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Integrating Deep Learning and Multiscale Ecosystem Connectivity of the Marine Habitat

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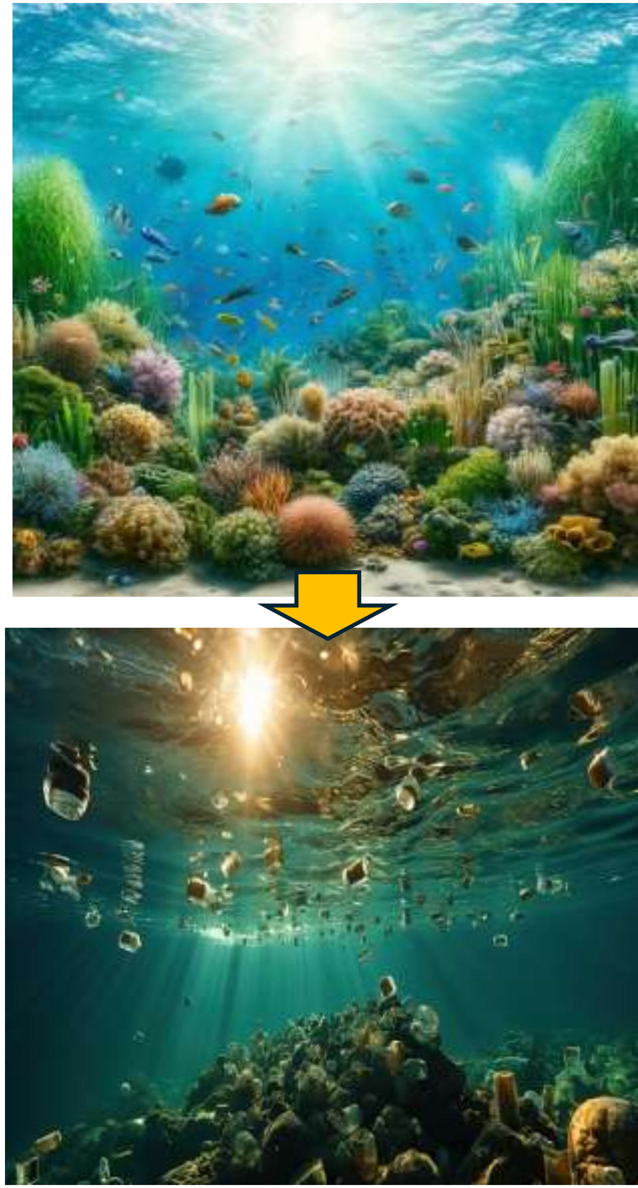
Introduction

Importance of Marine Ecosystems:

- Marine ecosystems are biodiversity-rich and vital for ecological balance. They provide essential services such as **oxygen** production, **carbon** sequestration, and support for marine life.

- These ecosystems are **under significant threat from human impacts**, including **overfishing**, **pollution**, and **climate change**, which disrupt their delicate balance.



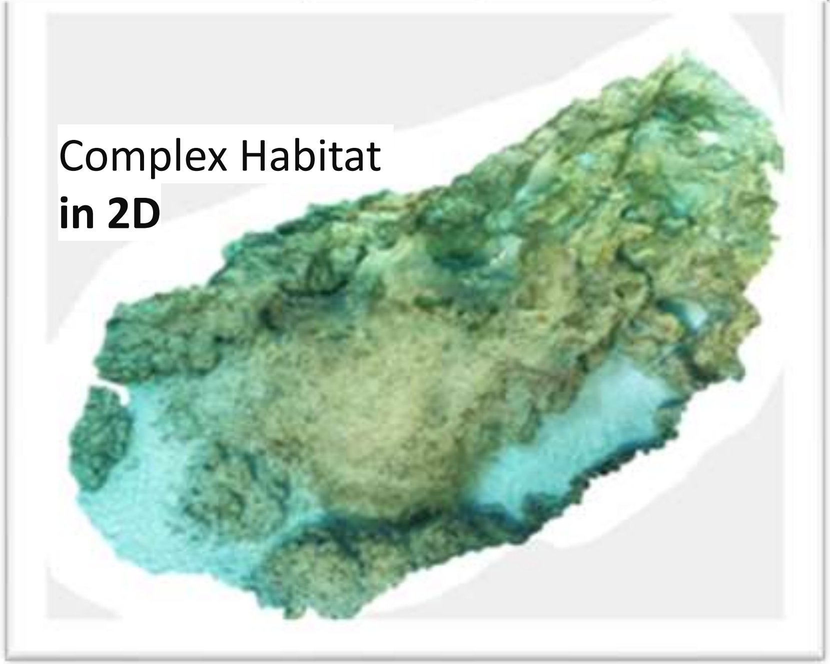
Introduction

Role of AI and 3D Modeling:

•**Artificial Intelligence (AI)** helps understand **complex** marine biodiversity and ecosystems by analyzing **large datasets** and uncovering previously **unknown patterns**, enabling more **effective conservation**.

• **AI** is also used to **deal** with the **vast number of unknown marine species**, aiding in their **classification** and **detection**.

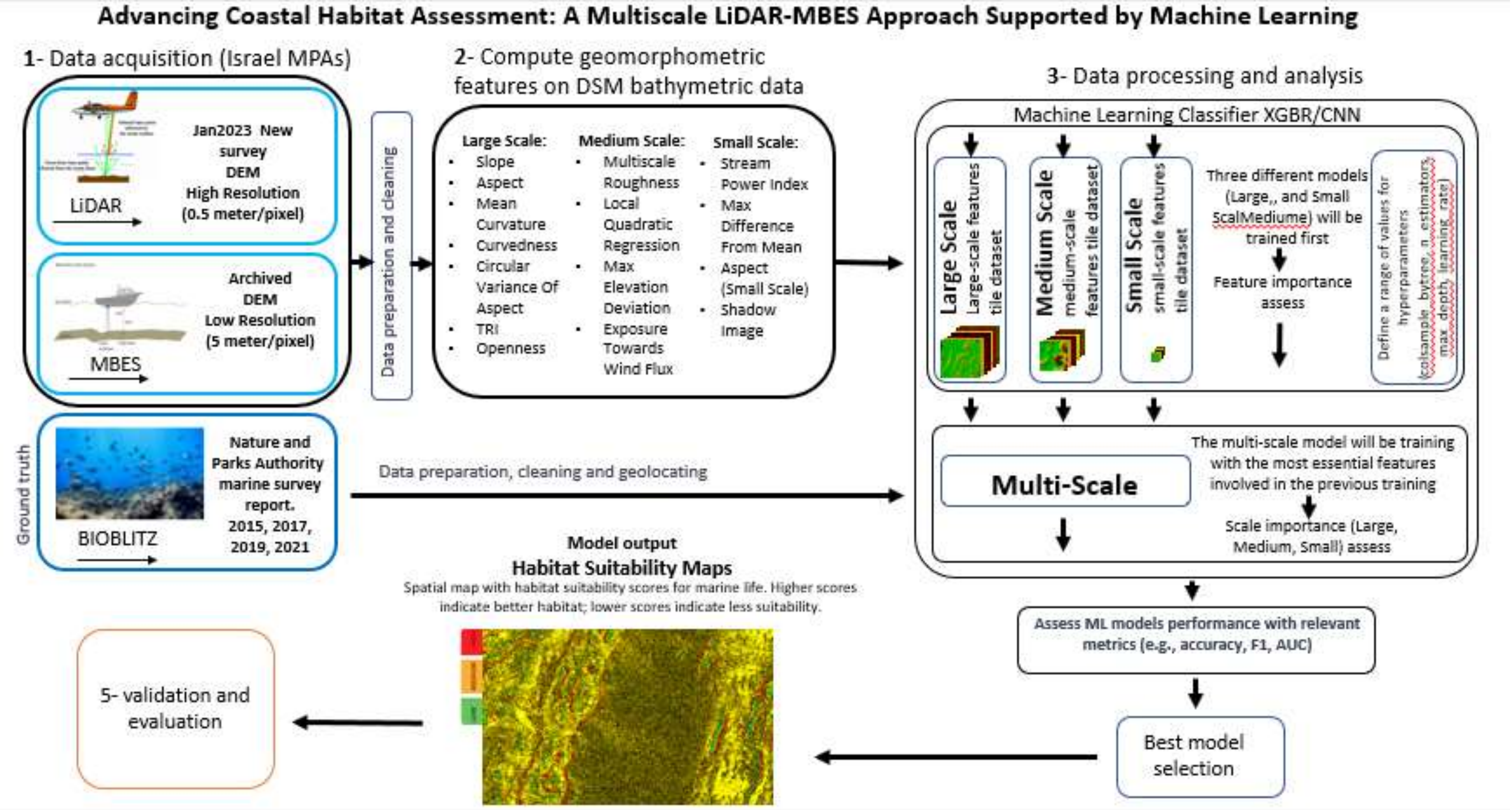
•**3D modeling** provides **precise mapping** of underwater structures, correcting **limitations of 2D models**. It offers a more **accurate view** of marine habitats, revealing detailed insights into **habitat complexity and connectivity**.



