Mapping of seagrass meadows in the Argolic Gulf in association with aquaculture development areas

Final report

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Baseline information

Seagrass

Seagrasses are a group of marine flowering plants with a distribution in the shallow coastal zone, found globally apart from Antarctica [1]. They play an important role in marine environments, as one of the most productive systems [2] supporting high biodiversity [3]. Healthy seagrass meadows provide important ecosystem services for humans, among these the stabilization of sediments [4], carbon sequestration and storage, contributing to climate change mitigation [5,6]. Despite their value, these important habitats have been increasingly impacted by human activities and climate change, which has brought about their recognised degradation globally [7]. In the Mediterranean Sea, a total of seven seagrass species are found [11]. The endemic species ***Posidonia oceanica*** (Linnaeus) Delile 1813 and the native species ***Cymodocea nodosa*** (Ucria) Ascherson, 1870 [9] are characteristic of the region. Among native species, a number of invasive species have been introduced, including ***Halophila stipulacea*** (Forskål) Ascherson 1869 [10]. According to Panayotidis et al. (2022) [11], in the Greek coastal waters, the species with the most extensive distribution is Posidonia. The species is characterised by its slow growth and the formation of extensive meadows [12]. *Cymodocea nodosa* has a higher growth rate with a lower life span than Posidonia [13], forming meadows with a more sparse distribution [14]. Cymodocea is known to colonize areas where the conditions are not beneficial for Posidonia growth, such as delta systems, brackish waters, and areas influenced by freshwater input and lower turbidity [15].

Posidonia oceanica and *Cymodocea nodosa*, are included in the European Union's Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats, and of wild fauna and flora. Specifically, they are listed in Annex I as natural habitat types of community interest whose conservation requires the designation of Special Areas of Conservation (SACs). *Posidonia oceanica* corresponds to habitat type 1120 ("Posidonia beds"), constituting a priority habitat, while *Cymodocea nodosa* corresponds to habitat type 1110 ("Sandbanks permanently covered by seawater of shallow depth").

Moreover, these species, being considered important angiosperm species, are included within the frameworks of the Water Framework Directive 2000/60/EC and the Marine Strategy Framework Directive 2008/56/EC through which the Good Ecological Status (GES) of all European Union marine waters is promoted, and they serve as indicators of health and good environmental conditions. These two seagrass species are protected by the Barcelona Convention (Annex II; List of the endangered or threatened species) and the Bern Convention (Appendix 1; Strictly protected flora species). Additionally, the EU Regulation (1967/2006/EC) regarding the management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, prohibits fishing with dynamic gears (trawls, dredges, beach trawls, etc.) on vegetated bottoms, especially those with *P. oceanica* or other marine phanerogams.

Furthermore, of particular importance is Regulation 2024/1991/EU on nature restoration, which aims at the long-term and sustainable recovery of biodiversity and ecosystem resilience through the restoration of degraded ecosystems. Notably, it obliges Member States to establish restoration measures for the marine habitats of species. Both are included in Annex II (Marine Ecosystems — Habitat Types and Groups of Habitat Types referred to in Article 5, paragraphs 1 and 2) of the aforementioned Regulation. In addition to international commitments and directives, Greece has enacted several national laws regulating human activities (e.g., fishing, aquaculture) over *Posidonia oceanica* meadows, such as Law 3937/2011 on the Conservation of Biodiversity, Natura 2000 Networks, and Urban Planning.

The Argolic Gulf

The Argolic Gulf is situated in the eastern Peloponnese, between the mainland of Peloponnese and the Argolic Peninsula, connected with the Aegean Sea [18]. A lot of river outlets end in the gulf [19] while its deepest point reaches over 700 m, located at the centre of the gulf, while depths over 500m occur following the morphology of the gulf in the NW and SE direction [20]. There is an absence of site-specific oceanographic information for the Gulf. Tsapakis et al. (2022) [22] created prediction models mainly presenting the conditions of the eastern side of the Gulf. Additionally, a detailed mapping of the habitats found has not been conducted. The western shore of the Argolic basin is characterised by steep slopes and drops, occasionally interrupted by soft bottom substrates (beaches) at outlets of torrents that flow through deep valleys, where the eastern shore is composed of cliffs, extensive soft bottom substrates (beaches), inlets of large bays, and small islands [18]. In the soft substrates of the Gulf, occasionally seagrass species distribution is found with an increase in the SE part towards the outer Gulf [21, 23]. Semi-submerged and submerged caves have also been observed, while there is a slight possibility of rhodolith bed occurrence [22]. In the terrestrial part surrounding the Argolic, three areas fall under the designation of a Natura2000 site (GR2510003, GR2520003, GR2520005), as well as the wider protected area of Mount Parnonas and Moustos Wetland that includes the coastal areas of Moustos Wetland, and from Akra Bornias to the southern border of the Regional Unit of Arcadia. The eastern side of the Lakonia Mountains is also recognised as an Important Bird Area (IBA). The Central Aegean Important Marine Mammal Area (IMMA) also extends from Ag. Nikolaos (Porto Heli) across the central Aegean, while from Livadi (Tyros) to western Crete lies the Myrtoon Sea Area of Interest for future IMMA [24]. The region is a known tourist hotspot considering its short distance from the country's capital, Athens, and presence of key archaeological sites (Epidavros Theatre, Mycenae, Nafplio) as well as the popular islands Spetses and Hydra. This high tourism activity poses threats for the marine environment and seagrass meadows, among which are pollution (discharges, litter) and mechanical damage (uncontrolled anchorage; coastal development). Aside from these pressures, several aquaculture facilities are currently active in this area, while plans to expand their number and production is foreseen.

