Biofouling in-water assessment with ROV and machine learning based image recognition software

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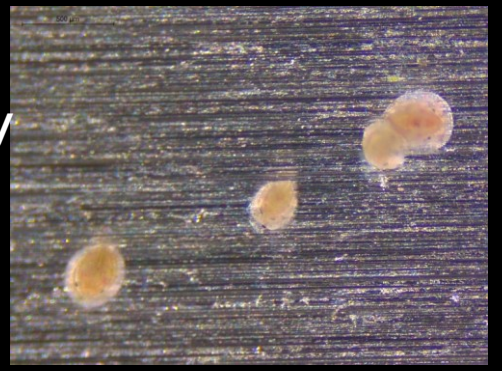
Laboatory and **semifield** falicity inside Genova Port



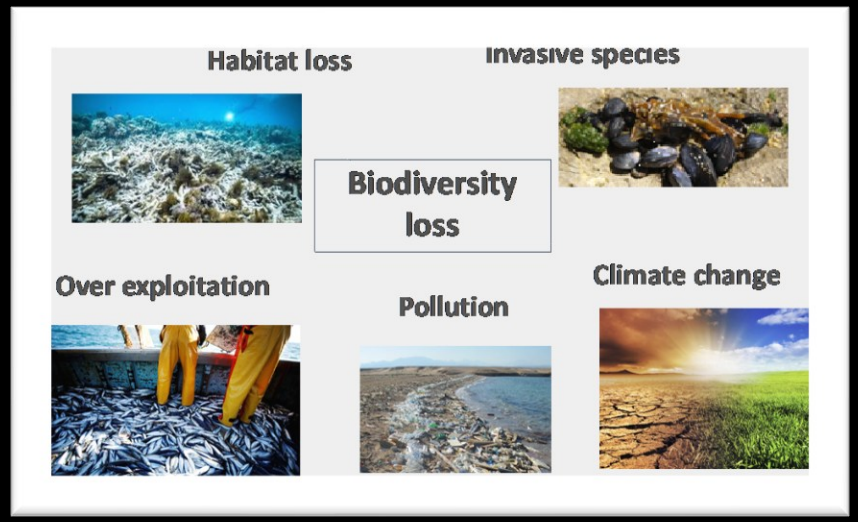
-Material testing in marine environment
-Atmospheric corrosion testing
-Semi-field testing under controlled condition
-Mesocosms
-Laboratory Amphibalanus settlement bioassay
-Laboratory Toxicity testing of paint leachates
-Surface characterization
-etc…

Biofouling related to planetary issues

Biofouling

- Invasive alien species
- Greenhouse gas emission

- Biodiversity loss
- Climate change



Planetary Boundaries

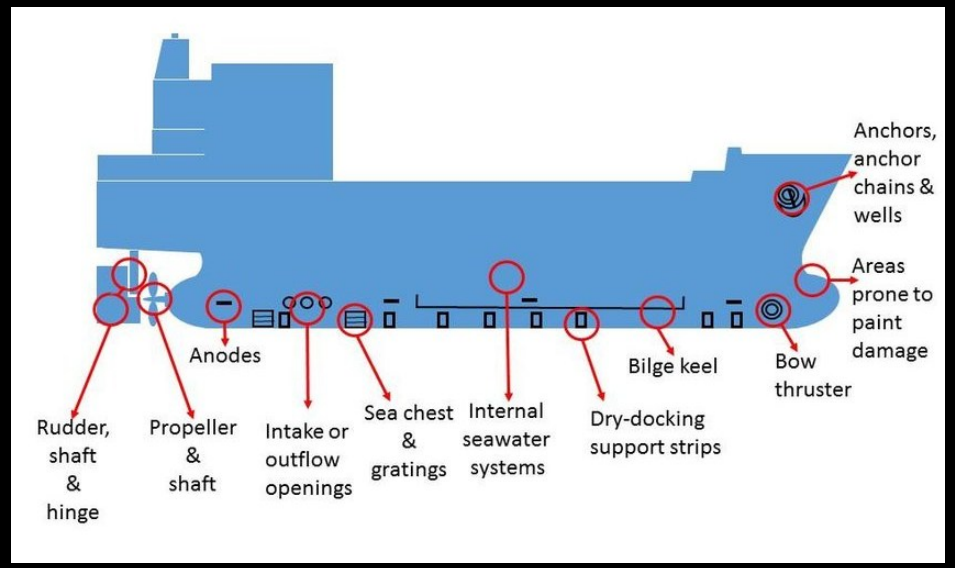
Johan Rockström (2009)

Introduction

Recently the **IMO** has published of the **resolution MEPC.378(80)** adopted on 7th July 2023 titled: "**2023 GUIDELINES FOR THE CONTROL AND MANAGEMENT OF SHIPS' BIOFOULING TO MINIMIZE THE TRANSFER OF INVASIVE AQUATIC SPECIES**".

This IMO document poses the bases to harmonization of biofouling visual estimation and cleaning procedures. This was the starting point for the preparation of a draft of a **review** that analyzes how automated systems could be implemented to perform an **automated biofouling assessment**

The document also specifies that niches area are of particular importance.



