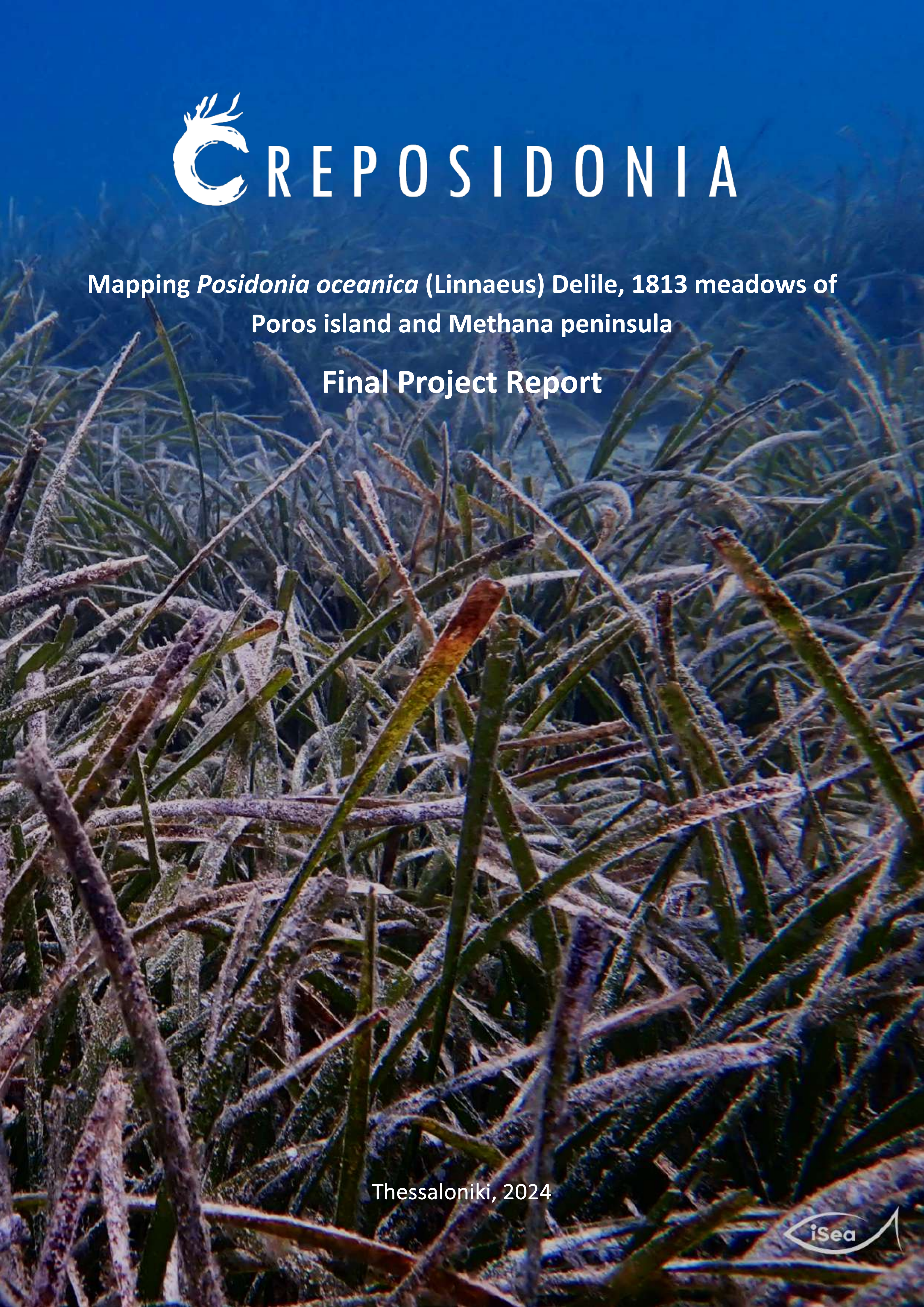

CREPOSIDONIA

Mapping *Posidonia oceanica* (Linnaeus) Delile, 1813 meadows of Poros island and Methana peninsula

Final Project Report

Thessaloniki, 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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iSea's work

iSea is a Not-for-Profit Non-Governmental Organisation founded in March 2016, in Greece, with the vision of a healthy Mediterranean Sea supporting sustainable development and resilience of local coastal communities, based on the values of collaboration, transparency, scientificity and equity. The organisations goals are 1) the protection of aquatic ecosystems through raising awareness and informing society about current environmental problems and good practices to address them, 2) promoting the adoption of measures and sound policies for the protection of the environment, and 3) the elaboration and promotion of scientific research, to be the basis for sustainable development with the aim of environmental, social and economic prosperity. iSea operates across four pillars: Vulnerable species, Marine Protected Areas, Aquatic litter and Human and Aquatic ecosystems. Since 2021, iSea has developed and implemented conservation projects involving *Posidonia oceanica* in many areas in Greece, including the Argosaronic, the Inner Ionian Archipelago, Corfu Island and Lemnos Island, through the collaboration and funding from several entities. The actions of these projects involve mapping the distribution of Posidonia meadows, assessing their health status using recognized indices and the evaluation of ecosystem services and threats they face locally. Actions also focus on raising awareness and creating open-access data to support improved management of this important habitat. Furthermore, iSea is a member of the Mediterranean Posidonia Network and collaborates with several scientists specializing in Posidonia conservation. Finally, as part of their 5 year strategy they have developed specific conservation goals regarding *Posidonia oceanica*. These include to i) promote the management and restoration of Posidonia meadows in Greece and ii) contribute to closing the knowledge gaps regarding Posidonia extent and health in the Greek seas.

Background of the project

Despite the ecosystem services they offer and their protection status, Posidonia meadows are some of the most threatened ecosystems globally, with estimations in the Mediterranean projecting a functional extinction by 2050 (Jordà et al., 2012; Telesca et al., 2015). To preserve and protect this precious habitat, we need to know their extent and distribution. Most maps existing in the Mediterranean are either outdated or lack common methodology. In Greece, there is no precise map of *Posidonia oceanica* although as an EU member state, the country is required to monitor this habitat and act to ensure a "Good Ecological Status", under Water Framework Directive, Marine Strategy Directive and Habitats Directive. The maps available regarding this habitat (produced in the late 90s) are limited in Natura2000 sites while a National map was created in 2015, by the Ministry of Agriculture to monitor large scale fisheries, whose resolution is very low showing only a coverage percentage, which is unsuitable for use as a management tool regarding anchorage and marine spatial planning. This important gap of knowledge regarding a habitat that is under threat undermines conservation efforts. Although in 2022, a map regarding the extend of seagrass was produced for Greek waters (Panayotidis et al., 2022) the map is a mosaic deriving from different methodologies most of which derive from large scale satellite images (~40m resolution) and have a low spatial accuracy when looking at the local scale.

Study area

The same is true for Poros island and Methana peninsula that lack detailed mapping of this precious habitat. Both Poros and Methana receive hundreds of visitors during the summer months daily, as they are among the most popular destinations given their proximity to Attica region. This high tourism activity arises threats for the marine environment and Posidonia meadows among which; pollution (discharges, litter) and mechanical damage (uncontrolled anchorage). One Natura2000 site is found in the wider area recognising its natural beauty, ecological and cultural importance. It includes the marine area north of Methana peninsula (THALASSIA PERIOCHI PAFSANIA – YPOTHALASSIA IFAISTEIA METHANON, Site code: GR2510005) designated under the Habitats Directive due to the presence of key habitats including hydrothermal vents and springs (Nomikou et al., 2013) while it mentions that Posidonia meadows here cover an area of 186ha (hectares).

Albeit aquaculture's impacts specifically on Posidonia meadows are known to be devastating, due to overflow of nutrients and sedimentation, there is a foreseen industrial fish farm expansion planned for both areas that involves both the spatial expansion of the facilities and the increase in intensity of production in each facility (APC, 2023; Ambio, 2015). Aside from other known impacts of fish farming on the marine environment, this will undoubtedly cause the local degradation of the Posidonia meadows. The meadows protection is hindered by the lack of a robust environmental impact assessment that accounts for their presence and the existing lack of knowledge regarding their current distribution. The present project is the continuation of REPOSIDONIA in Spetses and Hydra islands.

Aims: The aim of the current project was to better understand the coverage and distribution of the endemic seagrass *Posidonia oceanica* in the Argosaronic Gulf, specifically in Poros and Methana, and to raise awareness among local stakeholders and the public. This was achieved by a) mapping Posidonia meadows around Poros island and Methana peninsula to inform decision-making and serve as baseline for future management and conservation, and b) by sensitising local stakeholders.

More specifically, iSea worked with local stakeholders, such as the municipalities and Katheti, a nonprofit cultural and educational center, to disseminate informative materials produced. As an additional action, iSea explored the past presence of meadows adjacent to aquaculture facilities by investigating the surrounding area of the facilities looking for such evidence, i.e. old rhizomes and sheaths in combination with aero-orthophotographs from the National Cadastre's archive. Furthermore, an estimation was made regarding the Posidonia meadows that will be lost if the plan for more aquaculture facilities will be implemented. Finally, the results will be shared with NECCA and the Ministry of Environment to amplify the impact of this work.