POAY in the Argolic

Within the Argolic gulf, one proposed POAY (type PAY A) can be found. POAY Arcadia (Kynouria), Argolis (Korakia, Vourlia, Plateia), Methana proposes a **4.5-time increase in production** (from 7,496 to 32,340 tonnes) and a **35-time increase in area** (from 70.2 ha to 2,489.3 ha) [35]. The POAY proposal was based on data collected and analysed in 2015 and uploaded for public consultation on the 24/07/2023, but has not yet been established to date. A critical evaluation of the EIA was completed [36] and reports a number of weaknesses, amongst which the mapping of seagrass habitats was identified as a key gap.

Considering this, a total of **5 areas** were selected for seagrass mapping in the Argolic Gulf (Figure 1), including Kynouria region (Area of Interest, AoI 1), Bournias Cape (AoI 2), southern of Cape Thyni (AoI 3), Vourlias bay (AoI 4), and Plateia island (AoI 5).

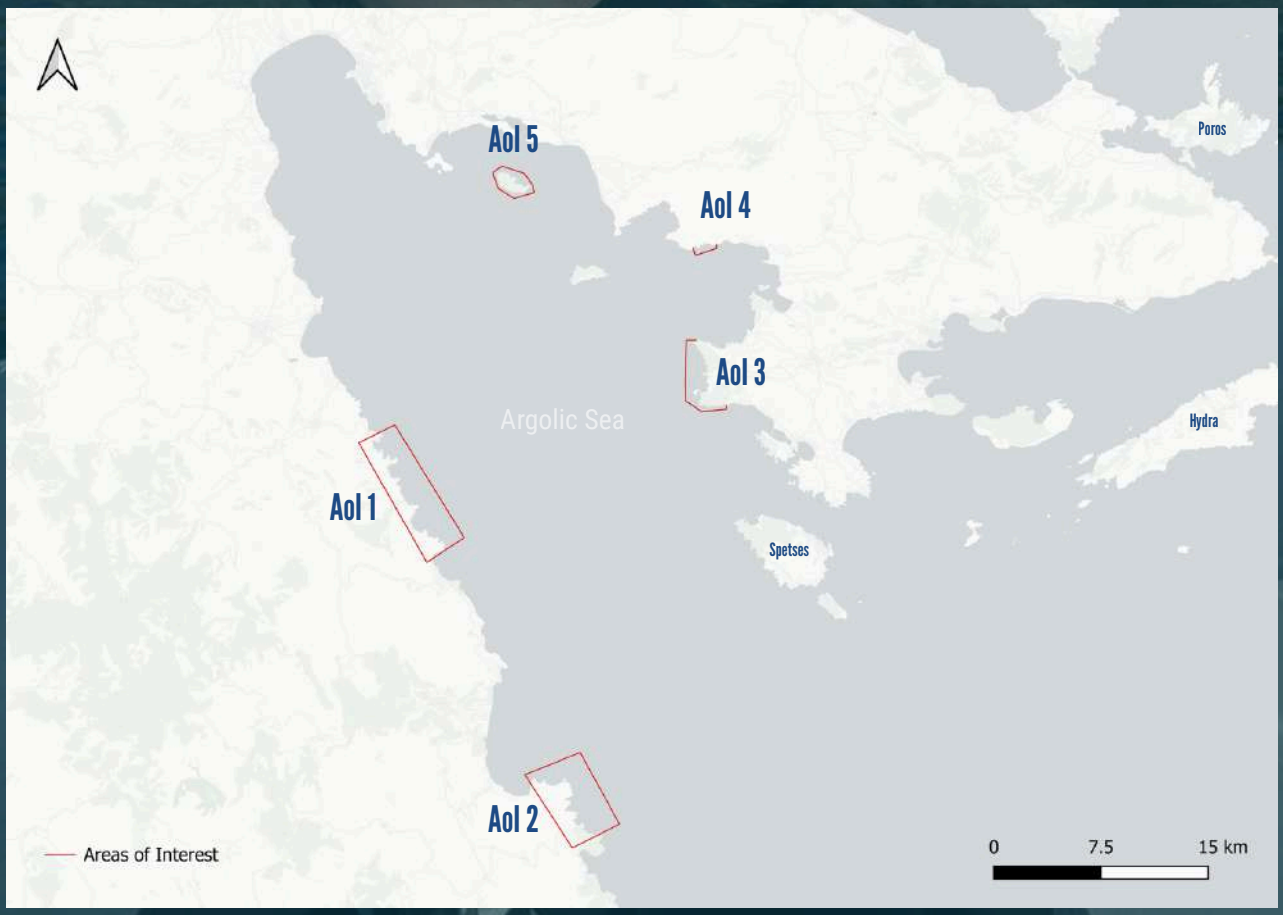


***Figure 1**. Visualization of the five Areas of Interest (AoI) in the Argolic Gulf.*

Proposed actions

iSea started working in the Argosaronic region in 2022 focusing on Posidonia mapping in Spetses and Spetsopoula [5], while the following year, the mapping of Hydra Island was carried out [6]. In 2024, the focus area was extended to include Poros and Methana [7]. The same actions were implemented to map Posidonia's distribution, while additionally given the areas association to aquaculture operation, the Posidonia's historical presence near aquaculture facilities was also investigated along with an approximation of the future threatened meadows given the expansion proposal (POAY) [7].

This year, the project intend to contribute to increase the knowledge on seagrasses' extent in the Argolic Gulf, specifically in association with aquaculture operation areas. More specifically, aims to:

1. Identify the species-specific distribution of seagrasses in aquaculture zones
