



CREPOSIDONIA

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

Final Progress Report



ENVIRONMENTAL ORGANISATION FOR THE PRESERVATION OF THE AQUATIC ECOSYSTEMS

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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 iSea is an Environmental Organisation founded in 2016 in Thessaloniki, 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, the evaluation of ecosystem services and threats they face locally including raising awareness and creating open-access data and reports to improve 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* which include 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

Posidonia meadows, despite the ecosystem services they offer and their protection status, are some of the most threatened ecosystems globally, with estimations in the Mediterranean projecting a functional extinction by 2050. 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, Greece 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 produced regarding this habitat are limited in Natura2000 sites (produced in the late 90s) while a National map was produced 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 2023, a map regarding the extend of seagrass was produced for Greek waters (Panayotidis et al., 2023) 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 tourists' activity arises threats for the marine environment and *Posidonia oceanica* among which; pollution (discharges, litter) and mechanical damage (uncontrolled anchorage). One Natura2000 site can be found in the wider area recognizing 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 is mentioned that *Posidonia* meadows cover an area of 186ha.

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 intensity of production in each (APC, 2023; Ambio, 2015). Among other known impacts, this will undoubtedly cause the local degradation of the meadows, and their protection is hindered by the lack of a robust environmental impact assessment that accounts for their presence and the lack of knowledge regarding the meadow's current distribution. The proposed project is the continuation of REPOSIDONIA in Spetses and Hydra islands.

Aims: To better understand the coverage, distribution of the endemic seagrass *Posidonia oceanica* in the Argosaronic Gulf and to raise awareness among local stakeholders and the public. This will be 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 will work with local stakeholders such as the local municipalities and Katheti to disseminate informative materials that will be produced from the project as well as participate in informative events regarding *Posidonia* meadows, and the maps produced. As an additional action, iSea will explore the past presence of meadows adjacent to the present 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 of 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 oceanica* around Poros island and Methana peninsula

A1.1 Field activities

An important aspect of the mapping process was to obtain accurate ground truthing points, representing the different seabed habitats, which was used as training data for the classification of the pixels of the satellite image in habitat types as well as for validation. The team of iSea traveled to Methana and Poros to complete the data collection that took place from the 20th-24th of May. Regarding the fieldwork, iSea developed a plan for the samplings using free source satellite images from Google Earth, and consulting with the external collaborator. 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 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 point (Table 1). A GPS device (Garmin 22x) was used with a minimum accuracy of 3m. The team was careful to record each point, of habitat covering approximately 10m² to avoid the reduction of the accuracy of the habitat classification due to the GPS's accuracy. All the points were then transferred in a text file, along with the coordinates and the affiliated habitat. The text file then was transformed into a shapefile using ArcGIS (Version 10.4) (attached with the report).

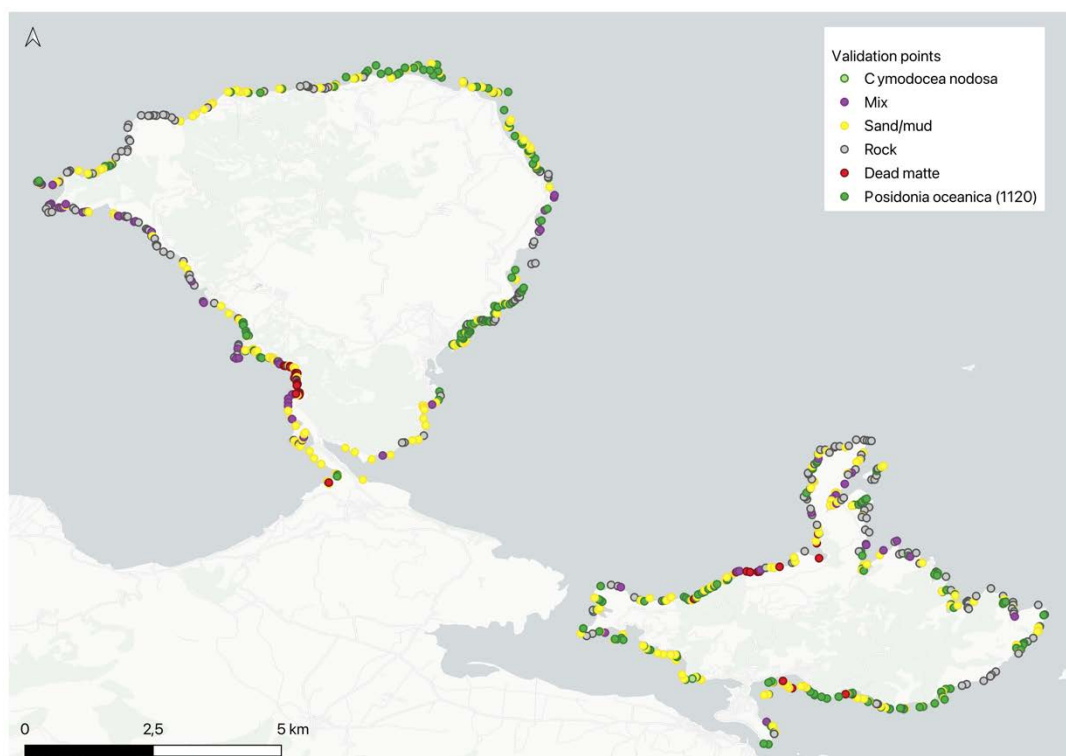


Fig 1: Map of validation points collected for Poros and Methana Posidonia mapping

Table 1: Validation points overview of data collected for Methana and Poros

Substrate type	Methana	Poros	Total	% of total
<i>Posidonia oceanica</i>	114	117	231	29,3%
<i>Cymodocea nodosa</i>	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).

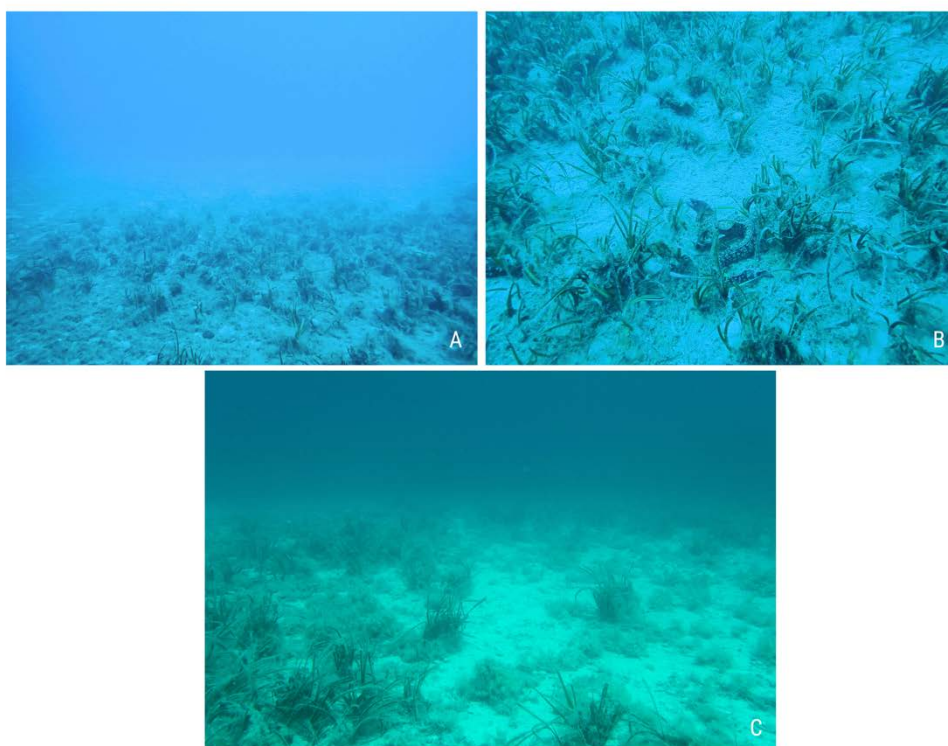


Fig 2: Recording deep limit of Posidonia meadows through scuba diving in Methana (A) and Poros (C). Mediterranean moray (*Muraena helena*) swimming between the meadows in Methana deep limit dive (B).