Methodology and results

A1. Mapping of Posidonia meadows around Poros island and Methana peninsula

A1.1 Field activities

An important process of the mapping was to obtain accurate ground truthing points for the representation of the different seabed habitats. These points were used as training data for the classification of the pixels of the satellite image in habitat types, as well as for validation. iSea traveled to Methana and Poros to complete the data collection from the 20th-24th of May. Regarding the fieldwork approach, iSea developed a plan for the samplings using open-source satellite images from Google Earth, and consulting with the external collaborator (terraSolutions m.e.r.). The validation points were collected by means of 1) visual confirmation from circumnavigation with a boat, 2) snorkelling/apnea and 3) scuba diving or ROV (remotely operated vehicles) use for the deeper limits of the meadow. All planned surveys were completed, and the team collected 789 validation points (359 for Poros and 430 for Methana, see Fig 1, Table 1).

The coordinates for each specific point were listed along with the habitat type observed for each (Table 1). A GPS device (Garmin 22x) was used with a minimum accuracy of 3m. The team was careful to record each habitat covering approximately 10m^2 to avoid the reduction of the accuracy of the classification due to the GPS's accuracy. All the points were then transferred in a text file. The text file then was transformed into a vector using ArcGIS (Version 10.4) (attached with the report).

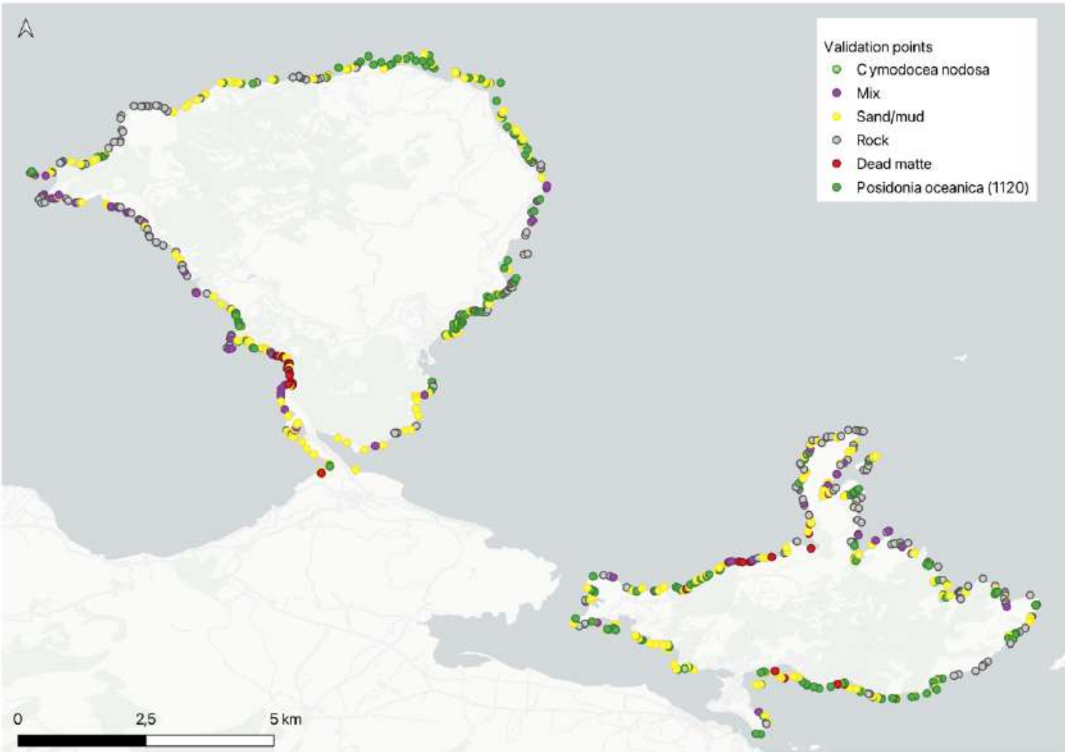


Fig 1: Map of validation points collected for Poros and Methana Posidonia mapping.

Table 1: Overview of the validation points collected for Methana and Poros. 'Dead matte' refers to dead Posidonia meadows. 'MIX' refers to more than 1 habitat type in surveyed area.

Substrate type	Methana	Poros	Total	% of total
Posidonia oceanica	114	117	231	29,3%
Cymodocea nodosa	0	2	2	0,3%
Dead matte	17	11	28	3,5%
Posidonia with dead matte	0	6	6	0,8%
MIX	40	19	59	7,5%
MIX with Posidonia	11	2	13	1,6%
MIX with dead matte	3	0	3	0,4%
Rock	105	97	202	25,6%
Sand	138	105	243	30,8%
Macroalgae	2	0	2	0,3%
Total	**430**	**359**	**789**	

A1.2 Defining the deep limit of the meadows

To define the deep limit of the meadows two field methods were used: 1) visual confirmation from circumnavigation with a boat, using the on-vessel bathymetry equipment and 2) scuba dives (Fig 2). In total, 10 deep-limit points were considered (4 in Methana and 6 in Poros; see Fig 3). From these, the deep limit was defined as 14.9m (average), with a minimum of 10m and a maximum of 19m for Poros, and as 22.9m (average), with a minimum of 18.9m and a maximum of 30.2m for Methana (Table 2).

Fig 2: Recording deep limit of Posidonia meadows through scuba diving in Methana (A) and Poros (C). Mediterranean moray (*Muraena helena*) swimming between the meadows in Methana deep limit dive (B).

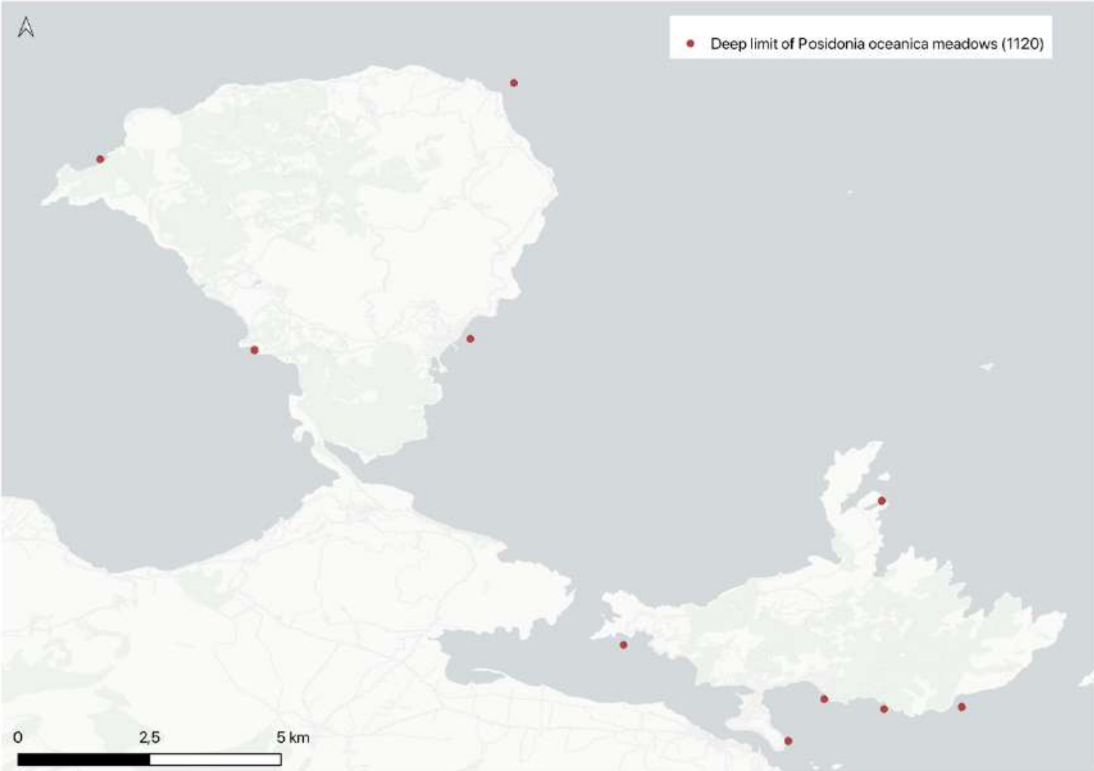


Fig 3: Deep limit of the Posidonia meadows recorded in both study areas. Habitat code 1120 Habitats Directive.

Table 2: Deep limit of Posidonia meadows collected for Methana and Poros. Method 1: circumnavigation with boat, Method 2: scuba dive

Location	Depth	Method	Latitude	Longitude	Date
Poros	19	2	37,5031088	23,5019996	22/05/24
Poros	13,9	1	37,5026961	23,4852779	22/05/24
Poros	11,5	1	37,5047825	23,472415	22/05/24
Poros	16	1	37,495811	23,464711	22/05/24
Poros	10	1	37,5164264	23,4292902	22/05/24
Poros	19	1	37,5473667	23,4847841	24/05/24
Methana	20,6	1	37,5817562	23,3959076	20/05/24
Methana	30,2	2	37,6370907	23,4057424	20/05/24
Methana	22	1	37,620716	23,3168188	21/05/24
Methana	18,9	1	37,5798739	23,3498153	23/05/24

A1.3 Analysis workflow

Satellite imagery mapping through classification.