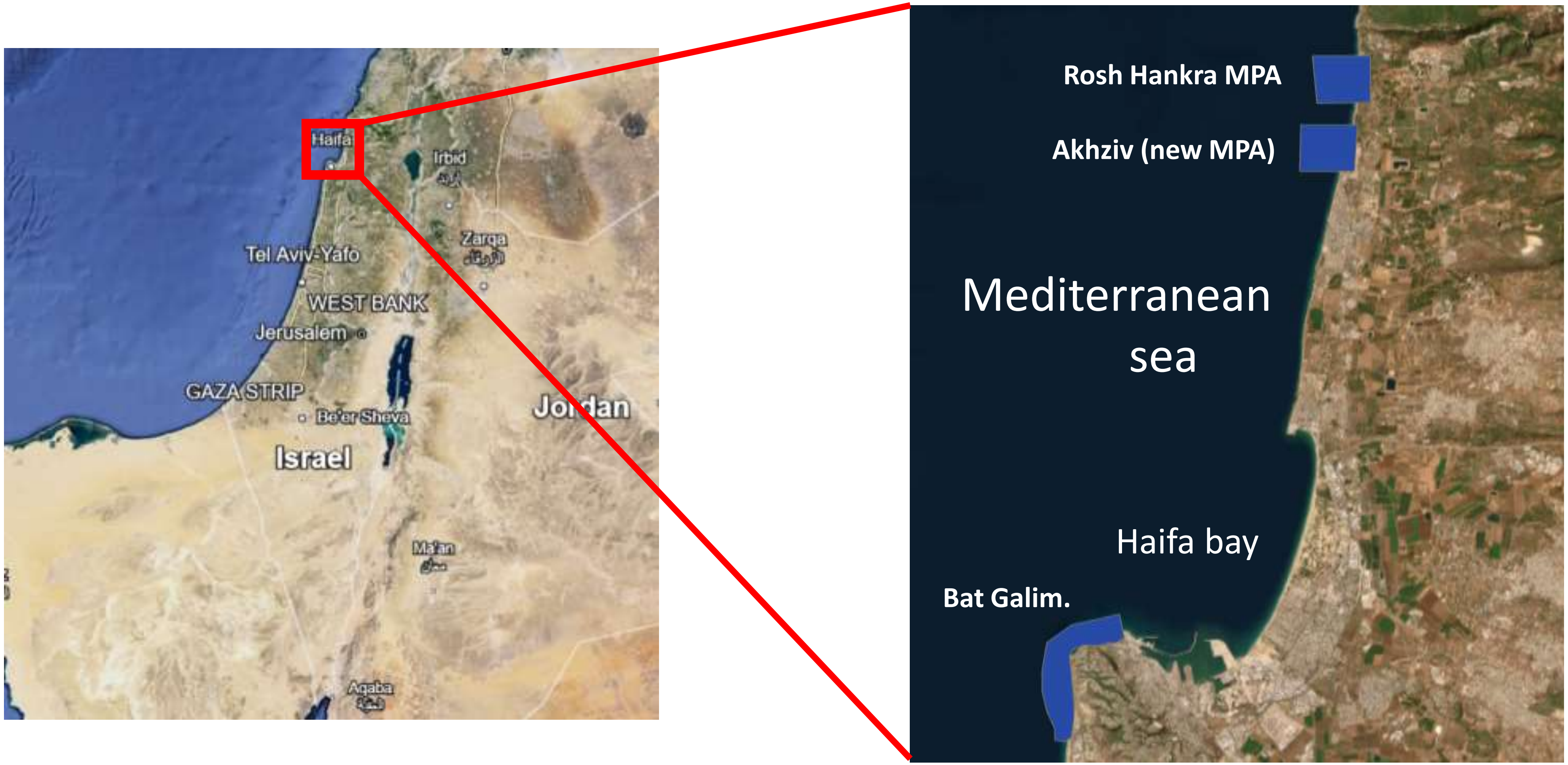
Objectives

1. Evaluate the Current State of Marine Biodiversity:
   Utilize AI and 3D modeling to analyze marine species distribution.
2. Advance Seascape Characterization Methods:
   Integrate AI-driven data analysis and 3D spatial modeling.
3. Develop Predictive Models for Conservation Efforts:
   Use machine learning algorithms to predict changes in biodiversity and seascapes.
4. Optimize Monitoring and Management of Marine Ecosystems:
   Improve efficiency and precision of monitoring programs.

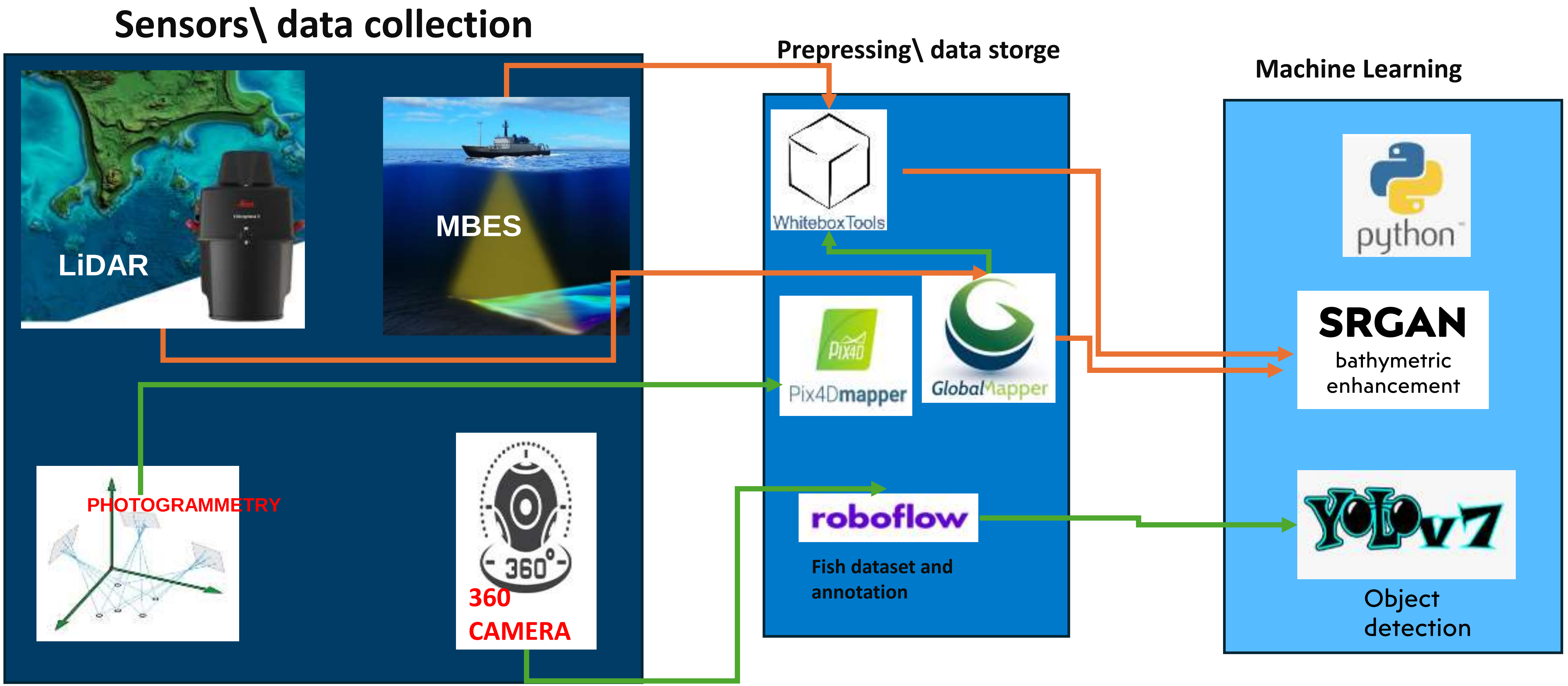
Methodology – Flowchart



Methodology - Data Acquisition – Research area

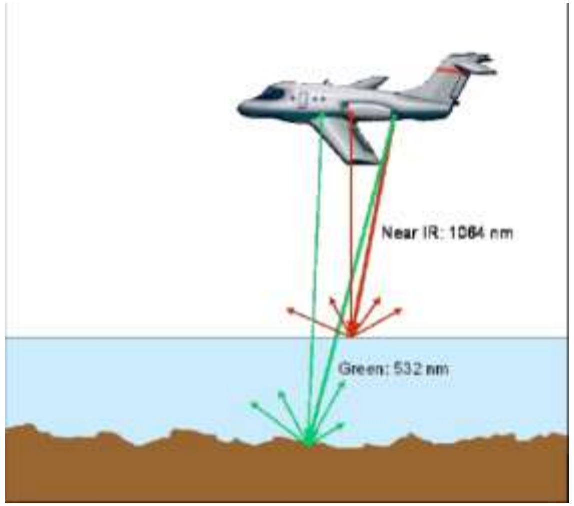


Methodology - Data Acquisition



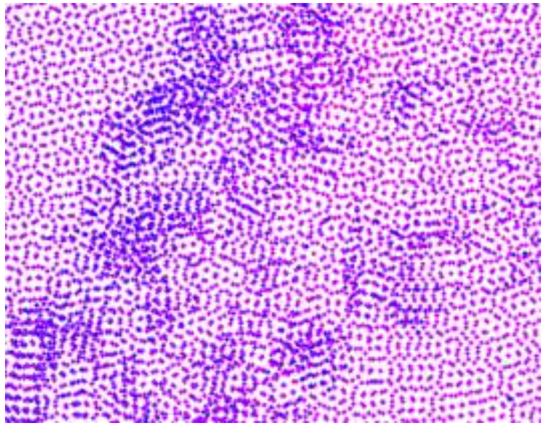
Methodology - Data Acquisition – LiDAR bathymetry

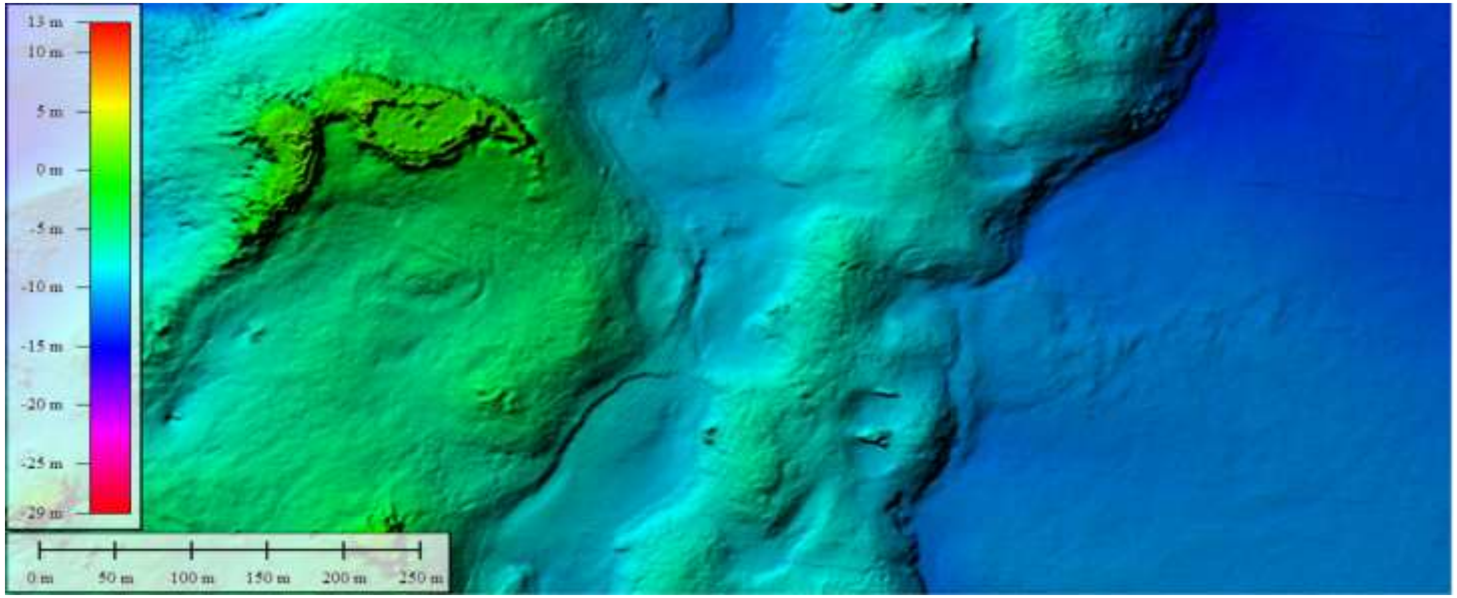
mounting a LiDAR sensor on an aircraft.



