

Can 3D image analysis reveal environmental signals preserved in mussel shells?



JESSICA DESSAU¹, JOSEFINE LARSSON², STEPHEN HALL³, HELENA L. FILIPSSON¹,

¹DEPT. OF EARTH AND ENVIRONMENTAL SCIENCE, LUND UNIVERSITY; ²MARINT CENTRUM, SIMRISHAMN; ³DEPT. OF CONSTRUCTION SCIENCES, LTH, FACULTY OF ENGINEERING, LUND UNIVERSITY

1 INTRODUCTION

The 2023 Marco Polo ferry grounding released oil into Hanö Bay, Sweden, an important coastal ecosystem supporting diverse marine life.

Blue mussels are ecologically important and widely used as bioindicators of coastal environmental change, and their continuously growing shells can preserve a record of past conditions.

Can 3D μ CT image analysis reveal spatially resolved environmental signals in shell structure?



- 7 coastal sites
- 4 oil-exposed 3 reference
- Autumn 2024 Spring 2026

2 NATURAL ARCHIVE

A mussel shell is a three-dimensional biological archive



New shell material is continuously deposited during growth, creating spatial variation that may preserve information about environmental conditions.

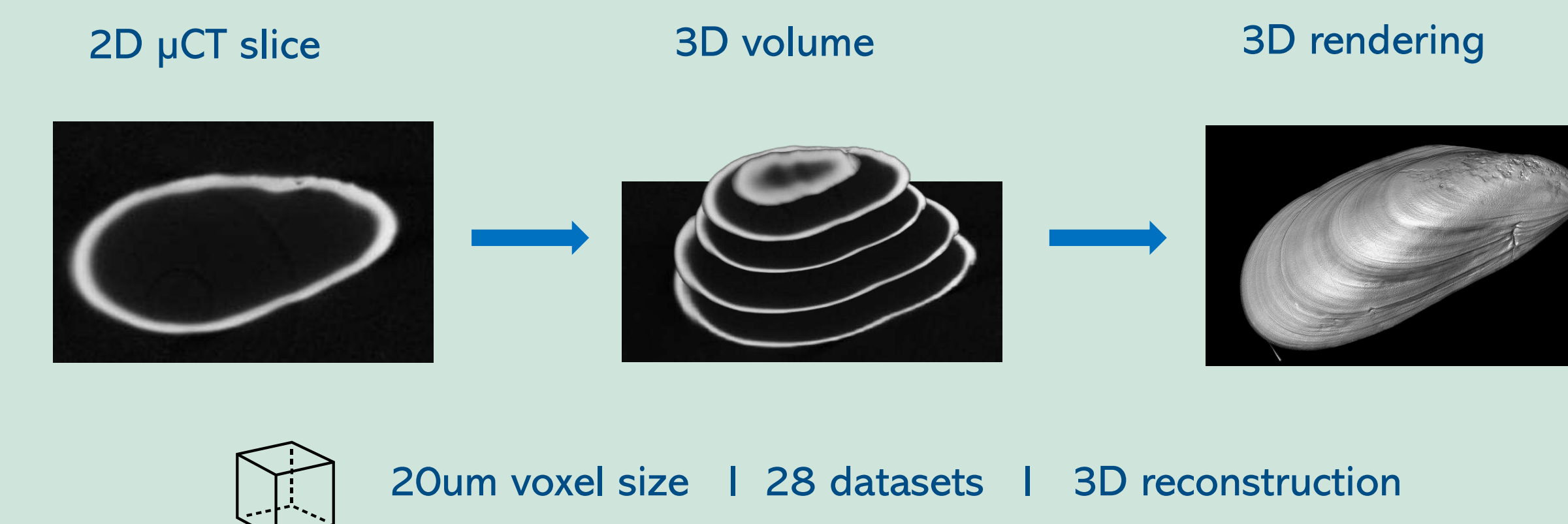
μ CT allows this record to be visualized and quantified in 3D.