The analysis consisted of 6 main steps. The steps are briefly described in the workflow below (Fig 4), and then are briefly explained in the following paragraphs accompanied with the produced results. Coastal habitat mapping with emphasis on the seagrass meadows, the priority habitat 1120*, was performed using Maxar WorldView III 8-bands (here after WVIII), at 2m pixel size. The selection of the imagery was done using the public available Maxar Discover tool (https://discover.maxar.com/) through the available archive imagery. The selection was based on the 8-band data (https://worldview3.digitalglobe.com/) with less than a 20% cloud coverage within the search area. The filtered imagery was visually inspected prior to order for further analysis. The 8-band WorldView II/III has previously been used for coastal bathymetry and habitat mapping with success at various water types (Mederos-Barrera et al., 2022, Poursanidis et al., 2018, Coffer et al., 2023). Three images (native, multi-spectral, Bundle 8-bands) were purchased for the analysis: one WorldView III acquired on the 06/05/2024 (Methana), one Pleiades NEO acquired on the 19/11/2023 (west Poros) and one Pleiades NEO acquired on the 18/09/2023 (east Poros) as seen in Fig 5**,** with almost complete clear sky conditions. Imagery was ordered in Top of Atmosphere Reflectance (TOAR) and the ACOLITE tool (Vanhellemont et al., 2018) was used as the proper atmospheric correction for aquatic environments. The final product is an aquatic reflectance image composite which includes a bottom reflectance signal in the shallow water and a mixed of bottom and water column signal in deeper waters. For the image classification towards seagrass mapping, a Random Forests Regression-based analysis workflow adapted from Poursanidis et al., 2021 was employed. The open source EnMAP toolbox (Van der Linden et al., 2015, Poursanidis et al., 2019) was used to allow appropriate creation of training data, image classification and product validation. The toolbox is a plugin in the open-source GIS software QGIS and can be used by any experienced user. For the analysis, a series of image-based training data was created, that were evenly distributed in each area of work. A binary scheme was designed aiming at the separation of the target habitat (seagrass meadows) from the other seabed habitats (sandy/soft bottoms, rocky surfaces/reefs and optically deep waters), where the spectral data recorded by the satellite sensor could have both a bottom and mid water origin. The areas with motion from speedboats were turned into wavy areas with no bottom reflectance information. The mapping product validation was based on the point-based dataset (ground truthing points), collected by iSea during May 2024. A radius of 5m was used to compensate for the GPS accuracy. For the image areas affected by wave action, sedimentation and terrestrial shadow, attributed to the oceanographic and geographic characteristics of the study sites, hand-delineation of the Posidonia meadows was completed. The method considered the combination of the validation points, bathymetric data, multiple satellite imagery sources (Google Earth, Maxar). The information on the imagery sources used in the hand delineation are included in the dataset submitted along with this report. According to the current work, the meadows cover an area of **0,70km^2** (70.05 hectares) **for Poros** (Fig 6) and **0,96km^2** (96.40 hectares) **for Methana** (Fig 7), with an overall accuracy of the final products as **87%** and **89%** accordingly.

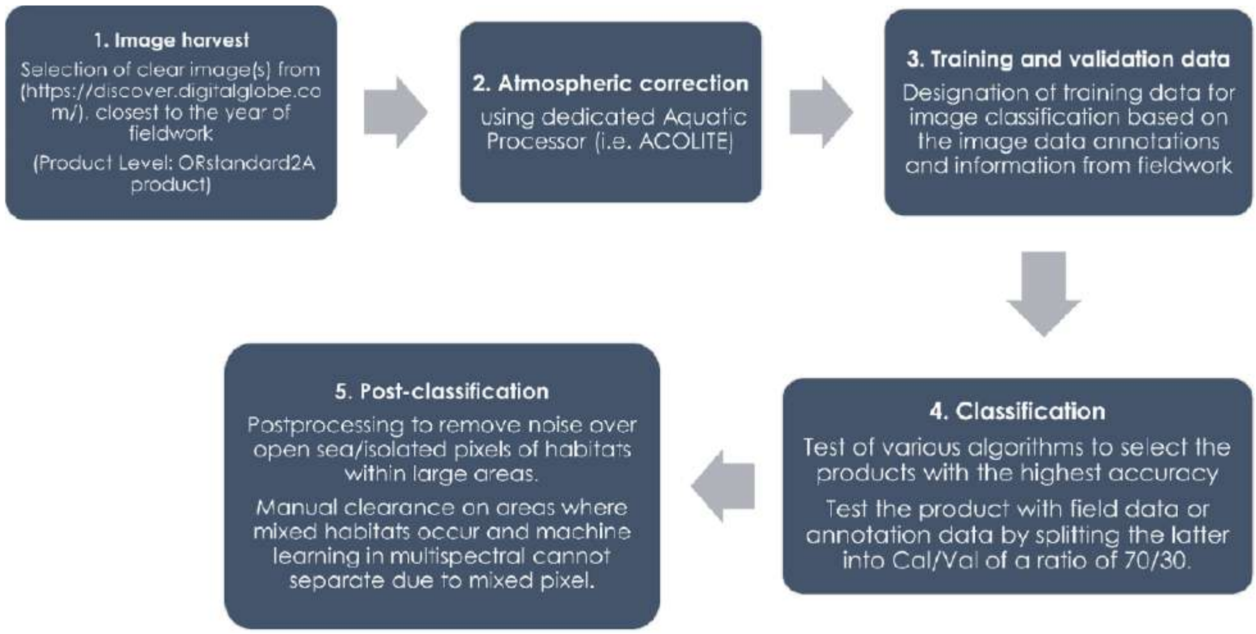


Fig 4: Workflow of the analysis followed for producing the final maps of Posidonia meadows.

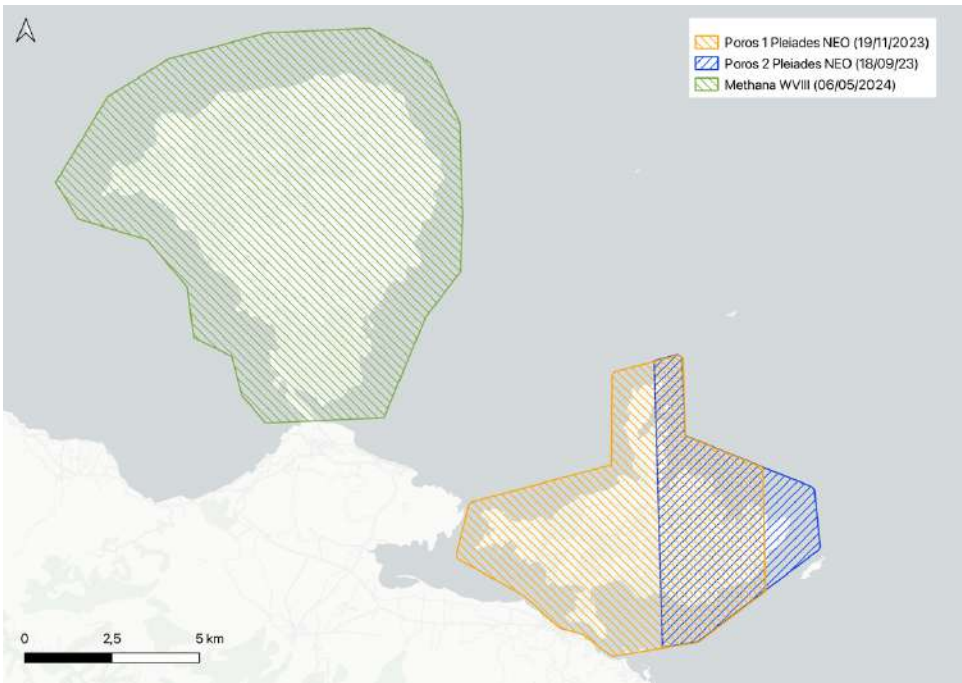


Fig 5: Footprints of the selected images for both study sites

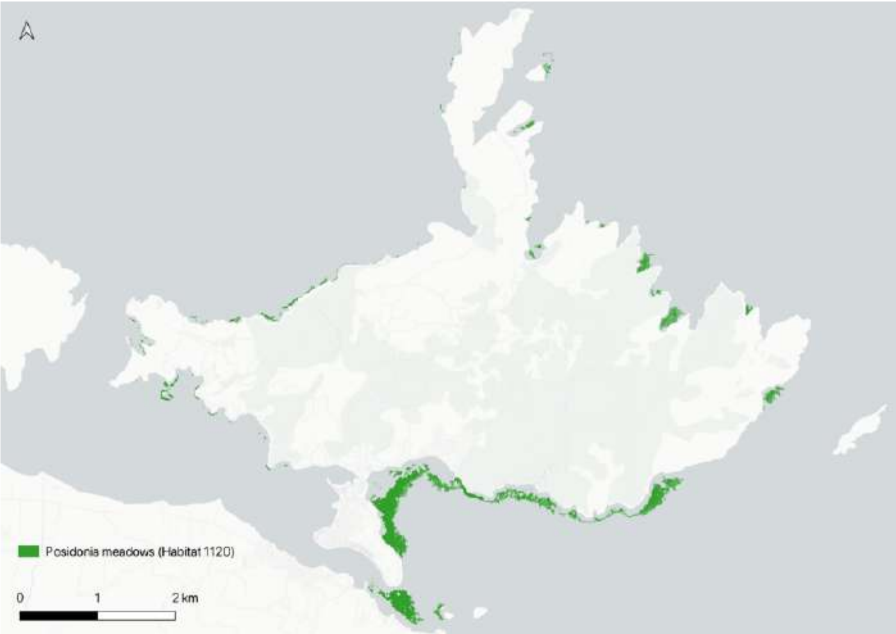


Fig 6: *Posidonia oceanica* (Habitat 1120, Habitats Directive) distribution in Poros island.