Typical niches areas found on a vessel (Georgiades e Kluza 2020)

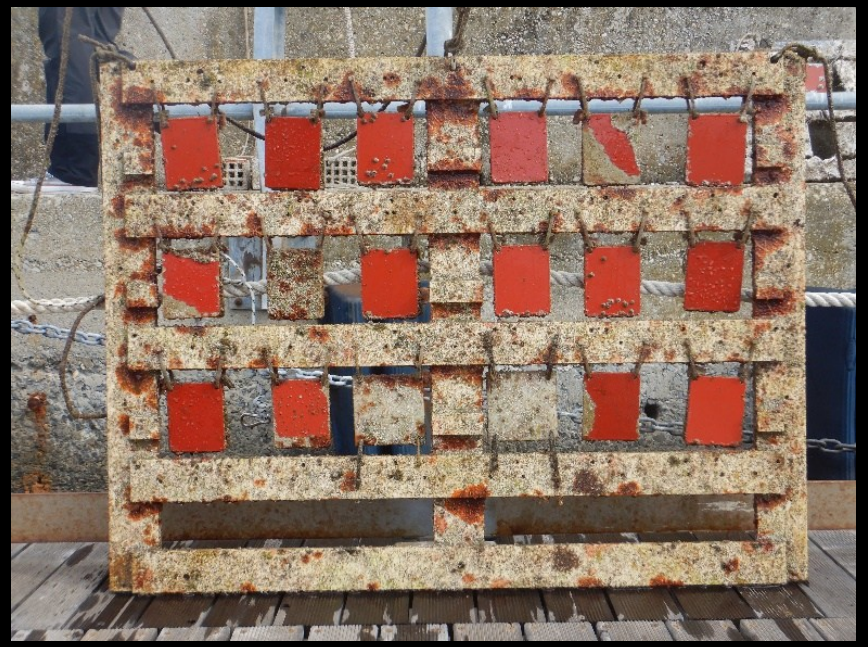
Rating	Description	Macrofouling cover of area inspected (visual estimate)	Recommended cleaning
0	**No fouling** Surface entirely clean. No visible biofouling on surfaces.	-	-
1	**Microfouling** Submerged areas partially or entirely covered in microfouling. Metal and painted surface may be visible beneath the fouling.	-	Proactive cleaning may be recommended as further specified in paragraph 9.4.
2	**Light macrofouling** Presence of microfouling and multiple macrofouling patches. Fouling species cannot be easily wiped off by hand.	1-15% of surface	Cleaning with capture is recommended as further specified in paragraph 9.9. It is recommended to shorten the interval until the next inspection. If the AFS is significantly deteriorated, dry-docking with maintenance and reapplication of the AFS is recommended.
3	**Medium macrofouling** Presence of microfouling and multiple macrofouling patches.	16-40% of surface	
4	**Heavy macrofouling** Large patches or submerged areas entirely covered in macrofouling.	41-100% of surface	

AIM of the work:

Automize as much as possible in-water biofouling assessment with the aid of new tools like robotics and deep learning

