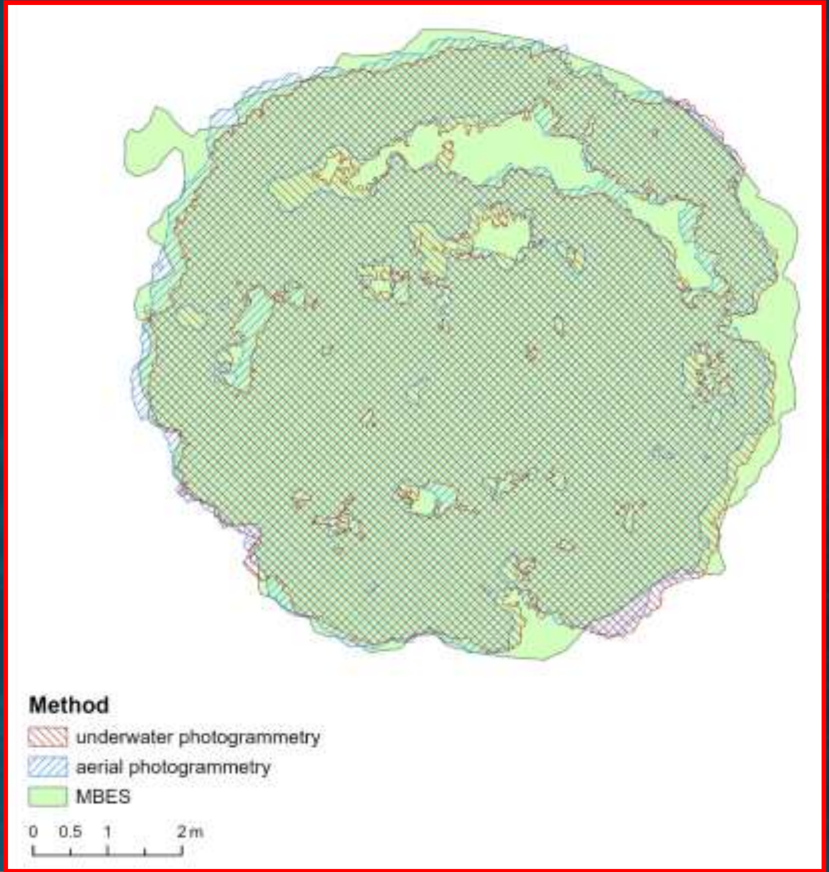
3. Aerial orthomosaic of coastal area at 1.5 cm resolution

4. Mapping of individual Posidonia features / meadows





Comparing different methods



Comparison of delineated *Posidonia oceanica* meadow outlines obtained from MBES (slope analysis), underwater and aerial photogrammetry:

