Protecting Eastern Lemnos Habitats

Final progress report

2024

iSea

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this report.

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Baseline information

In 2022, iSea selected eastern Lemnos to map the *Posidonia oceanica* meadows, including all the coastal regions from the northeast cape to the southeast cape and up to 40km offshore to the east, including the Natura2000 site "Limnos: Chortarolimni - Limni Alyki kai Thalassia periochi (GR4110001)". The reason for pinpointing eastern Lemnos was that it hosts the largest cohesive meadow of *Posidonia oceanica* in the Aegean Sea (Topouzelis et al., 2018) extending further than the limits of the Natura 2000 site of the region (Topouzelis et al., 2018; Traganos et al., 2018; Naasan Aga – Spyridopoulou et al., 2023). In 2022, iSea with the support of Blue Marine Foundation produced the most detailed available mapping of the meadow in Northeast Lemnos summing to a total of 83.7km^2. Among the other actions conducted, iSea documented the local ichthyofaunal biomass and abundance using visual census surveys. The preliminary results on the biodiversity, abundance and biomass of the local ichthyofauna, apart from being higher than in all areas examined that year, showed the importance of such an extensive habitat for the biodiversity of the area and natural resources. During 2023, iSea conducted further research on the meadows' health applying specific indices in four selected sampling sites where the meadow's conservation status had already been assessed by researchers, during 2013-2015 for the WFD and Natura2000 site inclusion (Gerakaris, 2017) to ensure comparability. All four stations were assessed as "High conservation status" when considering the CI index which is indicative of the meadows' conservation on a habitat level, whereas when looking at the BiPo index indicative of the plant's health, one station was assessed with a "High ecological status" while the other three with a "Good ecological status" while when compared with previous estimates the status of the meadows were in a lower health state compared to ten years ago. In 2022, the total Blue Carbon stock of the meadows was preliminary assessed with more than 270,000 tons of carbon, while in 2023, the total value of the mapped meadow regarding the ecosystem service provided by the Blue Carbon was estimated to be over 1 million euros. Other actions increasing our knowledge about the area and the habitats it hosts, can be found in the milestone diagram (Figure 1). While actions foreseen under this grant and their progress is described in detail in the following chapters of the report.

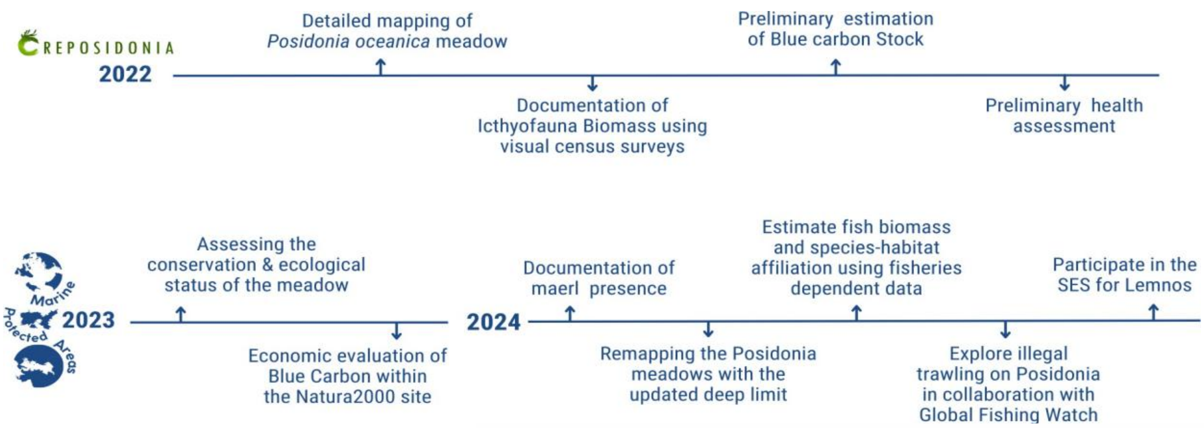


Figure 1. Milestone

Overall aim of the project

Contributing to science-based decision-making to achieve effective protection of Eastern Lemnos habitats by:

- Closing knowledge gaps for key habitats and species of Eastern Lemnos,
- Advocating for effective protection and management, and
- Engaging and empowering stakeholders in bottom-up management.

A.1. Estimate fish biomass and species-habitat affiliation using fisheries dependent data.

Seasonal onboard samplings were conducted at eastern Lemnos, from the port in Plaka to different locations and habitats within the project's area of interest. To date, 27 fishing trips (135 fishing operations) were monitored for two consecutive years 2023-2024 (winter samplings for 2024 were conducted early 2025), using trammel nets. During the onboard surveys apart from the target species, bycatch, discards, depredation, gear specifications, environmental parameters and habitats were recorded. As one of the main objectives is to examine species-habitat affiliation, fishing operations were conducted in three different habitats: *Posidonia oceanica* meadows (N=81), rocky reefs (N=19) and maerl (N=35). Apart from fishes, morphometrics were collected for elasmobranchs, crustaceans, and mollusks. While, other vulnerable benthic species were recorded (i.e. sponges, echinoderms, and corals).

In total 3,523 individuals were recorded and measured, from which 68 different species were identified at a species level and 8 at a genus level. On Posidonia meadows, a total of 2,379 individuals were recorded belonging to 66 species. On Rocky reefs, a total of 455 individuals were recorded belonging to 40 species, whereas on Maerl the total number of individuals caught was 689, belonging to 44 different species. On the sections below, a more detailed analysis is presented for each habitat type utilizing abundance, frequency of capture and the Catch per Unit of Effort (CPUE).

***Posidonia oceanica* meadows**

Regarding species composition in Posidonia meadows, the most abundant species in terms of numerosity was the stripped red mullet (*Mullus surmuletus*) accounting for 18.1% of the total individuals recorded, followed by the annular seabream (*Diplodus annularis*) with 16.6% and scorpionfish (*Scorpaena scrofa*) with 12.9%. Within the top 10 most abundant species more than 40% account for either primary or secondary target species (Figure 2).

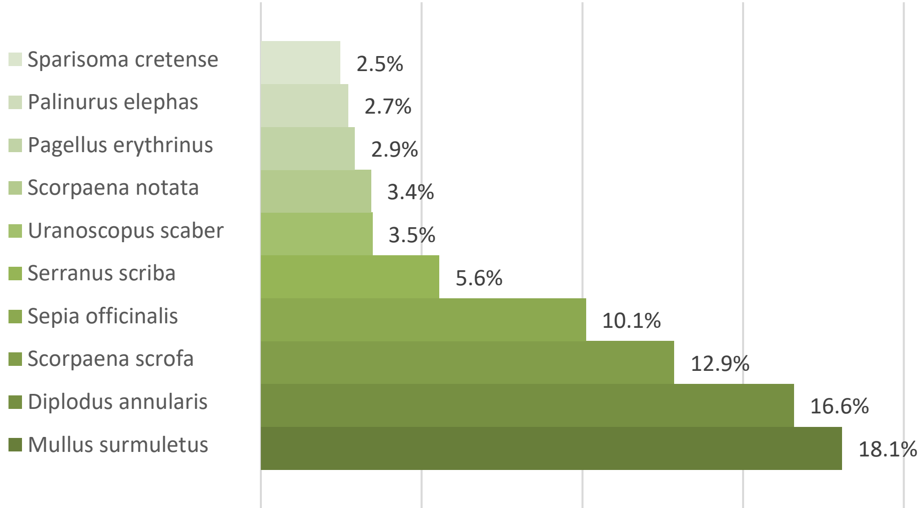


Figure 2. Composition expressed in abundance (No. of individuals) in Posidonia meadows.

Frequency of occurrence per fishing operation was calculated as an indication for species composition in relation to the habitat and to account for exceptional catches. Scorpionfish, annular seabream (*Diplodus annularis*) and cuttlefish (*Sepia officinalis*) had the highest percentages, 67.9% and 51.9% for the last two species respectively, followed by the striped red mullet (40.7%) and painted comber (*Serranus scriba*) (34.6%). Other frequently caught species were the common pandora (*Pagellus erythrinus*), the two-banded seabream (*Diplodus vulgaris*), lobster (*Palinurus elephas*), small red scorpionfish and *Dasyatis spp.* rays (Figure 3).