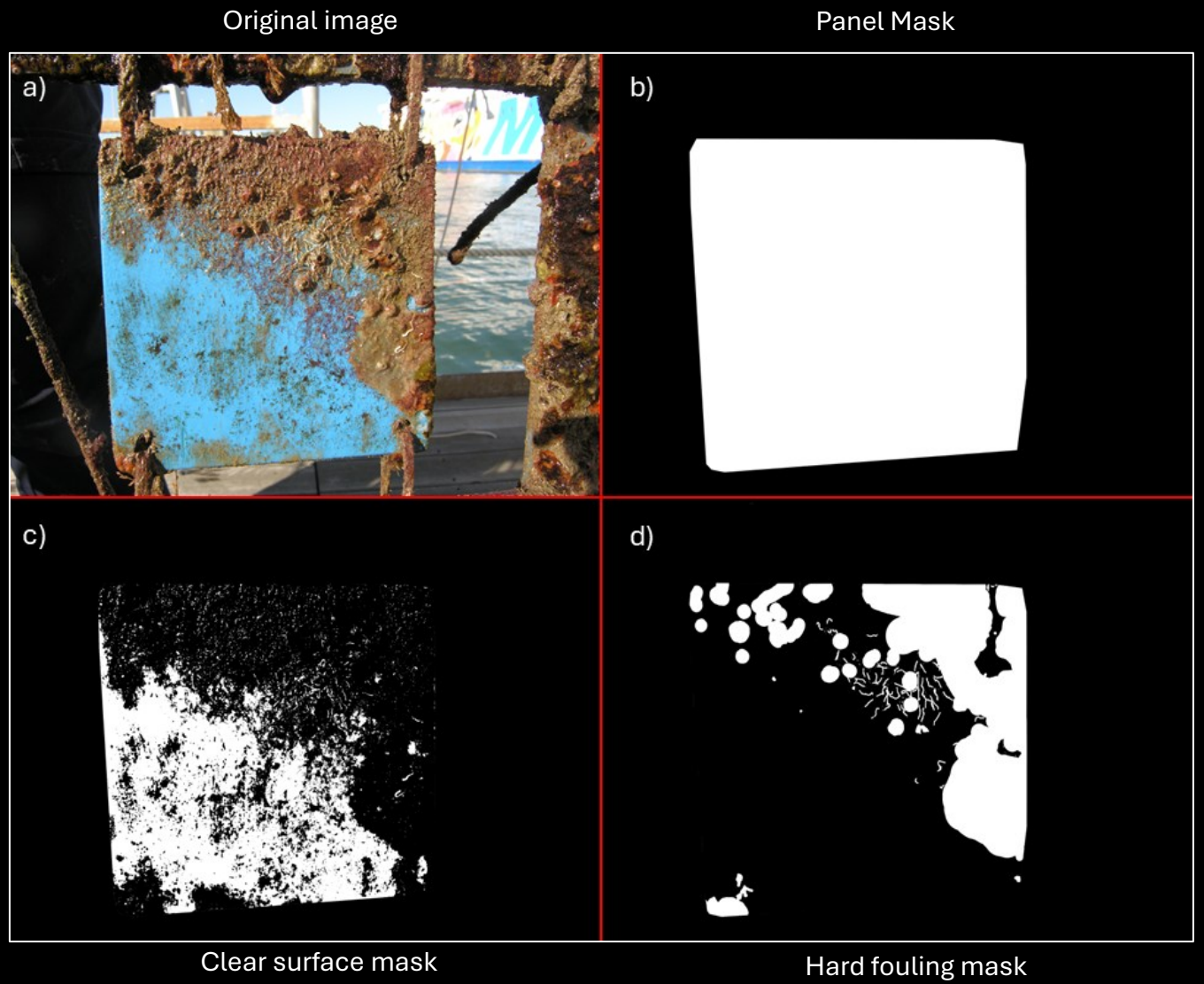
Dataset : test panels

To train the neural network on recognizing the presence and the type of fouling, **images of paint samples from the CNR-IAS archive were elaborated.** These image were available in large number with different lighting condition, at different stage of fouling coverage and with different colors of the surface.



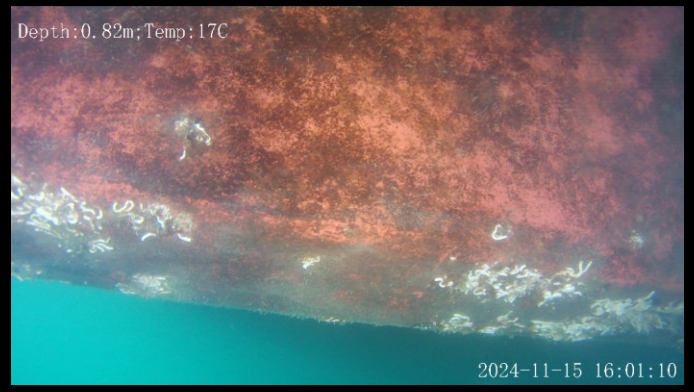
Dataset elaboration and masks production

These image were elaborated manually with to **create 3 masks**. The first highlight the total **area of the panel**, the second and the third highlight pixels corresponding to **hard fouling** and **clear surface**. The soft fouling is obtained by subtraction from the total area of the panel of the clear and the hard fouling.



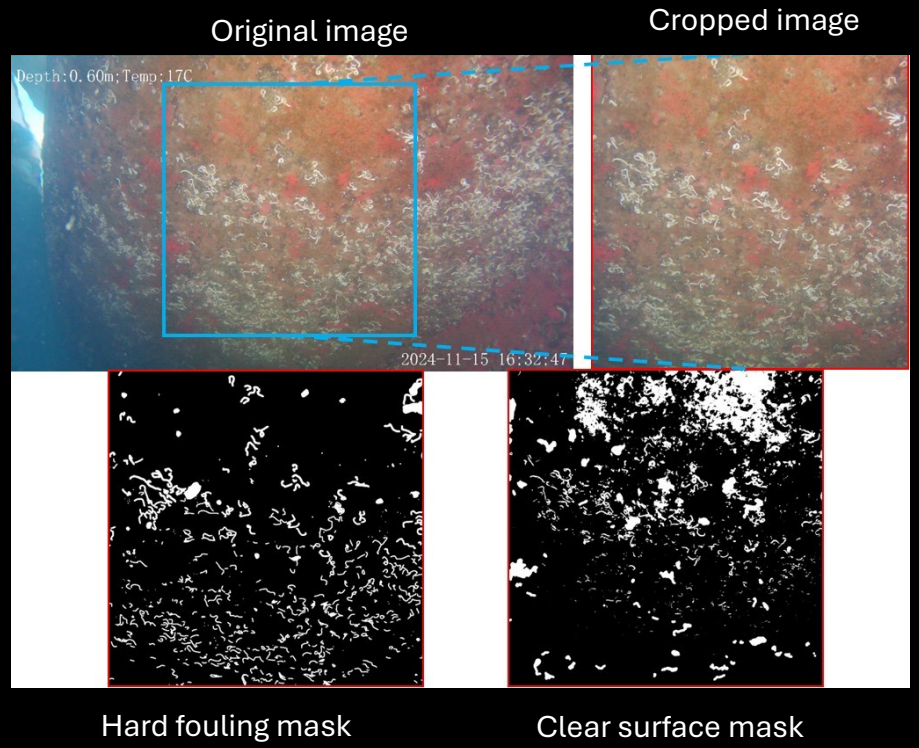
Dataset: ROV image acquisition and treatment

an **ROV with a high resolution camera (4K, 12Mpixel) was used to** capture videos of different type of hulls in different conditions



With the ROV, **high quality images of hulls were acquired**.
A **mission protocol** for the ROV observation is **under definition**, with the aim of **standardize the data acquisition**.