Points cloud

Preprocessing and classification



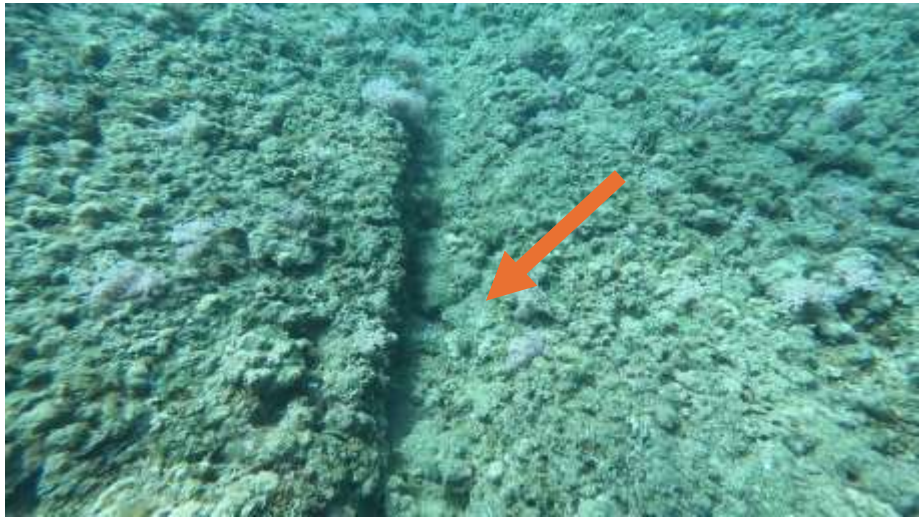


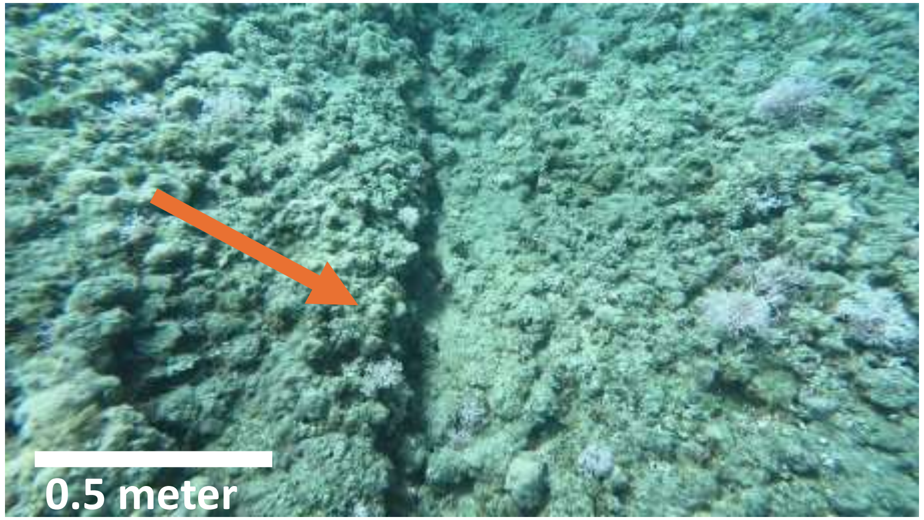
DEM
digital elevation model

Resolution of 0.5 meter/pixel

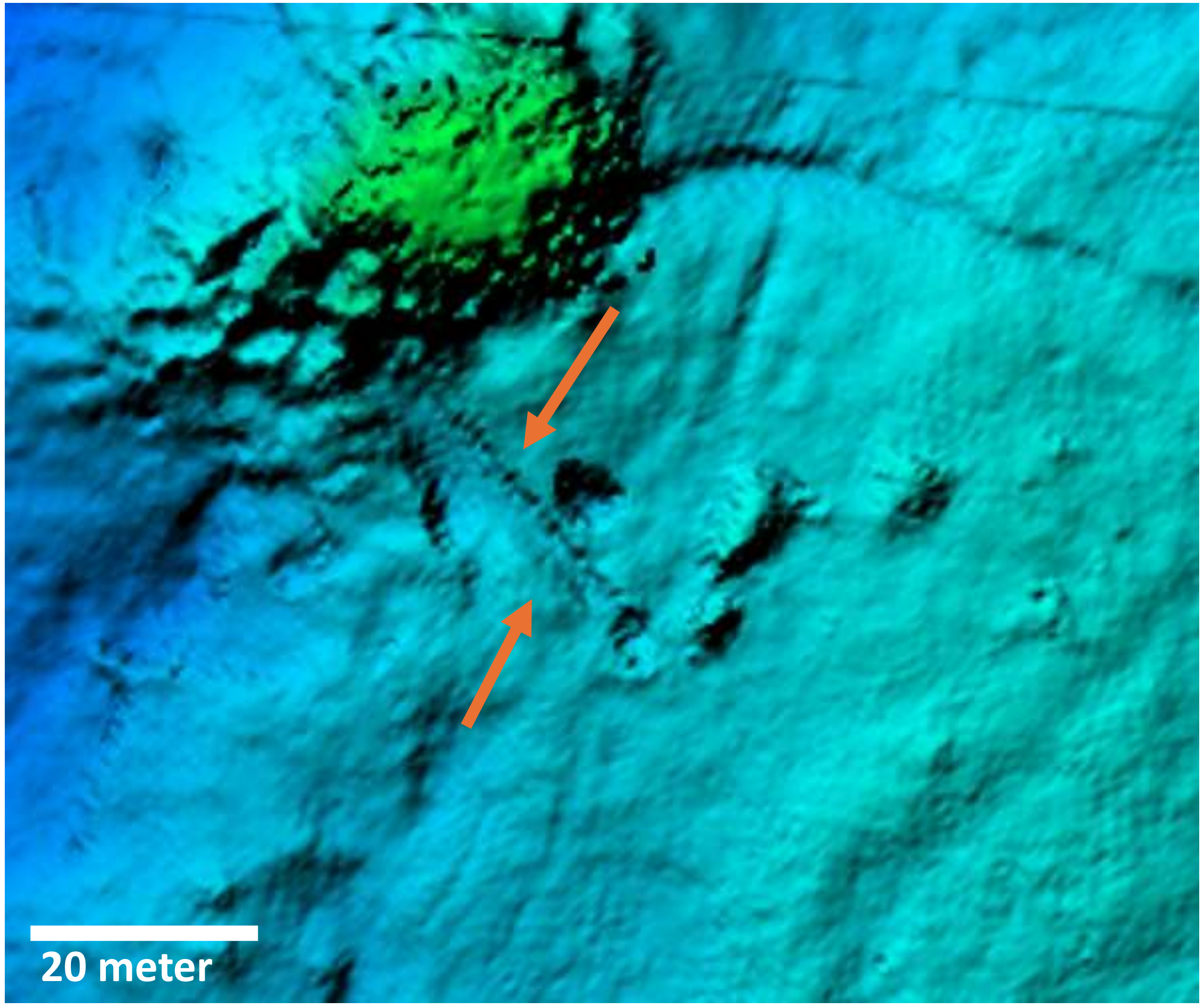
Methodology - Data Acquisition – LiDAR bathymetry

GoPro camera



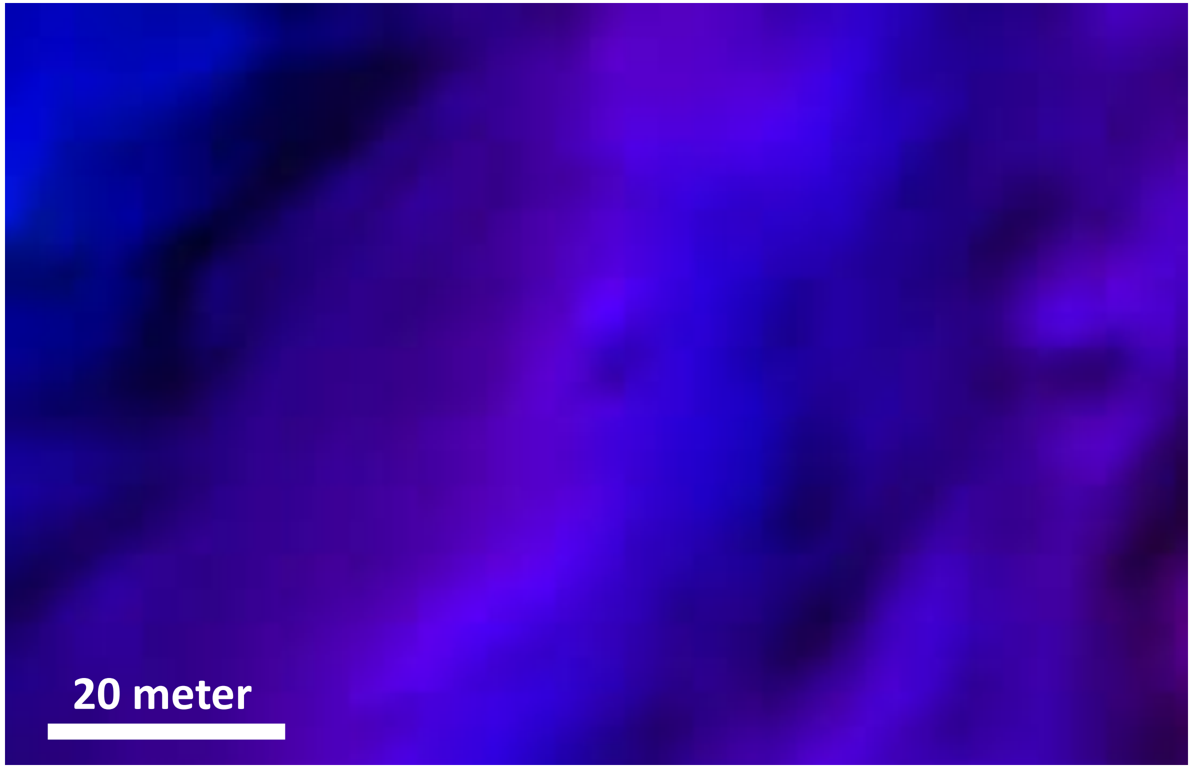


LiDAR

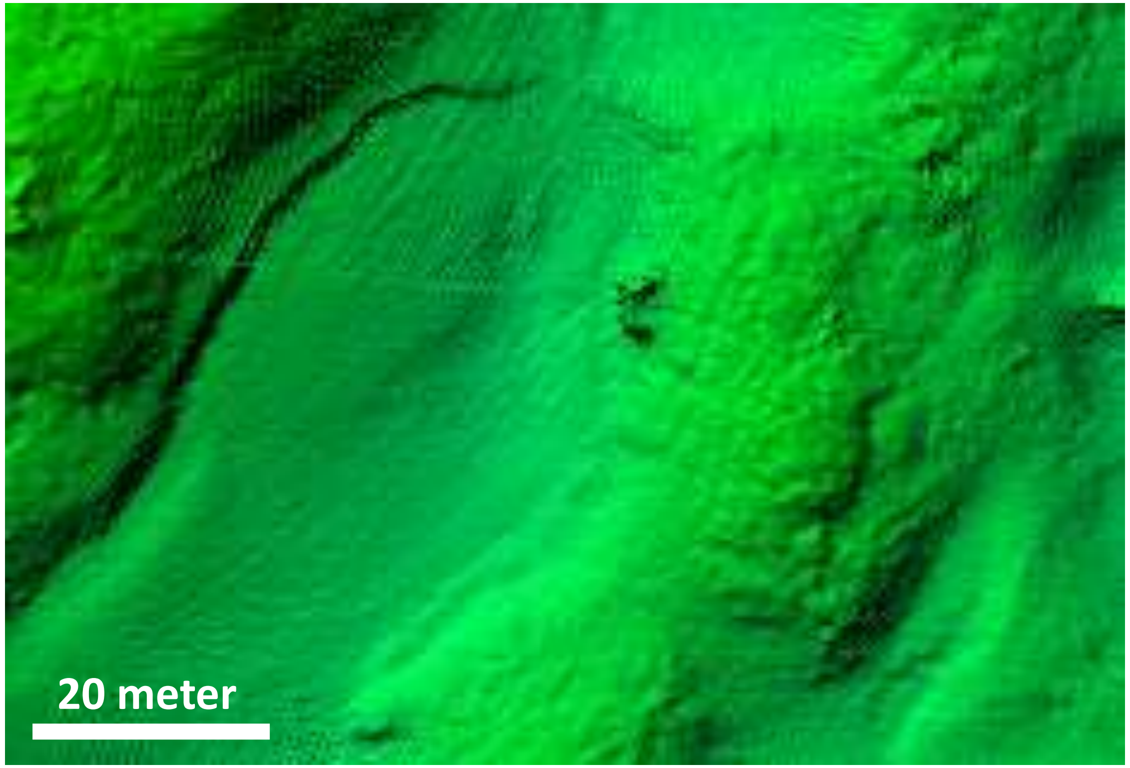


Methodology - Data Acquisition – MBES bathymetry

Archived (90s) MBES (5 meters per pixel)