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

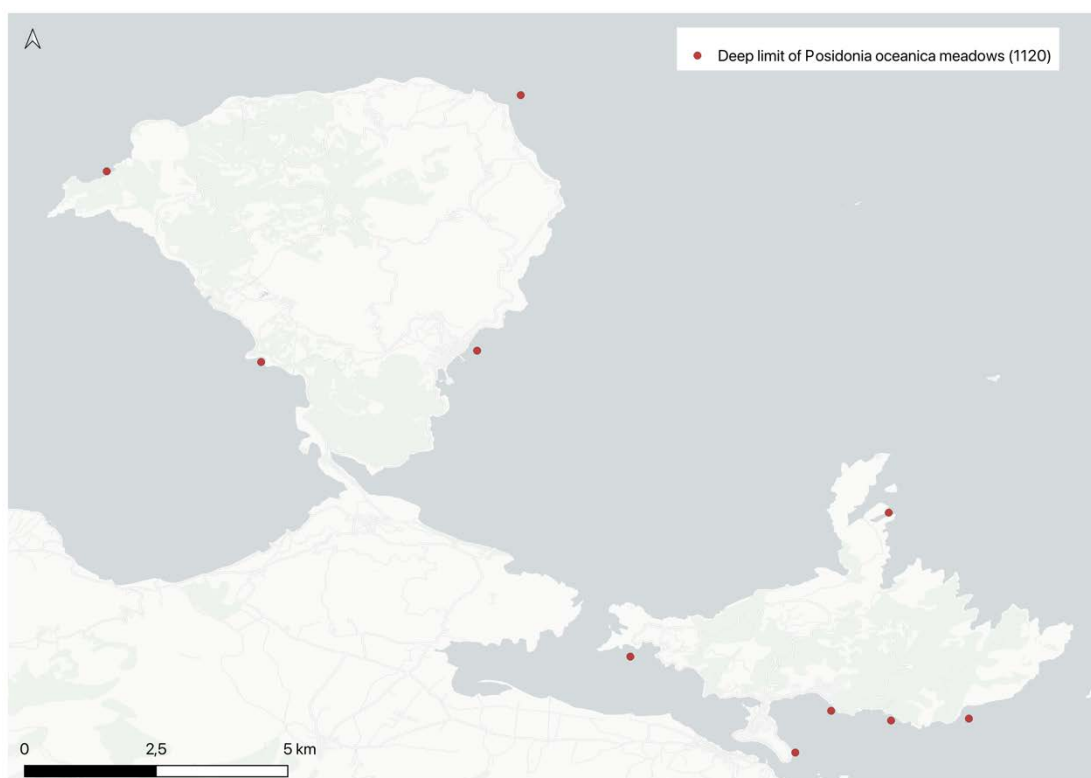


Fig 3: Deep limit of the Posidonia meadows recorded in both study areas.



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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, Coffey et al., 2023). Three Native multi spectral, Bundle 8-bands images were purchased for the analysis: one WorldView III acquired on 06/05/2024 (Methana), one Pleiades NEO acquired on 19/11/2023 (west Poros) and one Pleiades NEO acquired on 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 (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, where all necessary steps for proper creation of training data, image classification and product validation using the collected field data, can be found. 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. For the pixel areas affected by wave action, sedimentation and terrestrial shadow, attributed to the oceanographic and geographic characteristics of the study, hand-delineation was completed. The method considered the combination of the validation point data collected, 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. The 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. According to the current work, the meadows cover an area of **0,70km²** (70.05 hectares) **for Poros** (Fig 6) and **0,96km²** (96.40 hectares) **for Methana** (Fig 7), with an overall accuracy of the final products as **87%** and **89%** accordingly.

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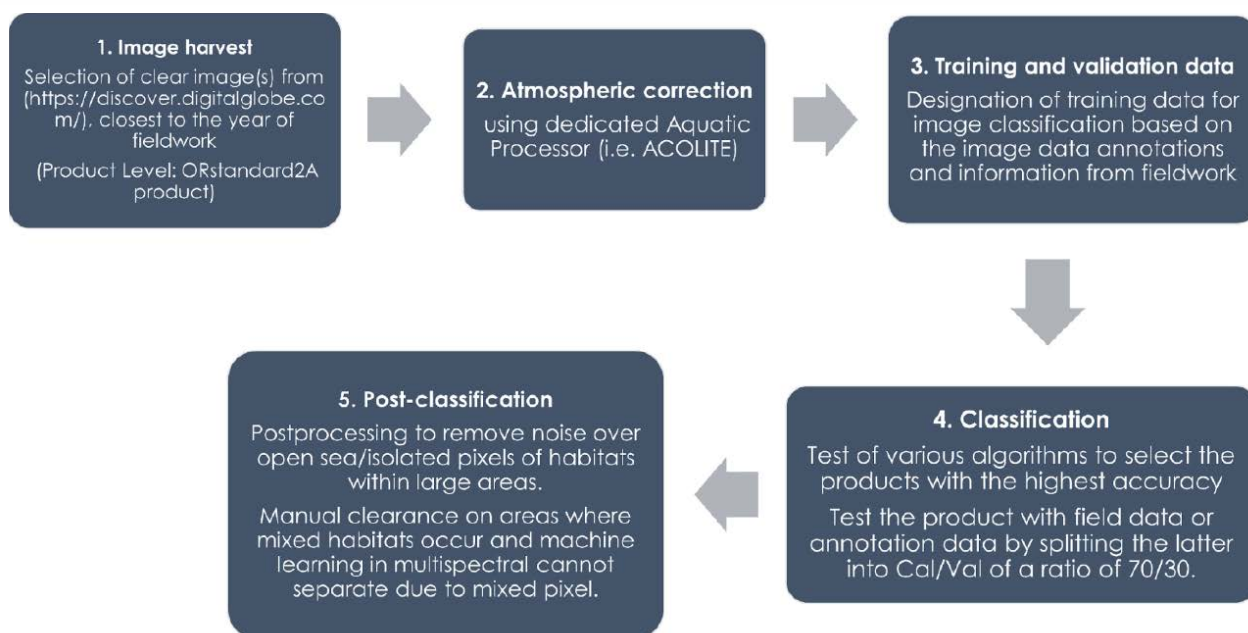


Fig 4: Workflow of the analysis followed for producing the final maps of *P. oceanica* meadows.

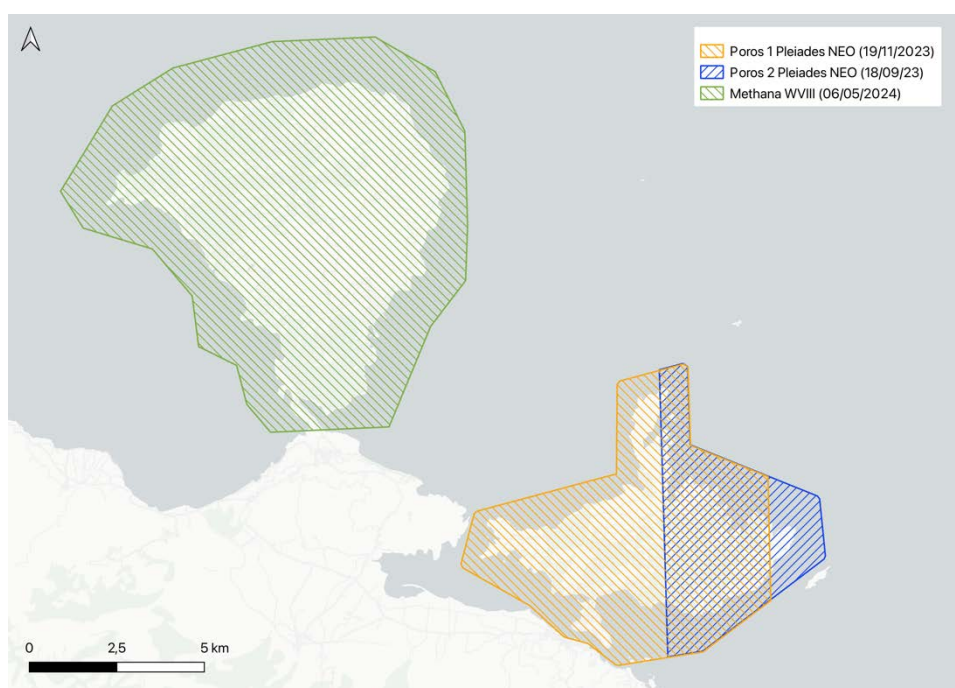


Fig 5: Footprints of the selected images for both study sites

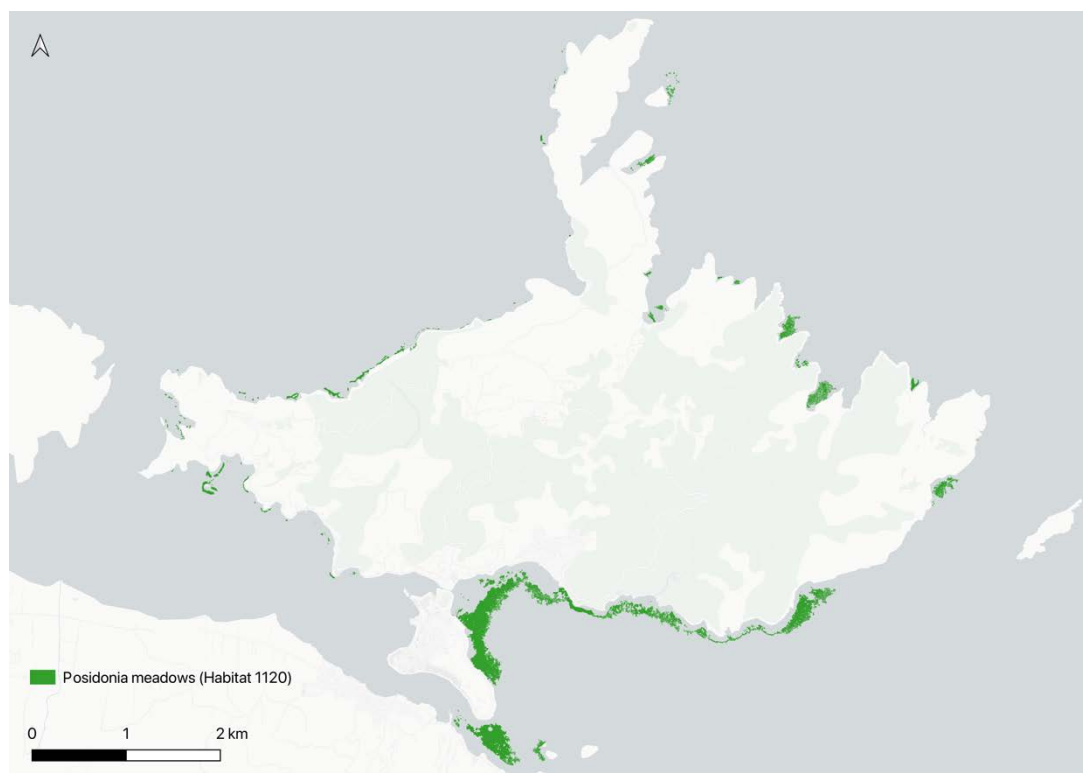


Fig 6: *Posidonia oceanica* (Habitat 1120, Habitats Directive) distribution in Poros island