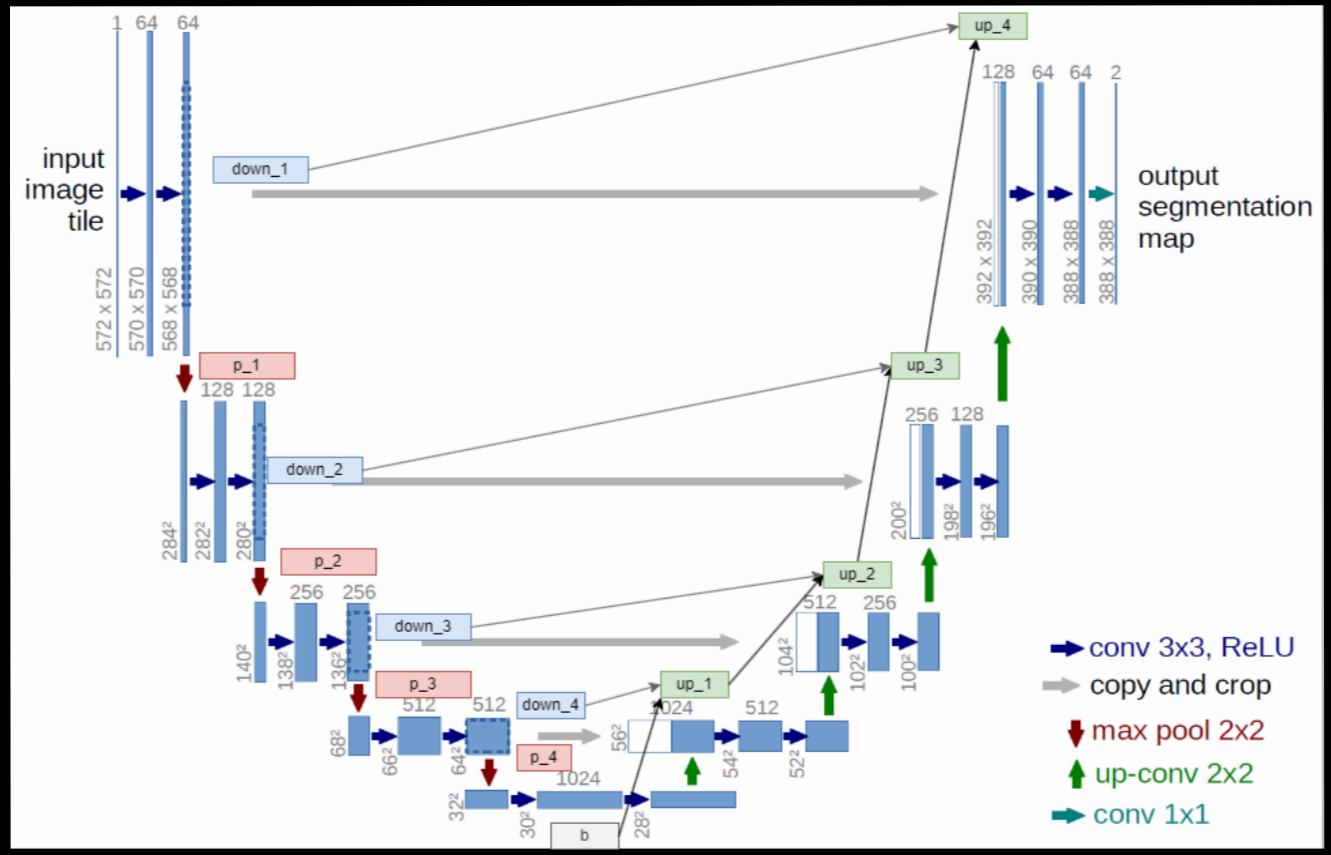
Images are elaborated to obtain masks for the database. The image is cropped to the central area where the lighting is uniform, and masks for hard fouling and clear surface are obtained manually.



Deep Learning Segmentation

Each image was preprocessed by extracting the region of interest and resizing it to a fixed resolution of 512×512 pixels.

For segmentation, we employed U-Net, a deep learning architecture designed to capture visual patterns and reconstruct them into a precise pixel-level map, indicating the location of each class.

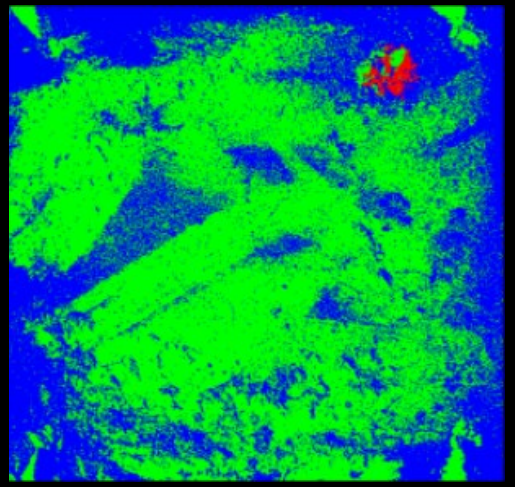


Segmentation Software Pipeline

From the input image, a region of interest is extracted. For hull images, the central 512×512 portion is selected to capture the area with the highest quality. In the case of panels, a dedicated panel detector is applied, followed by resizing to 512×512 pixels. The resulting region of interest is then passed to the segmentation model, which outputs a three-class mask (clear, soft fouling, hard fouling).