2. Exploring evidence of the historic distribution of seagrass in existing aquaculture zones in the Argolic
3. Assessing the extent of threatened seagrass in existing and proposed aquaculture zones in the Argolic

A1. Habitat groundtruthing points

For the mapping of seagrass species, it is important to acquire ground-truthing data of the actual habitat types that represent the area. These points are GPS points with the note of the habitat type observed in that exact location. This data will be used for training classification of the pixels of the satellite image in habitat types, as well as for validation points of the actual habitat. For each validation point, coordinates are taken using a GPS device (Garmin 22x) with a minimum accuracy of 3m. To ensure accuracy of the classification due to GPS's accuracy, each habitat recorded was covering approximately $9m^2$. All points taken were transferred to a CSV file and then were transformed into a vector layer using ArcMap (10.8 version). All activities were planned, consulting expert advice to identify expected areas of seagrass considering:

1) national level mapping of seagrasses in the Greek seas (Panayotidis et al., 2022)
2) bathymetry
3) available satellite imagery from Google Earth
4) local ecological knowledge reports on presence of seagrasses

In order to collect this data, iSea conducted a preliminary mapping of areas of interest using free source satellite images from Google Earth in accordance with the isobaths, to identify the specific sites needing validation. The validation points were collected through visual confirmation from circumnavigation with a boat, and snorkelling/apnea up to a maximum of 15m (Figure 2). No scuba diving was performed, as the deep limit detection was completed using apnoea.

Based on the compilation of the sites, a total of 243 points were identified for verification across all five areas (Figure 2), with 69 points in and near the aol 1, 9 in Aol 2, 81 in Aol 3, 33 in Aol 4 and 51 in Aol 5.