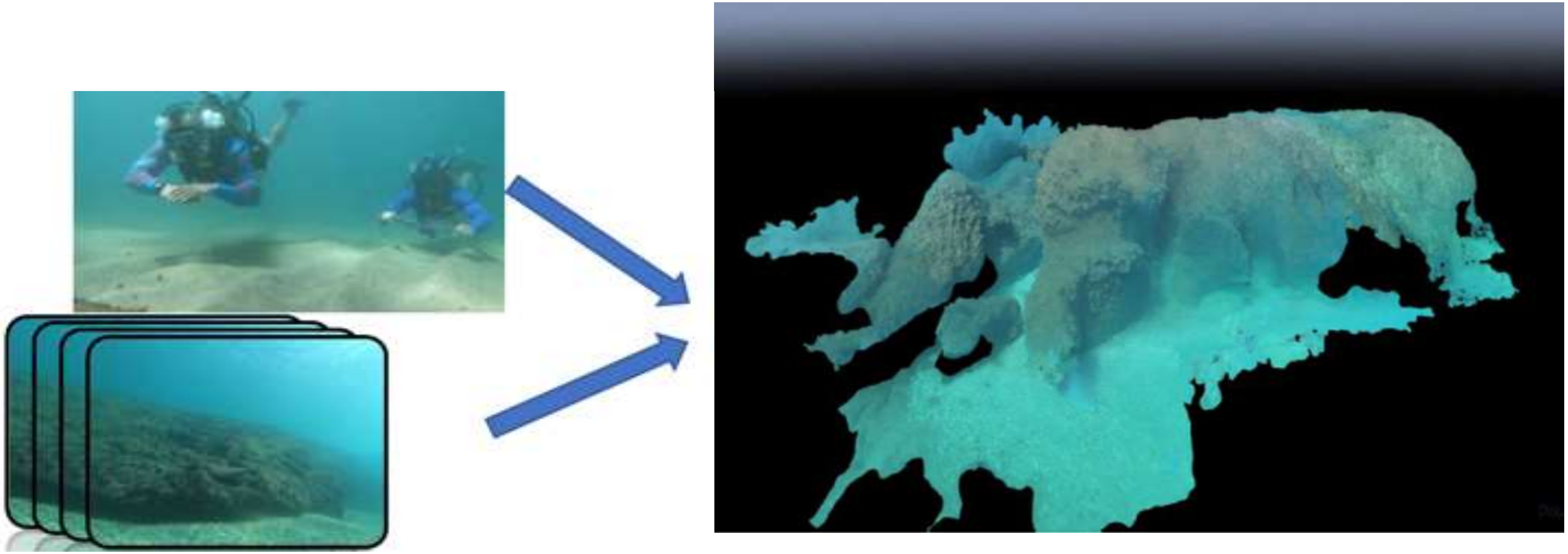


LiDAR Output (0.5 meters per pixel)



Methodology - Data Acquisition - 3D models from photogrammetry

1. **Photogrammetry** is essential for **validating LiDAR data** in specific areas where **data is missing**
2. This process **ensures the accuracy** and completeness of our marine habitat maps.
3. We perform photogrammetry using **scuba diving** expeditions to capture **high-resolution images.**
4. These images are processed with **photogrammetry software** to create detailed **3D models of** the underwater environment.



Methodology - Bathymetry enhancement

SRGAN

What is SRGAN?

A super-resolution Generative Adversarial Network (SRGAN) is a type of machine learning model used to **enhance image resolution**.

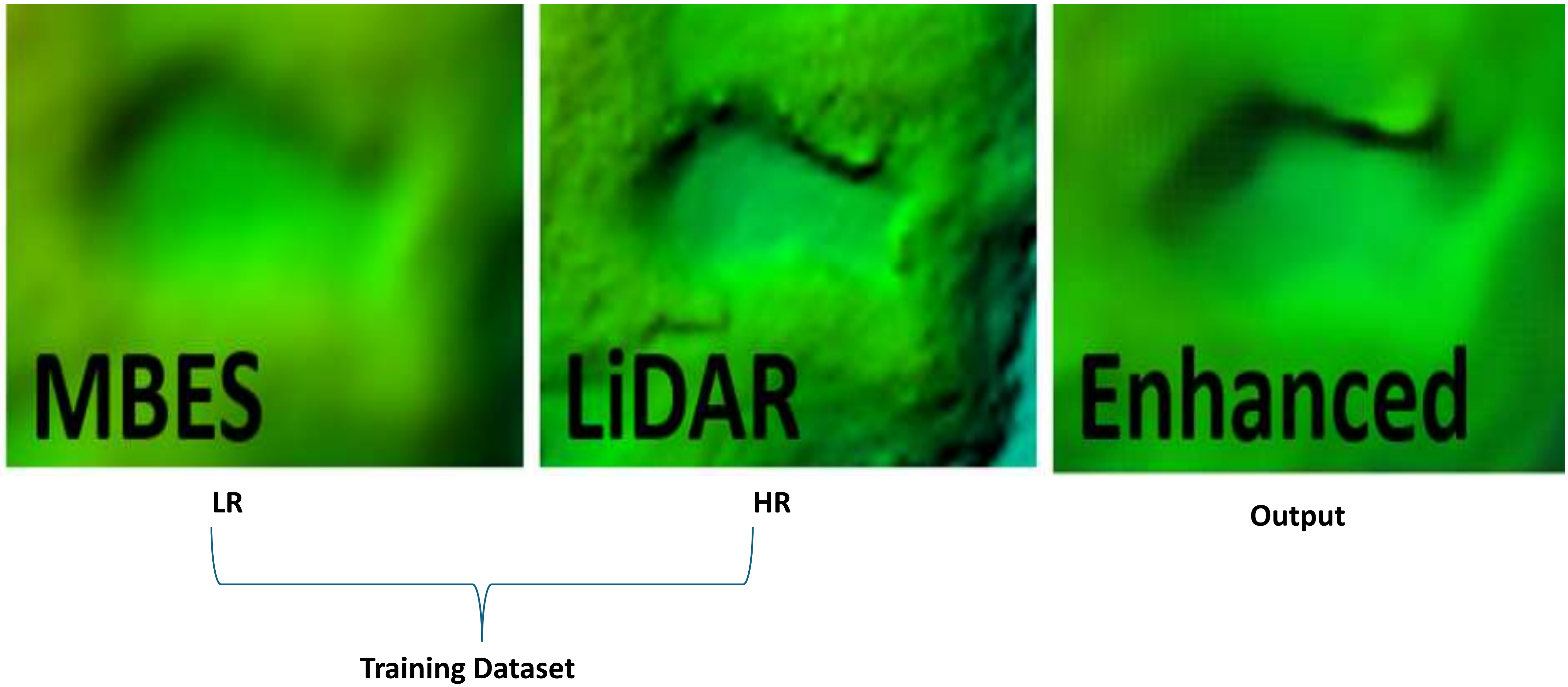
- It works by **training a neural network** to **generate high-resolution** images from **low-resolution inputs**, using a combination of adversarial training and perceptual loss.

Purpose of Bathymetry Enhancement

- Bathymetry maps created from multibeam echosounder (MBES) data **cover vast areas** but often lack the desired resolution for detailed analysis.
- **LiDAR data offers higher resolution** but is **limited in coverage** due to the **extensive time required for surveys.**
- **Enhancing MBES data using SRGAN** allows us to **achieve high-resolution maps** over large areas quickly, **meeting our needs for detailed marine habitat** studies.

Methodology Bathymetry enhancement

SRGAN



Methodology - Data Acquisition – Fish Dataset

- **Purpose of 360-Degree Cameras:**
  - We use **fixed 360-degree cameras** to record underwater **videos** during **various seasons** to monitor marine **biodiversity** and habitat changes.
  - These cameras provide comprehensive and **continuous data collection**, covering a **wide field of view**.
- **Advantages Over Traditional Methods:**
  - **Traditional BioBlitz** surveys rely on divers to **manually observe** and record marine life, which is **time-consuming** and prone to **human error**.
  - Using 360-degree cameras allows for more **accurate**, efficient, and **less intrusive** monitoring of marine ecosystems.

Methodology - Data Acquisition – Fish Dataset

Archive bioblitz for validation

Archive Bioblitz which was done 4 times a year in the following years 2015/17/19/21/22/23 by the Nature and Parks Authority

trans_ID, sampling,_site_ID location, date, year, season, reserve, status, site_n, trans,_letter, lat & lon, depth, depth_category, visibility, logger, photos, time_start, time_end, observer, species, abundance, length, distanc,e confidence, les commercial, new_a,,new_b, weight , main_diet, notes, complexity,