3 3D IMAGING

μ CT captures the shell as a high-resolution volumetric dataset.

Shell valves were scanned using an RX Solutions EasyTom 150 X-ray micro-tomograph (4D Imaging Lab, Lund University) and reconstructed as 3D volumes.

3D volumes were processed in Dragonfly 3D World v2025.1® for segmentation and quantitative morphometric analysis.



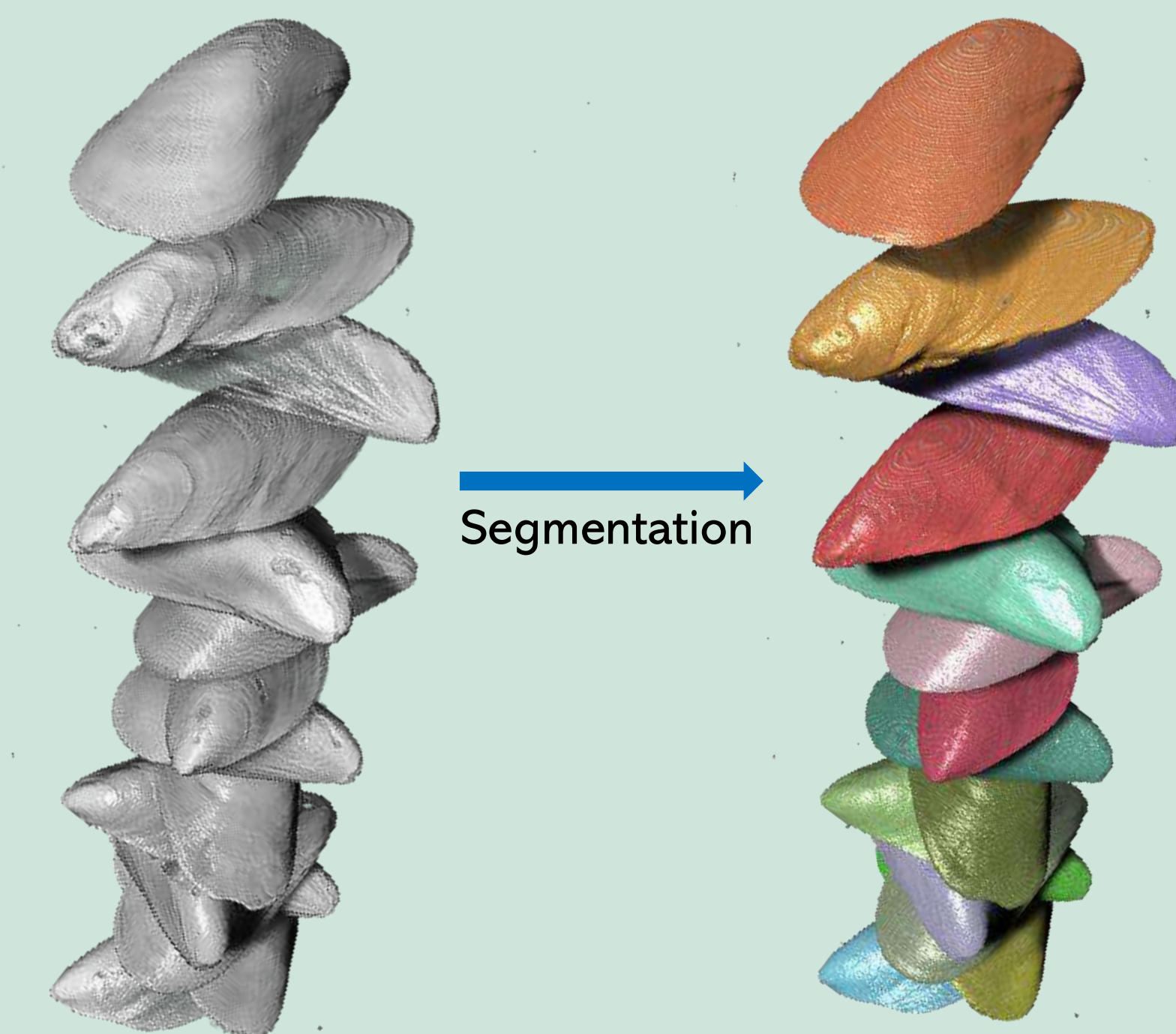
20um voxel size | 28 datasets | 3D reconstruction

4 THE SEGMENTATION CHALLENGE

From volume to measurable shell structure

The μ CT volume contains the information needed for quantitative analysis, but the shell must first be separated from the surrounding volume.