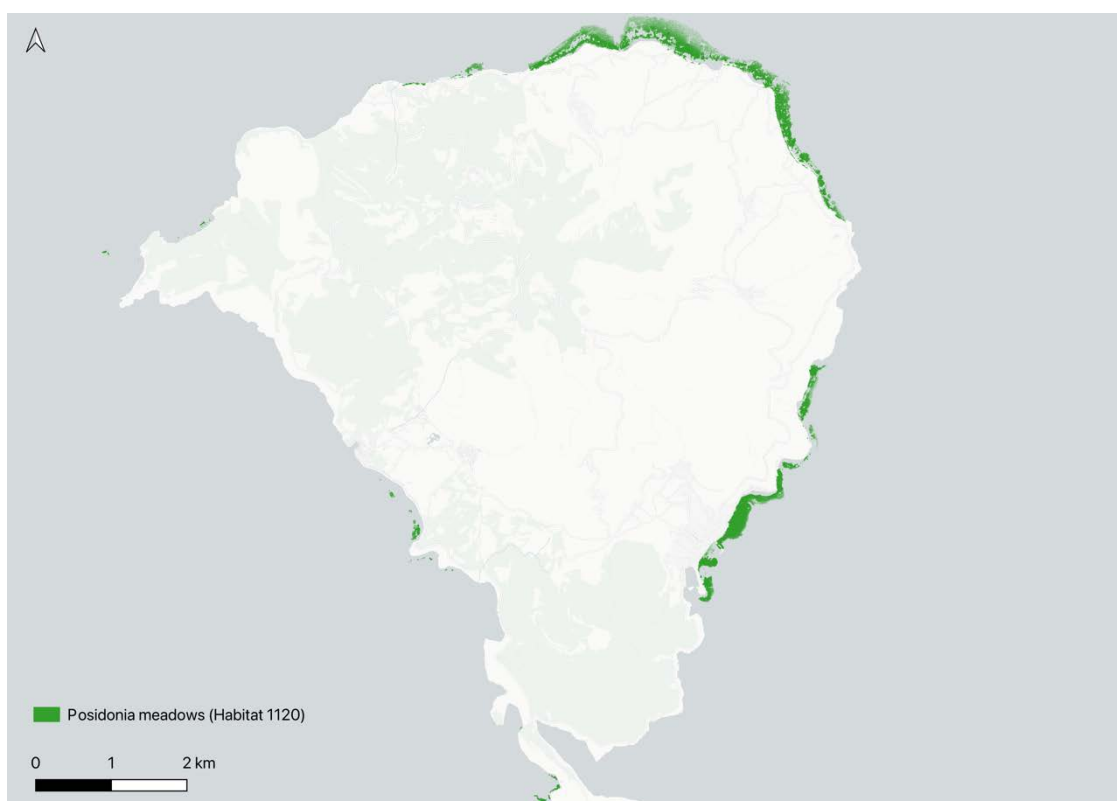


Fig 7: *Posidonia oceanica* (Habitat 1120, Habitats Directive) distribution in Methana

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 characterized 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 facilities.

No living Posidonia meadows were found below or within a 50m radius of the existing aquaculture facilities. This comes at no surprise as the operation of the facilities have 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) in a degraded state and characterised as a mix of dead matte with some live Posidonia shoots with extensive epiphyte coverage, a known effect of organic pollution (Gobert et al., 2009). When looking at sites with removed and/or relocated facilities, meadows can be found from distances of **20m** (Poros) showing 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). Finally, 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).

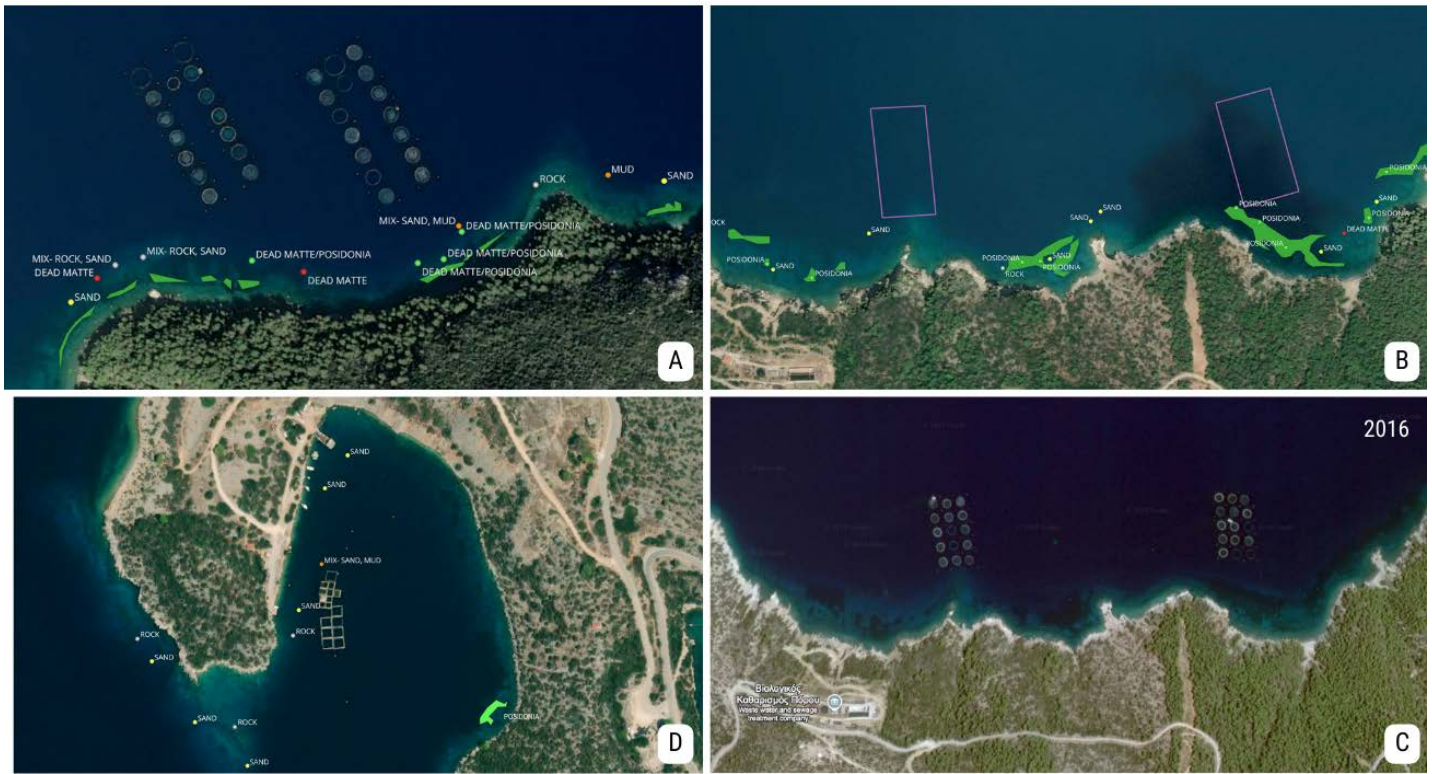


Fig 8: Presence of Posidonia meadows in existing aquaculture facilities in Poros and Methana. A: Live Posidonia meadows and dead matte in close association with existing facilities in Poros. B: Live Posidonia meadows and dead matte in close association with relocated facilities. C: Evidence of facilities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