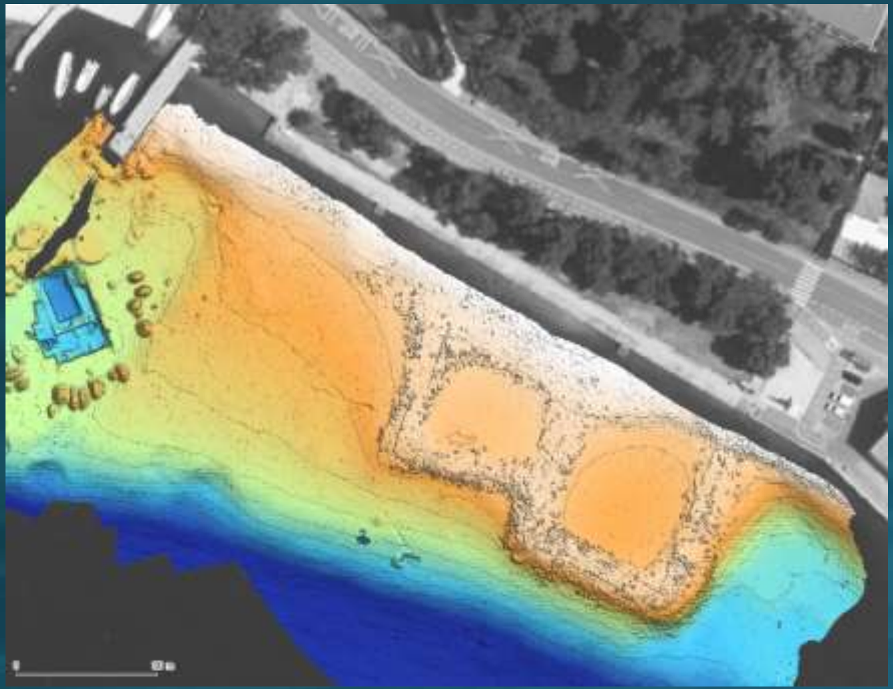
MBES: 58 m^2

Underwater photo.: 48.4 m^2

Aerial photo.: 48.3 m^2

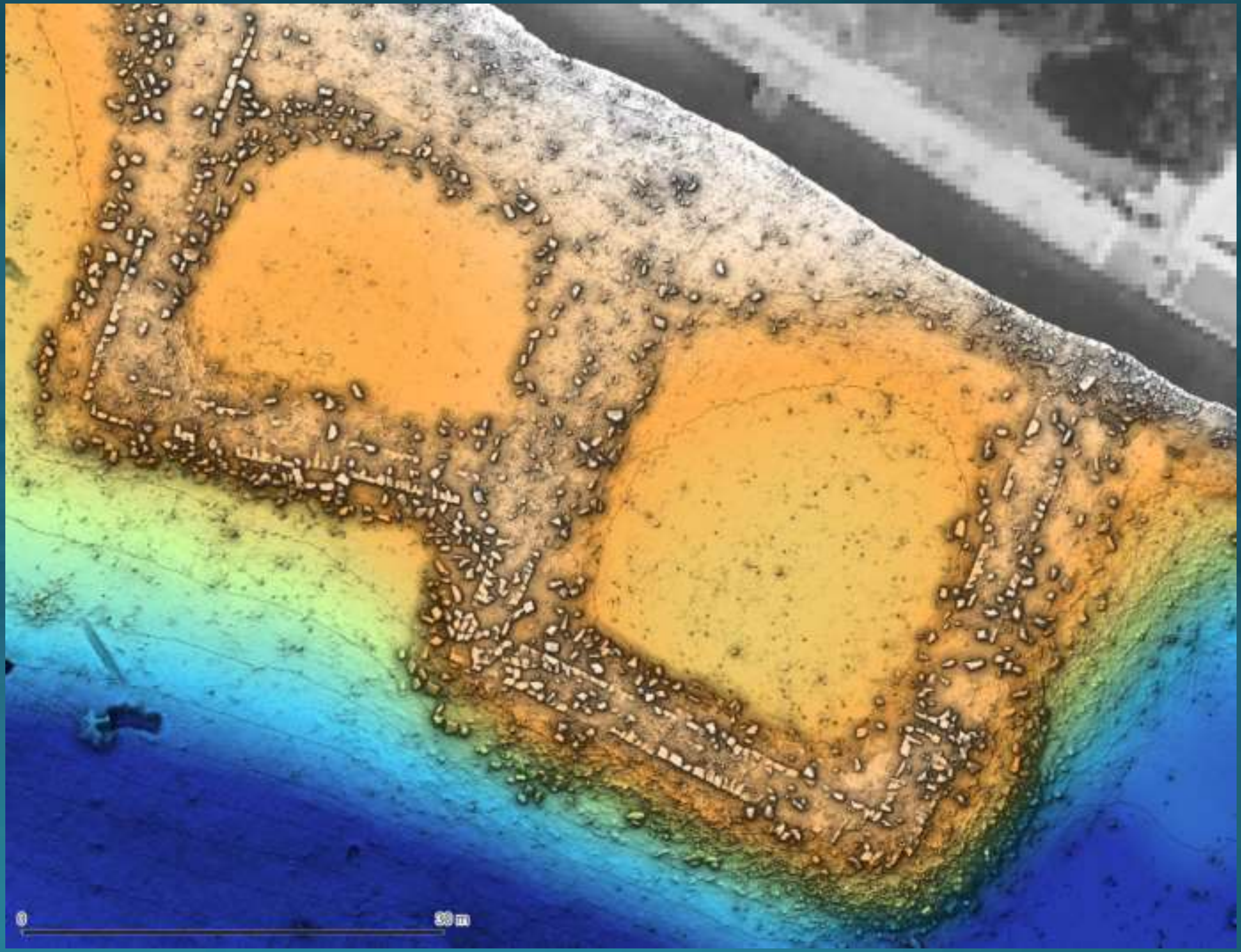
The figure illustrates spatial discrepancies between methods and highlights differences in boundary precision and surface extent.