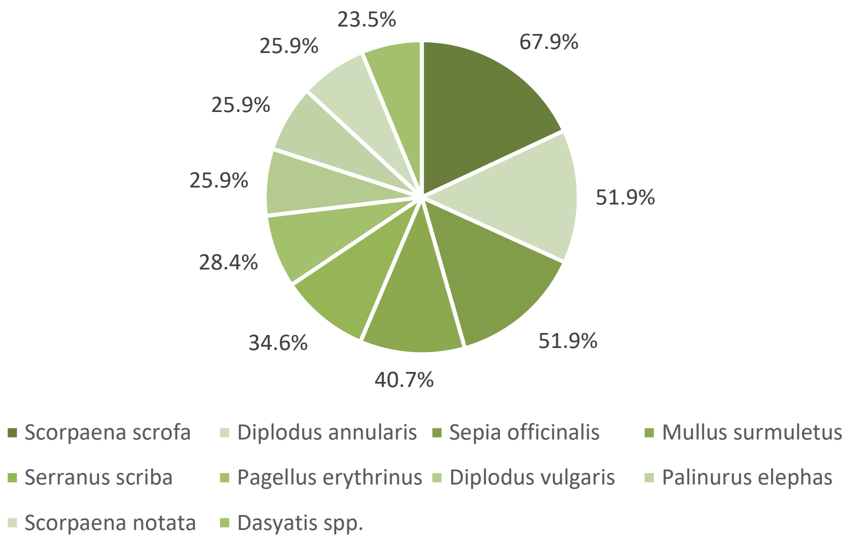


Figure 3. Top 10 species based on their frequency of occurrence per fishing trip in Posidonia meadows.

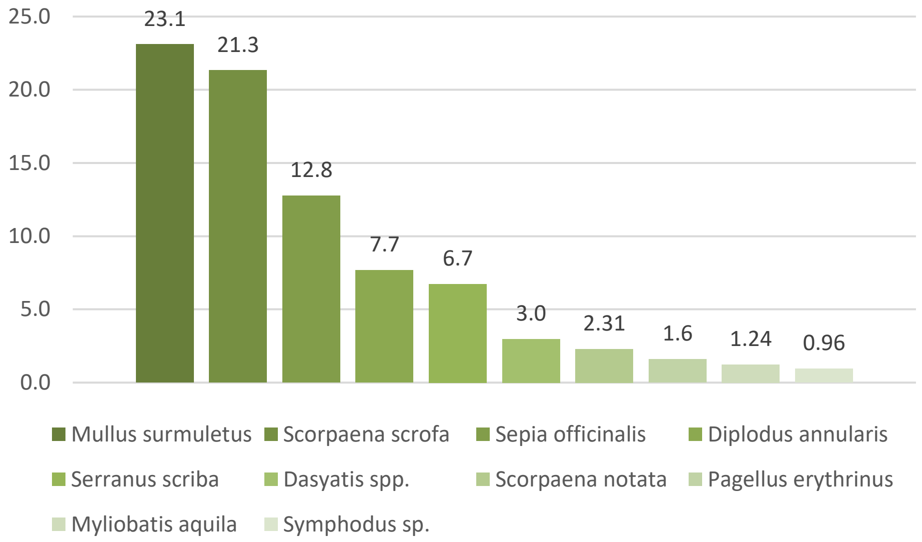


Figure 4. Top 10 species expressed in CPUE (kg/km/h) in *Posidonia meadows*.

Finally Catch Per Unit Effort (CPUE) was calculated for all species and standardised per 1km net per hour. Stripped red mullet, scorpionfish and cuttlefish had the highest numbers with 23.1, 21.3 and 12.8 respectively with their CPUE being multiple times higher from the rest, except for the annular seabream. (Figure 4).

Maerl

In maerl beds the most abundant species caught was lobster accounting for 27% followed by striped red mullet and scorpionfish accounting for 13.6% and 6.7% respectively (Figure 5). Regarding frequency of occurrence per fishing operation the top 10 most common species captured are lobsters, scorpionfish, common pandora, nursehound shark *(Scyliorhinus stellaris)*, the anglerfish *(Lophius piscatorius*), the john dory (*Zeus faber*), cuttlefish, *Dasyatis spp*. rays, the brown ray *(Raja miraletus)* and the marbled electric ray (*Torpedo marmorata)*. Regarding the target species, lobster had the highest catch percentage, at 74.3%, followed by scorpionfish at 54.3% (Figure 6).

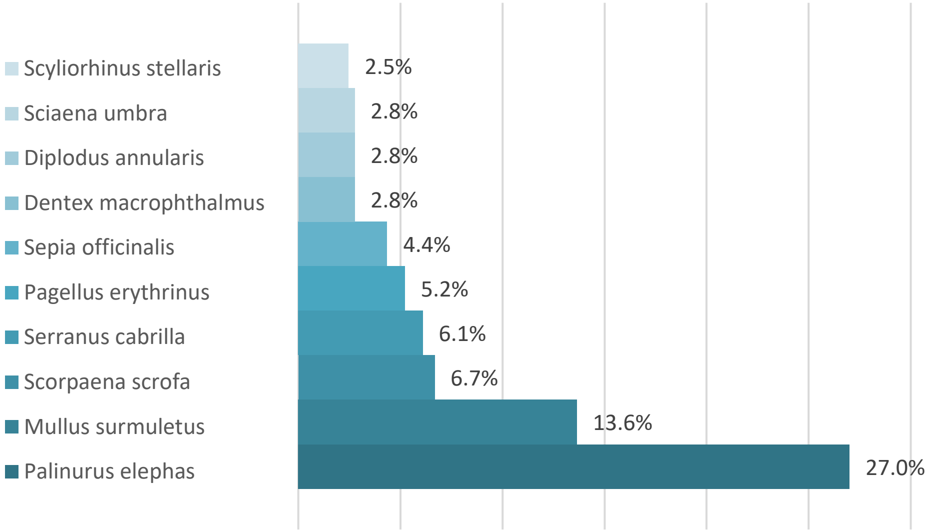


Figure 5. Composition expressed in abundance (No. of individuals) in maerl beds.

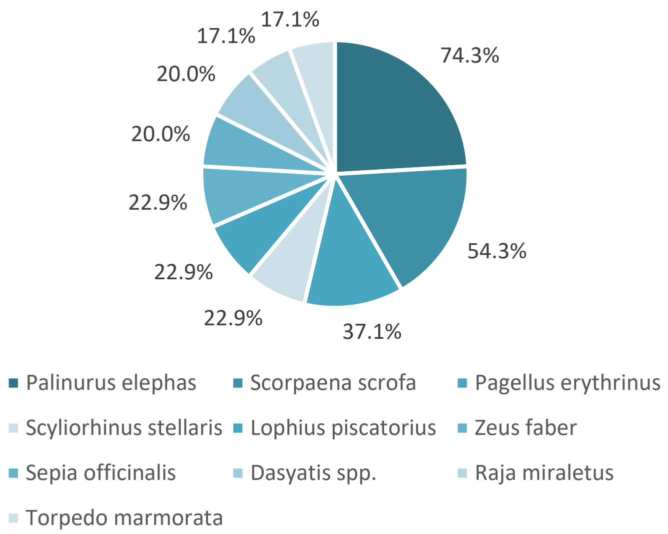


Figure 6. Top 10 species based on their frequency of occurrence per fishing trip in maerl beds.

Finally, Catch Per Unit Effort (CPUE) was calculated for all species and standardised per 1km net per hour, with most species among the top ten not following the same trends as above. Dasyatis spp. rays, recently protected, exhibited the highest CPUE with 3.3, followed by lobster with. Notably, in maerl among the 10 species exhibiting the highest CPUE three are elasmobranchs, which is unique comparing to the other habitats (Figure 7).

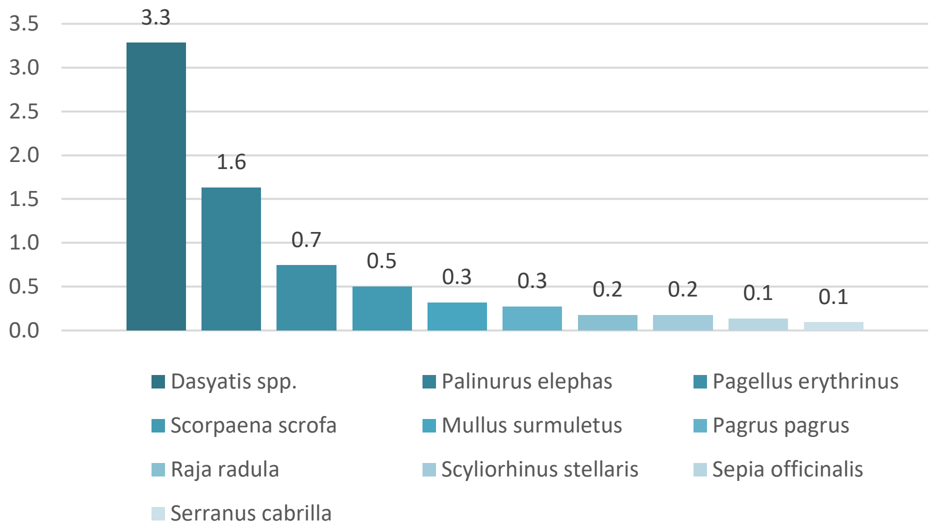


Figure 7.Top 10 species expressed in CPUE (kg/km/h) on maerl beds

Shallow rocky reef

Rocky reefs accounted for the least fishing operations than the other habitats. The composition of species resulted in cuttlefish being the most abundant accounting for 16% of the total individuals, followed by scorpionfish with 9% and lobster with 7% (Figure 8).