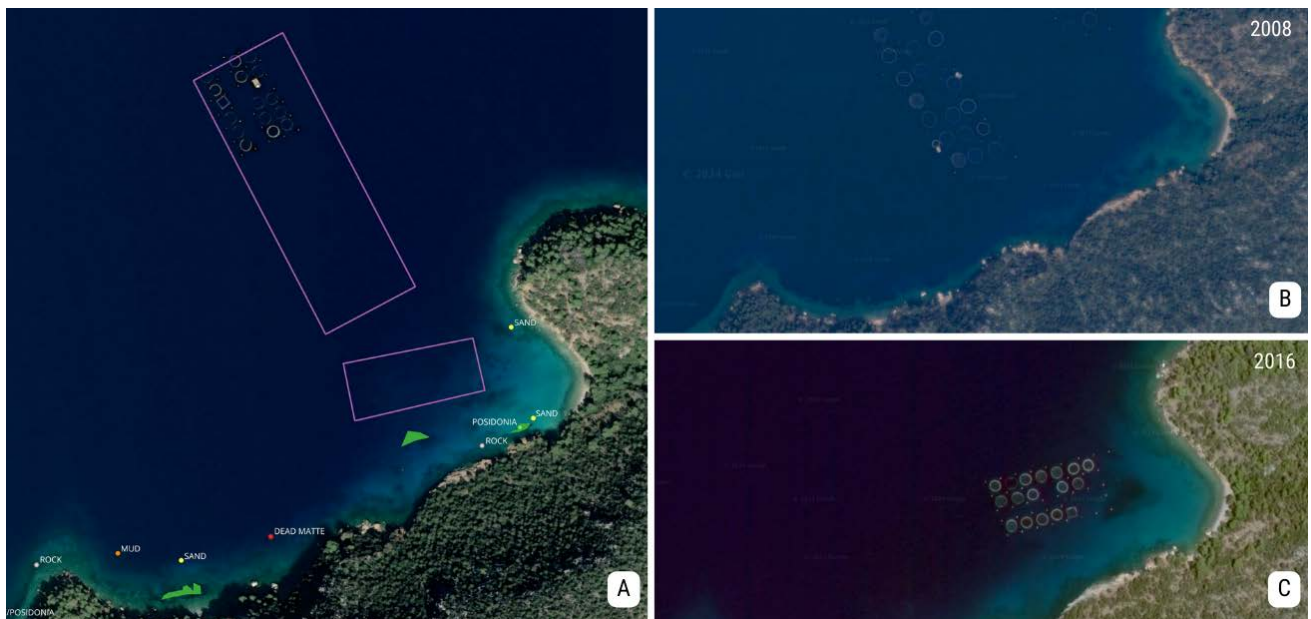


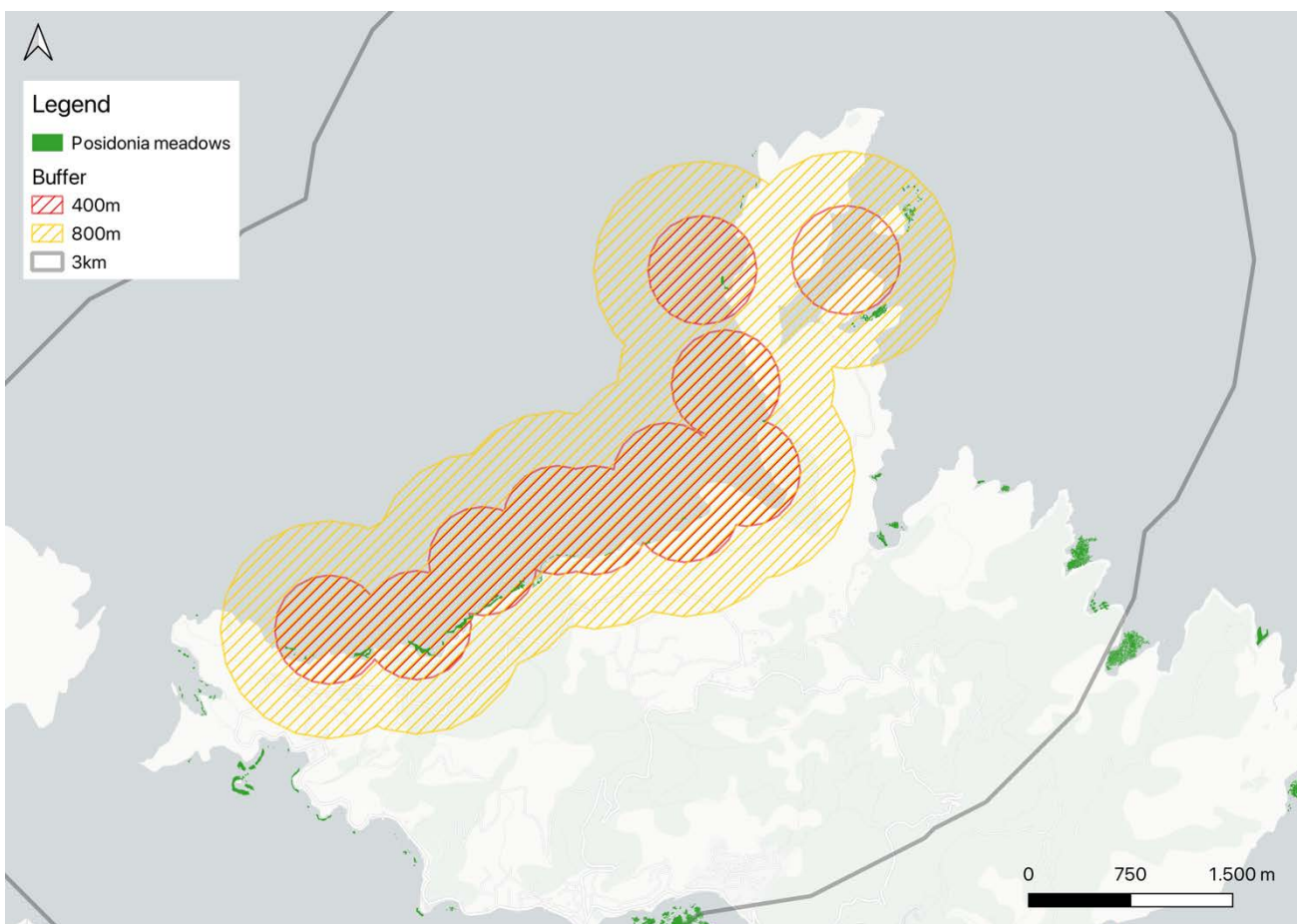
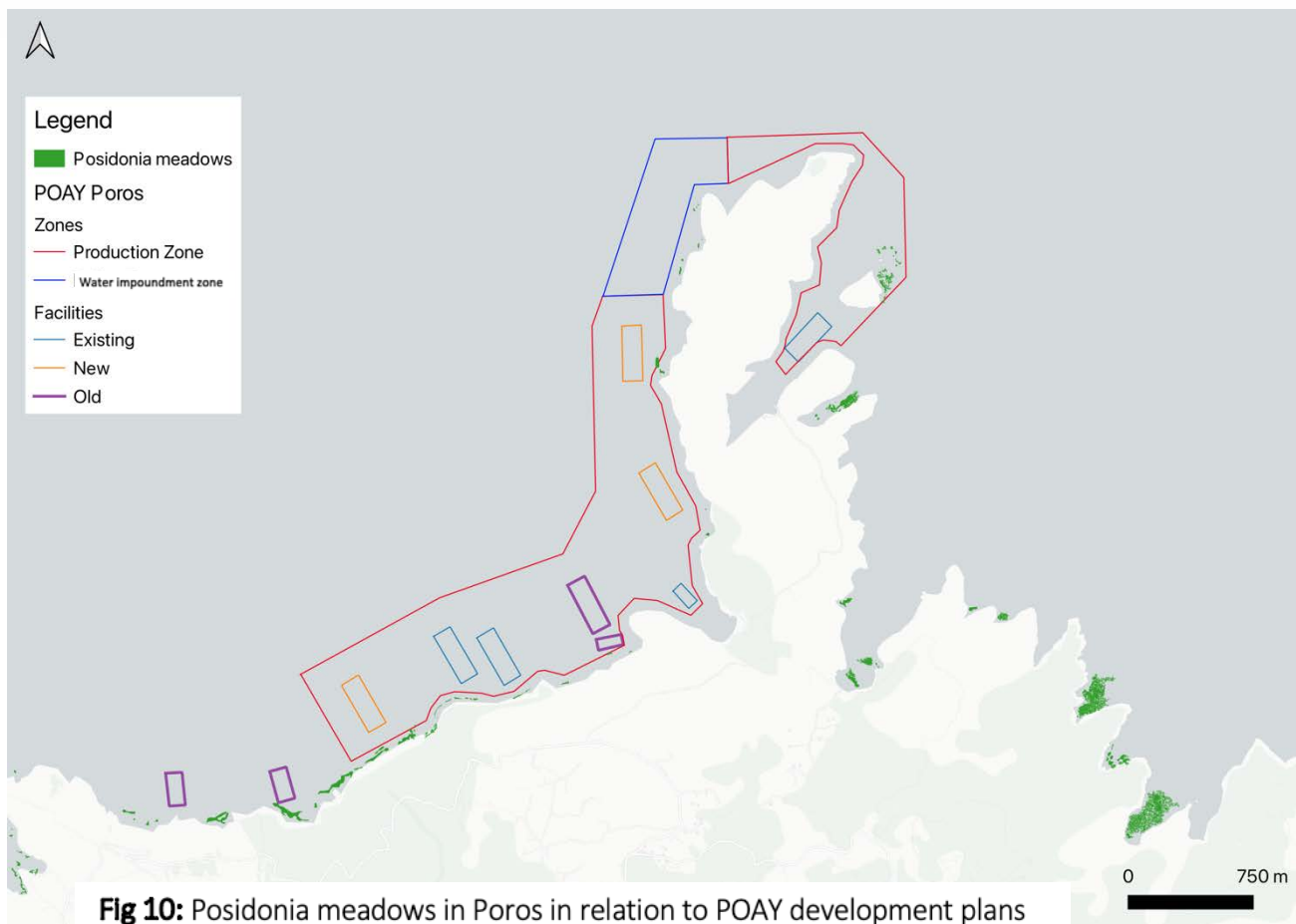
Fig 9: Presence of Posidonia meadows in relocated aquaculture facilities in Poros. A: Field validation habitat point data in relation to the facilities (old and current; purple polygon). B, C: Imagery showing presence of facilities in different locations with visible indication of past Posidonia distribution.