Input image

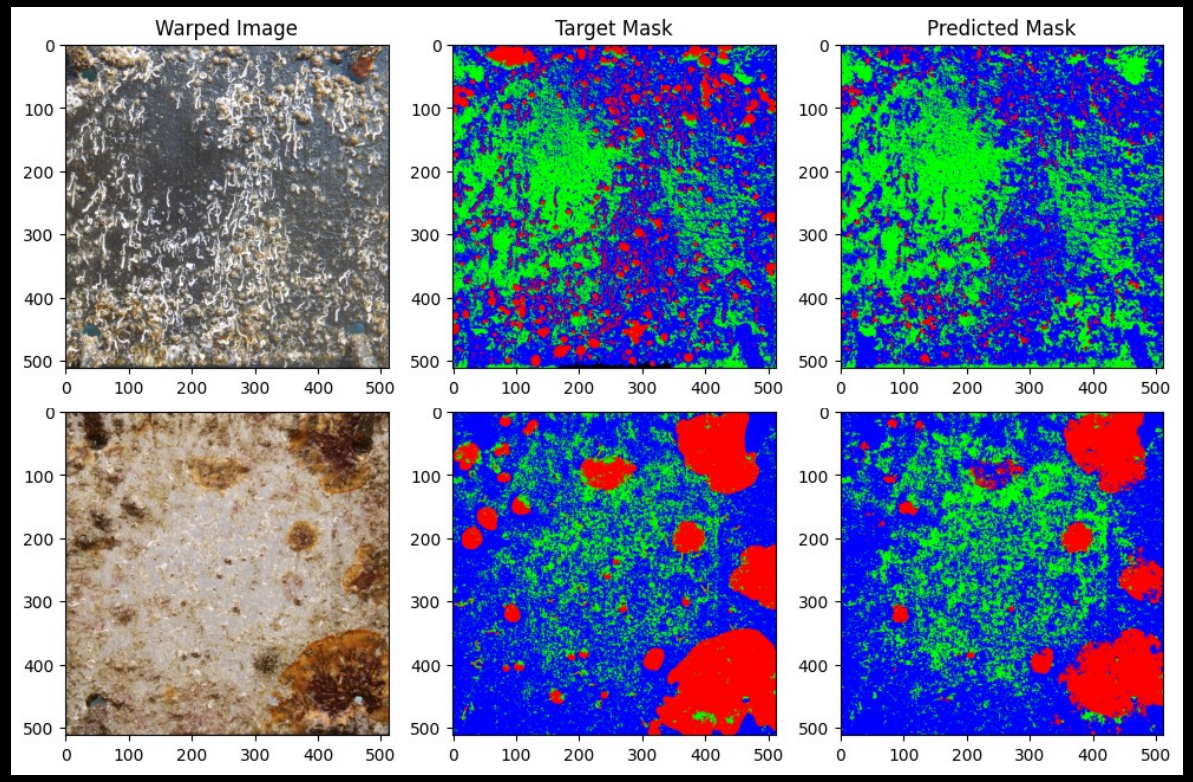
Panel detection

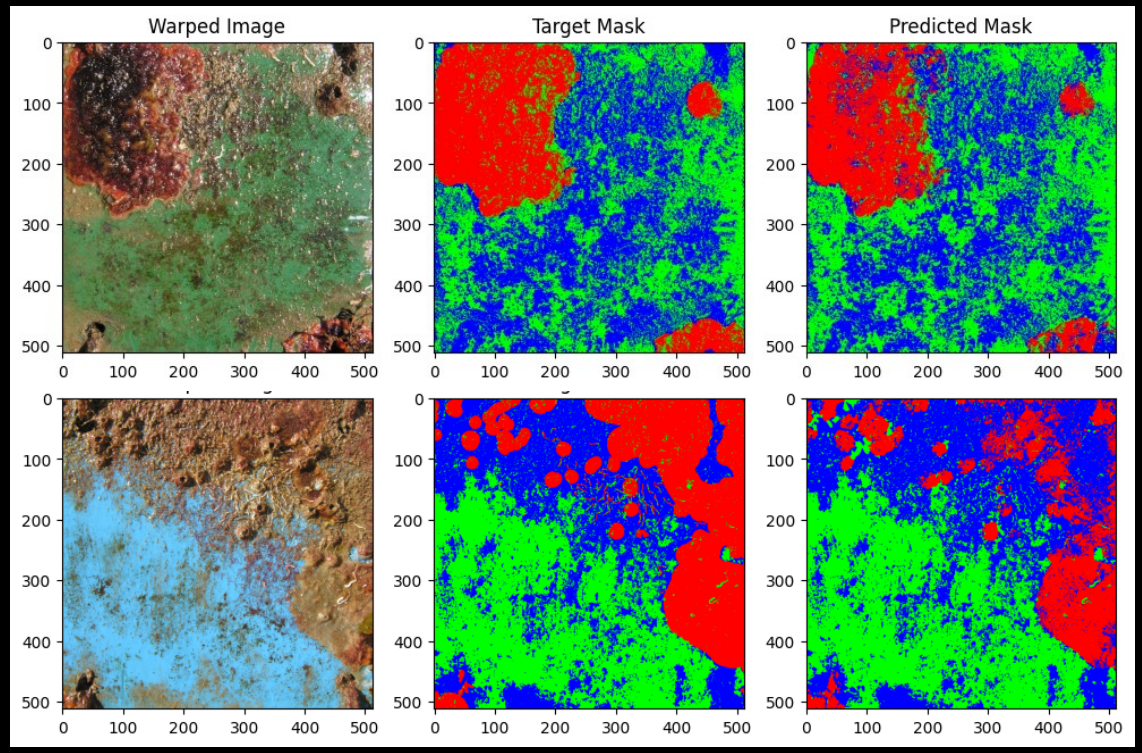


Output segmentation mask

Training results

Image present in the database compared with the target mask obtained by an operator