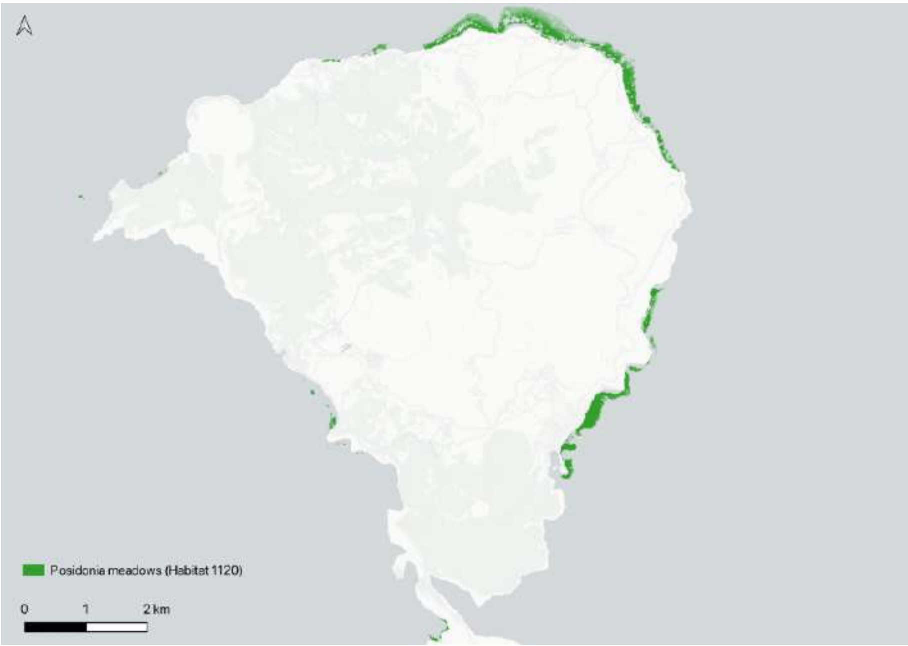


Fig 7: *Posidonia oceanica* (Habitat 1120, Habitats Directive) distribution in Methana

The distribution of Posidonia meadows is scarce and inconsistent along the western coasts of both study areas. The meadows appear denser and more continuous in the north region of Methana and the southern region of Poros. The distribution can be partly attributed to the bathymetric profiles of both areas that can be characterised at large by steep rocky underwater cliffs. The observed deep limit is relatively shallower in Poros compared to the known distribution of the species (that can reach to depths of 40m). The scarcity and patchiness of the meadows is highest in areas associated with aquaculture operation, while some sparsity in a number of touristic bays in Poros could be attributed to anchoring pressure. Specifically, for Methana, 2.45 hectares of Posidonia meadows are found within the Natura2000 site. A detailed discussion on the distribution of Posidonia near current and historic aquaculture facilities is presented in the following sections.

A2. Posidonia meadows in association with current and future aquaculture development zones

A2.1 Live Posidonia meadows near existing and relocated aquaculture facilities.

No living Posidonia meadows were found within a 50m radius of the existing aquaculture fascilities. This comes at no surprise as their operation has most likely eradicated the meadows present within these waters, suggested from the presence of dead matte areas (dead posidonia meadows). However, live meadows were found past this radius, at **90m** from an operational facility in Poros (Fig 8 A; 37.531164N, 23.458188E), and **174m** from an operating facility in Methana (Fig 8 D; 37.559605N, 23.362686E) both in a degraded state and characterised as a mix of 'dead matte' with some live Posidonia shoots. Meadows in areas of aquaculture were characterised with extensive leaf epiphyte coverage, a known effect of organic pollution (Gobert et al., 2009).

Considering sites with removed and/or relocated facilities, meadows can be found from distances of **20m** (Poros) and show a severely degraded state with extensive presence of dead matte (Fig 8 B,C 37.5257222N, 23.4445307E). The survival of the meadow in this site is likely due to the limited operation time of the facility that can only be traced for 6 years (2012-2018; Google Earth historic imagery). These facilities seem to have been relocated to the east where they are still found to date (2019-currently; Fig 8 A). Finaly, another live Posidonia patch was identified at 37.533448N, 23.468959E at **57m** distance from where a facility once operated until 2017 (Fig 9 C), and **420m** from the currently operating facility (Fig 9 A).

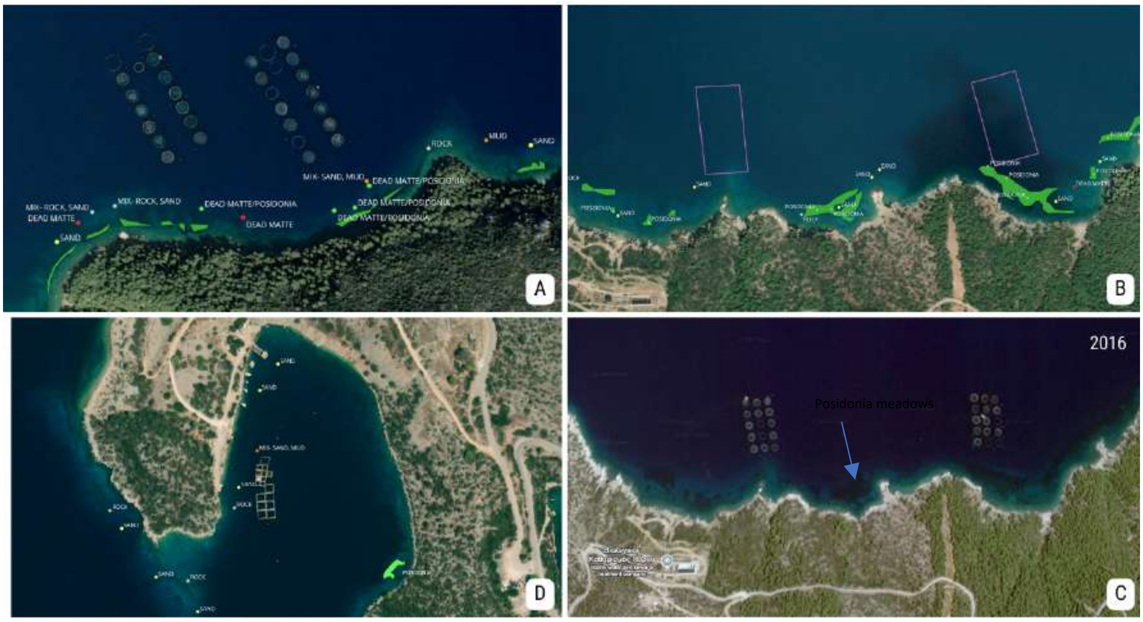


Fig 8: Presence of Posidonia meadows in existing aquaculture facilities in Poros and Methana. A: Live Posidonia meadows and dead matte in close association with existing facilities in Poros. B: Live Posidonia meadows and dead matte in close association with relocated facilities. C: Evidence of facilities seen in image 'B' presence in 2016 and visible Posidonia meadow in coastal area (arrow). D: Live Posidonia meadows identified through satellite imagery in 2024 in close distance to facility in Methana.

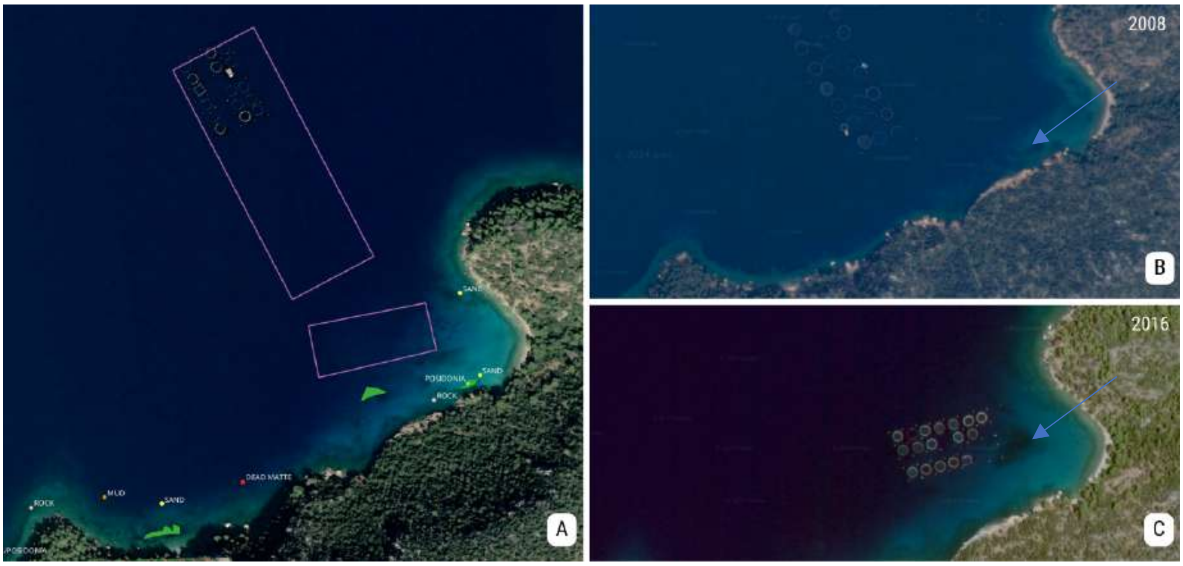


Fig 9: Presence of Posidonia meadows in relocated aquaculture facilities in Poros. A: Validation data of habitat types (colorful points) in relation to the facilities (purple rectangle) and current Posidonia meadows (green polygon). B,C: Imagery showing presence of facilities in different locations with visible indication of past Posidonia distribution.