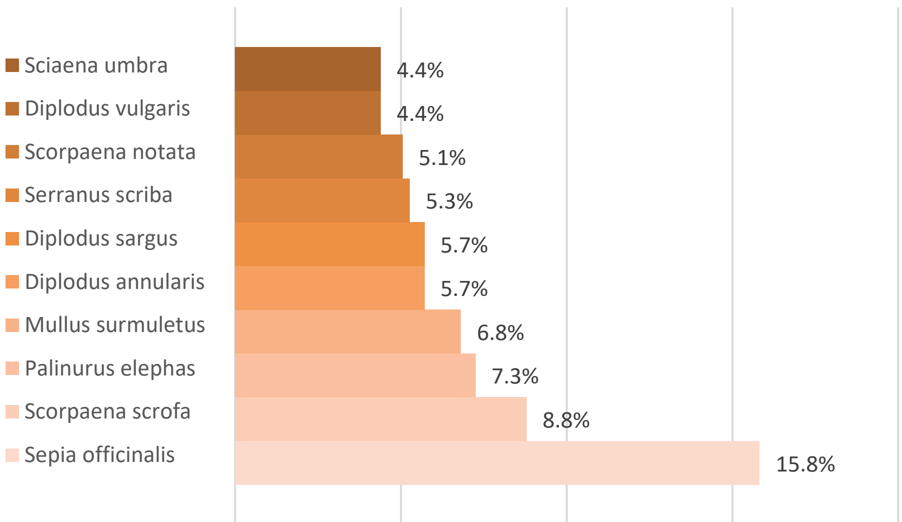


Figure 8. Composition expressed in abundance (no of individuals) in rocky reefs.

In rocky reefs, the top 10 most common species captured were: scorpionfish, cuttlefish, painted comber, small red scorpionfish, brown merge (*Sciaena umbra*), parrotfish (*Sparisoma cretense*), annular seabream, common two banded seabream, lobster and marbled electric ray. Scorpionfish and cuttlefish were the most frequently caught species, with 92,9% and 85,7% respectively (Figure 9).

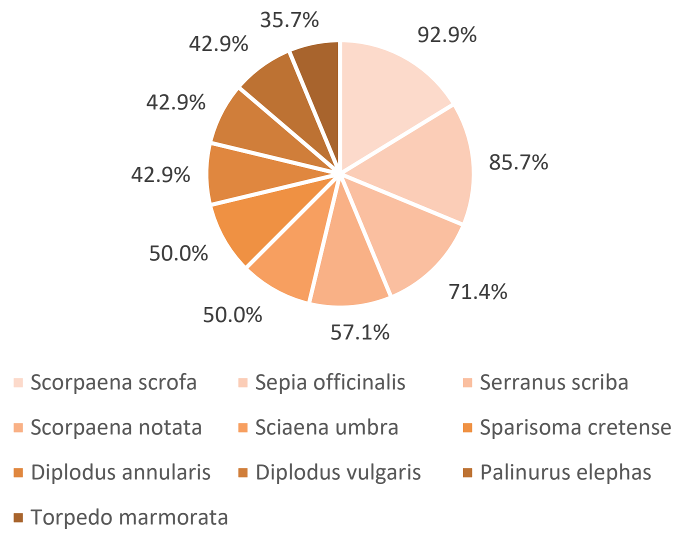


Figure 9. Top 10 species based on their frequency of occurrence per fishing trip in rocky reefs.

According to CPUE, cuttlefish exhibited the highest values with 5.6 kg/km/h, followed by scorpionfish with 1.9 kg/km/h, and the rest, including the European barracuda (*Sphyraena sphyraena*) and the stargazer (*Uranoscopus scaber*) having a CPUE of 0.5 or lower (Figure 10).

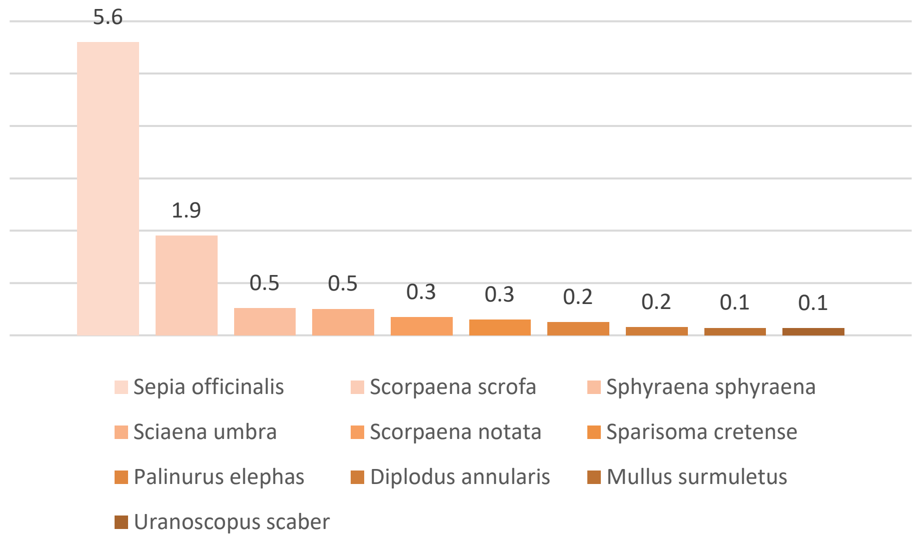


Figure 10. Top 10 species expressed in CPUE (kg/km/h) on rocky reefs.

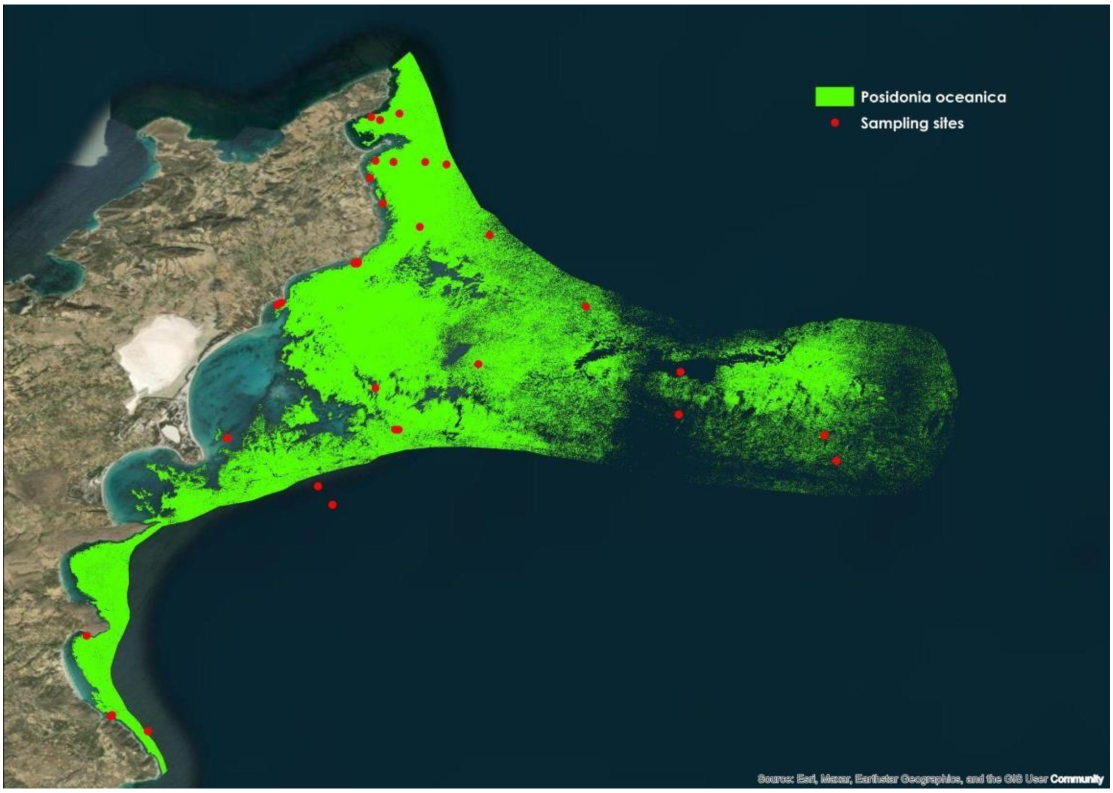
A.2. Evaluation of ecosystem services of the Natura2000 site of Northeast Lemnos Island.

