

Next-generation monitoring & mapping tools to assess marine ecosystems & biodiversity

Milestone M3.1

Literature review on existing softwares/AI tools

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Executive Summary

The use of underwater imagery for assessing the ecological status of benthic habitats is a standard methodology followed by marine conservationists, and several software applications have been developed over the years to facilitate this process. However, the manual analysis of photographic samples is a time-consuming process. To address this challenge artificial intelligence (AI) tools have drastically increased over the last decades. Marine ecologists have adopted such technology on tropical and temperate reefs, but it has not yet been systematically applied to Mediterranean ecosystems. In this task, we review available tools that use AI (e.g. Coral-Net) and evaluate their potential application and performance as accurate, repeatable and cost-effective monitoring tools in assessing rocky reef communities of the Aegean Sea.

An extensive search was conducted for available AI software applying machine learning and deep neural networks for automatic or semi-automatic benthic image annotation and quantification. We conducted broad market research to identify as many, potentially relevant AI solutions as possible. Following a snowball approach, combining a literature review, backward and forward citation searching, and searching for independent software through ChatGPT and online, we found 30 different tools which were evaluated according to our requirements.

The present report includes all the tools found during the review and the evaluation process, aiming to select the most promising tool/s to be tested for different levels of image classification.

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Aim of the Deliverable

The present deliverable is the Milestone of Task 3.1. The objective of Task 3.1 is to compile, advance, and develop AI methodologies for ecosystem descriptions of rocky reefs in the Aegean Sea.

This Milestone is part of WP3 aiming to assemble, integrate, and improve the most promising AI approaches and results into a comprehensive framework comprising new tools, methods, databases, recommendations, and background information. The framework will enhance our capacity to use open data to monitor and manage marine biodiversity.

Within WP3, Task T3.1 comprises a review, evaluation, and improvement of methods to support automated analyses of images of macroalgal communities.

The Milestone aims to report the review and evaluation process of the most promising AI application(s) that will be later trained and applied to our collection of underwater images in order to assess the ecological status of rocky reefs.

CONTRIBUTORS

TABLE 1 NAMES AND ROLES OF CONTRIBUTORS TO THIS DELIVERABLE.

Name	Affiliation	WP Lead	Task Lead
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1. Introduction

Coastal and marine ecosystems and their biodiversity are rapidly changing and, in many regions, severely degrading. In the face of growing global and local anthropogenic stressors, including the rapidly evolving climate crisis, new approaches are needed to facilitate regional conservation planning (Rilov et al. 2020), accounting for the dynamic and variable nature of the coastal ocean. In Europe, the emphasis is on the sustainable use of ecosystems and supporting their recovery through the principal operational instrument: the EU Biodiversity Strategy for 2030. The main ambitious goal of the Biodiversity Strategy is achieving healthy and resilient ecosystems by 2030 because “nature is in a state of crisis”. Specifically, “the biodiversity strategy aims to put Europe’s biodiversity on the path to recovery by 2030 for the benefit of people, climate and the planet”. The path to achieving the goals of the Strategy relies on our ability to measure, map and monitor biodiversity, its status and the functioning of its ecosystems at relevant taxonomic, temporal and spatial scales and to be able to detect potential biodiversity and ecosystem recovery. As these measurements are complex and costly, success greatly depends on advancing the state-of-the-art in effective and affordable methodologies and tools.

Many state-of-the-art monitoring and computer technologies are now mature enough to be integrated with traditional approaches to create next-generation assessments of the ecological status of the oceans. Artificial intelligence (AI) can enhance our ability to combine and analyse large amounts of data from various sources and recognise spatial-temporal patterns and trends in nature. However, these great advances in tools, platforms and societal actions need integration to achieve their full potential for biodiversity assessment.

The acquisition of benthic photographic samples taken by SCUBA divers using a quadrat (i.e. photo quadrat sampling) is the most commonly applied method for the assessment of the status of rocky reefs. Photoquadrat sampling is a fast and relatively easy-to-apply technique, which allows the acquisition of a large number of samples that provide a permanent record for present analysis and future comparisons, and visual evidence for communication with stakeholders. Analysis of photoquadrat samples is carried out in the laboratory, where experts annotate digital images manually, in order to obtain quantitative data. To this end, experts from the Marine Biodiversity and Ecosystem Management Lab, University of the Aegean have developed photoQuad (Trygonis & Sini, 2012) (www.mar.aegean.gr/sonarlab/photoquad), a scientific software specifically dedicated to the analysis of benthic image samples. The photoQuad software is widely used, and according to website metrics, it has been downloaded by more than 150 universities and research centres from over 50 countries, while the associated publication has more than 200 citations. Nevertheless, even through the use of dedicated software, image analysis is a very demanding task that requires highly trained experts, and it is very time-consuming, taking 15-40 minutes or even longer to

analyse an image sample, depending on the complexity of the biotic assemblage and the type of analysis carried out (Teixido et al., 2011). This is especially problematic when dealing with large spatio-temporal datasets, comprising hundreds to thousands of image samples.