Manual segmentation is time-consuming and operator-dependent, limiting consistent processing of larger datasets.

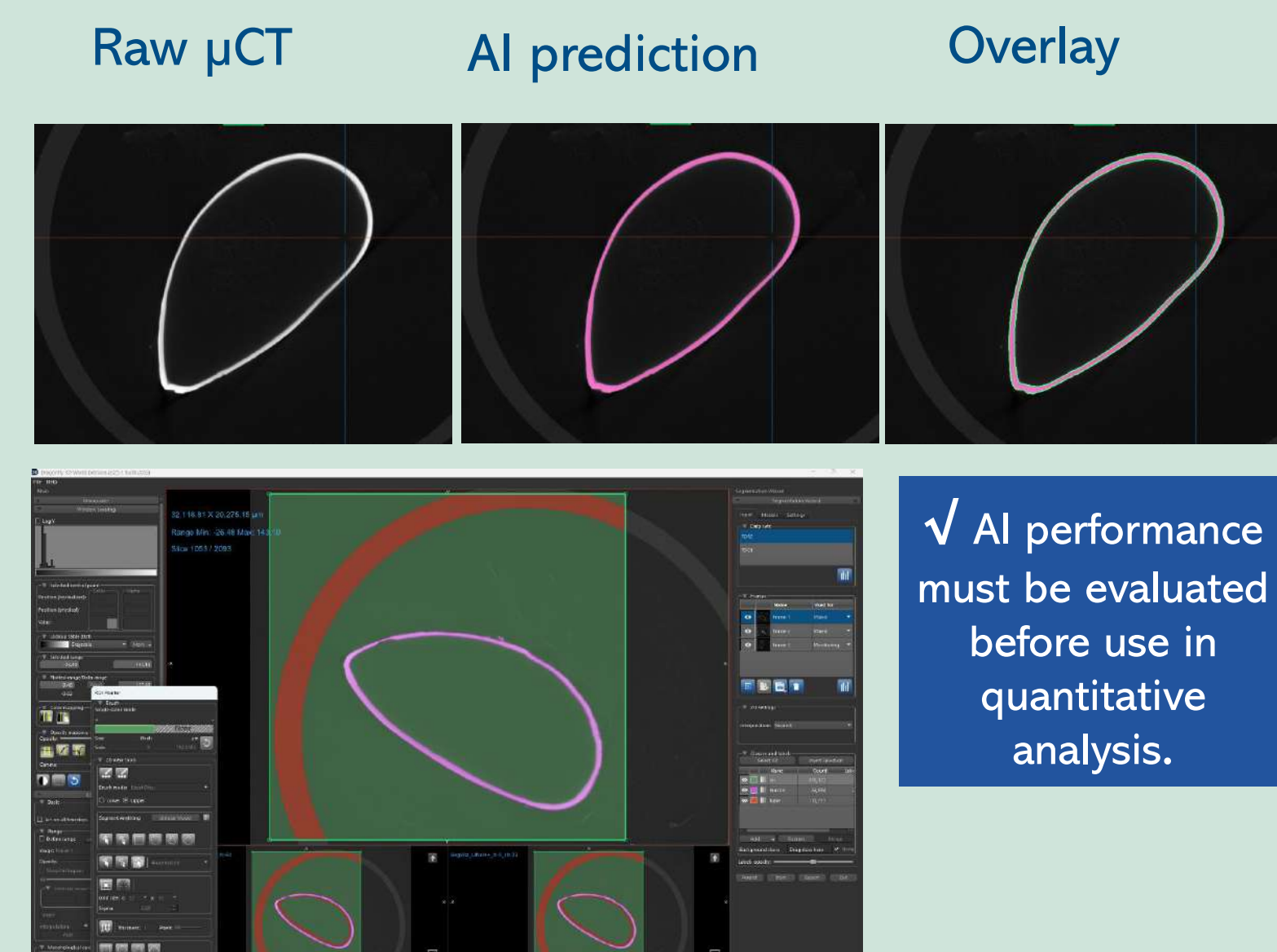


5 AI-ASSISTED SEGMENTATION

CAN COMPUTER VISION HELP US DO THIS MORE EFFICIENTLY AND REPRODUCIBLY?

AI-based segmentation is being explored as an alternative to manual segmentation.

A trained model is applied to μ CT volumes with the aim of improving efficiency and reproducibility across datasets.