A.2.1 Economic evaluation of blue carbon of the meadow hosted in the Natura2000 site. (M11- M12)

In 2023, a preliminary economic evaluation of the carbon stock of Northeast Lemnos hosted in the Natura2000 site was conducted by Dr. Dionysis Latinopoulos. The samples of this analysis were obtained during REPOSIDONIA project in 2022. In order to obtain better results of the value of carbon that gets sequestrated every year in the meadow. During the summer visit in the studied area, 12 more sediment corers were collected from the shallow limits of the meadows up to 10 meters depth, resulting in a total of 41 samples.

The map below (Map 1) presents the location of all the sediment samples. The sampling sites were selected across the meadow, near the edges of the meadow of E. Lemnos in order to obtain a more accurate representation of the blue carbon stock.

Out of these 41 samples, 35 were selected as they met the criteria for the analysis on Posidonia habitat. The methodology that was followed derived from the IUCN protocol (Howard et al., 2014) and it was completed in two parts, the sampling surveys and the laboratory analysis.



Map 1. Sampling sites of blue carbon in E. Lemnos (2022-2024).

Sampling was conducted during diving, using 1m long corers to collect the samples. Notes were taken regarding the length of the corer that was inserted into the sediment, the length of the extracted sample, and the depth at which the samples were taken. After the sampling process, the samples were extracted from the corer, labelled and stored on the refrigerator until the laboratory analysis took place.

In order to determine the percentage of organic carbon present in the samples, the laboratory technique selected was the utilisation of Loss on Ignition (LOI). This technique utilises an empirical relationship between the organic carbon and the organic material, determining the carbon content base on the lost organic material. LOI analysis was completed by an external laboratory.

Before the laboratory analysis, all samples were homogenised and weighted. After that, one subsample was taken from each and weighted, and then dried at 60°C from 24 to 72 hours until reaching a constant weight. From all dried subsamples, large items and leaves were removed, and the samples were sent to the lab for the analysis.

In addition to the percentage of LOI, the percentage of organic matter was calculated using the relationship proposed by Fourqurean et al. (2012), incorporated into the protocol mentioned above. Other parameters such as the dry bulk density and the soil carbon density were computed for every subsample. Subsequently, the total amount of carbon in the core section was calculated into megagrams of carbon per hectare (MgC/ha).

The total number of samples used in 2022 were 17, whereas 18 samples were used for the analysis of this year (samples collected between 2023-2024). On Figure 11, graphic representations are displayed showcasing the results of the blue carbon analysis for the 17 and 18 corers extracted, for 2022 and 2023-2024 accordingly.

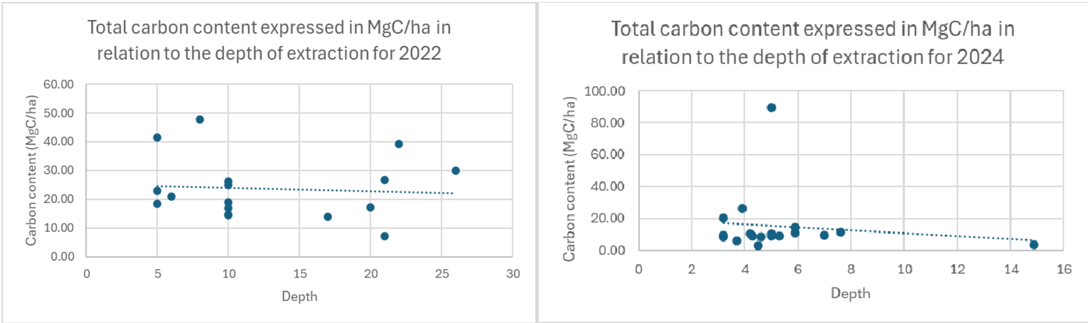


Figure 11. Total carbon content per corer expressed in MgC/ha in relation to the depth of extraction for 2022 and 2024 analysis.

Based on the results of the analysis, the outcome for both years were very divergent, with lower values found on shallower depths in 2024. According to Serrano et al. (2014), the carbon stock of the meadows should be reduced by the increase of the depth, as light availability decreases. Therefore, in order to be able to identify the cause of this divergence, further sampling and analysis must be conducted at a broader depth range, whereafter the determination of the average amount of organic carbon in a specific stratum for a given depth can be computed.

A.3. Habitat related research

A.3.1.1 Remapping the Posidonia meadows with the updated deep limit (M5-M12)

To remap the meadows the project manager has conducted meetings with the external collaborator who will perform the habitat classification regarding the extend of the satellite images this time using an AoI using the 50m depth contour derived from Hellenic hydrographic service.

The analysis was performed with over 190 ground truthing points (vs 83 in 2022) to ensure higher accuracy.

Methodology

Coastal habitat mapping with emphasis on the seagrass meadows, the priority habitat 1120*, has been performed using 8-band PlanetLabs SuperDove, at 3m pixel size for the area of interest, the N2000 GR4110001 (Figure 12) along with incorporation of a product from an industrial project and visual inspection of Copernicus Sentinel 2 imagery. The selection of the imagery has been done using PlanetLabs Search Toolbox, while under an NDA, the industrial product has been provided for use without the rights of sharing. Further, using Copernicus Dataspace Hub, selected Sentinel 2 imagery has been retrieved and used under a visual inspection approach.

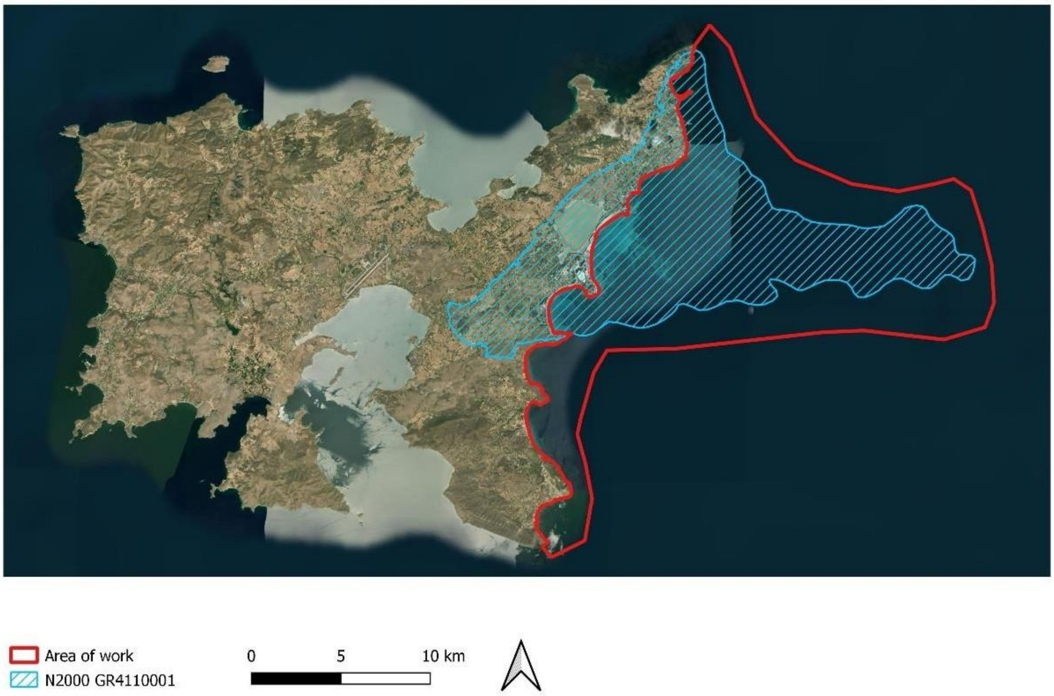


Figure 12. The area of interest in East Lemnos, covering the N2000 GR4110001 and moving beyond the limits of it.

Satellite Imagery and Image classification

Through the available imagery from the archive, the selection was based on the 8-band data (https://developers.planet.com/docs/apis/data/sensors/) and the cloud cover to be less than 20% within the search area. Further, the filtered imagery was visually inspected prior to order for further analysis. The 8-band PlanetLabs SuperDove has been used for coastal bathymetry and habitat mapping with success (Poursanidis et al., 2023). One image, acquired on 29/08/2022 under clear sky conditions has been selected. Imagery was order in Top of Atmosphere Reflectance (TOAR) and further we use ACOLITE (Vanhellemont et al., 2018) as the proper atmospheric correction for aquatic environments.