Accurate identification of marine organisms through automated or semi-automated tools using artificial intelligence (AI) and machine learning techniques provides a promising alternative for the accurate, repeatable and cost-effective monitoring of rocky reefs. The performance of such methods has drastically increased over the last decades, and their application has gradually been adopted by marine ecologists on tropical and temperate reefs using different classification schemes (e.g. from genus to functional group; Williams et al., 2019; Bravo et al., 2021). However, such technology has not been systematically applied to Mediterranean ecosystems yet.

To address this issue, the objective of Task 3.1 is to identify and compare readily available AI tools for analyzing underwater photographic samples in order to extract information about the ecological status of rocky reefs. Our main goal here is to understand the current state of technology at this point, concerning our scientific question. Specifically, our approach includes 3 questions: i) What readily available AI tools exist for annotating benthic images?; ii) Which tools meet our requirements?; iii) How can we achieve the most accurate results regarding the assessment of macroalgal communities in rocky reefs? (the latter will be issued in the Deliverable D3.1).

2. Methodology/Approach

The first step in this process was to research existing AI solutions that are readily available. This preliminary analysis included researching AI solutions developed by academic and industry organisations. Extensive research was conducted for available AI software that applies machine learning and deep neural networks for automatic or semi-automatic benthic image annotation and quantification. Following a snowball approach; combining a literature review, backward and forward citation searching, and searching for independent

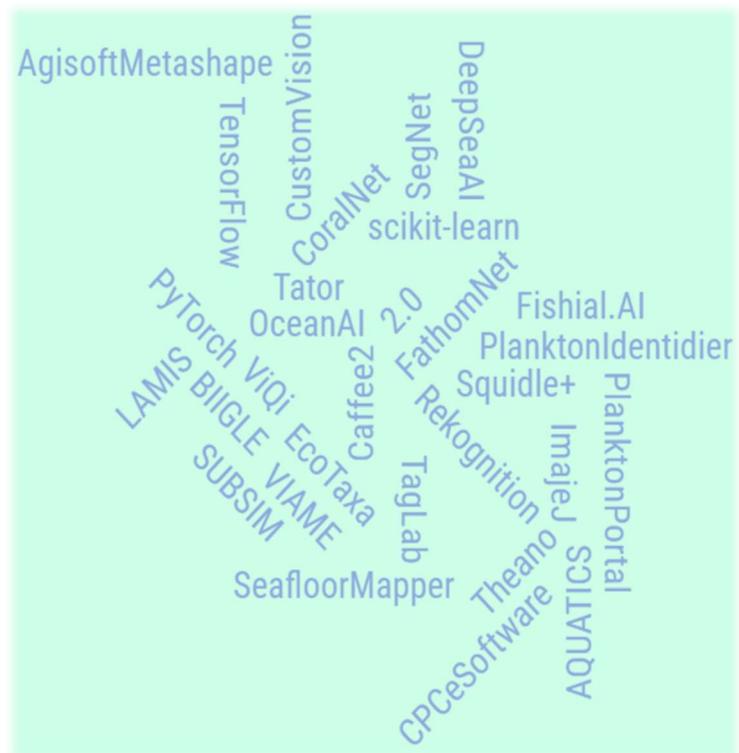


Figure 1. Names of the 30 AI solutions/ tools found during the research.

software through ChatGPT and online platforms, we found 30 different tools (Figure 1). The list of available AI solutions is not meant to be exhaustive, but rather representative of the currently relative and available AI applications.

Out of these 30 tools, we first excluded the outdated applications (e.g., inactive, not funded, or unavailable), and the solutions focused on a different scientific question or taxonomic group. Then, we excluded the not-ready-to-use solutions and the tools that did not support AI assistance for (semi)automated annotations/classifications (Figure 2).