A2.2 Posidonia in POAY zones and calculation of impacted meadows

Regarding Posidonia meadows present within the POAY zones (Organised Areas of Aquaculture Development) for both study sites the mapping produced in the context of this project were compared with the available POAY maps. The EIA's (Environmental Impact Assessments) for both areas mentions that no Posidonia is found in the proposed development sites and suggest a distance of more than 400m of any new facility from Posidonia meadows (following the recommendations produced from the MedVeg European project; Holmer et al., 2008). However, according to Karakassis et al. (2013) fish farming should not be permitted at least 800m from the boundaries of Posidonia meadows, while farms operating in proximity to these should either be relocated or not permitted to increase production effort or renew their operation permit. The EIA's of both Methana and Poros POAY refers to studies on the impacts of aquaculture that report an 150m effect radius a. However, studies addressing Posidonia meadows sensitivity show that aquaculture runoff effluents possibly extend to significant distances (Sarà et al., 2006) and impact on Posidonia meadows even at a distance of 3km (Ruiz et al., 2010). Taking the above into consideration, three buffer zones were created that extended for 400m (assumed high impact zone), 800m (assumed high and mid impact zone), and 3km (assumed total impact zone) from the existing and proposed aquaculture facilities. The Posidonia meadows present in each buffer zone were then calculated.

For Poros island a total of **1.78 hectares** of Posidonia have been identified within the wider area of the POAY (including the shallow regions; Fig 10). Considering the buffer zones, a total of **2.47 hectares** are withing the 400m zone of the proposed and existing facilities and can be characterised as the highly impacted meadows, while **4.02 hectares** are found in the 800m zone (Fig 11). When considering the 3km impact range, a total of **7.48 hectares** of Posidonia meadows will be somewhat affected by the proposed facilities. The final estimation did not include areas past the western edge of the island, assuming that no aquaculture effluents would travel past this point. When looking at the proposed facilities location, living Posidonia meadows can be found at distances as small as **85m** (at 37.548379N, 23.470205E; Fig 10) and **146m** (at 37.540856N, 23.473178E; Fig 10).

Similarly, for Methana, a total of **3.53 hectares** of Posidonia have been identified within the wider area of the POAY (Fig 12). Considering the buffer zones, a total of **0.19 hectares** are withing the 400m zone of the proposed and existing facilities and can be characterised as the highly impacted meadows, while **1.46 hectares** are found in the 800m zone (Fig 13). When considering the 3km impact range, a total of **7.19 hectares** of Posidonia meadows will be somewhat affected by the proposed facilities. Regarding the close distances of proposed facilities to live Posidonia meadows, this ranges from **126m** in the northern region of Methana (at 37.616398N, 23.303835E, Fig 12) to **445m** in the southern limit (at 37.554813N, 23.362537E, Fig 12).