The satellite data are of commercial nature, however under a special license (Education and Research Program, https://www.planet.com/industries/education-and-research/) are contributed as an in kind contribution to the project by Dimitris Poursanidis.

The final product is an aquatic reflectance image composite. For the image classification towards seagrass mapping, we employ a Random Forests Regression-based analysis workflow adapted from Poursanidis et al., 2021. We use the open source EnMAP toolbox (Van der Linden et al., 2015, Poursanidis et al., 2019), where all necessary steps for proper creation of training data, image classification and product validation using the collected field data, are in place. The toolbox is a plugin in the open-source GIS software QGIS and can be used by any experienced user. Figure 13 provides an overview of the methodology we follow for the delivery of the seagrass cartographic product.

We have to mention here that even if visually the selected imagery seems to be fine for use, as no wave caps, no sunglint and other effects obscure the image, this is not something that is guaranteed. In the process to select imagery from 2024, while visually, two selections have been ordered, during the preprocessing we saw that we have severe sunglint with cloud shadows and waving action, making this imagery not suitable for analysis (Figures 14, 15, 16). This is also because the specific area is not a common situation for seagrass mapping, as it extends over open sea, where the oceanographic conditions are not the same as where we have seagrass meadows close to the coast.

Further, since satellite sensors use the pushbroom technology, the selected frame is not collected simultaneously, allowing the changes of the water surface conditions within the delivered imagery. Therefore, there is a need of flexibility on the image types that can be used when commercial satellite image providers don does not cover the area of interest at sufficient quality or to be able to create fusion products by blending different data sources as we apply here. Satellite product with hydroacoustics product, from an industrial project.

For the analysis, we created a series of image-based training data that are evenly distributed in each area of work. A binary scheme has been designed aiming at the separation of the target habitat, here the seagrass meadows, from the other seabed habitats named sandy/soft bottoms, rocky surfaces/reefs and optically deep waters, where the spectral data that are recorded by the satellite sensor can have both a bottom and mid water origin.

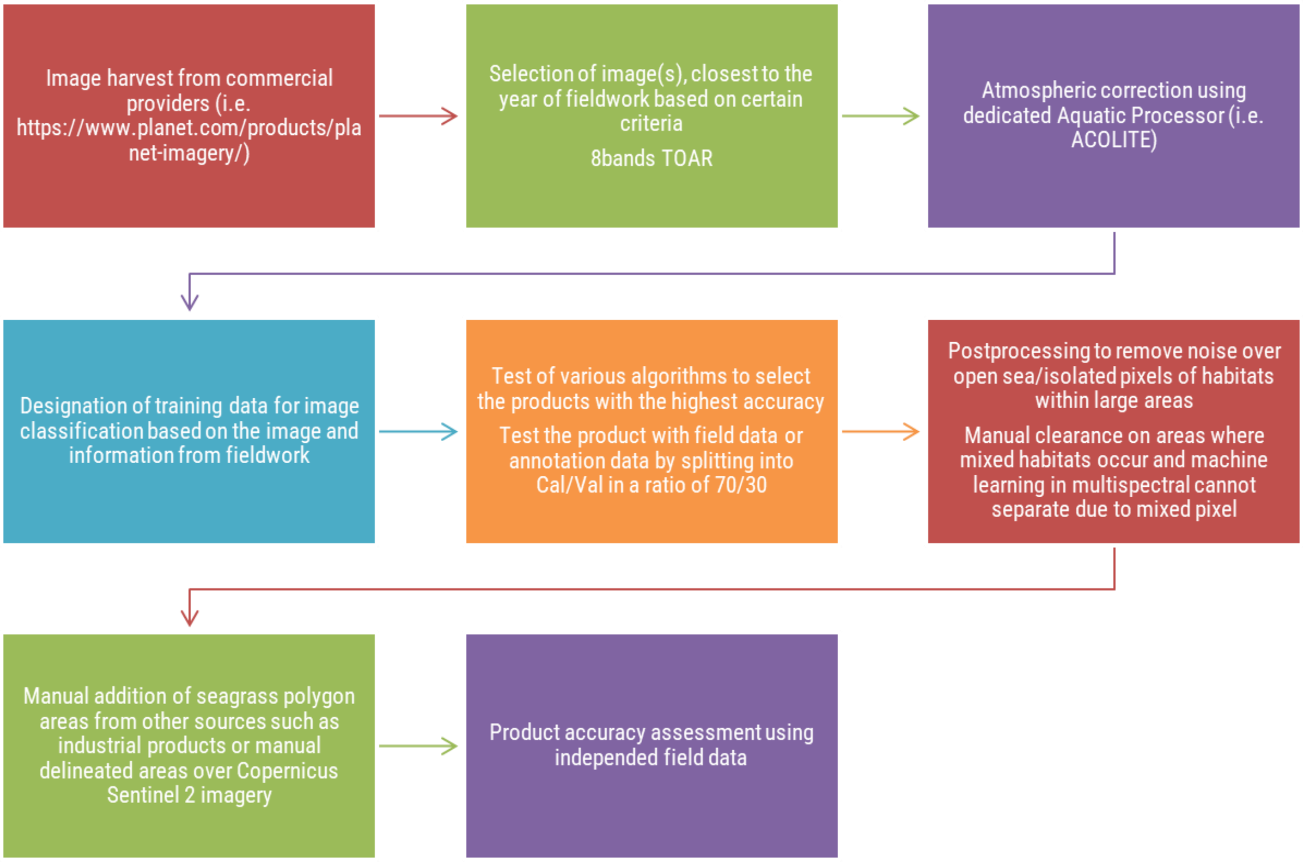


Figure 13. The developed methodology we follow on seagrass mapping in East Lemnos.

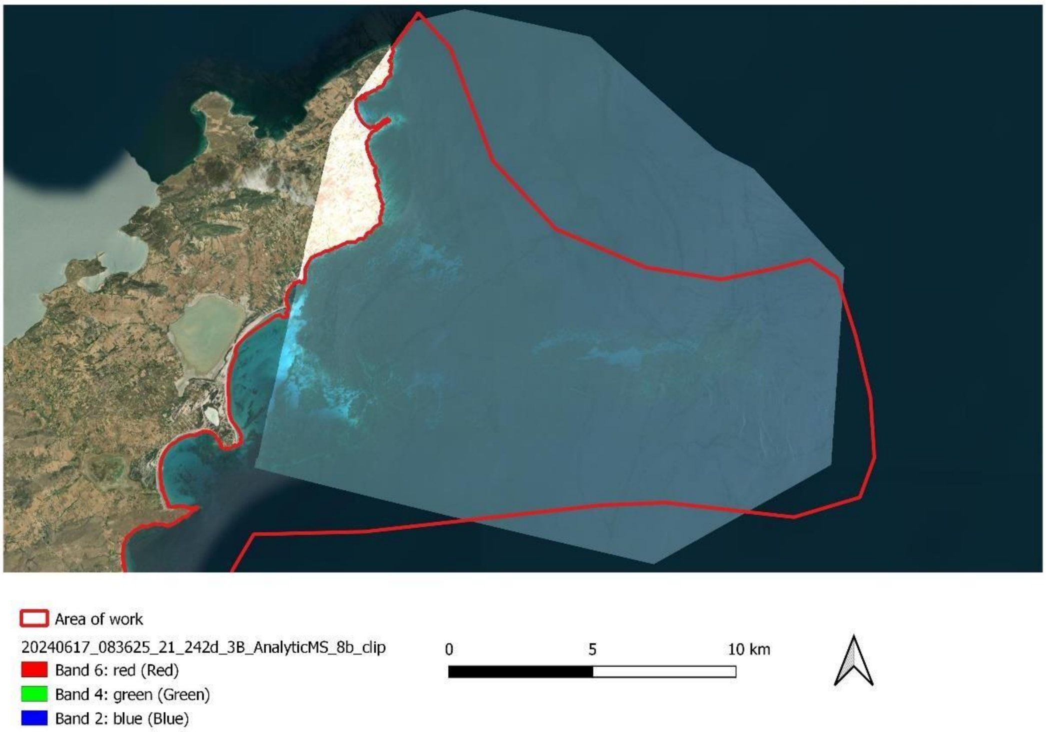


Figure 14. An RGB combination of an 8-bands Planet Labs imagery from 17/6/2024. Visually, minimum issues exist close to the coast, while moving to the open sea, swirls and potential sunglint areas might occur.