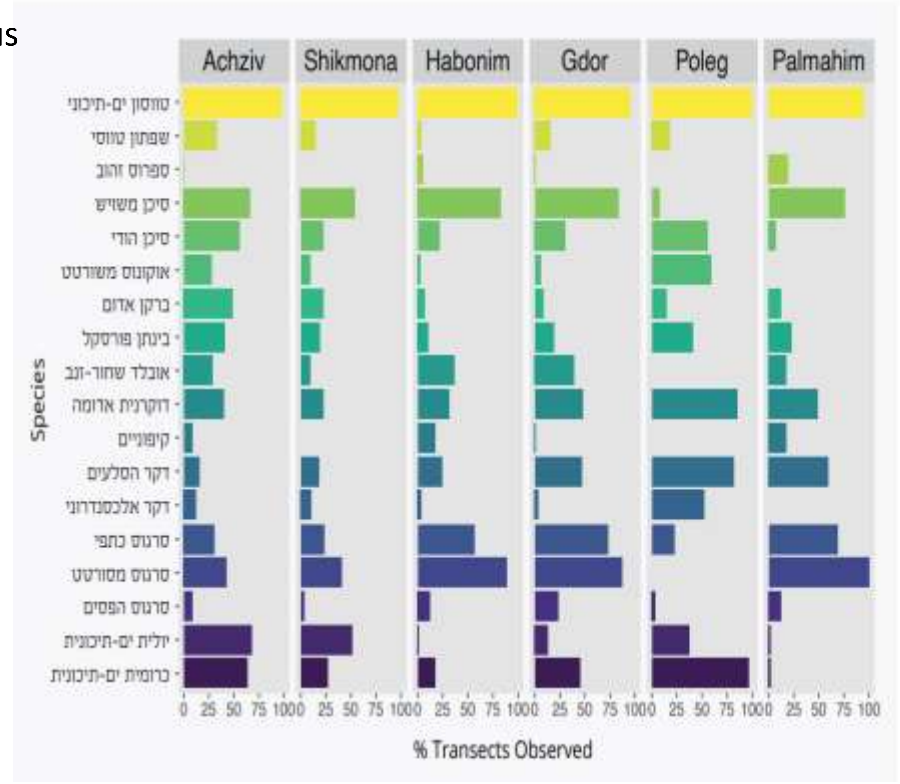
Epinephelus marginatus

Epinephelus costae

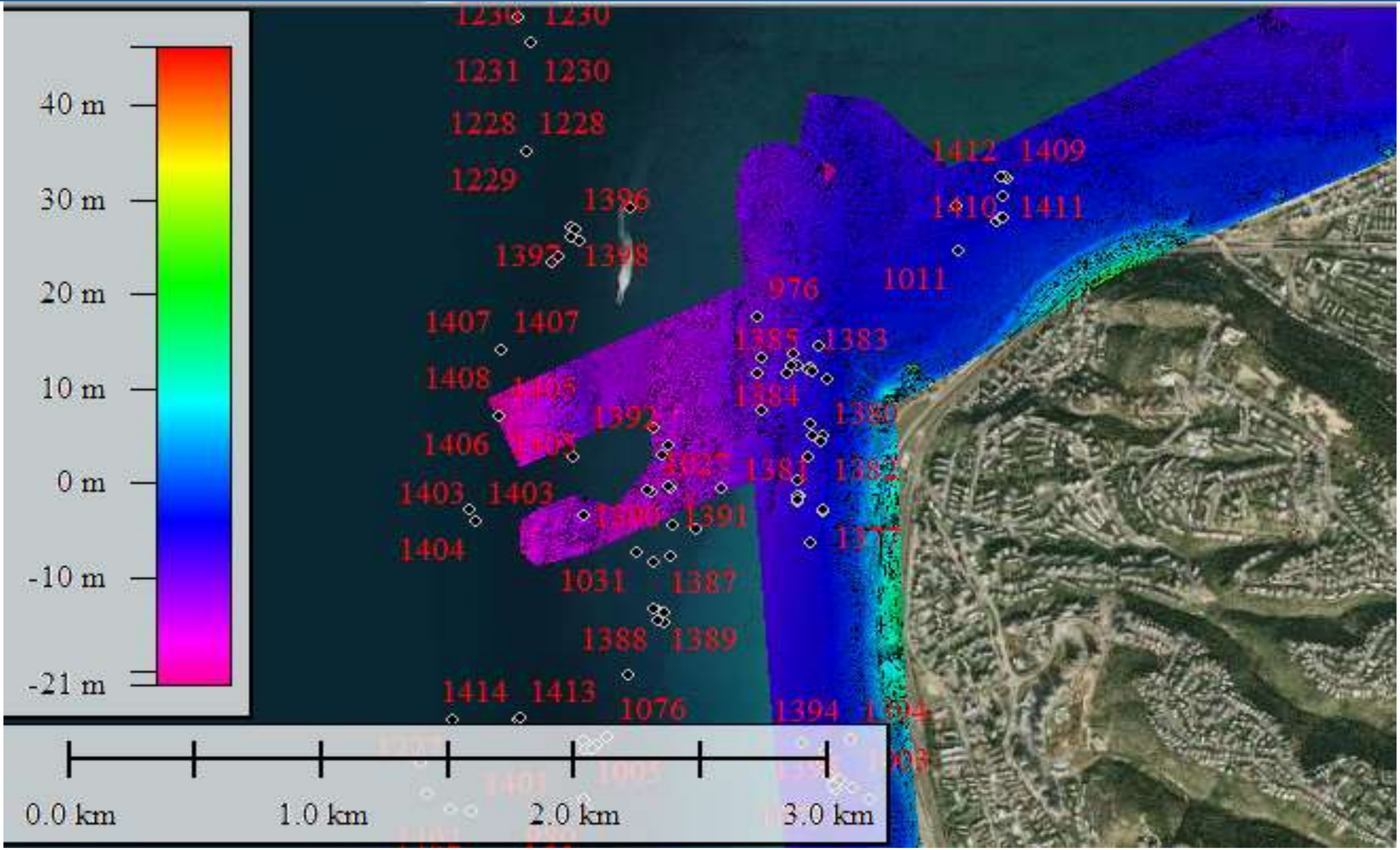
Mycteroperca rubra

Epinephelus aeneus

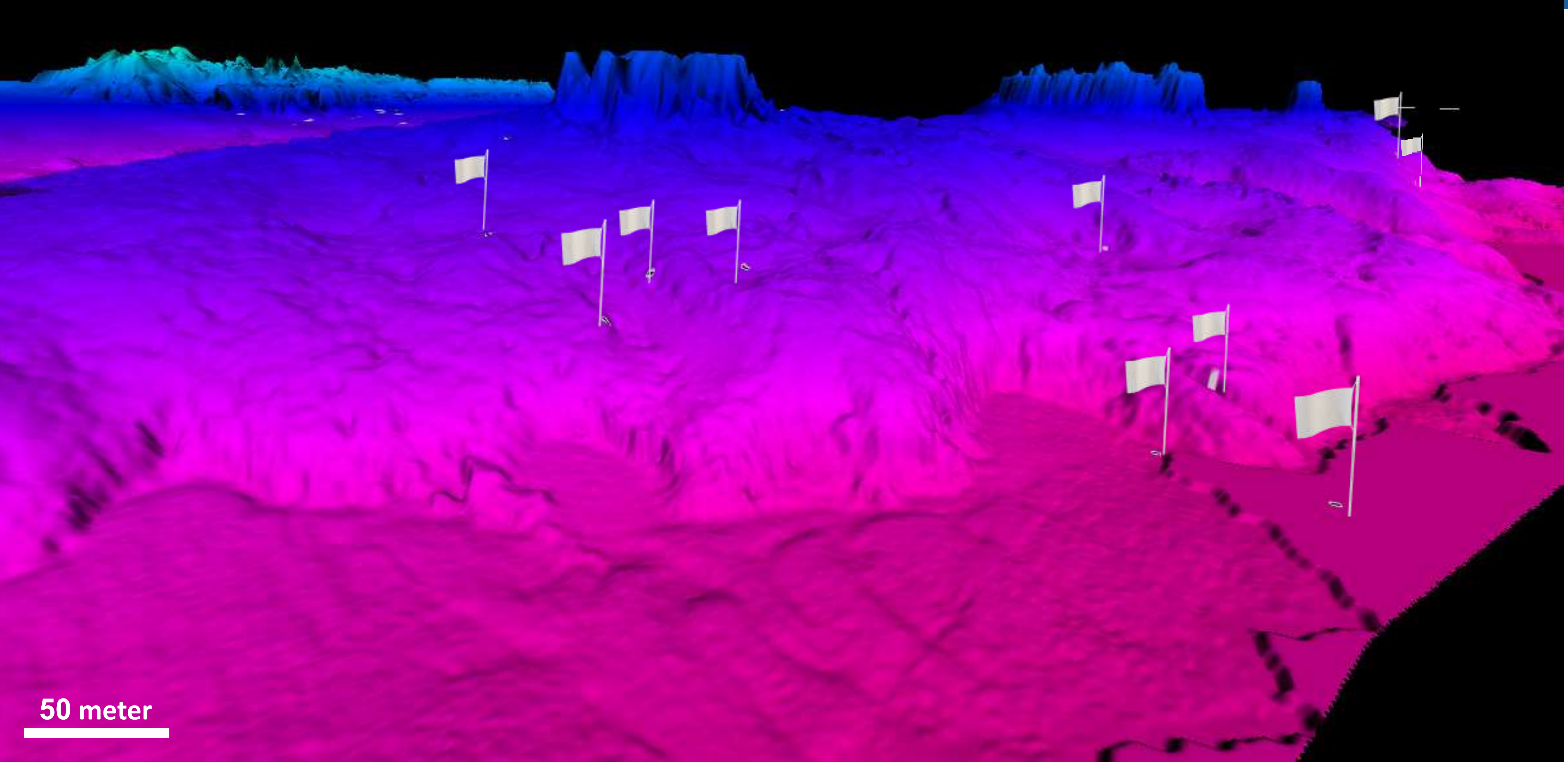
1. Abudefduf.saxatilis
2. Apogon.imberbis
3. Atherina.boyeri
4. Atherinidae
5. Atherinomorus.forskalii
6. Balistes.capriscus
7. Belone.belone
8. Boops.boops
9. Caranx.crysos
10. Cheilodipterus.novemstriatus
11. Chromis.chromis
12. Coris.julis
13. Diplodus.cervinus
14. Diplodus.sargus
15. Diplodus.vulgaris
16. Epinephelus.costae
17. Mycteroperca.rubra
18. Oblada.melanura
19. Parupeneus.forsskali
20. Sargocentron.rubrum
21. Serranus.scriba
22. Siganus.luridus
23. Siganus.rivulatus
24. Sparus.aurata
25. Symphodus.tinca
26. Thalassoma.pavo
27. Torquigener.flavimaculosus
28. Trachinotus.ovatus



Methodology - Data Acquisition – Fish Dataset



Methodology - Data Acquisition – Fish Dataset

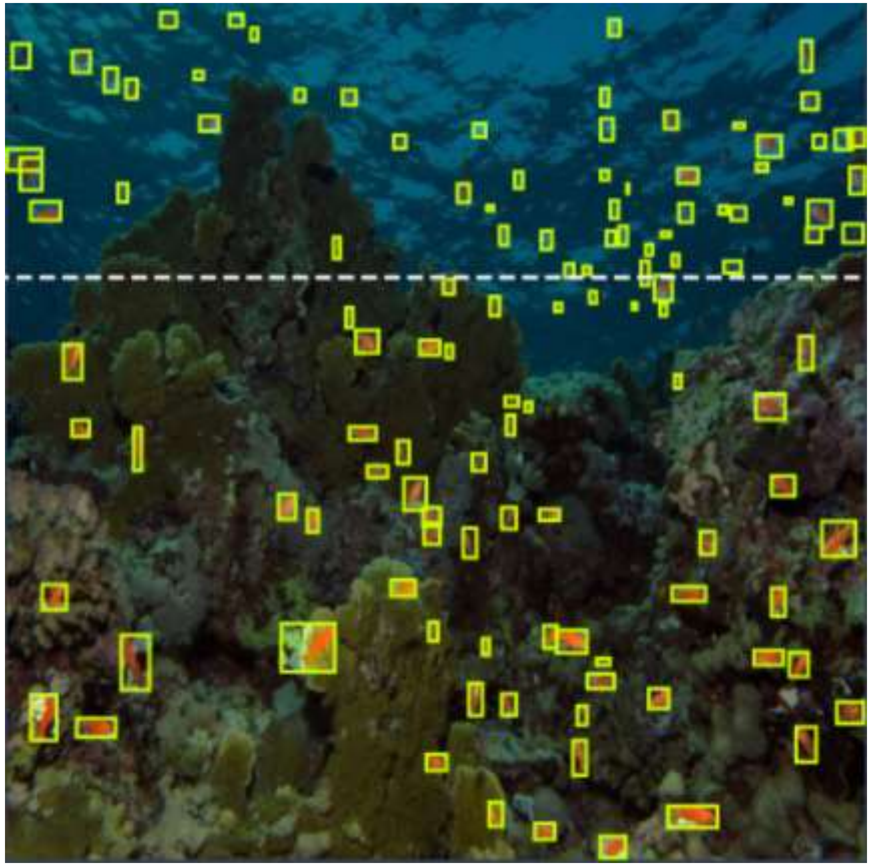


Methodology - prepressing– Fish Detection

YOLOv7 and Dataset:

- YOLOv7 is used for **detection and classification** of marine species in underwater videos.
- The dataset consists of **annotated** images from the 360-degree camera recordings.
- The YOLOv7 model is **trained** on this annotated dataset to accurately **detect and classify species from the videos**.