Results: Archaeological site mapping

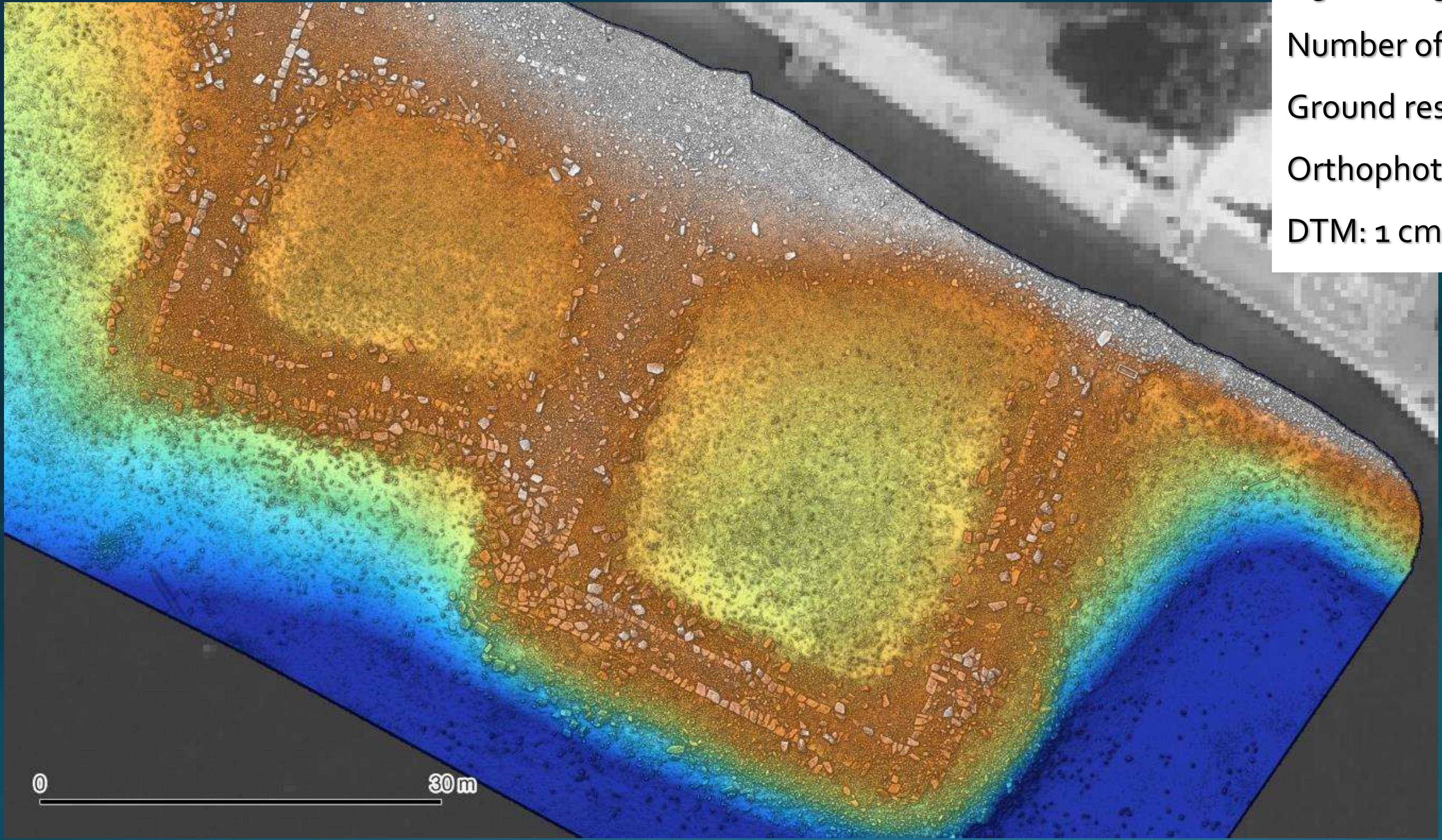


MBES derived DTM of the site with

horizontal resolution of 5 cm



Results: Archaeological site mapping



Video recording time:

1.5 h with 3 cameras

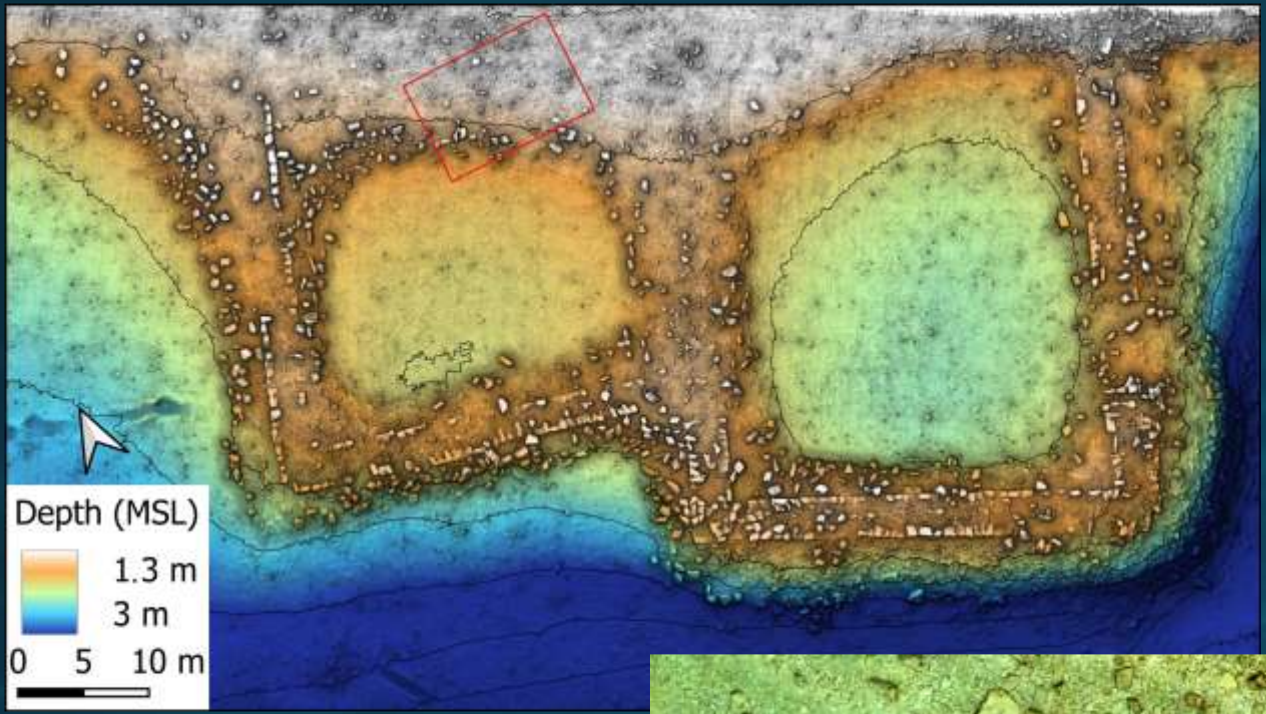
Number of frames: 52,488

Ground resolution: < 1 cm

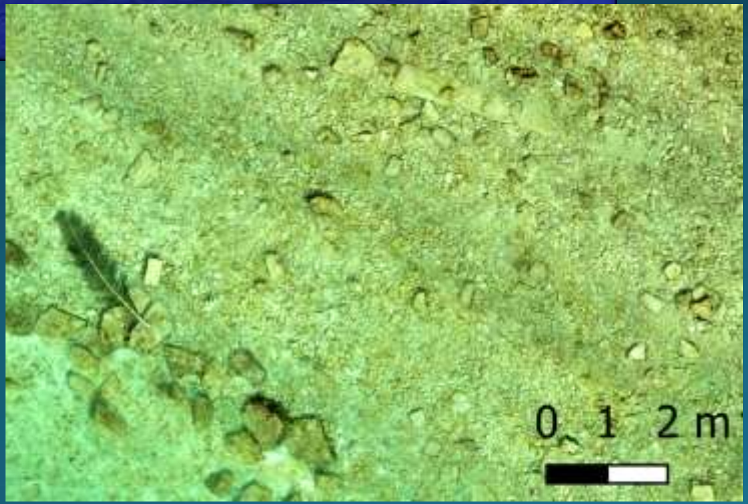
Orthophoto mosaic: 2.5 mm

DTM: 1 cm