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

Regarding Posidonia meadows present within the POAY zones (aquaculture development zones) for both study sites the mapping produced in the context of this project, along with the field observations, were compared with the available development plans maps. The EIA's (Environmental Impact Assessment) for both areas mentions that no Posidonia is found in the proposed development sites and suggest a distance of more than 400m 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 a Posidonia meadow while farms operating in proximity to these should either be relocated or not permitted to increase production effort and renewal. Despite general studies on the impacts of aquaculture referring to a 150m effect radius addressed in the EIA's for both areas, specific studies considering *Posidonia oceanica* habitats show 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). Considering this, the Posidonia meadows present within three different buffer zones at distances of 400m, 800m and 3000m from the proposed facilities are presented for both areas, along with a calculation of the hectares of Posidonia impacted for each buffer zone. For visual purposes the 3km buffer zone is not included in the figures.

For Poros island a total of **1.78 hectares** of Posidonia have been identified within the wider area of the POAY (Fig 10) the coastal area in the shallow borders of the production zone and water impoundment zone has been included in this estimation. Out of this, **2.47 hectares** are within the 400m zone of the new/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 affected by the proposed facilities. The final estimation did not include areas past the western edge of the island. 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). Out of this, **0.19 hectares** are within the 400m zone of the new/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 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).



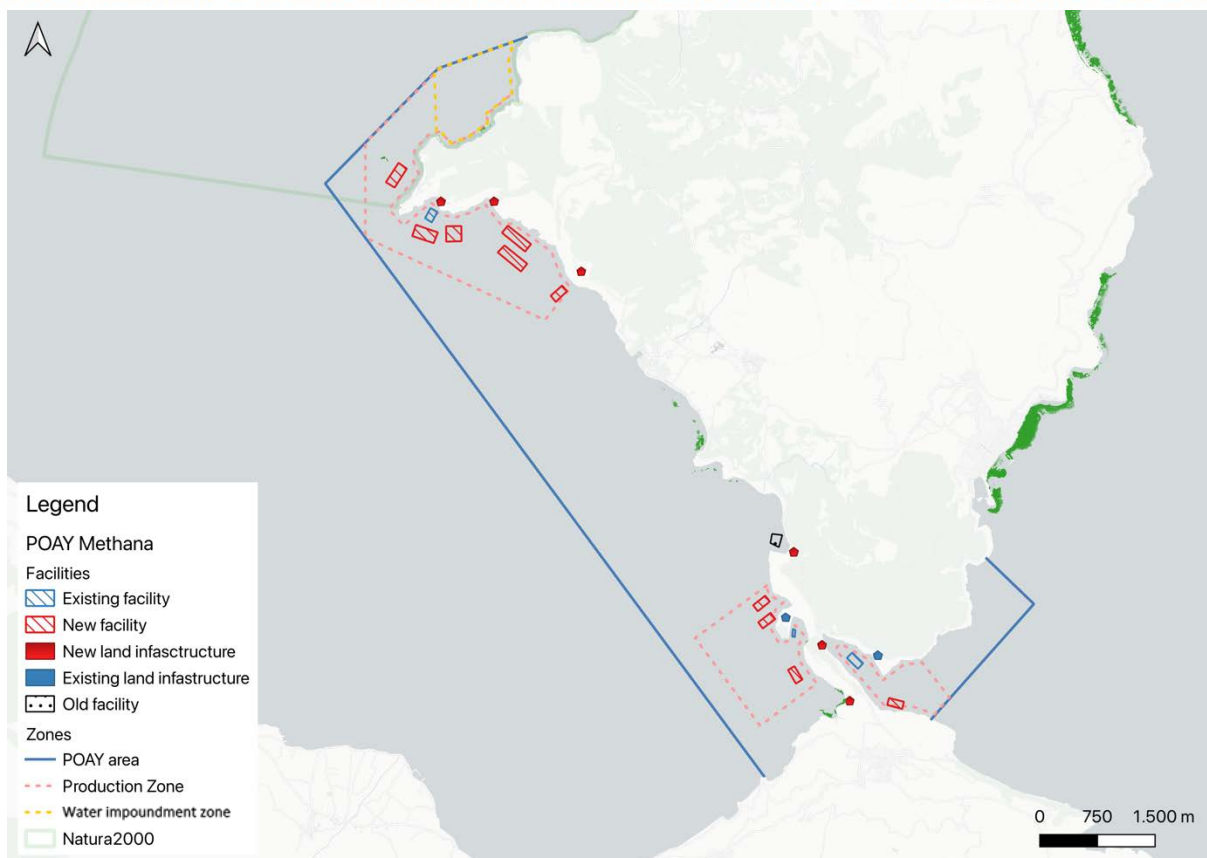


Fig 12: Posidonia meadows in Methana in relation to POAY development plans

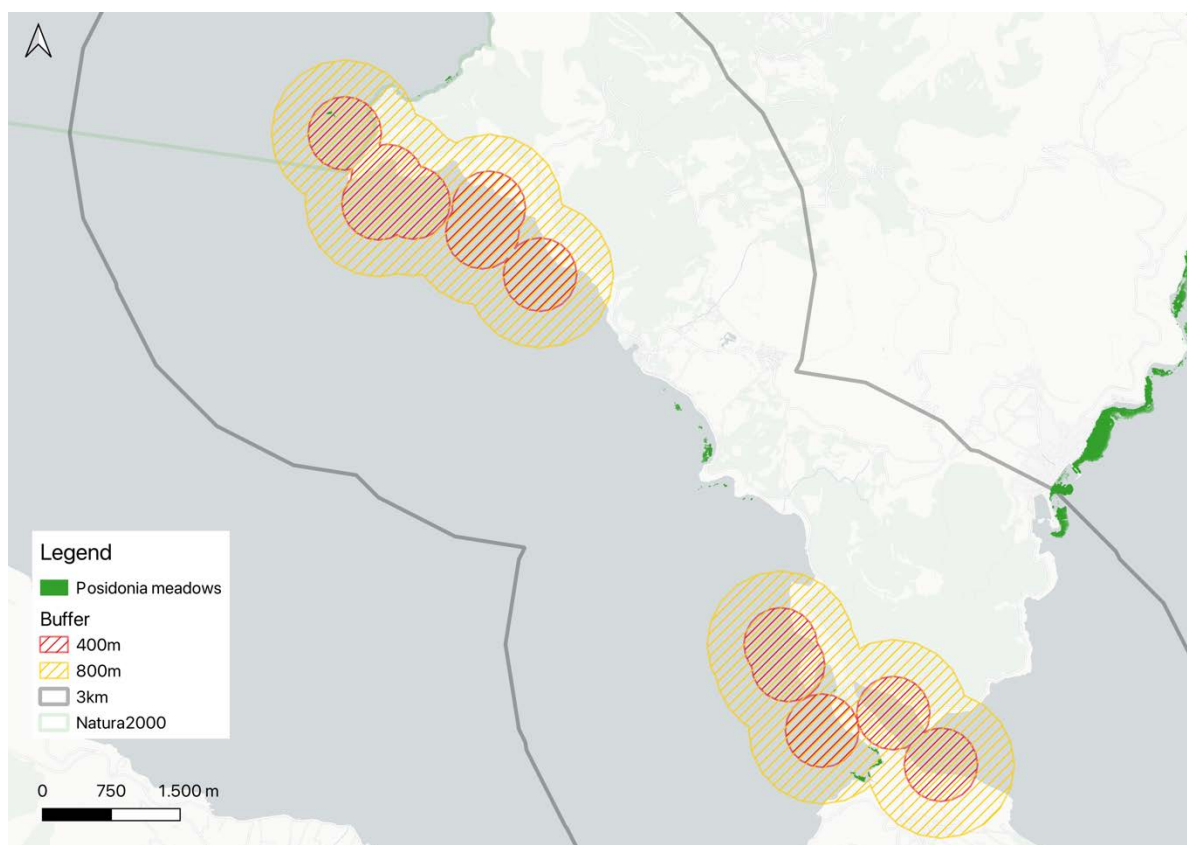


Fig 13: Posidonia meadows in Methana in relation to buffer zones of facilities

A.3 Exploring the past 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/>) in 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).