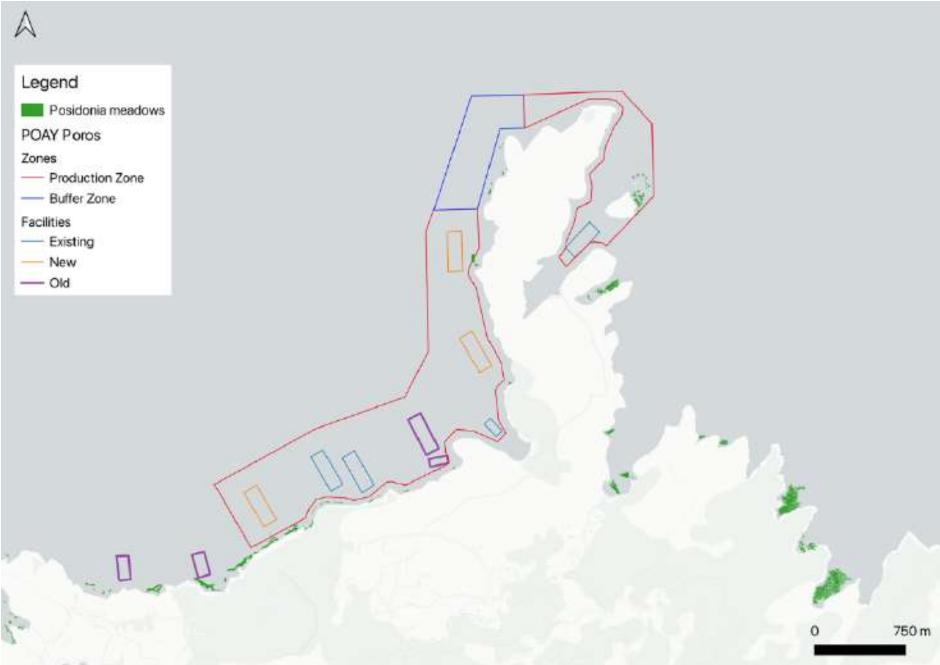


Fig 10: Posidonia meadows in Poros in relation to POAY development plans

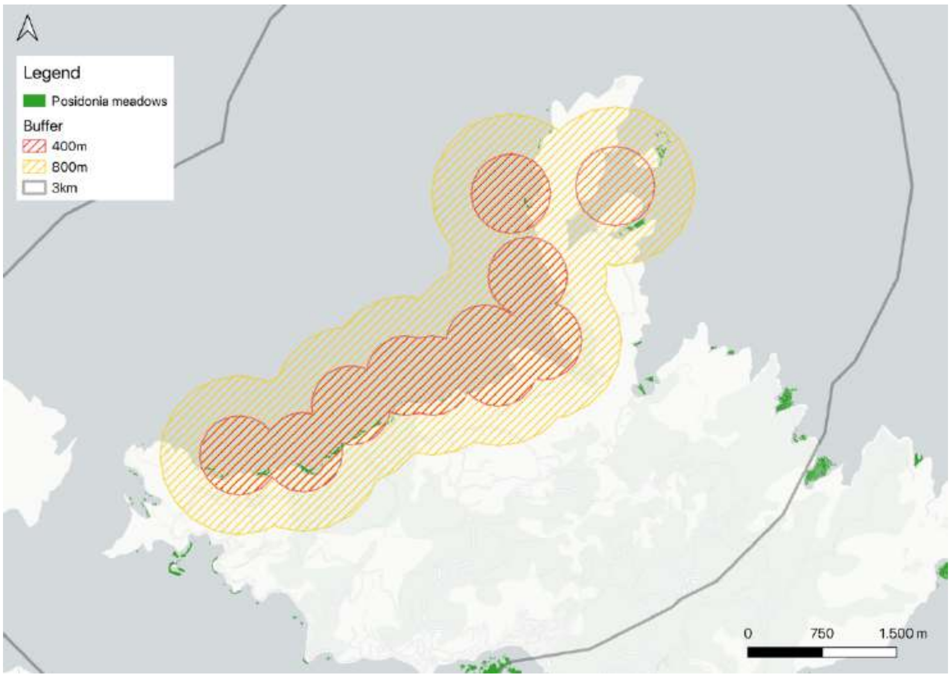


Fig 11: Posidonia meadows in Poros in relation to buffer zones of facilities

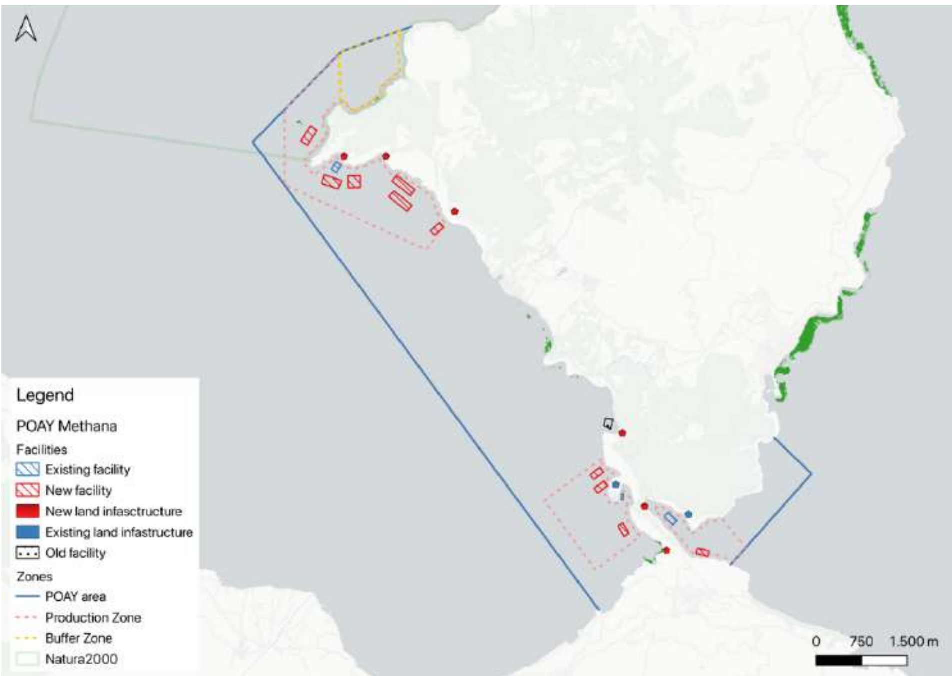


Fig 12: Posidonia meadows in Methana in relation to POAY development plans

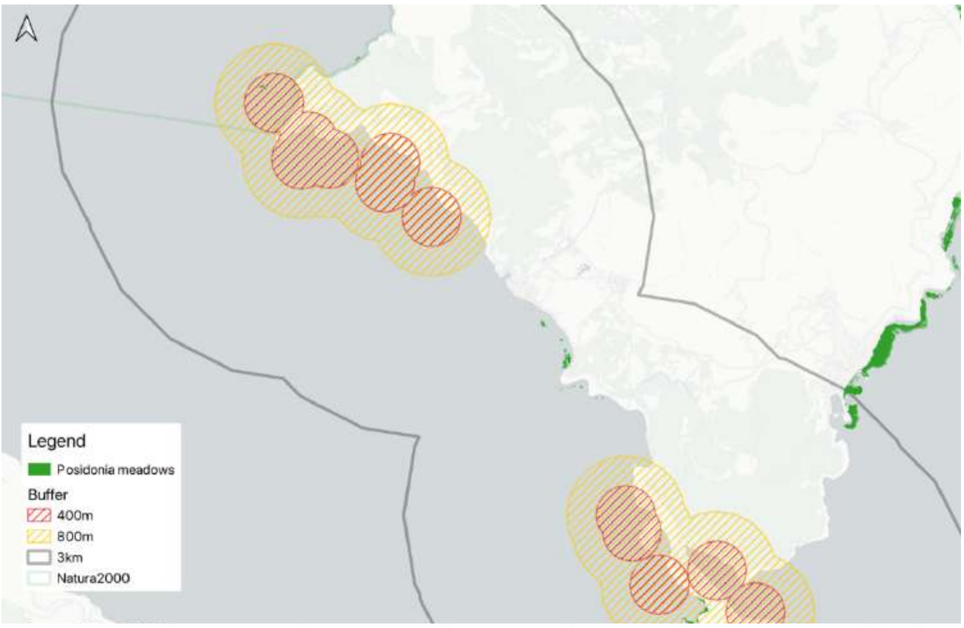


Fig 13: Posidonia meadows in Methana in relation to buffer zones of facilities

A.3 Exploring the historic presence of Posidonia meadows adjacent to aquaculture facilities

This action involved 1) visits to bays closely associated with the existing and historic aquaculture facilities (operational and abandoned) to search for evidence of historic presence of Posidonia meadows (dead matte), as well as 2) investigation of historic aerial orthoimagery from the National Cadastre's archive (https://gis.ktimanet.gr/gis/apr/). The images were products of grayscale 8bit imagery from the period 1940-1984. As an extra sub-action, the collected historic images were analysed to give an estimation of the area of Posidonia meadows lost due to the operation of aquaculture facilities in a number of case study bays in Methana and Poros.

The ROV was used to capture images near the aquaculture cages at locations 37.612257N, 23.309209E in Methana and 37.535170N, 23.473186E in Poros (Fig 14 A,B) while dead matte was visually observed at location 37.534535N, 23.474803E in Poros through snorkeling/apnea (Fig 14 C).

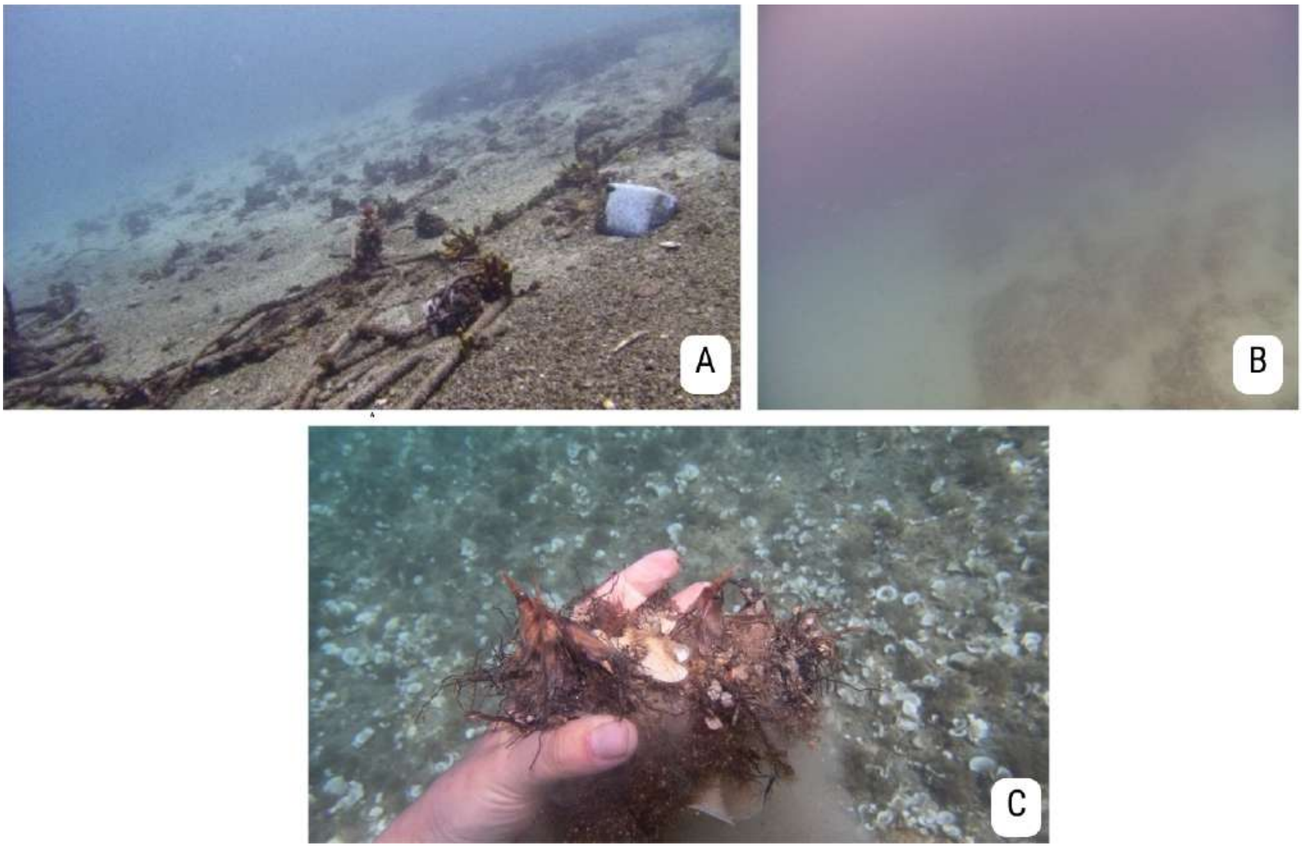


Fig 14: ROV footage near operating facilities in Methana (A) and Poros (B), and old rhizomes from dead matte site observed in Poros (C)

The southwestern bay of Methana at point 37.570476N, 23.359991E (Peristeri cave beach) was explored for evidence of historic existence of Posidonia meadows after multiple reports from locals on the scale of degradation caused by the aquaculture facilities that once operated at the site. During the exploratory dive, a large area of dead matte was identified (Fig 15 A) with clear evidence of old rhizomes (Fig 15 B). The site was also characterised by accumulated debris and abandoned materials associated to the aquaculture facilities (ropes, buoys, tires, chains, concrete mooring blocks) as well as other waste (litter pollution). Despite the halt of operation and removal of the facilities that took place over a decade ago, the meadow shows no signs of recovery. Regarding the fauna and flora identified, the biodiversity was limited and comprised of decomposers and opportunistic species, mainly including gastropods (snails), polychaeta (tube worms), sponges (*Aplysina aerophoba*), dead bivalves and brown/green algae. Multiple invasive species were observed (Fig 16) including Lionfish (*Pterois miles*), Toadfish (Lagocephalus spp.), Black longspine urchin (*Diadema setosum*) and the invasive seagrass species Halophila (*Halophila stipulacea*). The species present are known for their ability to thrive in degraded habitats, while Halophila seagrass often colonises dead matte sites (Sghaier et al., 2011). All observations of dead matte were recorded and included in the validation point dataset presented in section A1.1.

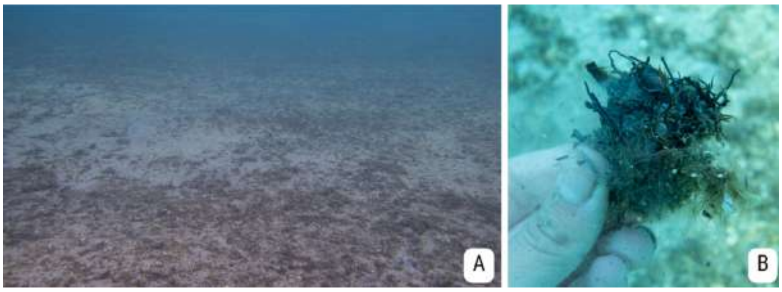


Fig 15: Dead matte area identified in Methana in removed facility (A) and evidence of old Posidonia rhizomes in the same site (B)

Fig 16: Invasive species identified in old aquaculture site. A: Lionfish, B: Toadfish, C: Black longspine urchin, D: Halophila seagrass.