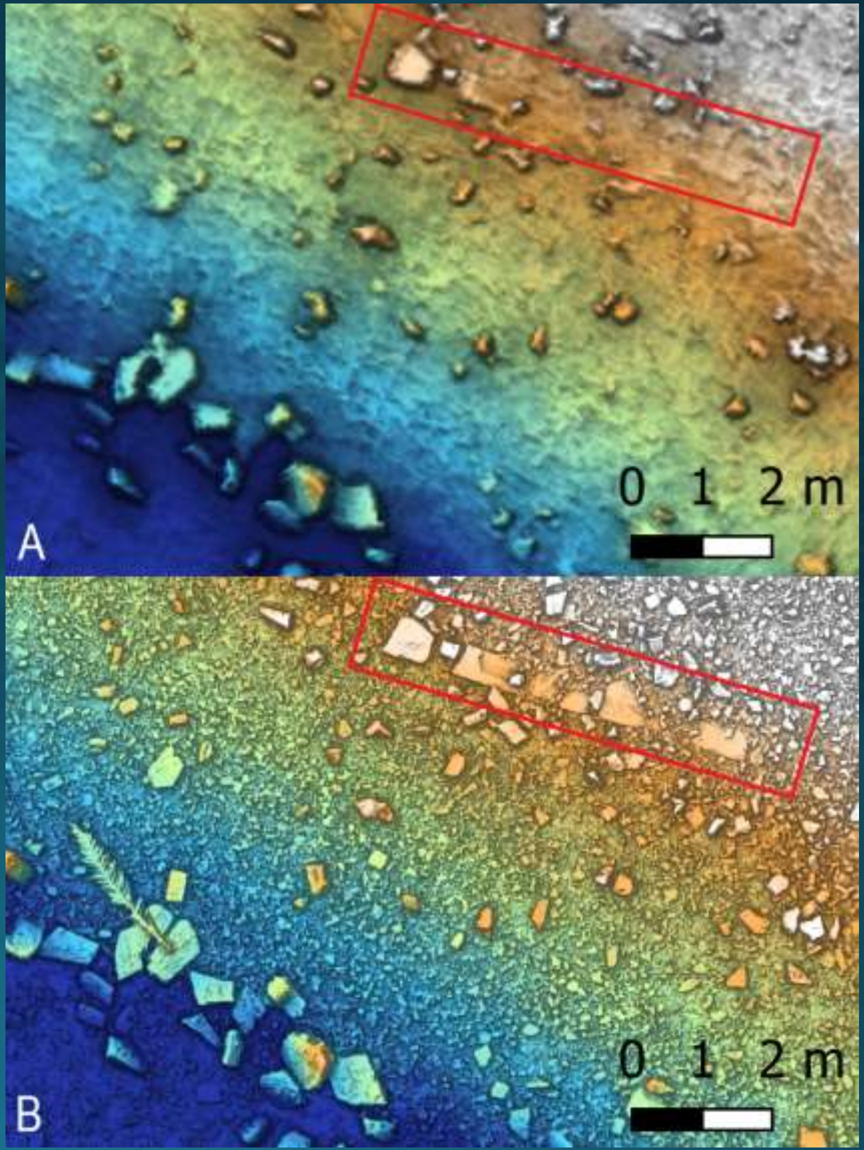
Results: Archaeological site mapping



MBES derived DTM at 5 cm



Detail from orthomosaic

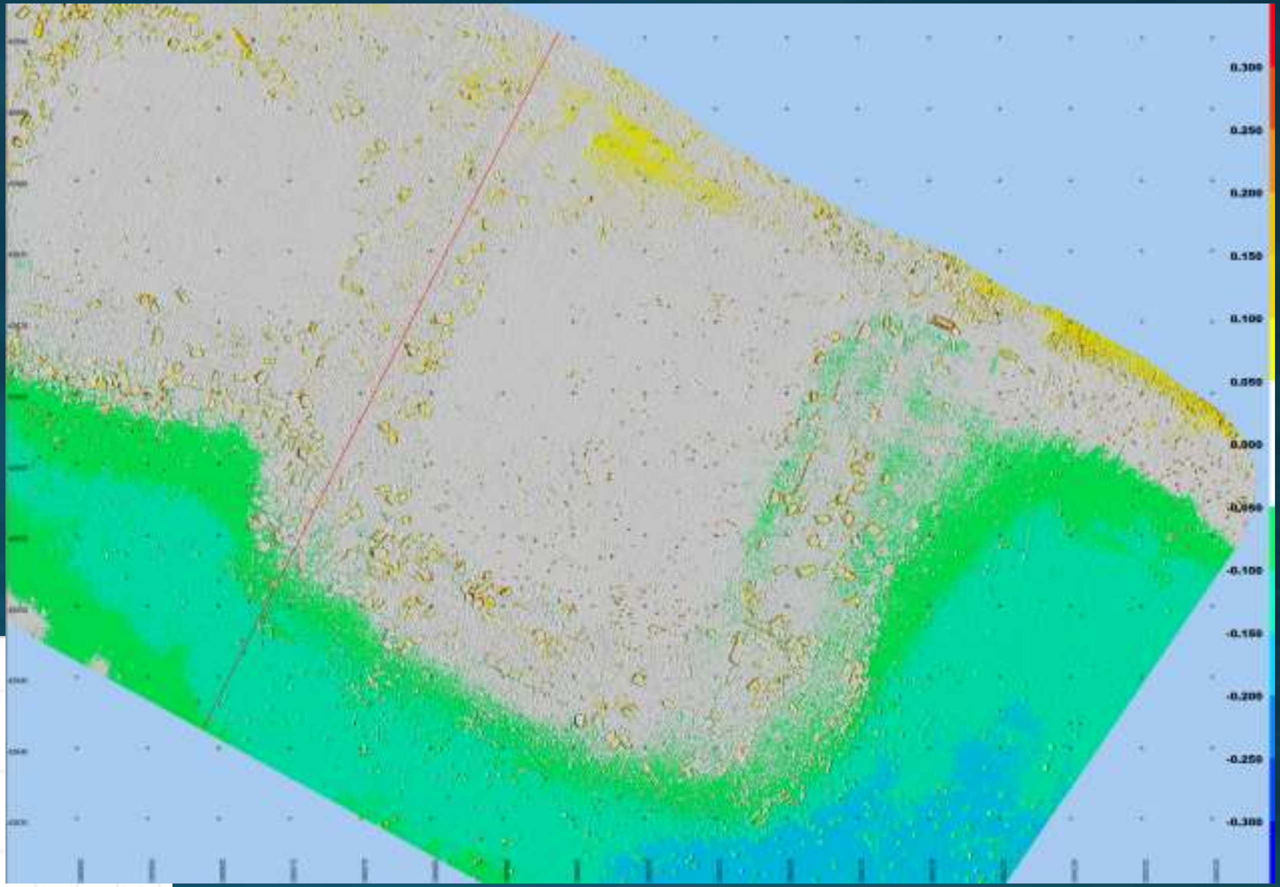


Quality control?