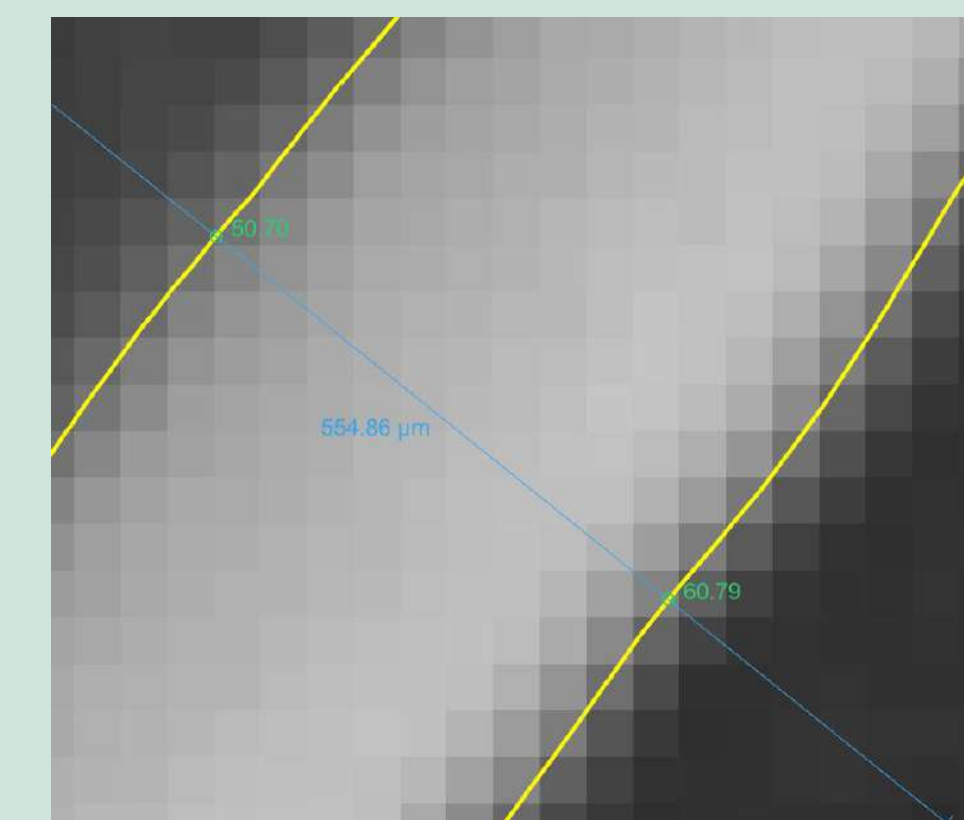
✓ AI performance must be evaluated before use in quantitative analysis.

6 VALIDATION

DOES THE SEGMENTATION CORRESPOND TO THE RAW μ CT DATA?

- **Boundary agreement**
Surface Determination was compared with manually identified shell boundaries.
- **Parameter sensitivity**
Key settings were varied to assess their effect on shell geometry.
- **Reproducibility**
Individual-shell and complete-dataset processing were compared.