Historic aeroimages (n=7) were obtained and analysed to derive an estimate of the area of Posidonia meadows lost since the operation of aquaculture fascilities in close proximity to these meadows in specific case study areas. In total, six case study areas are presented, 3 for Methana peninsula and 3 for Poros island, chosen for their proximity to operating/historic fascilities and the presence of dead matte, as well as the availability and quality of historic imagery. The purchased images were delivered along with this report and the details of each can be found in Appendix 1. Two control sites were included for the validation of the methodology, one for each area of study, to confirm the approaches' relative accuracy by finding bays with historic meadow presence and validation points with confirmed posidonia meadows in the present day. The selected images had minimal sun glint/reflection and gave a clear indication of Posidonia presence (dark shadded shapes in coastal areas with patterns resembling meadows characteristics). For the analysis, the historic images were georeferenced in QGIS. Then, the created vector was reclassified (each colour of the greyscale was given a value from 1-200) the values representing the darker pixels (Posidonia meadows) (example: 1-60) were then extracted and cropped to a selected area of interest. The area of interest excluded the locations where Posidonia meadows were not likely present by considering i) the terrestrial area ii) the deeper limits of the meadow considering bathymetric profiles, iii) the validation point data collected for action A1 and iv) the image quality. It is important to note that due to this, the analysis does not assess the distribution of the meadows in its deper limits and only gives indication for the visible shallow limits. The historic imagery cannot be shared due to the providers copyright restrictions and so have been removed from the present report.

Control Sites of historic distribution

Control site 1 is located in Poros at point 37.514752N, 23.517723E. The site represents a relatively undisturbed area where the distribution of Posidonia meadows shows minimal changes since 1972 which can be confirmed by the resulting historic Posidonia meadow distribution (Fig 17). The validation points match the historic meadow distribution at a satisfactory level.

Control site 2 was located in Methana at 37.552028N, 23.367399E. The imagery used for the site was dated from 1984 prior to the operation of the nearby aquaculture facilities. The deep limit of the meadow is likelly overestimated. The site, although affected by human distrubance (aquaculture, coastal contruction, pollution), shows similarities in the distribution of Posidonia meadows pre and post aquaculture farms. However, a reduction can still be noted when comparing the results (Fig 18).

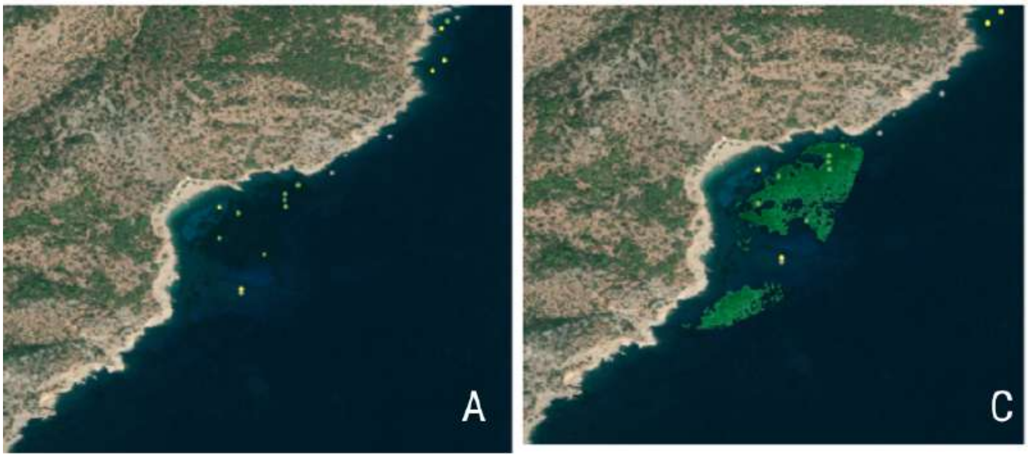


Fig 17: Control site 1 validation points (A) historic aeroimage (B, hidden due to copyright restrictions) and calculated historic distribution of Posidonia oceanica (C; green polygon area)

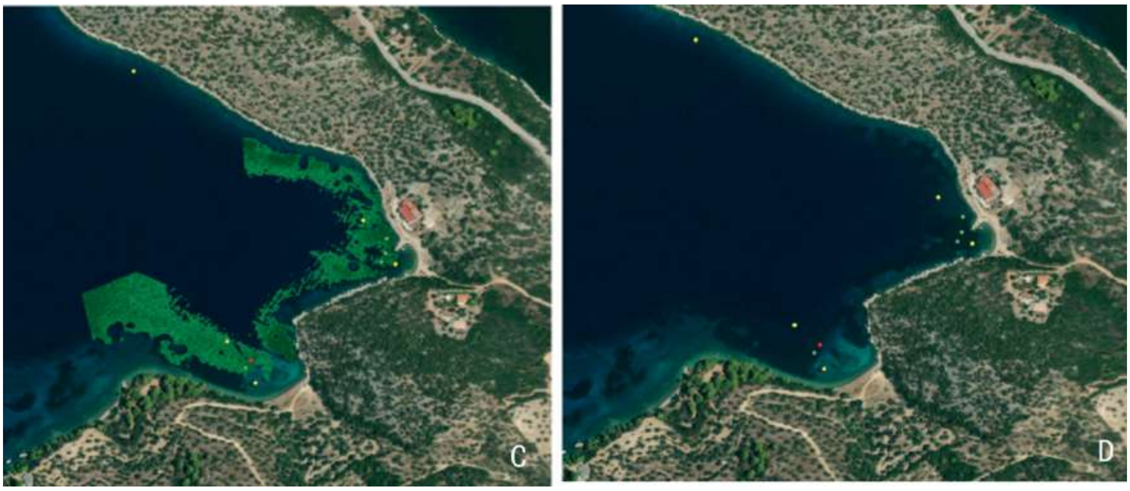


Fig 18: Control site 2: Selected bay in Methana and available aeroimages (A, hidden due to copyright restrictions) validation points (B, hidden due to copyright restrictions), calculated historic meadow presence (C) and current satelite view (D)

Case study areas of historic distribution in aquaculture sites

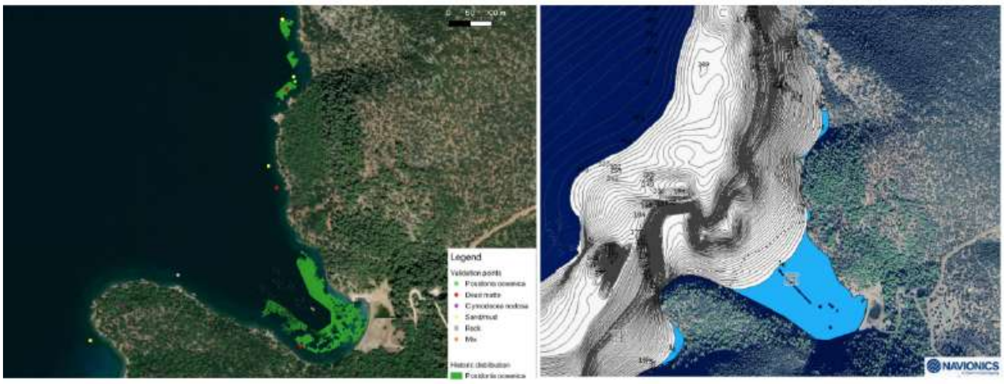
Poros

Case study 1 is located at at 37.534535N, 23.474803E. For the analysis, two images were used due to the increased sun glint, both dated from 1972. The historic pressence of a Posidonia meadow is confirmed by the evident pressence of dead mate and observation of dead shoots. The operation of the aquaculture facilities have caused the complete recession of the meadow in the study site with only one small surviving patch of Posidonia remaining (see validation points). The pre-aquaculture area of *P. oceanica* distribution was calculated as 4.06ha (hectares; 0.04km^2, Fig 19: Case study 1). Considering bathymetric data for the area, the meadow likelly extended deeper than presented, reaching the limits of the facility, while additional coastal meadows seem to have been present between the two mapped areas (indicated by dead matte identification).

For **Case study 2** at 37.531330N, 23.460264E, two images were used to derive the results dated from 1972. Similarly with the first site, the operation of the facilities has caused a significant decline in distribution of seagrass (Fig 19: Case study 2). The pre-aquaculture seagrass area was calculated as 3.43ha (0.034 km^2). The deep limit for the present case study was derived considering Google Earth imagery from 2016 (prior to the operation of the local facilities) which agrees with the expectations given the steep bathymetric profile of the area.

Case study 3 at 37.546352N, 23.477177E represents a site with significant aquaculture activity. Despite the lack of observation of dead shoots/rhizomes or dead matte, it is evident from the aeroimages (also dated from 1972) that the bay once hosted a meadow. The lack of observations of dead matte could be attributed to the vast buildup of sediment/organic waste that covered any remaining signs of rhizomes or dead matte. The surviving Posidonia can be found behind the islet of Bisti and the bay to the east that also show signs of degradation concluded from the historic images and the dive survey at the site (reduced distribution, shallow deep limit of the meadow, high epiphyte coverage). The pre-aquaculture seagrass area calculates to 0.62ha (0.006km^2, Fig 19: Case study 3). The limit of the historic meadow distribution has been derived considering the steep bathymetric profile of the bay and limited to approximately 20m depth withing the shallow bays of the area.

Case study 1



Case study 2

Case study 3

Fig 19: Case study sites 1-3 in Poros island. Left: Produced historic distribution of Posidonia, right: Bathymetric profiles and considerations during analysis, Navionics.