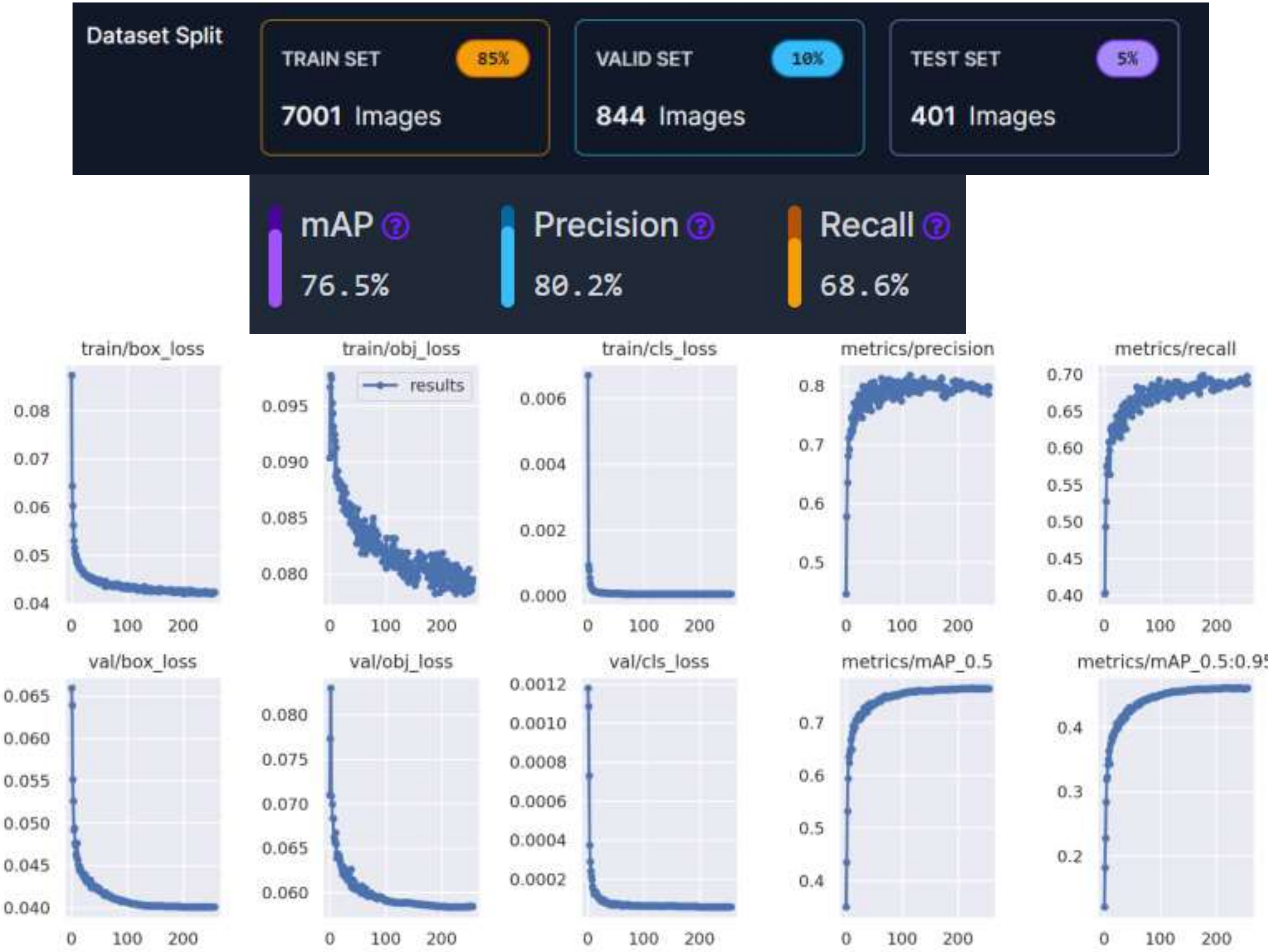
Objects annotation



Methodology – ML training model– Fish Detection

Training Dataset

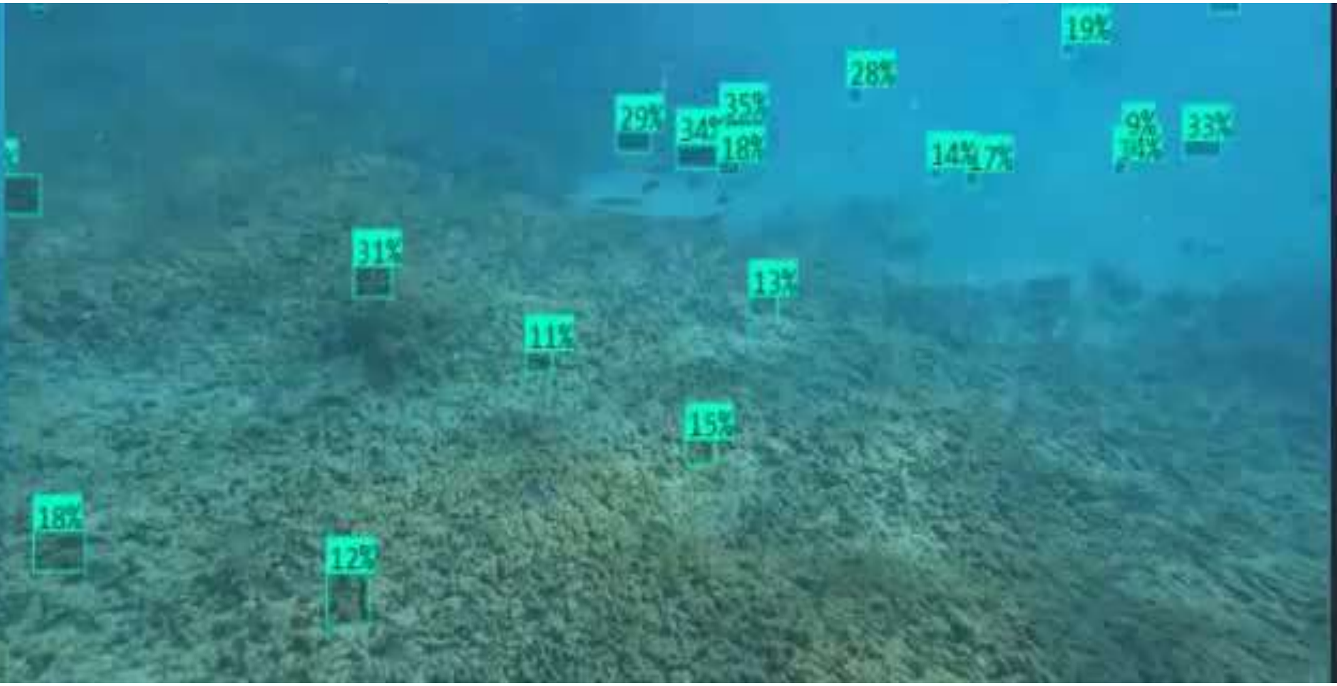
Training model performance



Methodology Fish Detection - results

Input

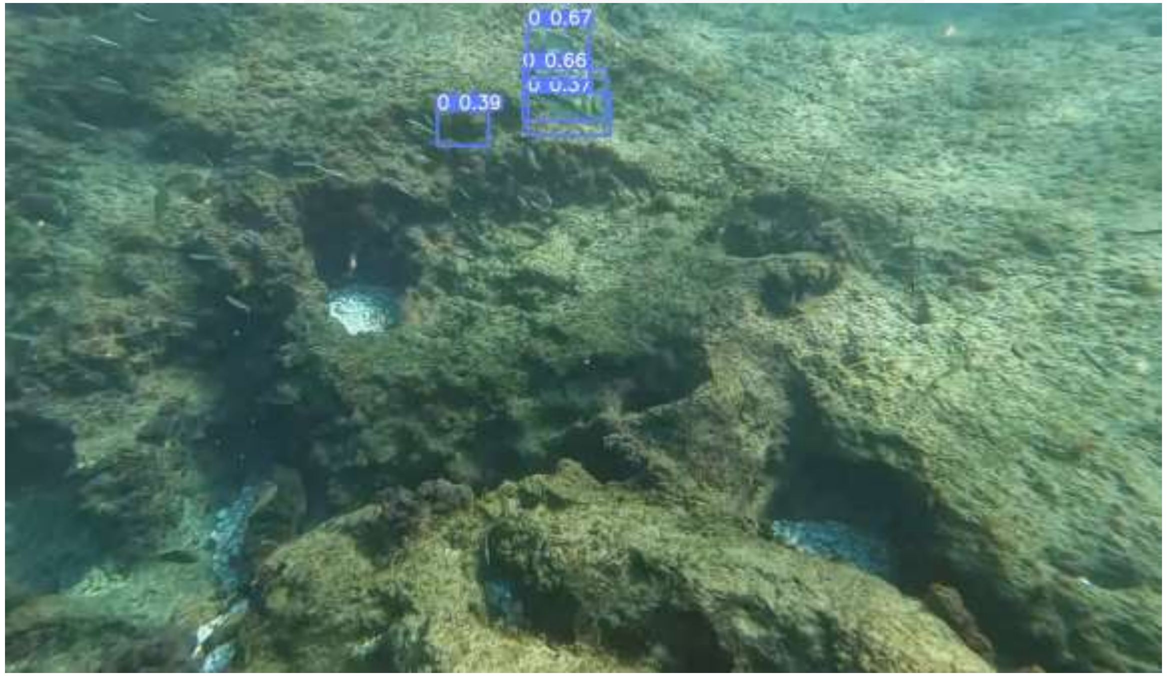
Output



Methodology - Fish Detection - results

Input

Output



Methodology - Multi-Scale habitats- geomorphometric features

Combine multi-scale and **multi-level seascape attributes** (three different footprints: low, mid, and high)

Large Scale:

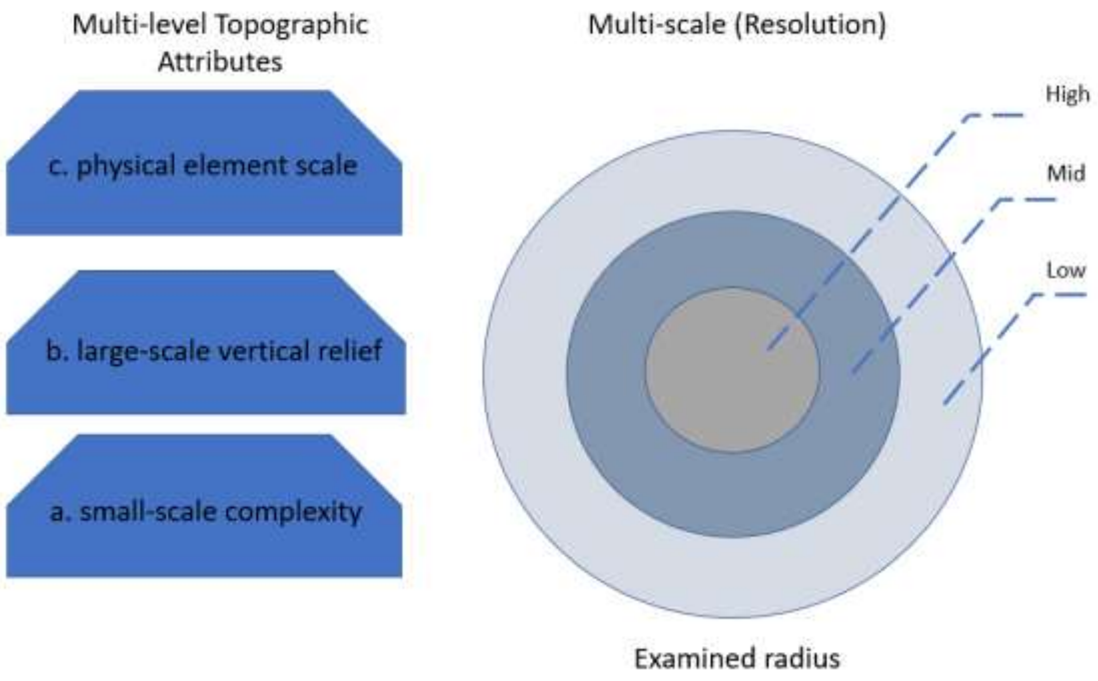
- Slope
- Aspect
- Mean Curvature
- Curvedness
- Circular Variance Of Aspect
- TRI
- Openness

Medium Scale:

- Multiscale Roughness
- Local Quadratic Regression
- Max Elevation Deviation
- Exposure Towards current Flux

Small Scale:

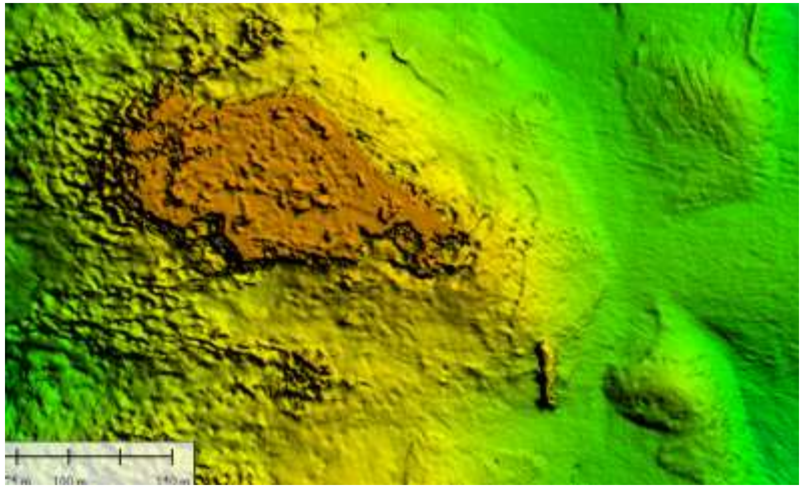
- Stream Power Index
- Max Difference From Mean
- Aspect (Small Scale)
- Shadow Image



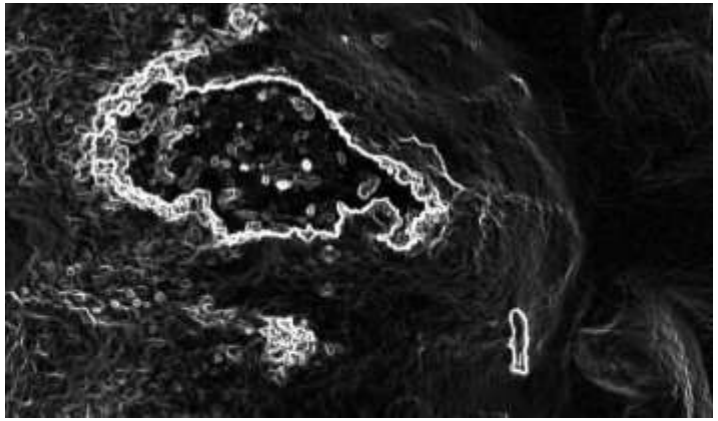
Methodology - Multi-Scale habitats- geomorphometric features

Compute geomorphometric features on DSM bathymetric data.