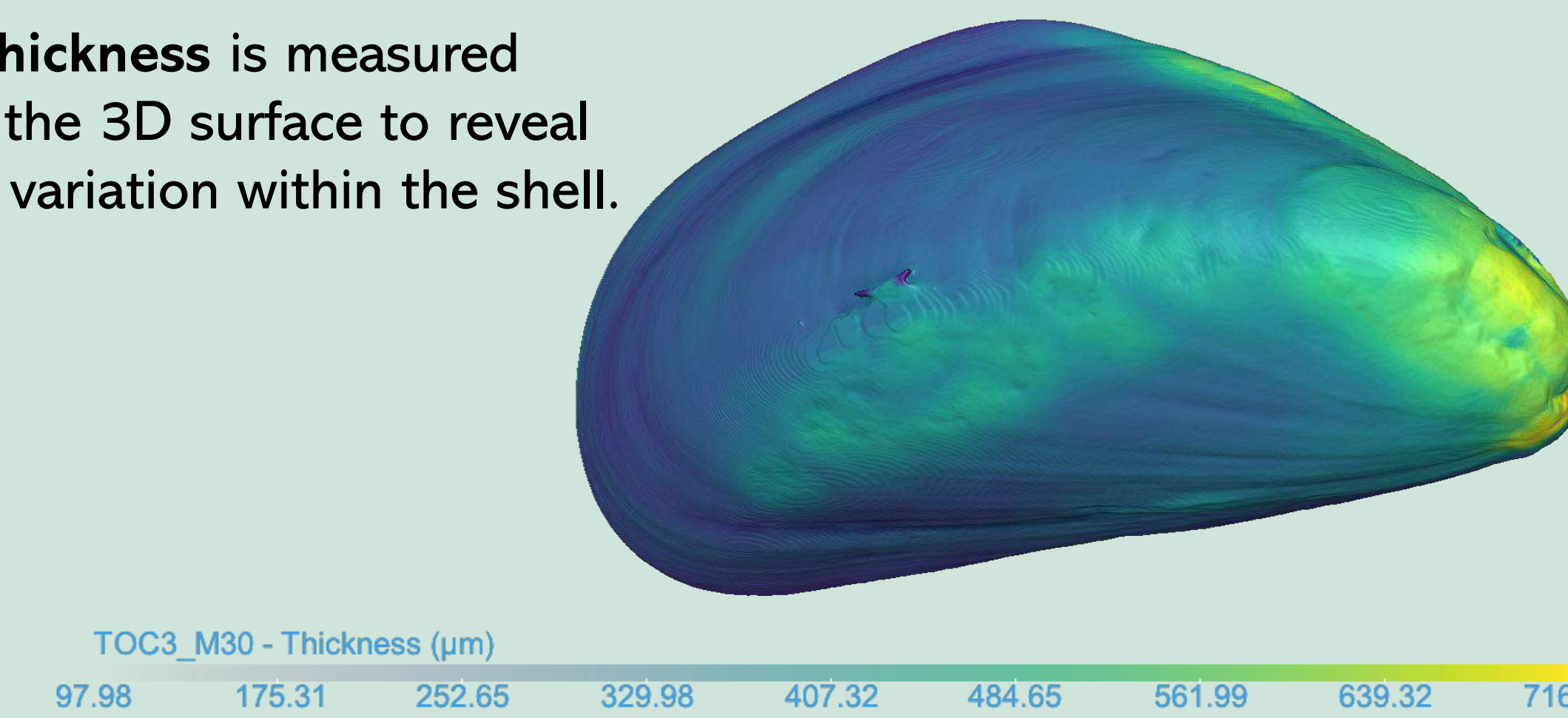
Surface Determination identifies the shell boundary at sub-voxel resolution.