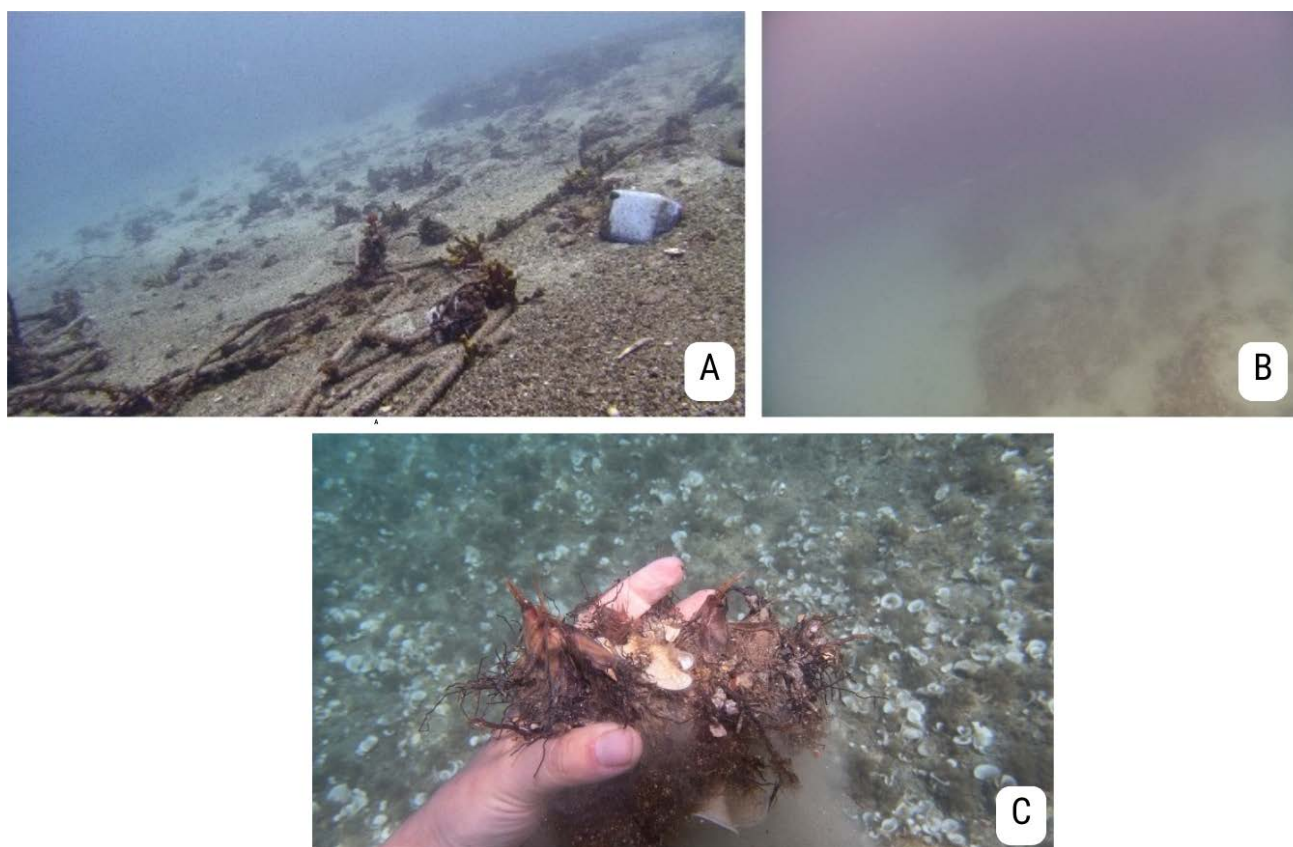


Fig 14: ROV footage near operating facilities in Methana (A) and Poros (B), and old rhizomes from dead matte site observed in Poros (C)

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.

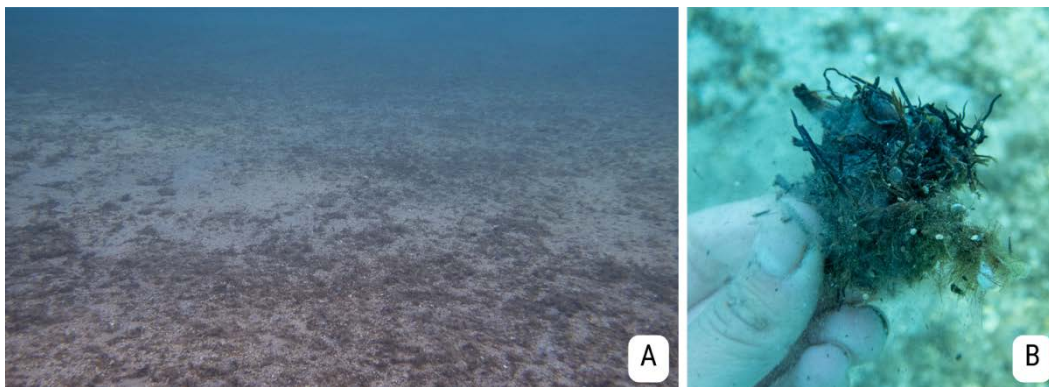


Fig 15: Dead matte area identified in Methana in removed facility (A) and evidence of old *Posidonia* rhizomes in the same site (B)

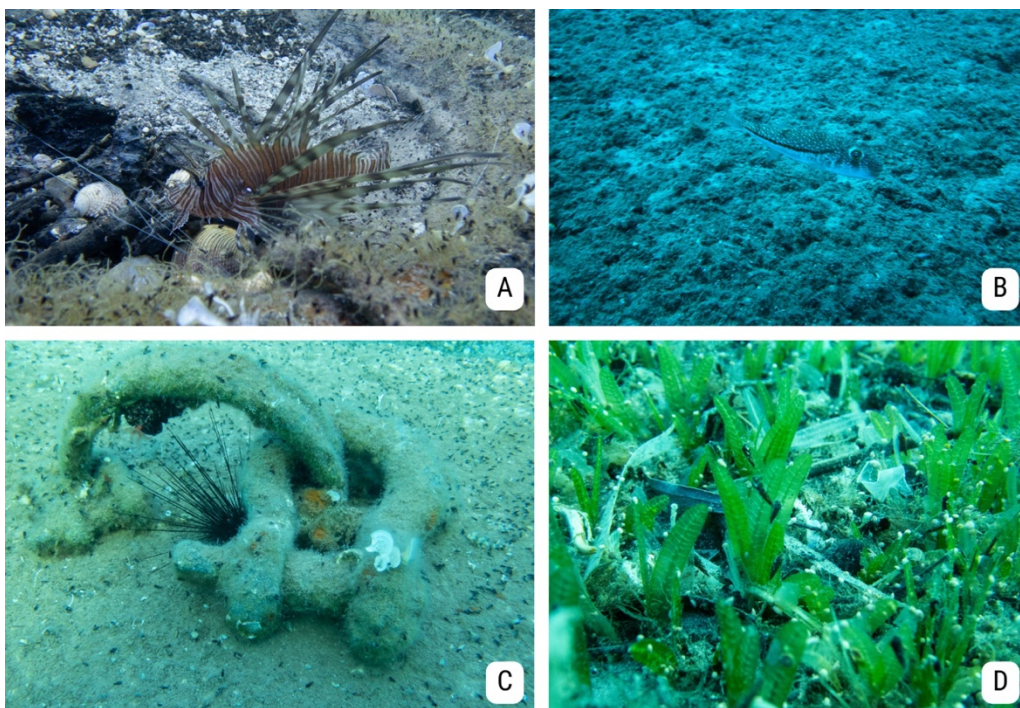


Fig 16: Invasive species identified in old aquaculture site. A: Lionfish, B: Toadfish, C: Black longspine urchin, D: *Halophila* seagrass.

Historic aeroimages (n=7) were obtained and analysed to derive an estimate of the area of Posidonia meadows lost since the operation of aquaculture facilities in close proximity to these meadows in specific case study areas. Six case study areas are presented, 3 for Methana peninsula and 3 for Poros island, chosen for their proximity to operating/historic facilities and the presence of dead matte, as well as the availability and quality of historic imagery. The purchased images have been delivered along with this report and the details of each can be found in Appendix 1. Two control sites are additionally included for the validation of the methodology, one for each area of study to confirm the methodologies 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 give a clear indication of Posidonia presence (dark shaded shapes in coastal areas with patterns resembling Posidonia meadows characteristics). For the analysis, the historic images were georeferenced in QGIS (version: 3.36.0) then the created vector was reclassified with values representing the darker pixels (Posidonia meadows) extracted and cropped to a selected area of interest. The area of interest excluded the non viable locations which included 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 reclassified image quality. Due to this, the analysis does not assess the distribution of the meadows in its deeper limits and only gives indication for the visible shallow limits.

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 likely overestimated. The site, although affected by human disturbance (aquaculture, coastal construction, 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).