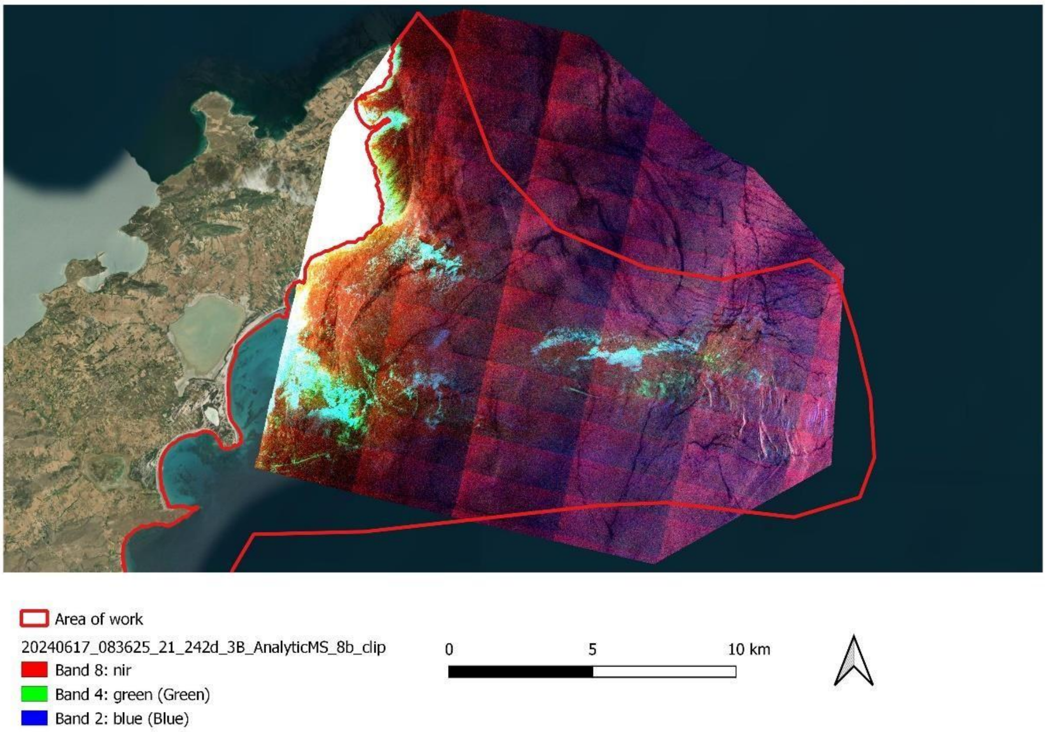


Figure 15. The same image but with the NIR band on top. Severe swirls obscure the use of imagery in the open sea while close to the coast remains usable.

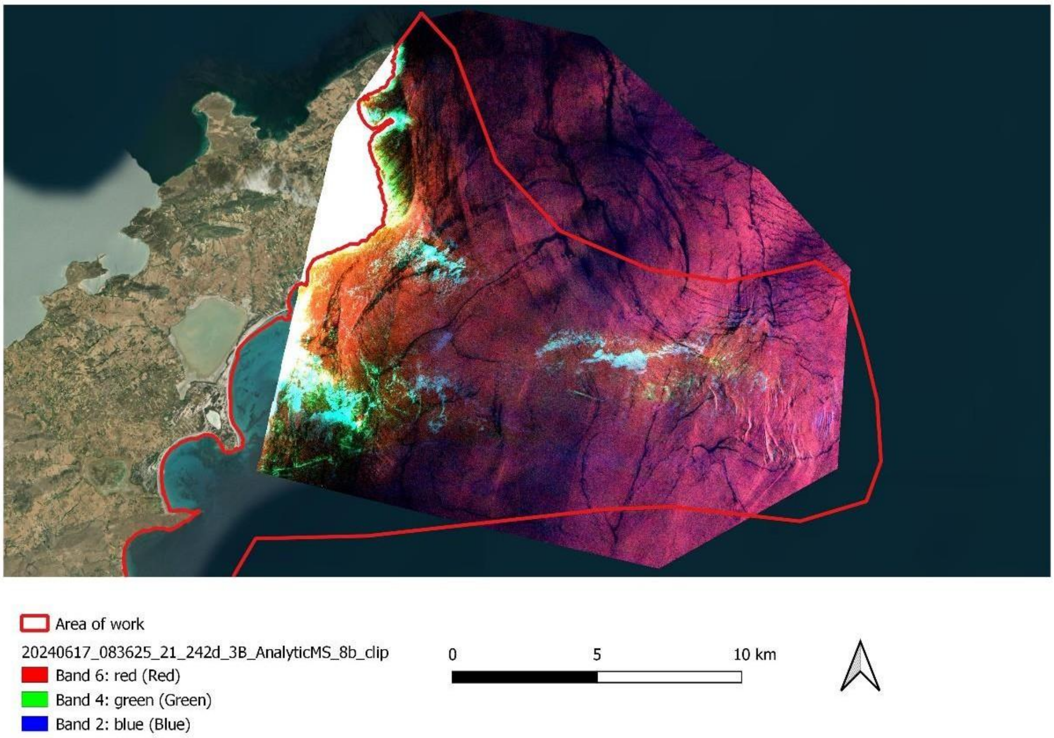


Figure 16. The same image in RGB but with a histogram stretch at 95%. Sunglint and swirls make a large portion of the image usable.

The final cartographic product of the seagrass meadows in East Lemnos is presented in Figure 17.

Following the work in 2022, here we update the product ending in mapping 13,943 hectares in total and 9,262ha within the N2000 site. Using 193 independent validation point coming from field work by iSea and the overall accuracy of the product is estimated at 87%.

This site of work provides a good benchmark on what Earth Observation cannot provide and why synergies among tools and methods are required to achieve the final target. Moving beyond the coastal zone, in the open sea, the oceanographic conditions are different and challenging as shown in Figures 15 and 16. The use of multiple imagery from various sensors and the use of hydroacoustics (side scan sonar, multibeam echosounder) are important to be considered for an end-to-end solution aiming for a perfect baseline mapping action where Earth Observation will have specific role but also high-quality data to test limitations.

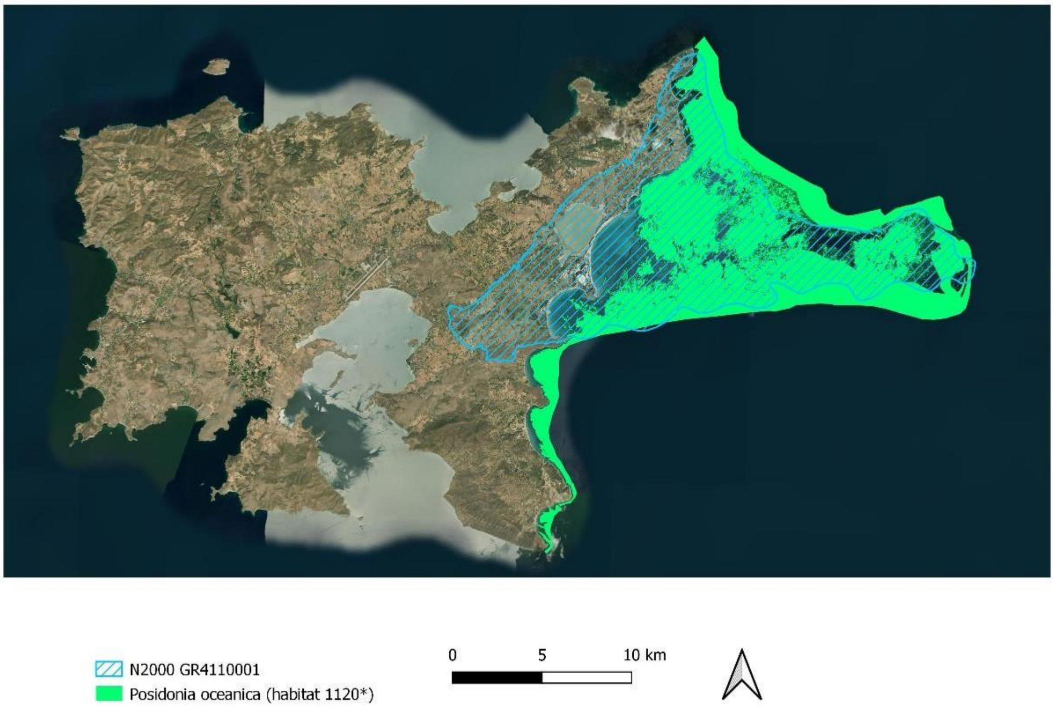


Figure 17. The spatial distribution of *Posidonia oceanica* in East Lemnos.

A.3.1.2 Documenting maerl presence using ROV and fisheries dependent data

Regarding the documentation of Maerl a total of 518 points were collected deriving from fisheries data, while the presence of Coralligenous was also documented with *Eunicella cavolini* (Figure 18).