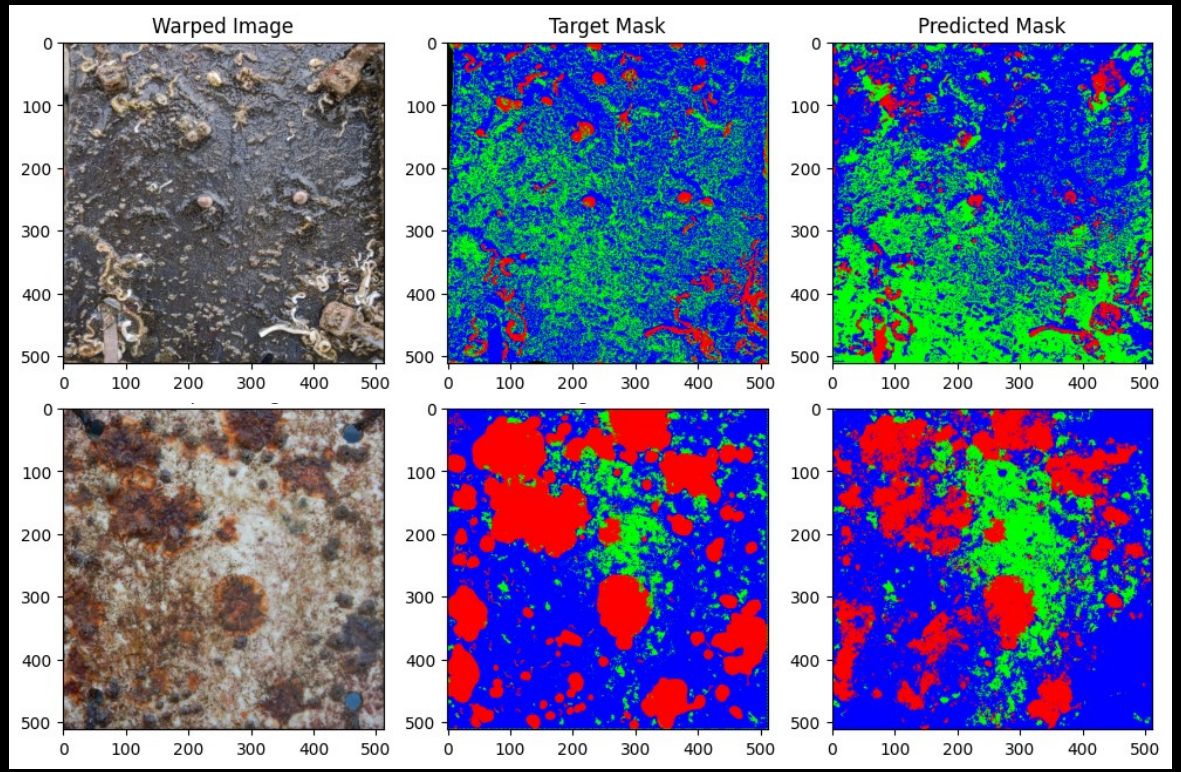


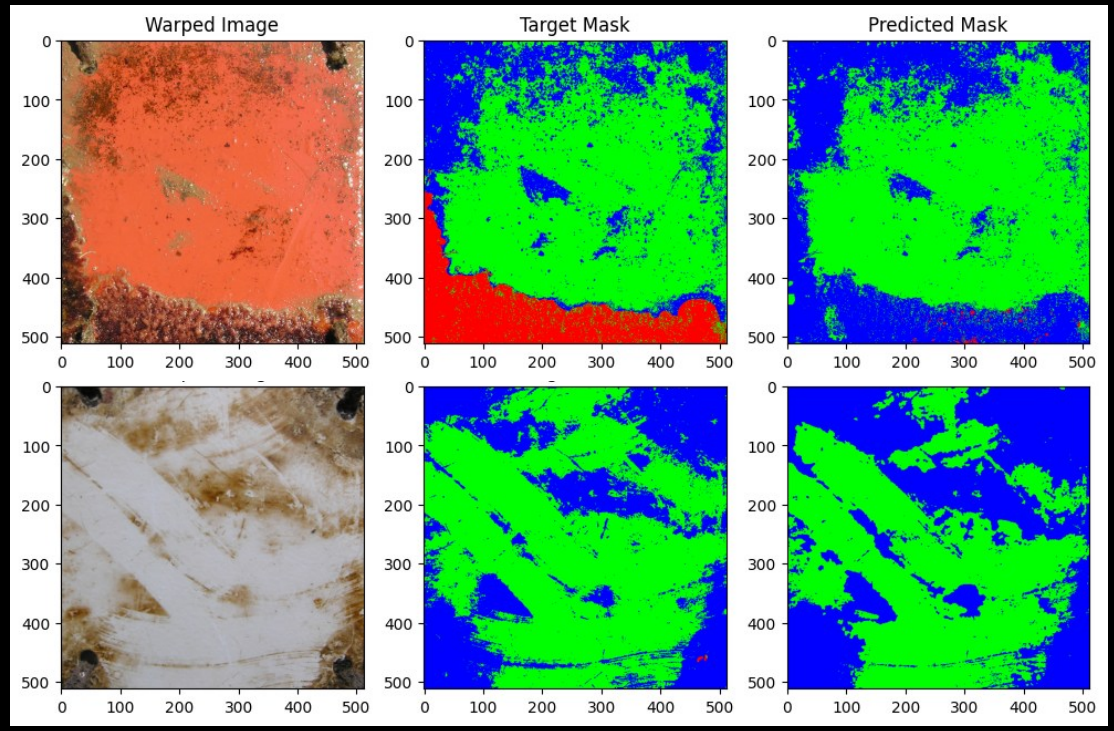
Legend:

- **Green**: indicates the clear surface,
- **Blue**: represents soft fouling,
- **Red**: marks areas of hard fouling

Test results

Image not present in the database compared with the target mask obtained by an operator





Legend:

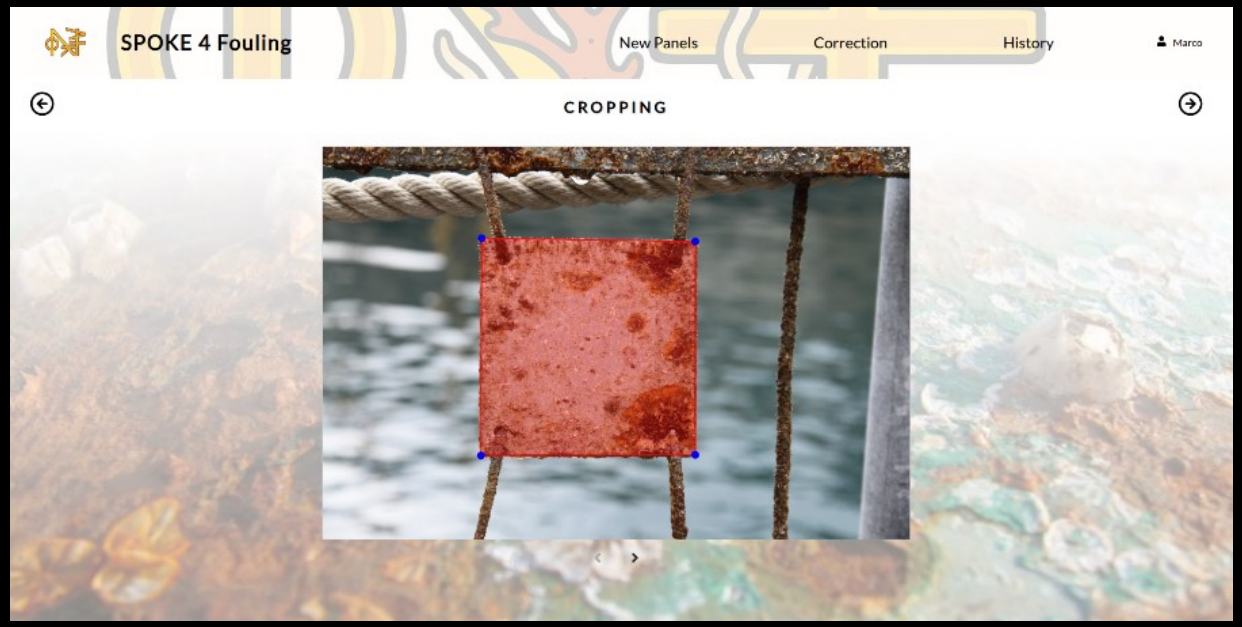
- **Green**: indicates the clear surface,
- **Blue**: represents soft fouling,
- **Red**: marks areas of hard fouling