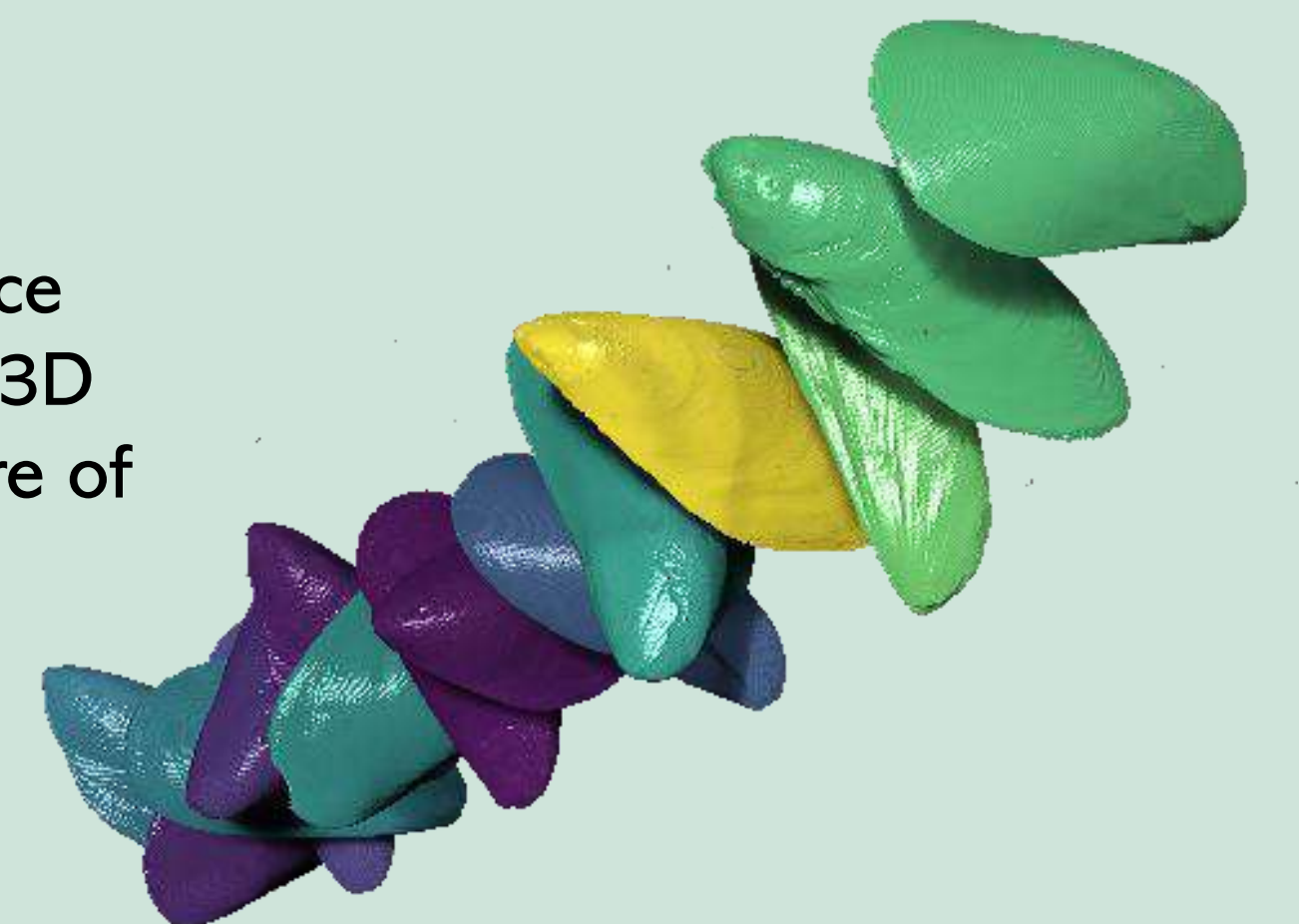
7 3D QUANTITATIVE ANALYSIS

FROM 3D IMAGING TO QUANTITATIVE DATA

Shell thickness is measured across the 3D surface to reveal spatial variation within the shell.