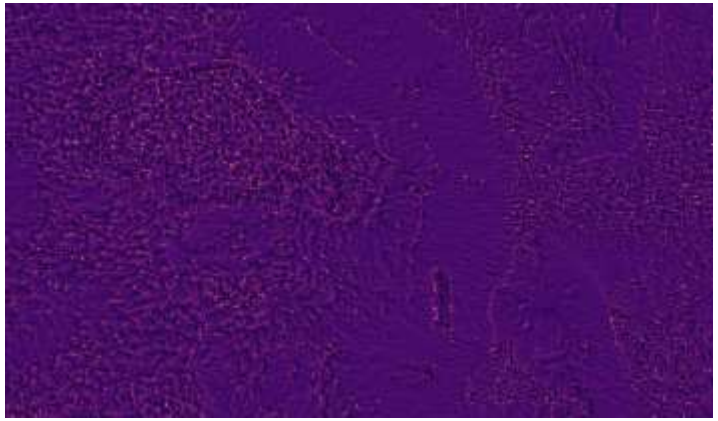
DEM Raster



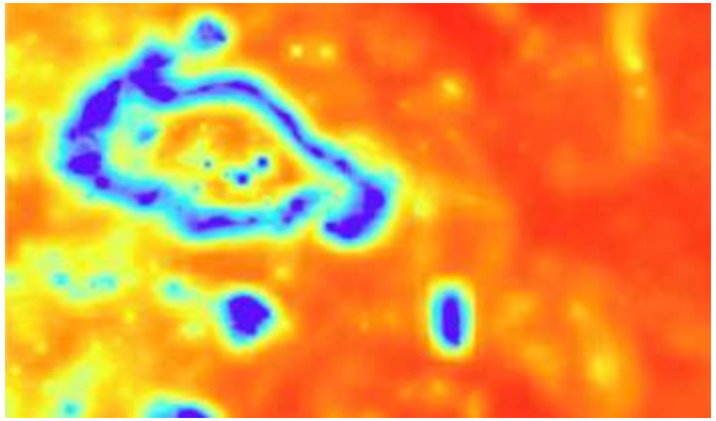
Slope



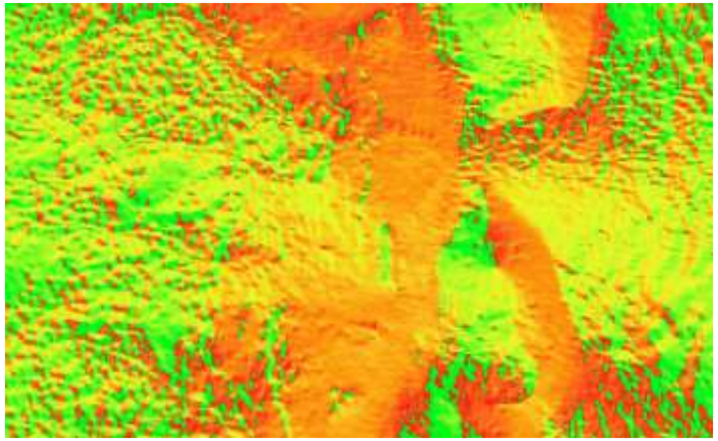
Profile curvature



Multiscale roughness



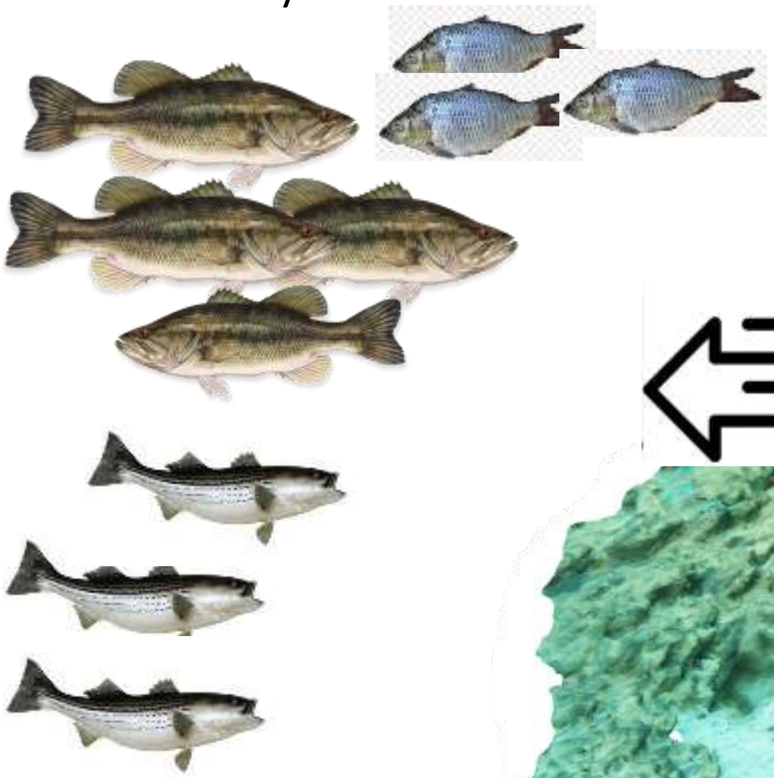
Aspect



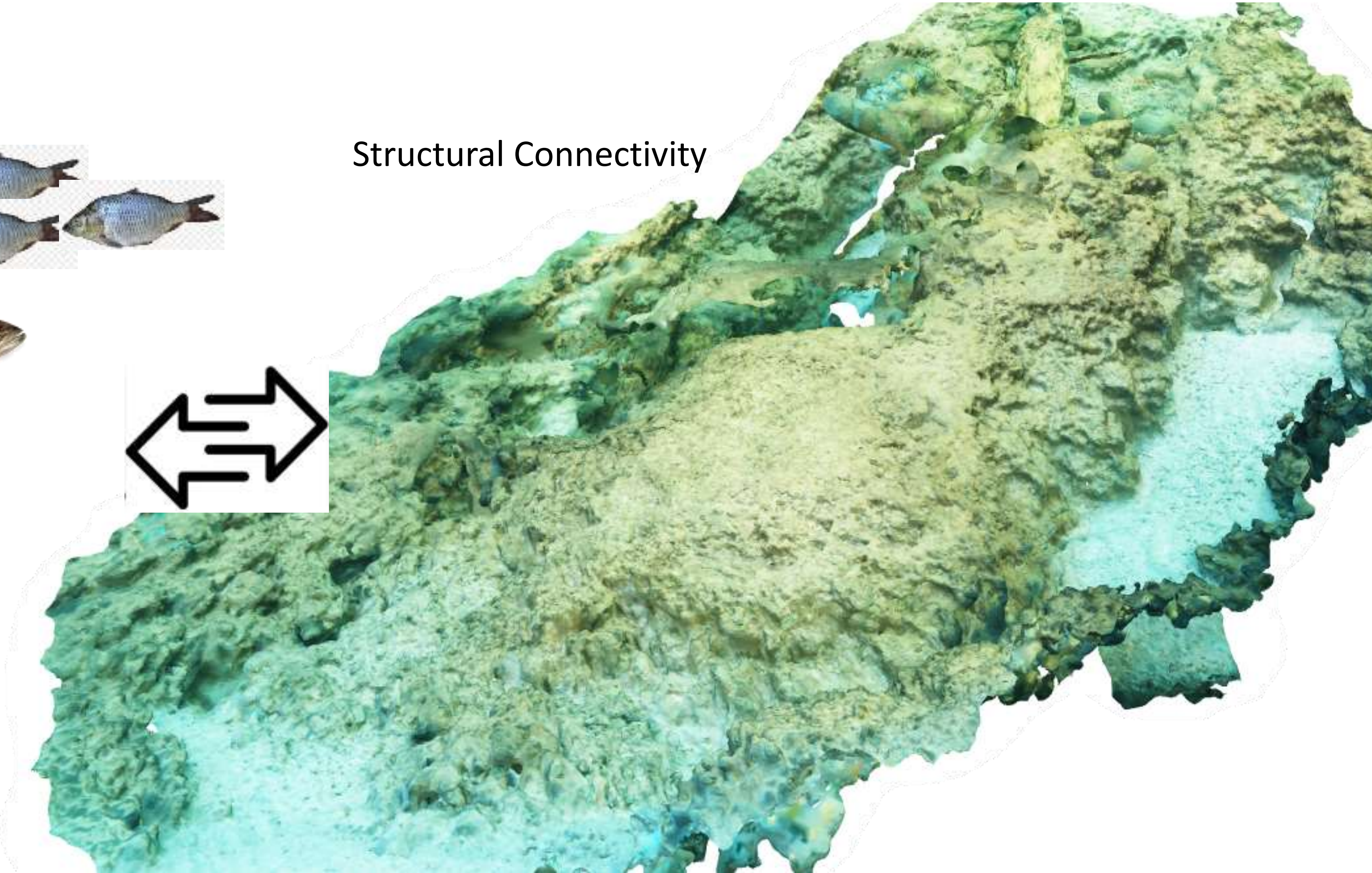
Methodology - Integrating Connectivity in Seascape Ecology

Bridging Structural and Functional Connectivity

Functional Connectivity

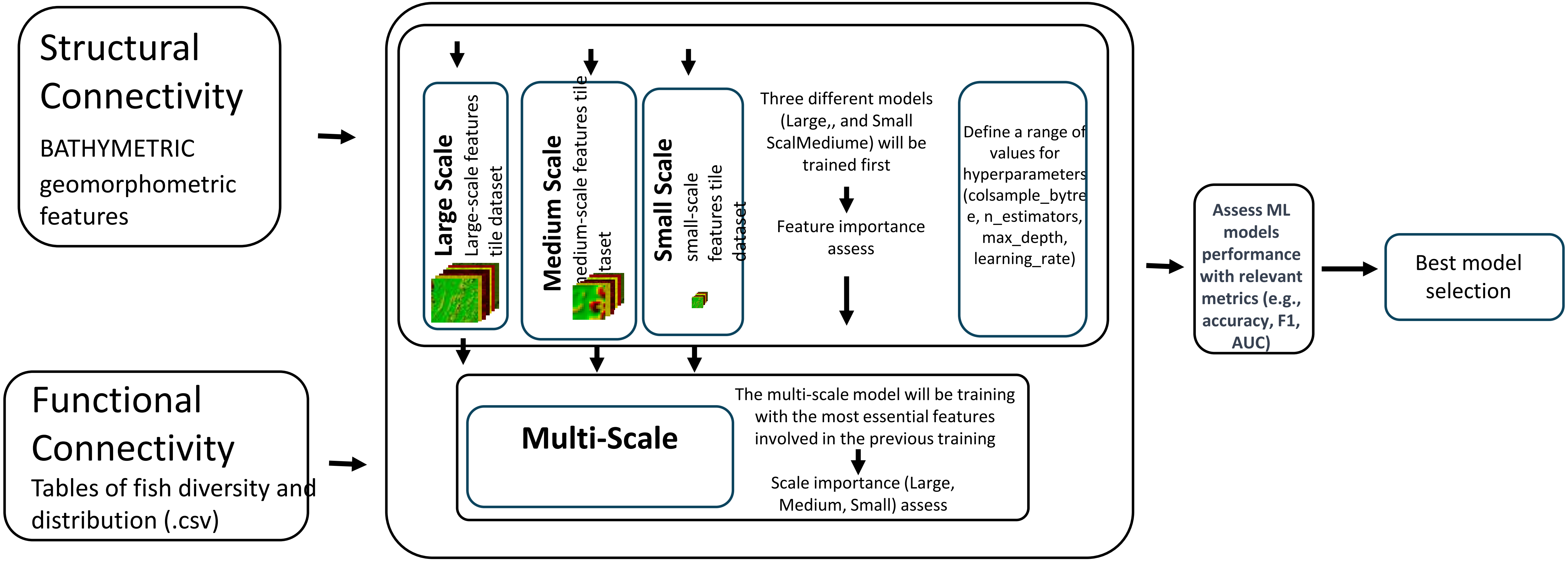


Structural Connectivity



Methodology - Integrating Connectivity in Seascape Ecology

Machine Learning Classifier XGBR/CNN



Results

Such results are expected

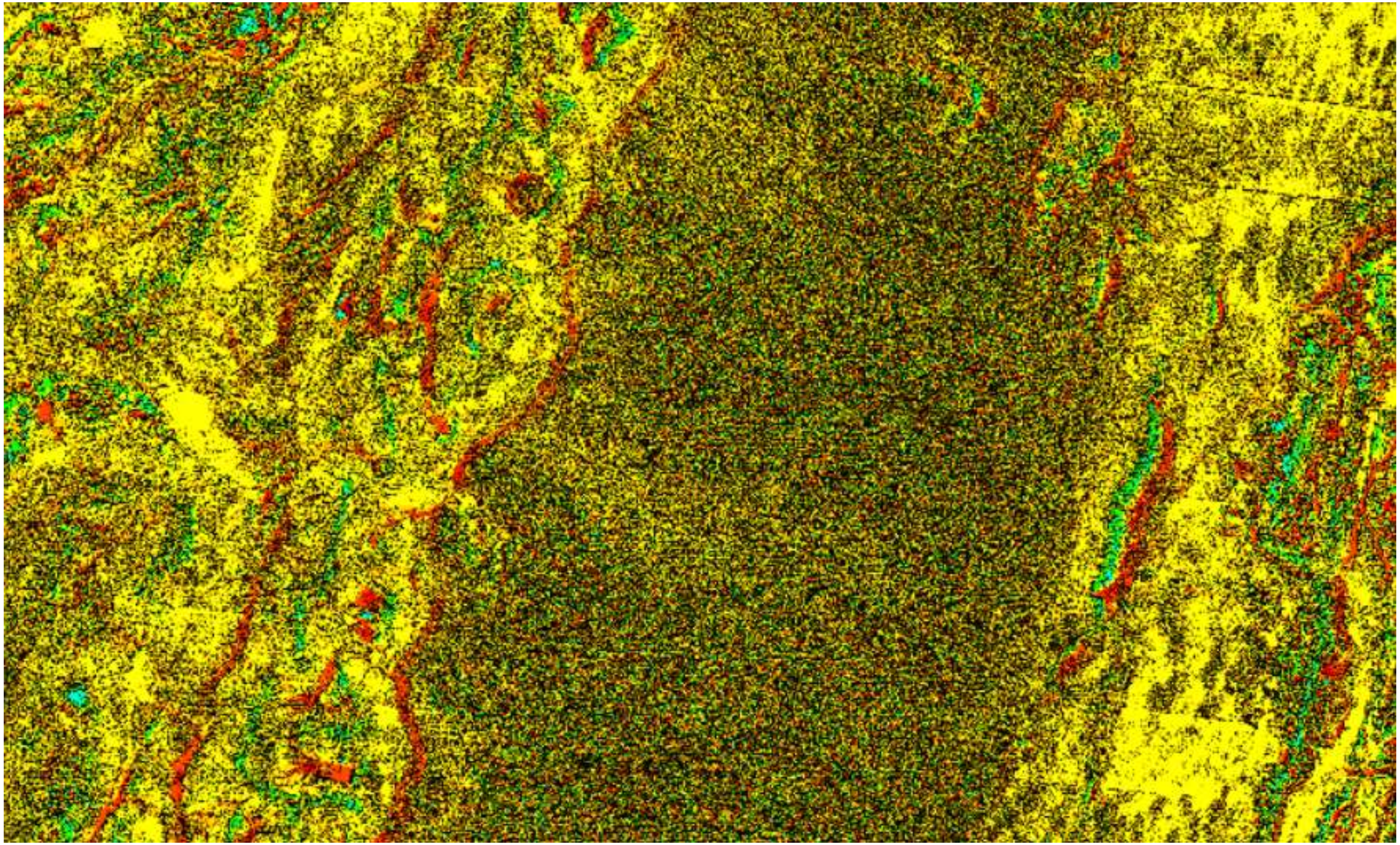
spatial map with habitat suitability scores

Low

Medium

High

Very High



Results

- SRGAN-Enhanced MBES Data:
  - Decrease in RMSE to 14.22 from a baseline of 20.4.
- Future steps to achieve LiDAR-level detail in seafloor reconstructions.
- Deep Learning Model for Fish Detection:
  - - Current recognition of 80% of fish from five species.
  - - Aim to increase accuracy to 90% with more varied data.
- Habitat Suitability Mapping:
  - - Generating spatial maps with habitat suitability scores

Conclusion

- **Enhanced Seafloor Mapping:** SRGAN improves LiDAR and MBES resolution.
- **Biodiversity Assessment:** AI and **3D** modeling analyze **species distributions**.
- Seascape Characterization: Multi-scale data enhances habitat insights.
- **Monitoring Techniques:** 360-degree cameras and YOLOv9 for efficient monitoring.
- AI in Conservation: Predict changes in biodiversity.
- **Data Validation:** Photogrammetry ensures **accurate habitat maps.**
- Future Directions: Refine AI models for broader use.
- Seascape Mapping: Integrate geomorphometric and biological data.
- **Collaboration:** Share data to advance marine conservation.

Questions and Discussion

Integrating Deep Learning and Multiscale Ecosystem Connectivity of the Marine Habitat

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