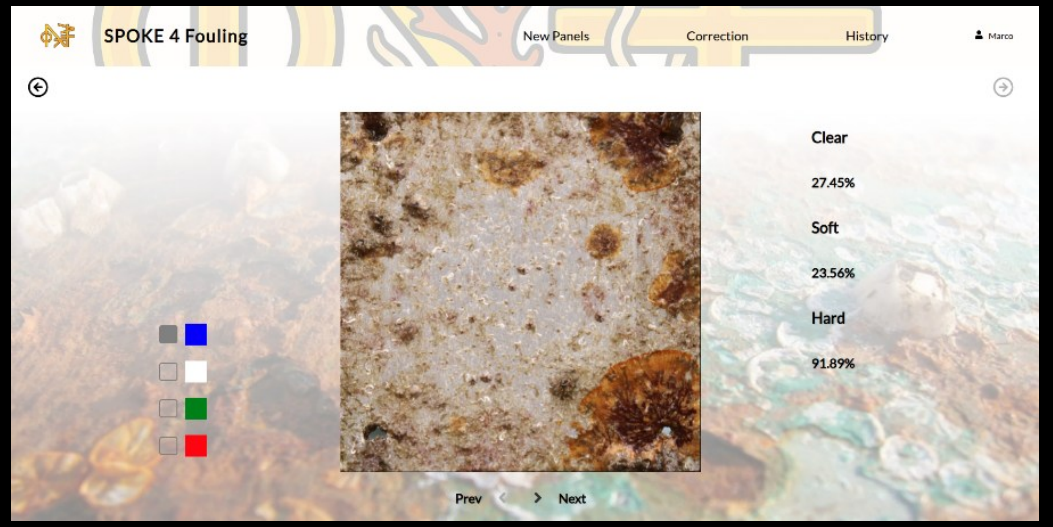
Discussion

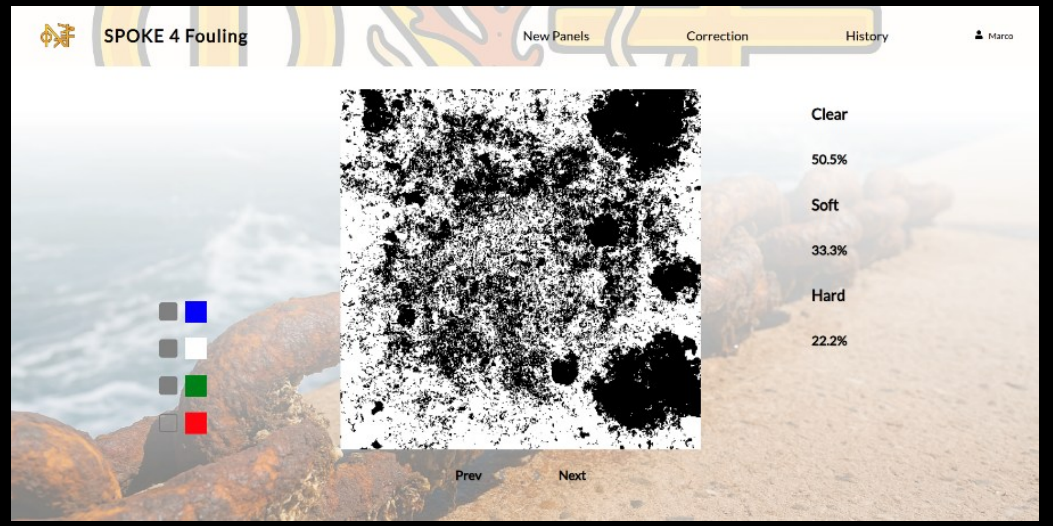
- The model is responding positively recognising properly each type of fouling
- We have an underestimation of hard fouling, probably because is less represented in the dataset (we are currently adding more hard fouled images)

Perspectives: Graphical User Interface

The **user interface under development** will allow users to upload a video and extract cropped frames from it, or alternatively upload individual images. These **images are then cropped and segmented by the neural network** into three fouling classes. **Each** automated **step can be reviewed** and manually adjusted if needed.

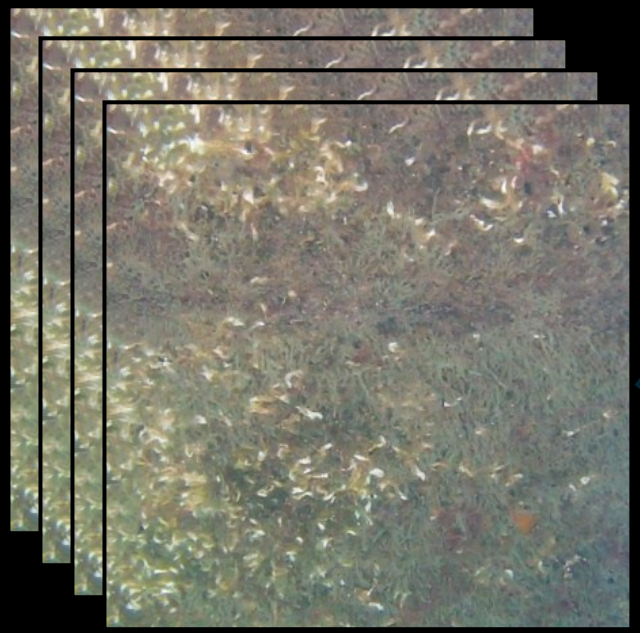




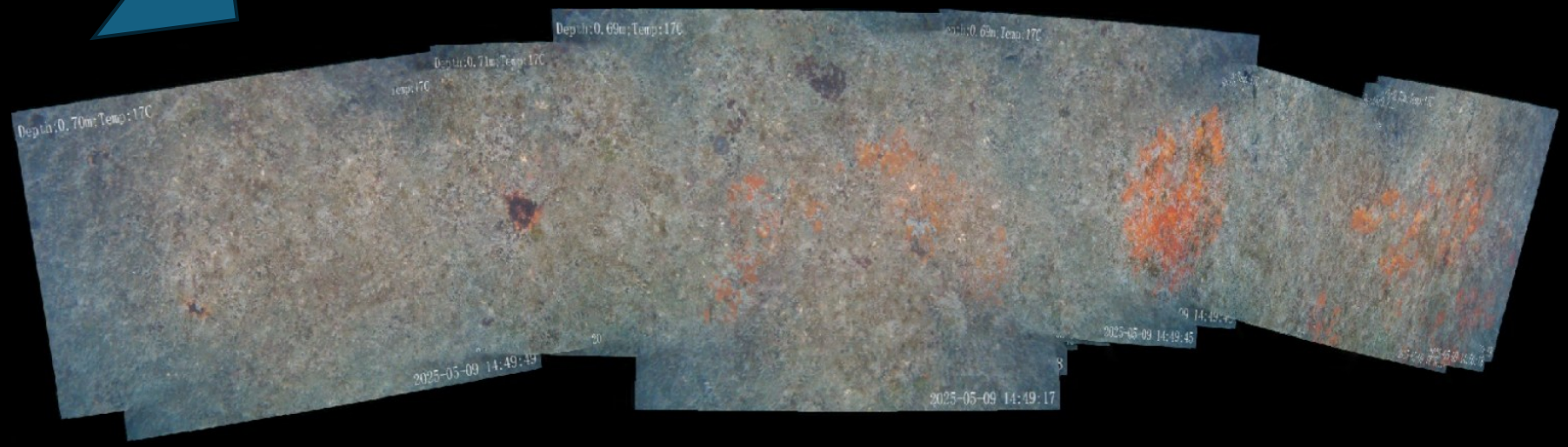


Pespectives:

Stitching feature



The interface will allow users to **download data tables**, an automatically generated **report**, and **images of the hull reconstructed** by stitching the frames from video.



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P8.2.1 Automated underwater inspection of fouling on ships hull

Thanks for your attention

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