Cross section of the two data sets:

Green – acoustic

Red – optical



Difference model of acoustic and optical DTM

(white: ±5 cm)

Conclusions

- Integrating MBES and photogrammetry provides a powerful approach for high-resolution mapping in shallow coastal waters.
- MBES ensures dependable baseline coverage, while photogrammetry enhances spatial detail where and when environmental conditions permit.
- Errors between methods remained within an acceptable range, supporting the use of this dual-sensor approach in long-term, cyclic monitoring efforts.
- However, optical methods remain sensitive to environmental constraints factors particularly relevant in optically variable zones like the northern Adriatic.
- Seamlessly integrating these two datasets, each with different resolution, scale, and error characteristics, remains an area of active methodological development.

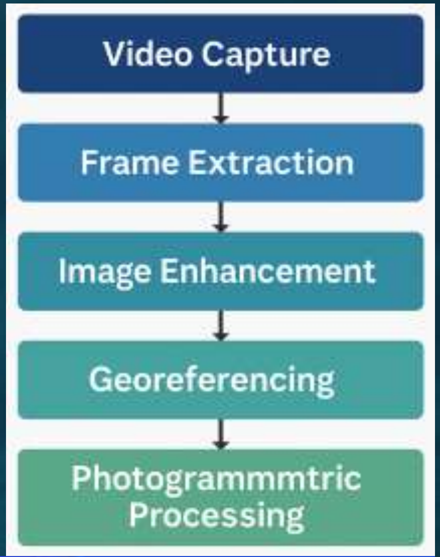
Thank you for your attention!

Sašo Poglajen, Sirio d.o.o.

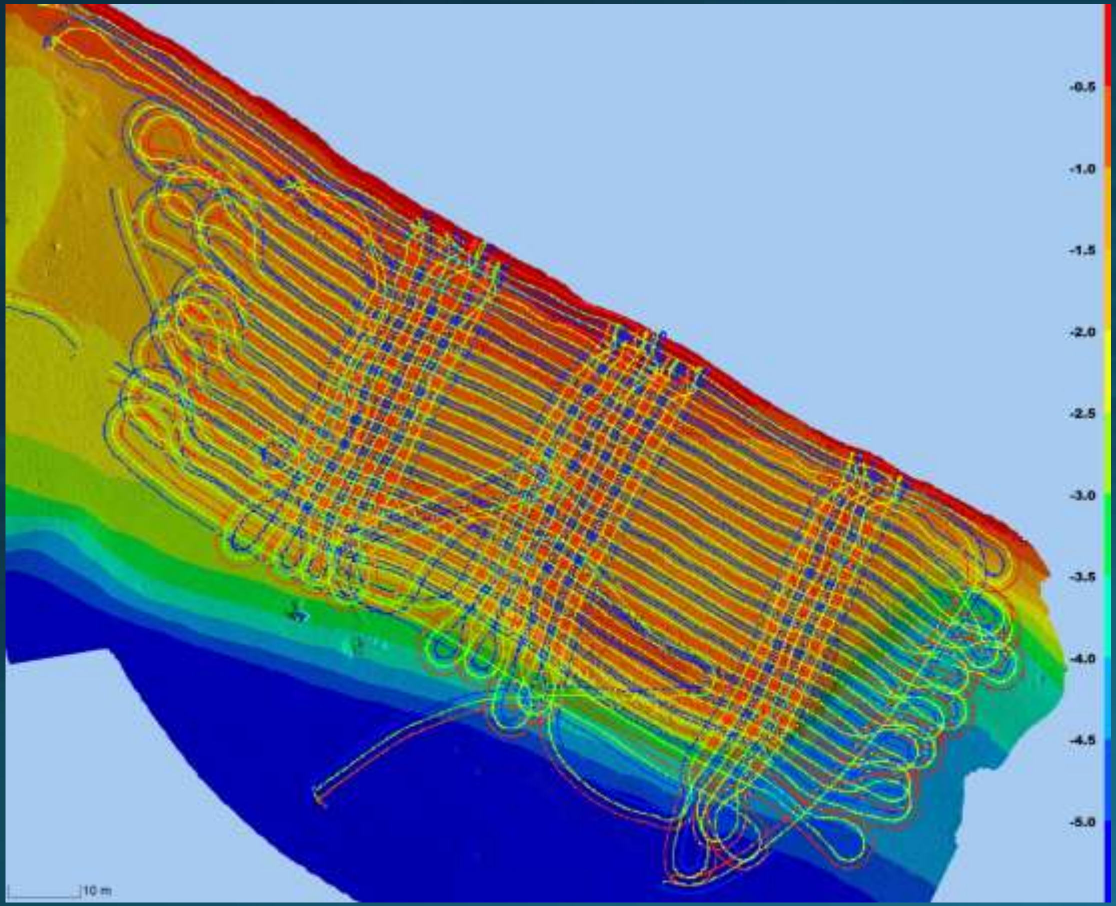
Acknowledgments:

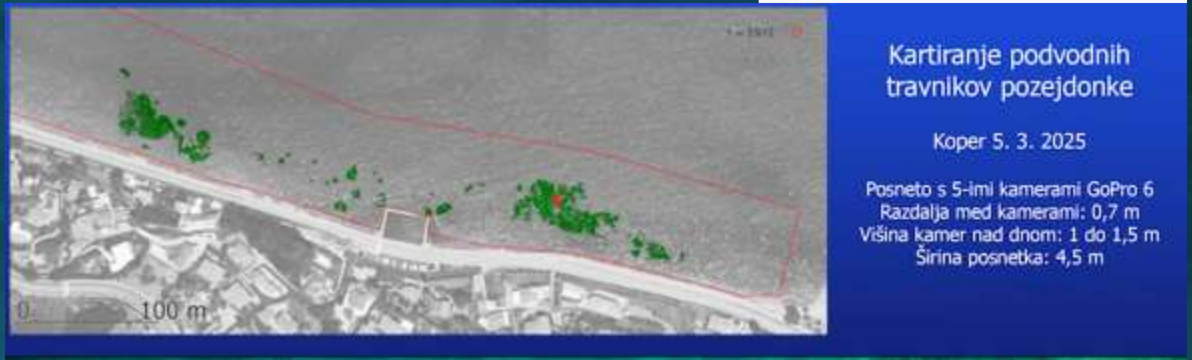
Iztok Rant, Marko Jeklar and Dean Mozetič from Sirio d.o.o.

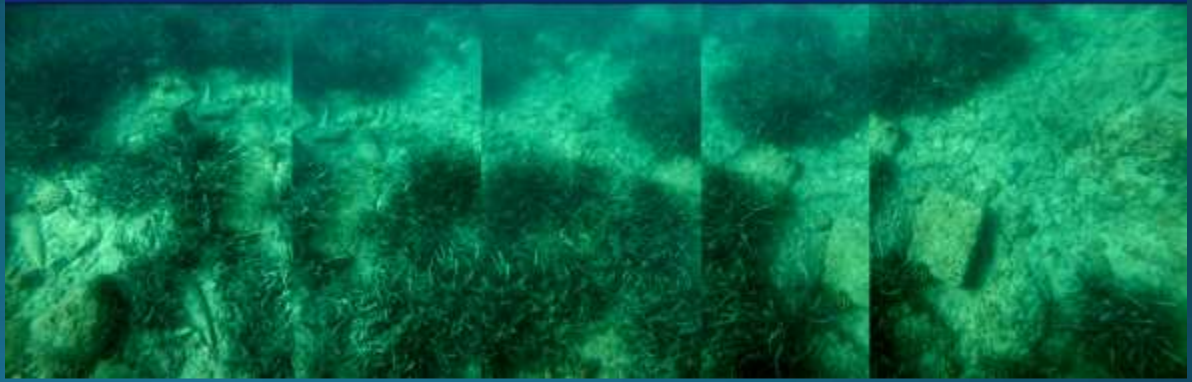
Underwater photogrammetry



Most demanding in terms of acceptable environmental conditions, acquisition and processing.