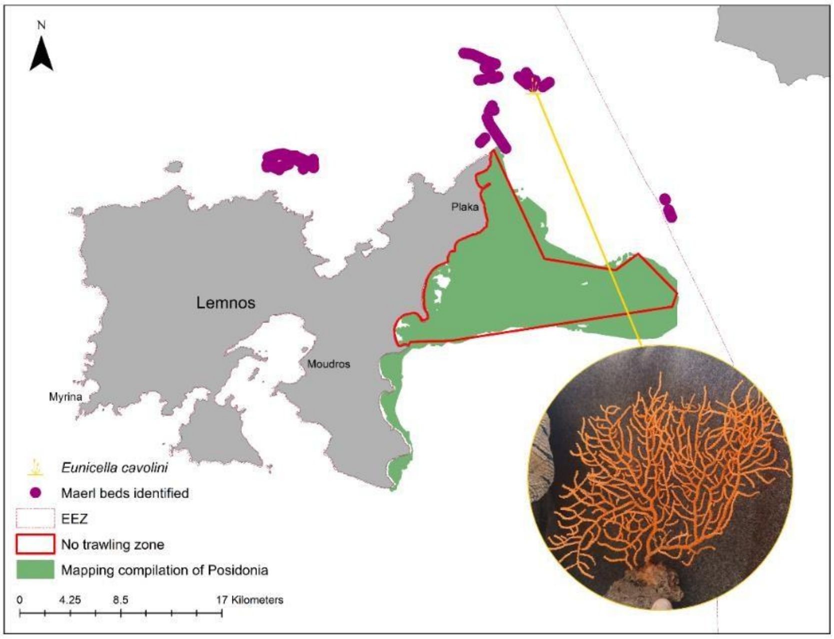


Figure 18: Identified maerl beds and the location of the corraligenous.

This effort is key as maerl beds have insufficient information available on their spatial distribution which hampers the effective application of European Council Regulation (EC) No. 1967/2006, which prohibits bottom trawling over them (Basso et al., 2016), while the latest model predicting their spatial distribution in Greece has no prediction in the Northeastern area (Fakiris et al., 2023).

The documentation will continue in the next field visits of 2025 using more fisheries data and ROV surveys.

A.3.2. Explore illegal trawling on Posidonia in collaboration with Global Fishing Watch (M5- M12)

For investigating illegal trawling in the eastern Lemnos, we collaborated with the Global Fishing Watch (GFW) team to obtain relevant data. Our study area was defined by four polygons (Figure 19) highlighting key regions of interest, considering the local habitat of Posidonia meadows and local fishing bans:

a) The no-trawling zone above Posidonia oceanica meadows within the Natura site, established by the ministry of agriculture (OJ 241/4-6-2007, Ministerial Decision 167378). The eastern distribution boundary of Posidonia meadows, produced from merging various mapping analyses (Naasan Aga – Spyridopoulou & Poursanidis, 2023; Topouzelis et al., 2018; Traganos et al., 2018; Panayotidis et al., 2022), with an additional 100m buffer adopting a precautionary approach

b) The bathymetric zone up to 50m depth on the eastern seas of Lemnos using the bathymetry Digital Terrain Model (DTM) layer from Hellenic Navy Hydrographic Service, aligned with European Council Regulation (EC) No. 1967/2006.

c) The buffer zone of 1.5nm distance from the shore, where trawling is forbidden (EC) No. 1967/2006.

d) The buffer zone of 6nm from the shore to international waters (>6nm), where trawling is strictly forbidden on an annual basis during the months June, July, August, and September (Article 134 of Law 4799/2021 (Government Gazette 78A')), as well as between 24-31 of December, and 24- 31 of May (No. 271/2576 Ministerial Decision). The use of it allows the monitoring of this spatiotemporal regulation and the distribution of fishing within the area of interest.

e) Using these polygons on the Global Fishing Watch (GFW) platform, we explored the "Apparent Fishing Effort (AFE)" data for each zone for the period January 2012 - 1st of November 2024 to gain a comprehensive understanding of fishing activity within these areas. "AFE" data derive from Self-Reported Automatic Identification System (AIS) and processed with algorithms to determine fishing activity (Kroodsma et al, 2018). The activity of trawlers was analyzed by year, seasonality, and country. While the gear of several vessels is identified as "Fishing" by GFW database, their activity remains unidentified. Therefore, the activity hours of these vessels reported as "Fishing unknown gear" (FUG) were also quantified in order to gain a general idea of the potentially trawler-related data.

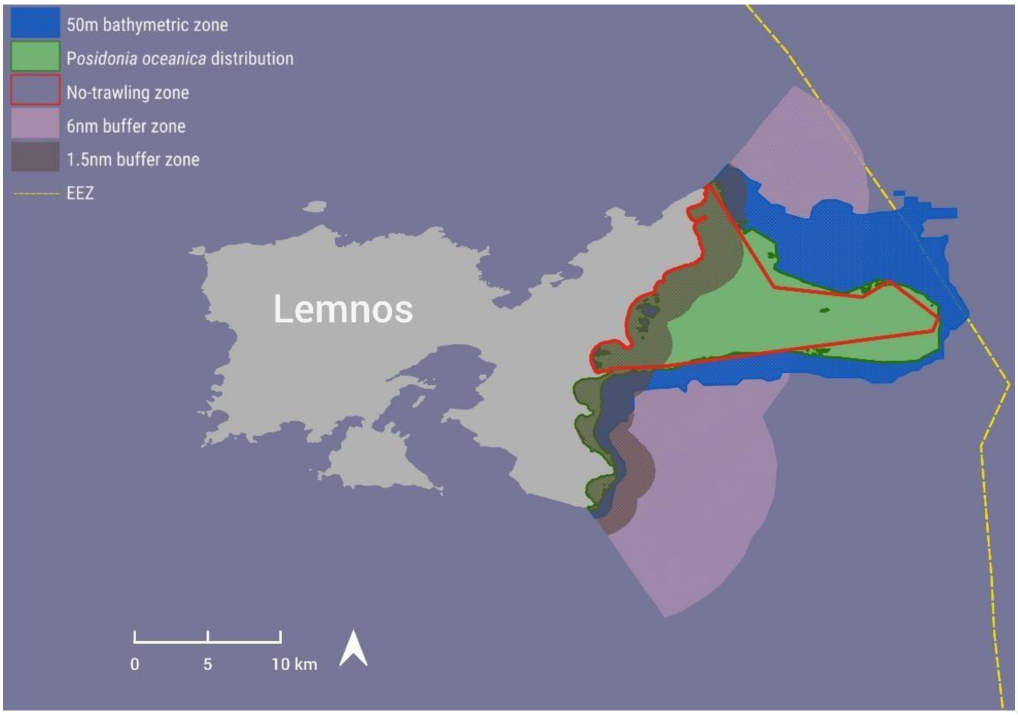
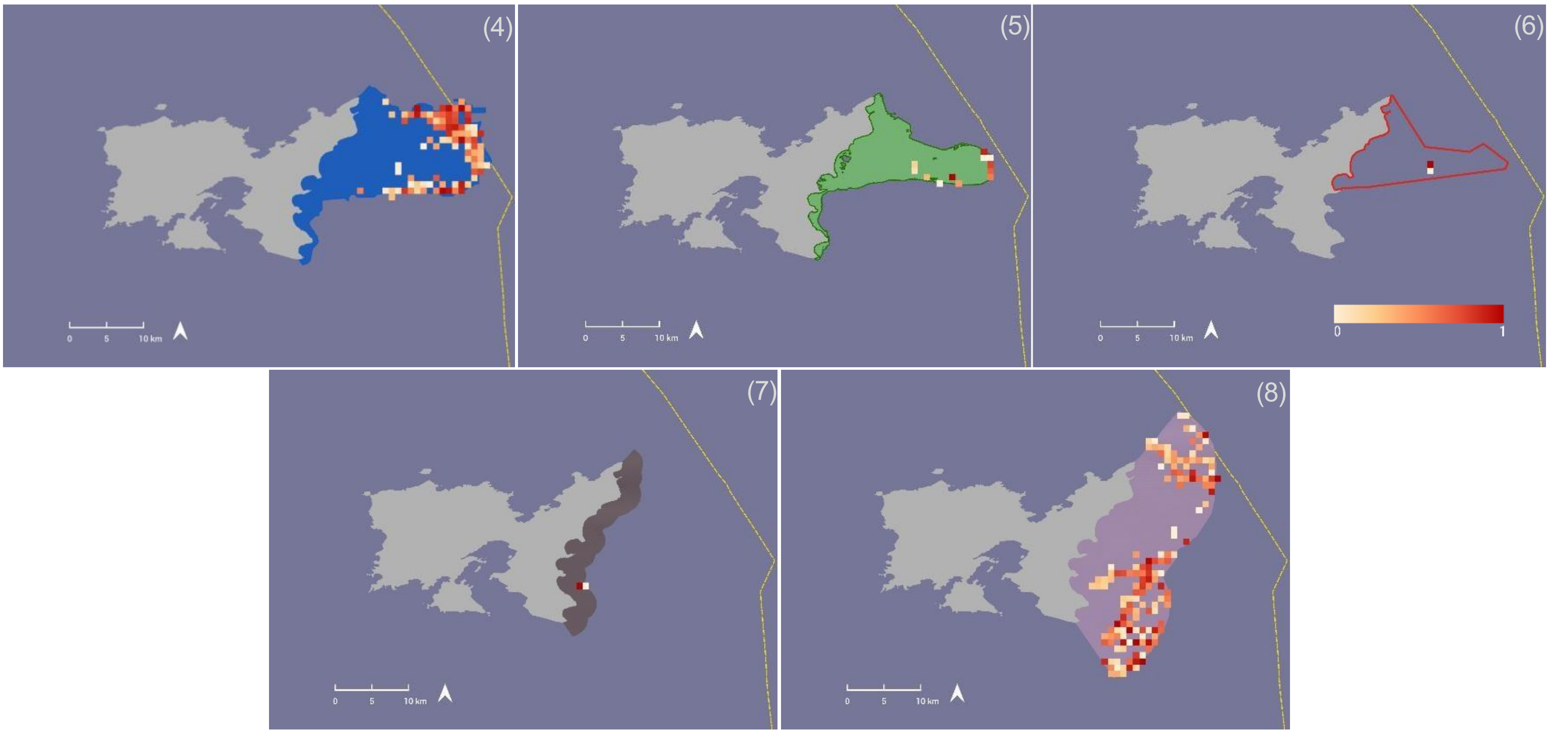