Maximum Feret diameter describes the largest distance between two points on the 3D shell and provides a measure of shell size.



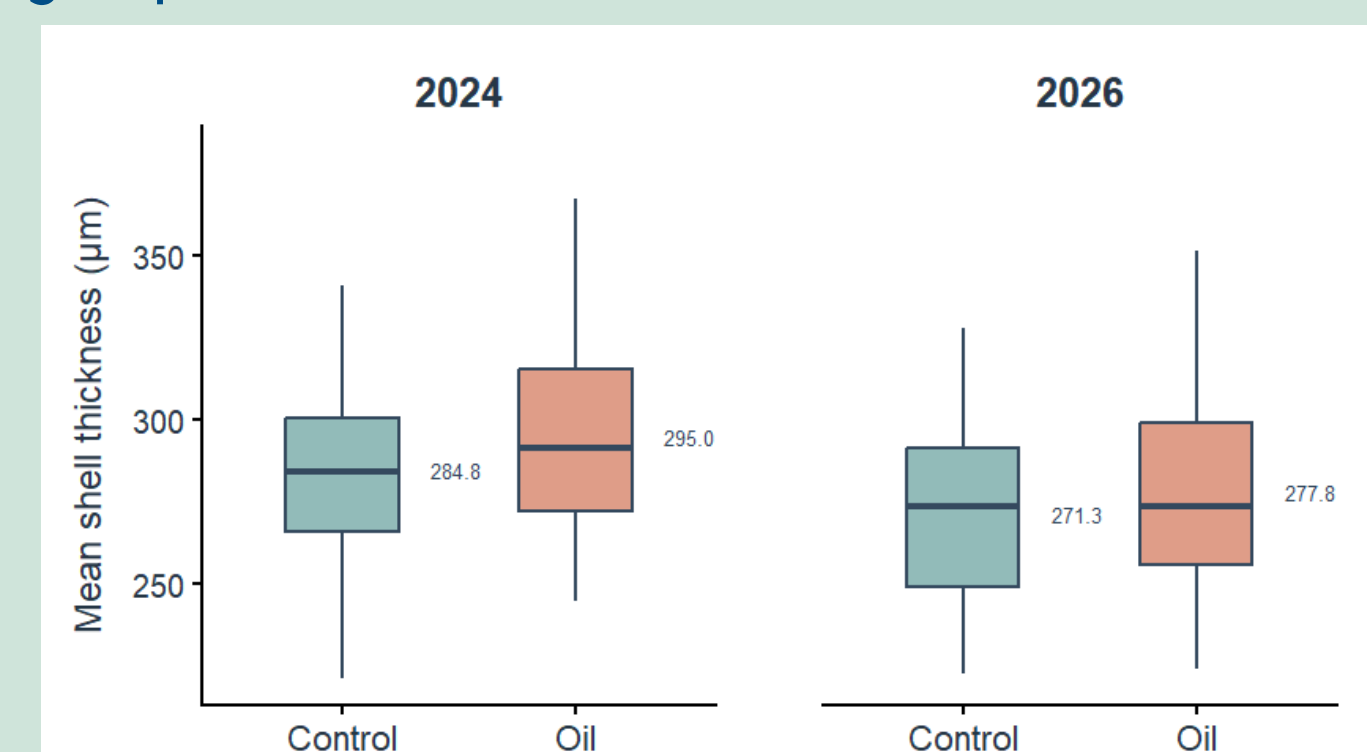
SIZE: Feret diameter · Volume SHAPE: Surface area · Volume Index STRUCTURE: Shell thickness · Spatial variation

8 ENVIRONMENTAL SIGNAL

Whole-shell thickness varied between years, with no consistent difference between oil-exposed and reference mussels.