3. Results/Validation process

There were 13 available, up-to-date, ready-to-use, AI-assisted solutions examined for their fitness to our purposes. This project required finding a tool that is: a) able to automatically or semi-automatically annotate benthic images with the assistance of Artificial Intelligence, b) able to calculate cover percentages of species with the assistance of AI, c) able to annotate multiple different habitat types and species on each photographic sample, d) able to train the AI with pre-annotated sets of photos, e) does not require special software or hardware to run, f) preferably free to use (Table 1). These requirements from an AI solution are based on the existing (manual) annotation workflow we wish to enhance and support with this tool.

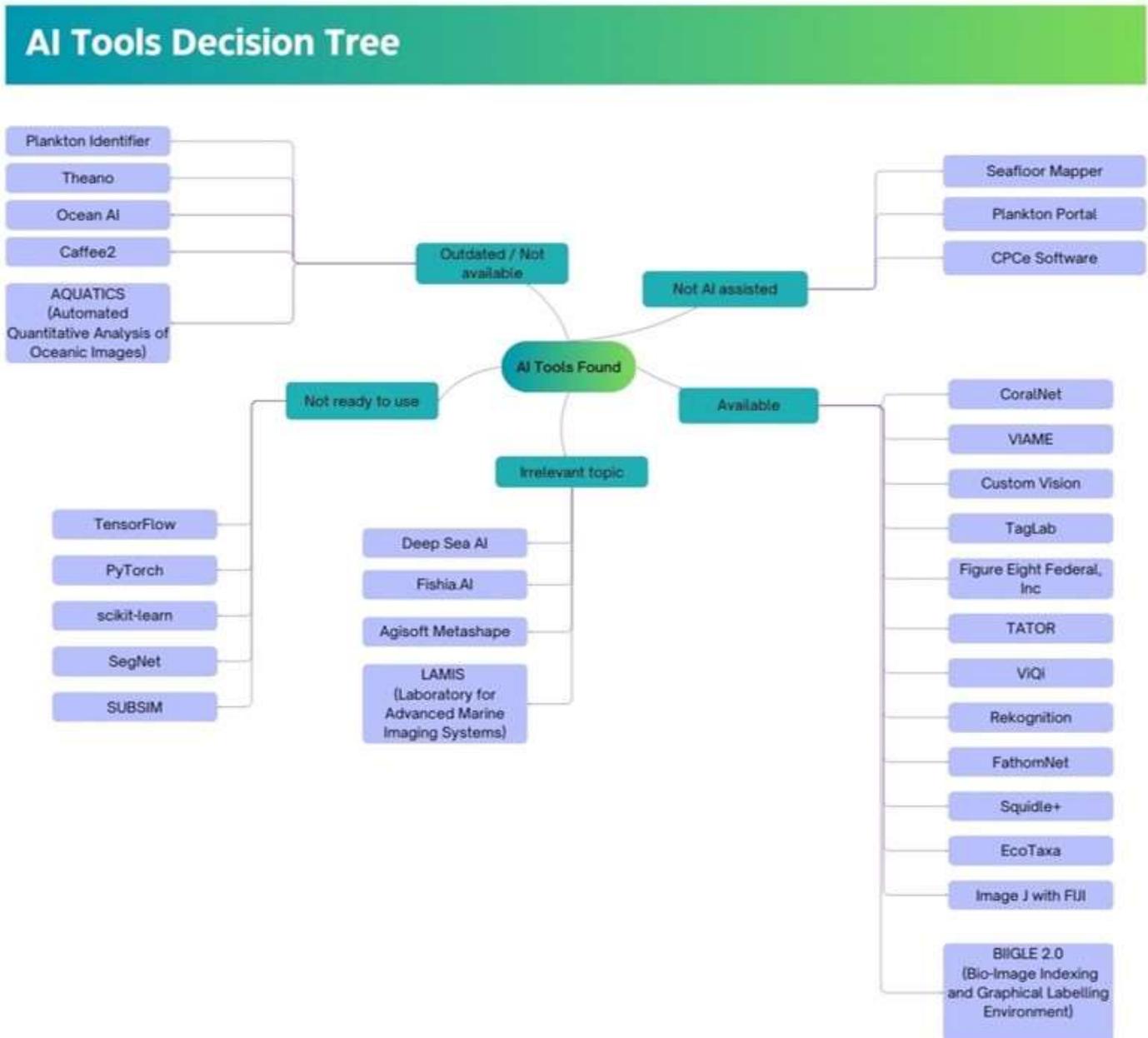


Figure 2. Categorization of AI tools based on their availability, relevance and AI assistance. Bottom right list includes the 13 available, relevant, ready-to-use, AI-assisted tools found during the research.