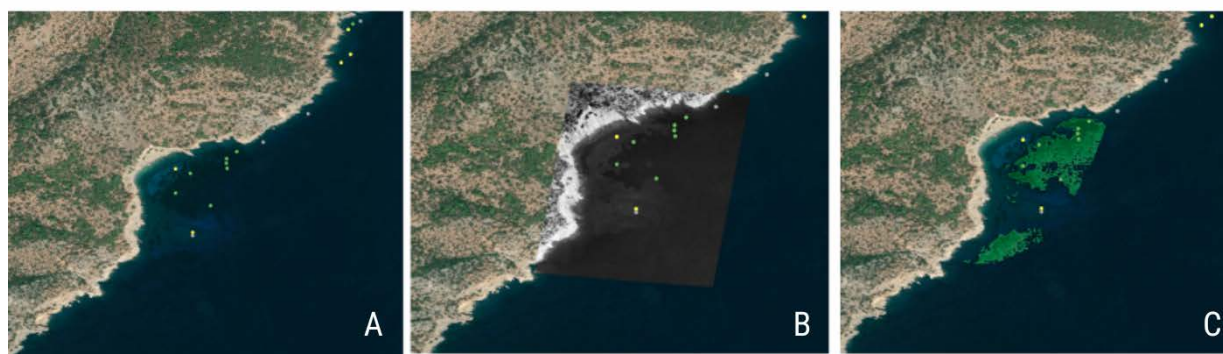


Fig 17: Control site 1 validation points (A) historic aeroimage (B) and calculated historic distribution of *Posidonia oceanica* (C; green polygon area)

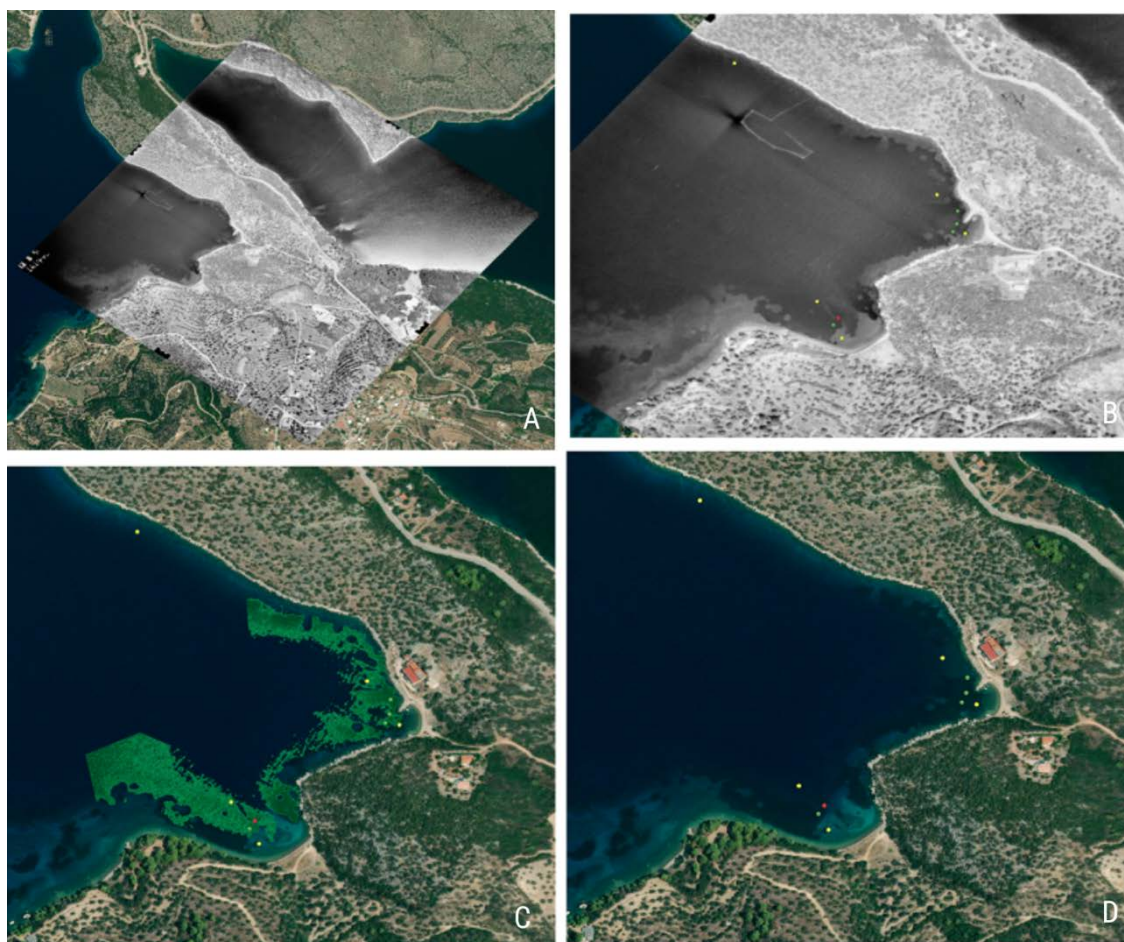


Fig 18: Control site 2: Selected bay in Methana and available aeroimages (A) validation points (B), calculated historic meadow presence (C) and current satellite view (D)

Case study areas of historic distribution in aquaculture sites

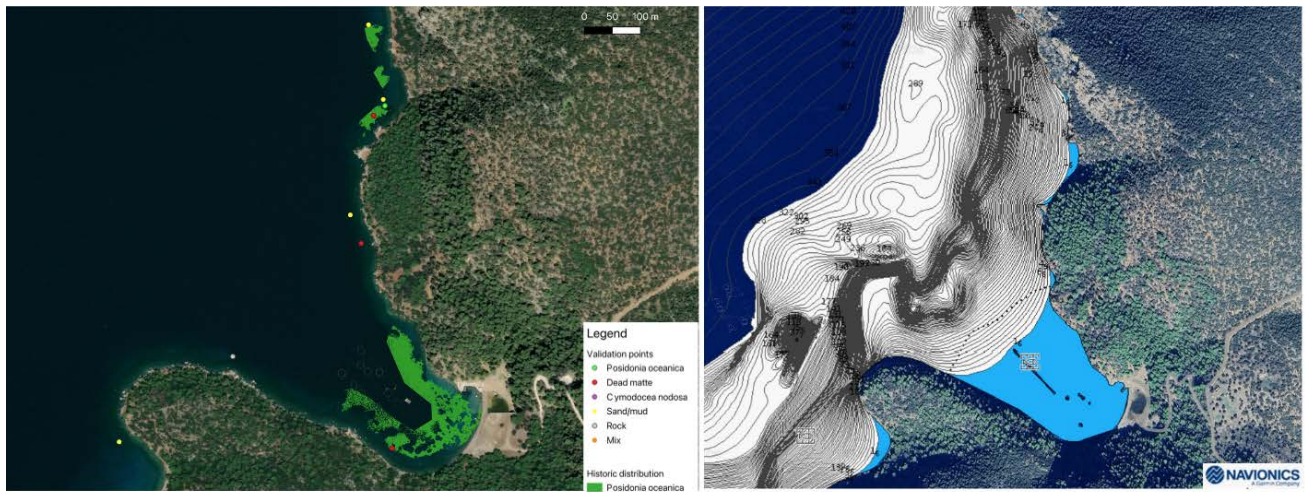
Poros

Case study 1 is located at 37.534535N, 23.474803E. For the analysis, 2 images were used due to the increased sun glint, both dated from 1972. The historic presence of a *Posidonia* meadow is confirmed by the evident presence of dead matte 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; 0.04km², Fig 19: Case study 1). Considering bathymetric data for the area, the meadow likely 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 km²). 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 aerial images (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 (0.006km², 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 within the shallow bays of the area.

Case study 1



Case study 2



Case study 3

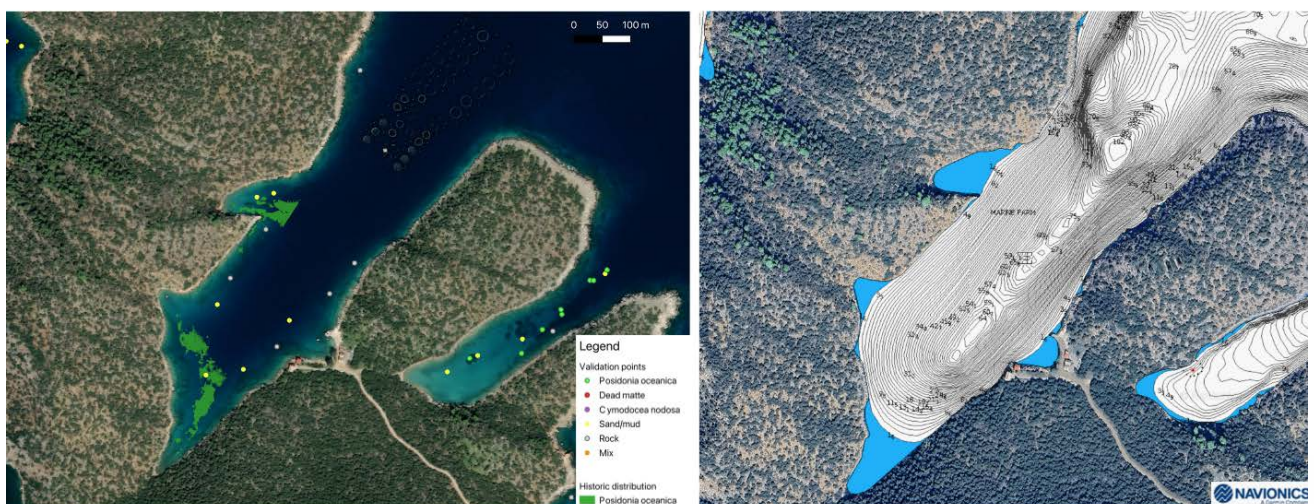


Fig 19: Case study sites 1-3 in Poros island. Left: Produced historic distribution of Posidonia, right: Bathymetric profiles and considerations during analysis, Navionics.