Figure 19. Eastern Lemnos study area and key regions of interest

In total, **20.3h** of trawling and 6h of unidentified activity of FUG were detected within the Posidonia meadow. In the no-trawling zone, **0.5h** of trawling and 3h of unidentified activity of FUG were detected. Within the bathymetric zone up to 50m depth from the northernmost cape to the southernmost cape, a total of **434.35h** of trawling and 147.3h of unidentified activity of FUG were recorded. Within the 1.5nm buffer 2h of trawling were detected and 0h of unidentified activity of FUG while within the 6nm buffer a total of **46tı.2h** of trawling were detected and .13h of FUG.

Annual maps of the AFE for trawlers were downloaded from the GFW platform for each polygon, within the mentioned time period, in the form of raster layers at a 0.01 degree spatial resolution, representing fishing hours/square kilometers. All the annual raster layers were rescaled separately to the range 0-1 and resized to the same extent. Then all the annual raster layers per zone were combined in a total raster, using QGIS Cell Statistics, representing the mean fishing effort. The mean AFE (h/km²) from January 2012 to November 2024 within the bathymetric zone up to 50m, the Posidonia meadow, the no-trawling zone, the 1.5nm buffer zone, and the 6nm buffer zone is presented in Map 4, Map 5, Map 6, Map 7, and Map 8, respectively.



Maps 4-8. Mean AFE (h/km²) for trawlers, since 2012 to 2024 within (4) the bathymetric zone up to 50m, (5) Posidonia meadow, (6) no-trawling zone, (7) 1.5nm buffer zone, and (8) 6nm buffer zone**.**

We expect that this is an underestimation and for this reason we manually explored, using the GFW interface, the "vessel tracks" that seem to vanish and/or appear suddenly without any prior consistent track close to the 50m depth zone aiming to detect potential hidden fishing activities within the different zones. Due to discrepancies in the platform's algorithm and graphics over time, vessel tracks will be reanalyzed from scratch in collaboration with GFW experts in the coming year

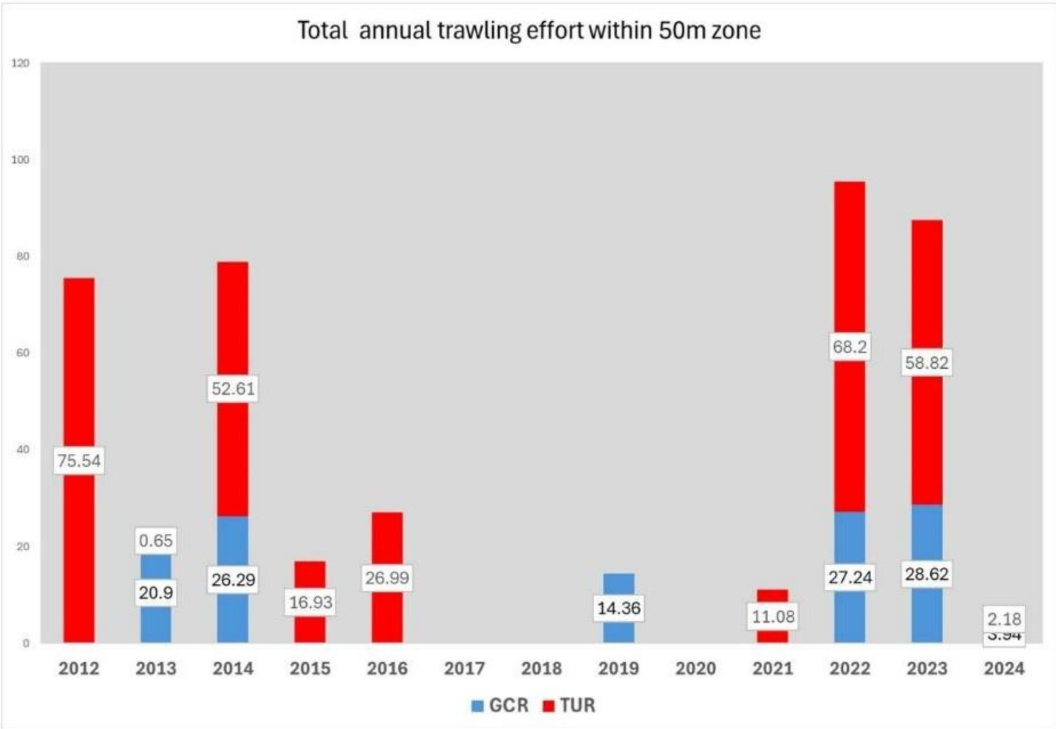


Figure 20. Total annual trawling effort within the bathymetric zone up to 50m.

By investigating the total annual trawling activity within the 50m bathymetric zone, significant differences in the activity were reported between vessels from Greece and Turkey across the majority of the years, as seen in Figure 20. 313h of fishing were recorded by 28 Turkish vessels, while 3 of them revisited the area. On the other hand, 121.35h of fishing were recorded by 6 vessels, the majority of which (4 out of 6) had revisited.

On 08/07/2024 we had an in-person meeting with the local port authorities to ask for the records of incompliance within the area however they were never aquired. In addition, a dataset of "hauls" was obtained from an anonymous bottom trawler for which we explore its potential to be used as validation with GFW.

A.4. Advocacy and management

A.4.1 Participate in the SES for Lemnos (M5-M12)

To participate in the SES, the project manager contacted the company that has uptook the development of the Management Plans for N2Ks in the North Aegean "ENVIROPLAN S.A." on the 30th of January. We provided the company with the mapping of Posidonia, and all the data collected throughout the years for the "characterization of protected species and habitats" as well as the pressures. The company responded very positively and provided provisional management measures for all the marine sites within the SES. On the 1st of March suggestions on measures were submitted to the company, while on April a revised version along with complementary sources was provided (available in the server). Finally, iSea on 2nd of July conducted an in-person meeting with the president of the fisher's association of Lemnos "Agios Nikolaos", Mr. George Pakos and other board members Mr. Vaggelis Tsikovas, regarding the SES and agreed to collaborate for the proposal of measures regarding fisheries. On the 4th of December we received an invitation for the event on Monday 16 December at 11:00 pm, where we registered to attend online. The invitation was shared with the local Fisher's Association "Agios Nikolaos" in order to be in line and organize to co-draft possible comments. It is worth noting that within the SES the mapping conducted in 2022, along with data on IAS and threats were incorporated within the relevant chapter. Comments on the SES were submitted on the 15th of February 2025. The proposals were developed collaboratively with 18 different entities from the local communities of Lemnos and Lesvos, including the Fishers Association of Lemnos "Agios Nikolaos".

A.5. Coordination of the project

A.4.1 Monitoring the project actions, ensuring high-quality deliverables, and reporting.

One project manager has been assigned to the project, who is closely monitoring its actions to ensure their timely implementation, while a broader team is also involved in some of the activities (e.g., diving, financial reporting, analysis, communication).

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