Table 1. Table of the 13 available, relevant, ready-to-use, AI-assisted tools found, with a short description of their basic applications for benthic imagery, system operation details and a validation of our requirements

AI Tool	Benthic imagery applications	Desktop/Web	Cost	AI assisted annotations	AI estimation of % cover	Multiple habitat types/species	Pre-annotated datasets	Software/Hardware requirements
CoratNet	% cover, leverage existing annotation library from online community to enhance training, publish AI models through API	web	free	yes (point based)	yes	yes	yes	no
VIAME	Object detection, tracking, annotation, image mosaicing, rapid model generation, and stereo measurement	desktop	free	yes (full frame & object-based)	no	yes	yes	no
Custom Vision	Object detection (draw boxes), classify images, scalable, publish AI models through API	web	Pricing depends on services, processing time and power	yes (full frame & object-based)	no	yes	maybe (via interface or SDK)	no
TagLab	% cover, import/export GIS ready files, track colony level changes spatially over time	desktop	free	yes (segmentation approach)	yes	yes	yes	yes
Figure Eight Federal, Inc	Labeling and categorizing various features within benthic imagery, (different species, substrate types, and physical features). By annotating these images, the AI tools can learn to identify and classify these features automatically.	web	Pricing depends on project	yes (full frame & object-based)	no	yes	maybe	yes
TATOR	Data management, extraction, transformation, annotation can be accelerated with AI assistance using standing inference servers or client side processing	desktop	Pricing depends on project (free trial 30 days)	no (not integrated, can be paired with external)	no	yes	maybe	yes
VIQI	Data annotations, classification, detection, semantic segmentation, % cover automation (not entirely automated). For identifying different components (eg. Substrate characteristics and fauna) 2 different models should be created	web	Pricing depends on project	yes (point based or segmentation)	no (not entirely automated)	yes	maybe	no
Recognition	Objects and scene detection	web	Pay-as-you-go pricing model	yes (full frame & object-based)	no	yes	no	no
FathomNet	Object detection and identification based on the algorithms developed using FathomNet's data	web	free	yes	no (requires additional processing and analysis tools)	no (requires additional processing and analysis tools)	no	no
Squidle+	Annotation of benthic features, automated labelling, categorization of species, and possibly the assessment of substrate types and coverage	web	potentially free	yes (point based)	no	yes	maybe	no
EcoTaxa	Annotation, categorization of species	web	free	yes	no	yes	yes	no
BIIGLE 2.0 (Bio-Image Indexing and Graphical Labelling Environment)	Detection and identification of objects in images/video, hierarchical classification, % cover, integration of environmental data	web	free, but there might be fees associated with extensive usage or additional services	yes (object detection)	yes	yes	yes	no
Image J with FIJI	Depending on the plugins	desktop	free	yes (with pre-trained models or custom models)	no (not AI-assisted)	yes	maybe (with plugins)	yes

From these 13 available, up-to-date, ready-to-use, AI-assisted solutions, CoralNet is the solution that meets all our criteria (Table 1), followed by VIAME and TagLab. CoralNet is a free tool, easy to set up, that does not require any user hardware and focuses on benthic imagery analysis.

In a similar study (Costa et al., 2022) authors trained and evaluated CoralNet, VIAME and TagLab (among other AI solutions), with CoralNet ranking better on a list of 10 criteria that the authors had set (e.g. training complexity, training time, required computing resources). Regarding the prediction accuracy, CoralNet scored 51.9%, VIAME 40.7%, while issues with the installation of TagLab did not allow the estimation of this percentage.

4. Next steps

This report aimed to answer the following questions:

- a) What readily available AI solutions exist for (semi)automated annotation of benthic images that can assess the ecological status?
- b) Which AI solution best meets our requirements?

The goal was to understand the current state of artificial intelligence technology (without any customization) and to decide the solution that will be later trained within the framework of NEMO-Tools.

Overall, CoralNet seems as the most promising tool compared to other AI solutions, with a combination of ease to use and to train, and relatively good prediction accuracy results. The standard applications of CoralNet facilitate parts of the manual underwater image analysis process of the workflow we typically follow.

The chosen AI tool will be trained and tested with a set of images from the Marine Biodiversity and Ecosystem Management Lab, University of the Aegean, aiming to increase the prediction accuracy for better results.

To conclude, it is worth noting that the field of AI is now emerging and is constantly evolving. The dynamic nature of this field will inevitably birth a new tool sooner or later with similar (if not more) abilities. Bearing that in mind, we now consider CoralNet as the most promising ready-to-use AI solution and we will put effort into increasing the prediction accuracy to include it in our workflow, without neglecting other AI tools that will emerge in the future.

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