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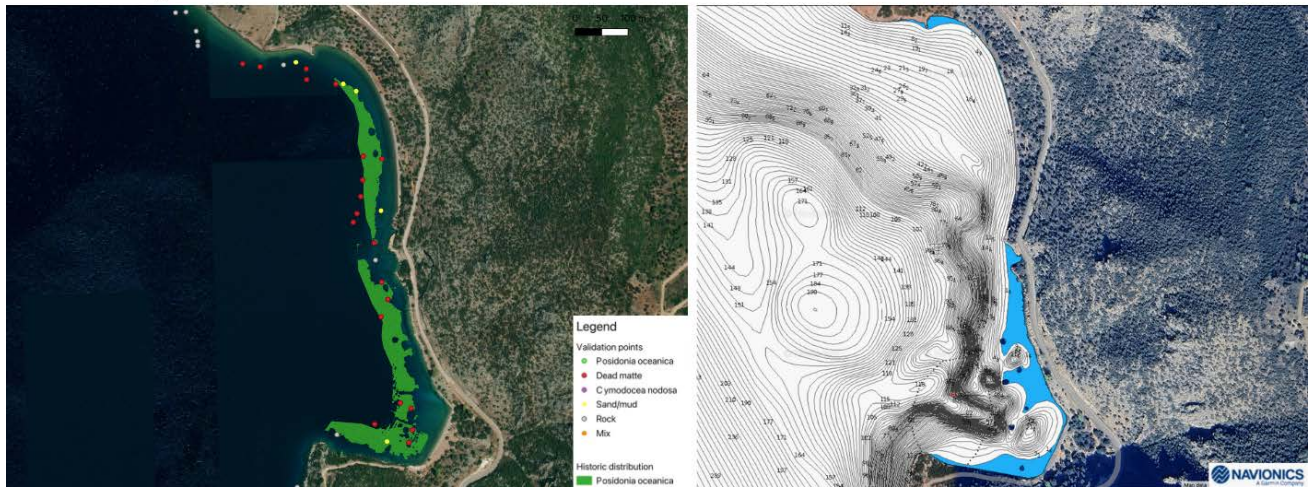
Methana

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 since over 10 years ago, there were no signs of recovery. The pre-aquaculture seagrass area was calculated as 2.43ha (0.024km², 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 (0.0095km², Fig 20: Case study 5). Currently no posidonia can be found within the bay, excluding the small area on the southeastern edge.

Finally, in **Case study 6**, located at 37.559108N, 23.366552E, the analysis of historic imagery revealed a meadow covering 0.28ha (0.003km²) pre-aquaculture operation that seemed to been heavily affected and showing complete absence of live Posidonia possibly given the geological characteristic of the site (enclosed gulf) (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 extensively was found in the shallow bay north west 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, the present analysis gives a satisfactory representation of the historic shallow distribution of the meadows given i) the limited resources available for pre-aquaculture distribution ii) the fact that dead matte and old rhizomes were observed in several of these locations and iii) 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 inclusion 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 porposed sites, the sampling extend appears to be small (focused in the area of cage placement) and 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 the species in their 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 halt in operation for the site in Methana.

On multiple occasions, the proposed sites are located in smaller distances than the recommended 400m, while specifically in Methana, the northern proposed facility lies with the Natura2000 site in close distance with live Posidonia. The 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 under and 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) and it's persistence causing continuous losses of Posidonia even five years after the cessation of fish farming activities (Delgado, et al., 1999), agreeing with the lack of recovery observed 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 Karakassis et al. (2013) recommendations, 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 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 managements 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 can be found in Appendix 2. The finalization of the materials as well as the dissemination of these will be concluded collaboratively between the project partners in 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 (see Appendix 3, 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 will be communicated on this page while the materials will be made publicly available to increase engagement and use of these to improve and guide the management of the habitat locally. Furthermore, in the effort to create open-access data, the reports and data 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.

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. While a broader team was involved in the implementation of various actions of the project. The project manager works with the team and coordinates the implementation of the project.



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An unfortunate delay of the deliverables took place due to the extended analysis period of the satellite imagery and final map production. In the effort to collect footage of the seabed near the aquaculture facilities using the ROV, a propeller blockage occurred which did not allow for further footage collection in deep waters.

The list of deliverables sent with the present report:

- Figures used in report (png)
- Historic imagery (tiff)
- Fieldwork images (png/jpg)
- Shapefiles of Poros and Methana Posidonia mapping (shp, xls)
- Shapefile of field validation points (shp)
- Shapefile of deep limit points (shp)
- Layman's report for Methana GR (pdf)
- Layman's report for Methana ENG (pdf)
- Expenses sheet (xls)

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 project are listed in Table 3. All original receipts are kept in iSea's headquarters and copies can be given to the funder upon request.

Table 3: List of Project expenses

Date	Description	Ref	Amount
13/5/2024	Diving insurance for volunteer	1306541	-49.00 €
16/5/2024	Accommodation	RC5EY58JPH	-455.53 €
17/5/2024	Tank fillings	706	-50.00 €
17/5/2024	Subsistence	53545	-35.16 €
19/5/2024	Fuel	184511	-109.64 €
19/5/2024	Subsistence	229609	-7.80 €
19/5/2024	Fuel	369518	-101.17 €
19/5/2024	Tolls	981667	-2.40 €
19/5/2024	Tolls	634241	-3.40 €
19/5/2024	Tolls	861697	-2.70 €
19/5/2024	Tolls	644177	-4.30 €
19/5/2024	Tolls	38908	-3.70 €
19/5/2024	Tolls	136332	-1.90 €
19/5/2024	Tolls	114611	-2.05 €



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19/5/2024	Tolls	192742	-4.20 €
19/5/2024	Tolls	179494	-3.55 €
19/5/2024	Tolls	7027	-2.30 €
19/5/2024	Tolls	2043989	-2.80 €
19/5/2024	Tolls	895615	-1.90 €
19/5/2024	Tolls	22783	-0.90 €
19/5/2024	Tolls	115921	-4.15 €
19/5/2024	Bus Tickets	635285	-17.20 €
20/5/2024	Subsistence	217294	-31.50 €
20/5/2024	Subsistence	13523	-8.55 €
20/5/2024	Subsistence	13534	-6.90 €
20/5/2024	Subsistence	128	-30.50 €
20/5/2024	Subsistence	228	-7.00 €
21/5/2024	Subsistence	22762	-45.30 €
22/5/2024	Subsistence	518	-17.00 €
22/5/2024	Subsistence	13551	-9.45 €
22/5/2024	Subsistence	13552	-1.80 €
23/5/2024	fuel	37373	-186.00 €
23/5/2024	fuel	37360	-97.03 €
24/5/2024	Subsistence	279	-84.50 €
24/5/2024	Subsistence	534	-17.00 €
24/5/2024	Fuel	1401	-290.00 €
25/5/2024	Tolls	744003	-1.90 €
25/5/2024	Tolls	101764	-2.05 €
25/5/2024	Tolls	103989	-3.70 €
25/5/2024	Tolls	119166	-4.15 €
25/5/2024	Tolls	159761	-3.70 €
25/5/2024	Tolls	122694	-1.90 €
25/5/2024	Tolls	208802	-2.30 €
25/5/2024	Tolls	809945	-2.70 €
25/5/2024	Tolls	940668	-4.30 €
25/5/2024	Tolls	704631	-2.40 €
25/5/2024	Tolls	487908	-3.40 €
25/5/2024	fuel	141225	-87.05 €



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25/5/2024	fuel	141226	-20.00 €
25/5/2024	Subsistence	40060002	-3.90 €
25/5/2024	Subsistence	453471	-3.90 €
25/5/2024	Subsistence	69442	-12.10 €
25/5/2024	Bus Tickets	253929	-17.20 €
26/5/2024	Subsistence	450001	-2.10 €
31/5/2024	Consumables	4617	-28.23 €
28/6/2024	Consumables	1474	-20.00 €
1/7/2024	Aeroimages Poros Methana from ktimatologio	5148	-34.22 €
22/8/2024	Boat maintenance	00035	-620.00 €
19/9/2024	Satelite images	12	-2,926.40 €
28/11/2024	Satelite images κτηματολόγιο	9217	-22.82 €
28/11/2024	Satelite images κτηματολόγιο	9218	-11.41 €
29/11/2024	External partner mapping	9	-3,500.00 €
May-Aug	Project management and fieldwork		-3,341.09 €
Sept-Dec	Project management and fieldwork		-1,559.01 €
May-Aug	Accounting		-349.17 €
Sept-Dec	Accounting		-320.29 €
May-Aug	Administrative costs		-296.55 €
Sept-Dec	Administrative costs		-403.30 €
May-Aug	Graphic designer		-297.65 €
Sept-Dec	Graphic designer		-192.60 €
May-Aug	Overheads		-787.08 €
Sept-Dec	Overheads		-787.08 €
TOTAL			-€ 17,373.94



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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

Appendix 2: Sample infographics (posters and brochures) for Poros and Methana Posidonia Distribution mapping and evaluation of threats.





ENVIRONMENTAL ORGANISATION FOR THE PRESERVATION OF THE AQUATIC ECOSYSTEMS





ENVIRONMENTAL ORGANISATION FOR THE PRESERVATION OF THE AQUATIC ECOSYSTEMS

Appendix 3: Layman's report on Posidonia in association with the POAY zones in Methana for the municipality of Methana and community of Krasopanagia.





iSea, 2024