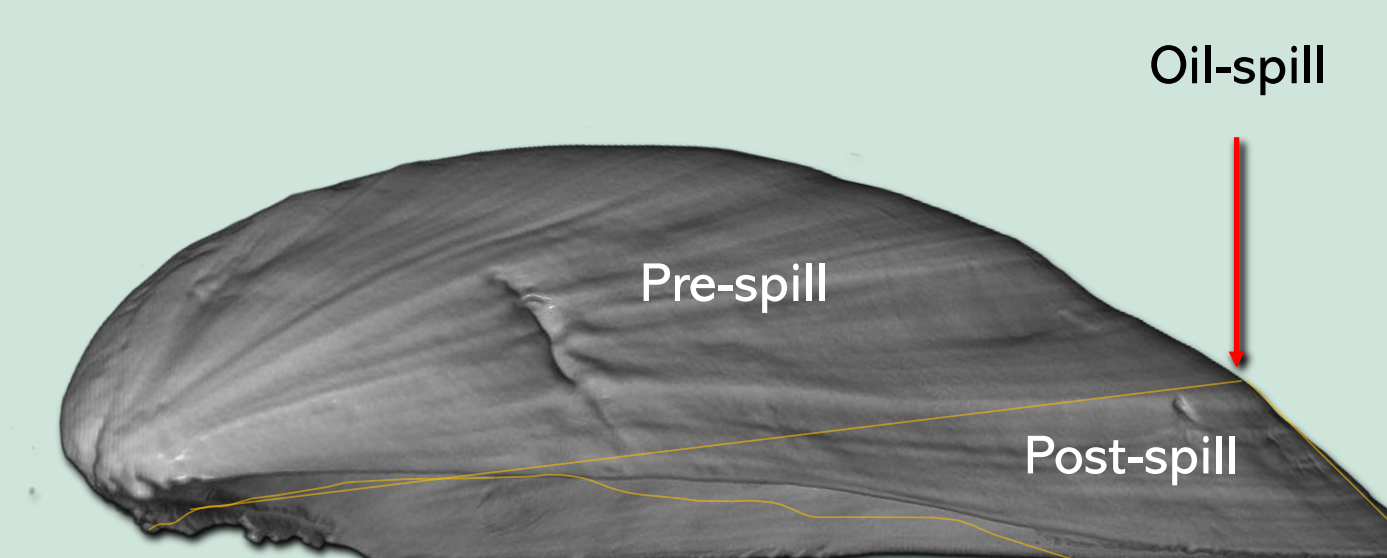
Because whole-shell measurements combine material formed before and after the spill, localized responses may be obscured.

Mean shell thickness (μ m) for control and oil-exposed mussels sampled in 2024 and 2026. Numbers indicate group means.



9 NEXT STEP: ISOLATING PRE- AND POST-SPILL GROWTH

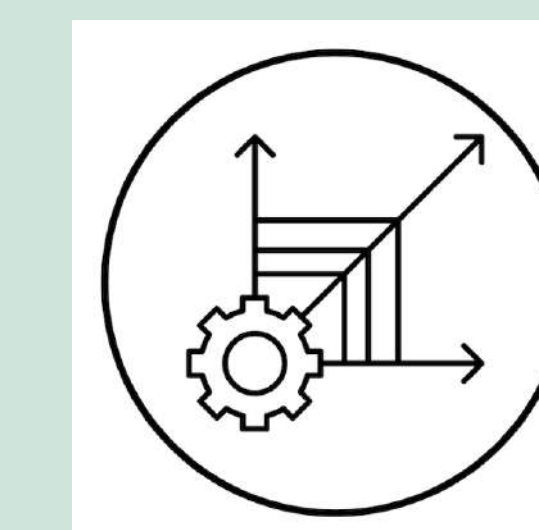
The next step focuses on spatially defined growth regions to isolate shell material formed after the spill and investigate potential environmental signals in 3D.



10 TAKE-HOME MESSAGE



μ CT captures the shell in 3D



Computer vision can make segmentation more scalable and reproducible



3D analysis unlocks environmental information

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Contact: jessica.dessau@mgeo.lu.se