Methana

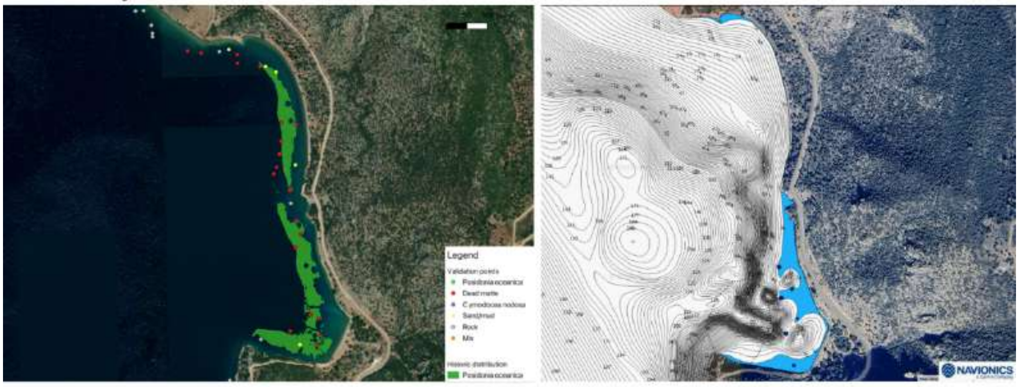
For **Case study 4** located in Methana at 37.570727N, 23.359896E a dive was completed, where a large dead meadow was observed. The historic images used were dated from 1984**.** The analysis shows a complete recession of the meadow in the bay and despite the fact that the facilities have halted operation and were removed for over ten years, there were no signs of recovery. The pre-aquaculture seagrass area was calculated as 2.43ha (0.024km^2, Fig 20: Case study 4). Considering the dead matte point data recorded during fieldwork, the estimation is likely underestimated due to reduced image quality and lack of imagery for the northern part, and thus the historic meadow is suspected to have once extend to the recorded points (red dots).

For **Case study 5**, located at 37.561216N, 23.361646E, clear evidence of historic Posidonia meadows were visible, while despite the operation of facilities the mapping also revealed the existence of surviving Posidonia (Fig 7) at a much smaller extent than pre-aquaculture coverage, that was estimated as 0.95ha (0.0095km^2, Fig 20: Case study 5). Currently no posdionia can be found within the bay, excluding the small area on the southeastern edge.

Finaly, in **Case study 6**, located at 37.559108N, 23.366552E, the analysis of historic imagery revealed a meadow covering 0.28ha (0.003km^2) pre-aquaculture operation. No dead Posidonia shoots were observed in this site possibly given the geological characteristic of the site (enclosed gulf) which has caused the build-up of mud/waste (Fig 20: Case study 6). The historic distribution seems to have been limited to a small area characterised by rocks and cliffs in its shallow limit, and more extensivelly was found in the shallow bay northwest of the facility.

Imagery from the final two case studies were dated from 1984.

Case study 4



Case study 5

Case study 6

Fig 20: Case study sites 4-6 in Methana. Left: Produced historic distribution of Posidonia, right: Bathymetric profiles and considerations during analysis, Navionics.

The present results should be considered as preliminary data. Due to the reduced image quality, image availability, possible camera tilt and increased surface sun glint the distribution is likely overestimated in the shallow limits and greatly underestimated for the deeper limits of the meadow, as this was not assessed in the present methodology. The analysis accuracy cannot be determined due to the absence of validation points for the specific time interval and therefore, results should be interpreted with caution. Nevertheless, given the limited resources available for pre-aquaculture distribution, the present analysis gives a satisfactory representation of the historic shallow distribution of the meadows considering i) the fact that dead matte and old rhizomes were observed in several of these locations and ii) the results of the control sites that show a satisfactory match with current distribution mapping.

Discussion

The mapping produced in the context of this study provide an accurate and most up-to-date representation of the presence of Posidonia meadows in Poros island and Methana peninsula, that available bibliography did not perviously represent. The lack of such vital information has been an important factor leading to the lack of inclution of Posidonia meadows in environmental impact assesements specifically related to aquaculture facilities. Despite some small effort in some of these studies to identify present fauna and flora of the proposed sites, the sampling extend appears to be small (focused in the area of cage placement) and does not account for presence of Posidonia in the surrounding area (within 400m of facilities). This can be concluded as live Posidonia was found nearby stations that had reported absence of it in the EIA's, specifically for the case of Poros. There is strong evidence on the impacts of aquaculture facilities on Posidonia meadows locally for both areas, given i) the extensive presence of dead matte areas nearby the facilities, ii) the poor health state and high epiphytic coverage of surviving posidonia meadows in these areas, iii) the evident reduction in distribution when comparing ortho-imagery pre and post aquaculture operation and iv) the lack of Posidonia recovery despite the decade-long hault in operation for the site in Methana.

On multiple occasions, the proposed sites are located in smaller distances than the recommended 800m and even 400m mark, while specifically in Methana, the northern proposed facility lies with the Natura2000 site in close distance with live Posidonia. The negative impacts of aquaculture on Posidonia meadows have been evaluated in a number of studies across the Mediterranean and have been characterised as diverse and complex. These ecosystems have been identified as highly sensitive to fish farm effluents while the sedimentation of waste particles in the farm vicinities is the main cause of benthic deterioration (Pergent-Martini, et al., 2006; Marbà, et al., 2006; Holmer, et al., 2008; Apostolaki, et al., 2009, 2010, 2011). A study undertaken by iSea in an abandoned aquaculture facility in Kalamos island shows a strong effect on the health status and distribution of Posidonia meadows located in the adjacent bay (distanced 200m away) characterised with a poor ecological status and an advanced degree of regression (Athinaiou et al., 2024). Studies show Posidonia losses nearby fish farms (e.g., Diaz-Almela, et al., 2008; Ruiz, et al., 2001) with sediments showing a strong increase in organic matter, that could lead to anoxia phenomena (Pergent-Martini et al., 2006). The persistence of this phenomena has been seen to cause continuous losses of Posidonia even five years after the cessation of fish farming activities (Delgado et al., 1999), which agrees with the lack of recovery observed in this study, in the old aquaculture site in Methana. Impacts on Posidonia can be observed even as far as 3km away from the facilities (Ruiz et al., 2010) while according to the recommendations of Karakassis et al. (2013), fish farming should not be permitted at least 800m from the boundaries of a Posidonia meadow. Recommendations also stress for the establishment of permanent seagrass plots (marked seagrass quadrants) revisited annually for monitoring the health of the meadows past this distance (Holmer et al., 2008).

Considering this, along with the fact that part of the development site of Methana is within a designated protected area, and that Posidonia meadows are protected in national and international legislation, there is a strong need to reconsider the proposed development, both in terms of the location of this expansion and the production effort in each facility. It is a necessity to assess the current carrying capacity of the environment, complete a rigorous and extensive environmental impact assessment for a complete understanding of the species, habitats and whole systems affected without fully depending on publicly available datasets. Finally, proposals should include management plans for long term monitoring of the surrounding area, in line with legal requirements and European standards, as well as considering the socioeconomic impacts of such development through a site-specific socioeconomics study and the inclusion of the local community and local governing bodies in the decision-making process.

A.4. Communication

A.4.1 Producing informative materials

This action relates to producing informative materials for local stakeholders and visiting tourists. The deliverables for this action include i) 4 infographic posters for social media, ii) 2 posters as informative signs and iii) 2 brochures (3-fold leaflets). The posters created highlight the distribution of the Posidonia meadows in Poros and Methana with the mapping results produced as well as notes on the threats the habitat faces in these areas. Sample materials were sent to the funders along with the present report. The finalisation of the materials as well as the dissemination of these will be concluded collaboratively between the project partners over the following months. As an extra sub-action, a Layman's report on the distribution of Posidonia meadows in the POAY zones in Methana was produced for the municipality of Methana and the community of Krasopanagia affected by the proposed POAY (delivered with the present report).

A.4.2 Communication

There is a dedicated page for the project in iSea's website (in Greek and English) that can be seen following this link: https://isea.com.gr/argolic-gulf/?lang=en. Results of the project are communicated on this page while the materials are made publicly available to increase engagement and use of these to support and guide the management of the habitat locally. Furthermore, in the effort to create open-access data, the reports and mapping produced in this project will be made available in the open-access platform of Zenodo where the past work of iSea has also been uploaded. The results will also be shared with NECCA to increase knowledge of present habitats within the Natura2000 site in Methana and in the Argosaronic.

A.5 Project coordination

A.5.1 Monitoring the project actions, ensure high-quality deliverables and reporting.

A project manager was assigned to the project who was closely monitoring the projects actions ensuring the timeline, and the actions of the project are being met. A broader team was involved in the implementation of various actions of the project such as fieldwork and report writing. The project manager worked with the team and coordinated the implementation of the project.

A.5.2 Financial monitoring

The project manager, the director and the accountant followed the finances of the project ensuring that the expenses stay within the budget. The expenditures of the have been submitted along with the present report. All original receipts are kept in iSea's headquarters and copies can be given to the funder upon request.

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APPENDICES

Appendix 1: Historic aero orthoimages used for the analysis of past distribution delivered along with the present report. For internal use only (copyright restrictions from the provider apply). Purchased at: the National Cadastre's archive (https://gis.ktimanet.gr/gis/apr/)

Table a: Details of the historic imagery purchased

Image ID	Area	Year	Case study
Y_BW_72_946779	Poros	1972	Case study 2
Y_BW_72_946780	Poros	1972	Case study 2
Y_BW_72_946791	Poros	1972	Case study 3
Y_BW_72_946792	Poros	1972	Case study 1
Y_BW_84_161441	Methana	1984	Case study 5
Y_BW_84_161442	Methana	1984	Case study 6
Y_BW_84_161496	Methana	1984	Case study 4


iSea
iSea, 2024