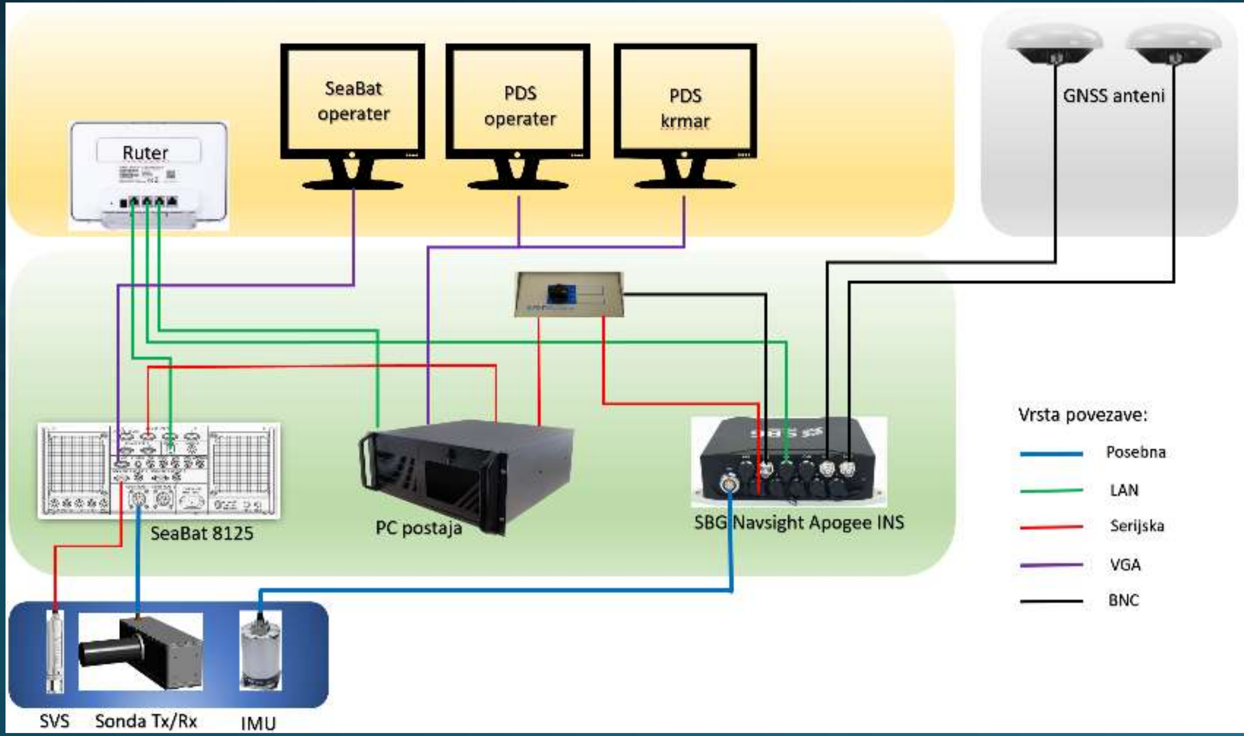


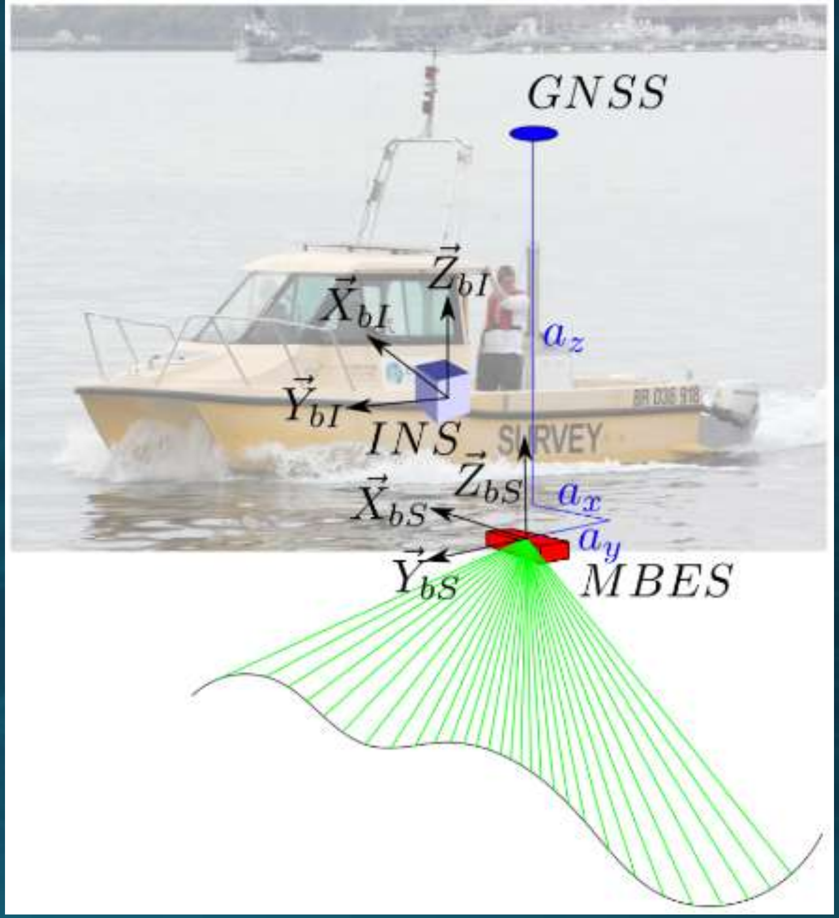
MBES interfacing

MBES operates as a mobile real time mapping platform.

For precise georeferencing of beams we need accurate vessel position (GNSS) and attitude (IMU/INS) in sync with the sonar.

Velocity of sound has to be measured!





Auxiliary sensors:

- GNSS receiver (RTK or PPK)
- IMU and/or INS
- Surface sound velocity
- Sound velocity profile