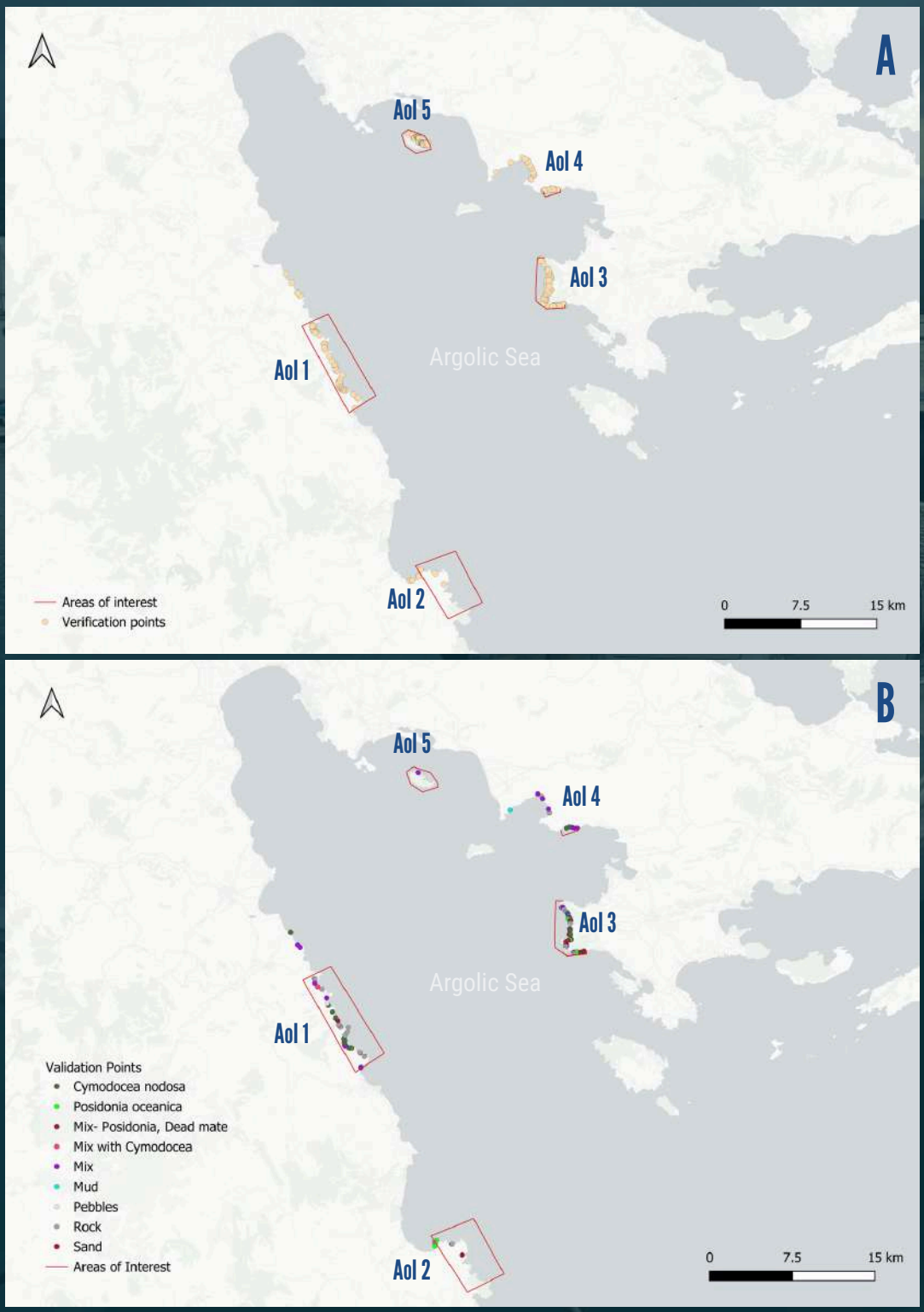


Figure 2. *For all the AoI's: (A) verification points in relation with the AoI's and (B) validation points collected in relation with the AoI's.*

Table 1. Overview of the validation points collected. *Mix habitat* refers to a combination of non-seagrass habitats.

Habitat	Mix	Rock	Cymodocea	Sand	Posidonia	Pebbles	Mix with Cymodocea	Mud	Mix Posidonia, dead matte
N points	44	40	30	28	19	8	6	5	1

iSea team carried out the fieldwork activities from 05/11 to 9/11 under the research permit Prot. No: ΥΠΕΝ/ΔΠΔ/26906/1818; ΑΔΑ: ΨΩΝ64653Π8-ΞΔΧ, during which a number of **206 validation points** were taken (Figure 3). Out of these, 25 points were recorded for depth observation. The remaining 181 points are presented in Table 1. The identification of most habitats was conducted using apnoea, as the visibility in the area was poor. The identification from the boat could be performed only to less than 10 meters and in some locations less than 5 meters.

Most of the habitat types were classified as mixed, with 44 points taken. The mixed habitat was combinations of rock, sand, mud and pebbles. Following was the rocky substrate with 40 points recorded. Additional habitat types included 28 points of sand, 8 points of pebbles and 5 points of mud.

Regarding the seagrass species observed, the surveyed areas were **mainly** consisted of ***Cymodocea nodosa*** meadows, accounting for 30 points. *Posidonia oceanica* was largely absent in most locations while it was found only in the southern areas (AoI 2, AoI 3) where 19 points were recorded mainly indicating patchy formations.

Figure 3. *Collection of validation points from the boat using a bottom scope (A,B) and apnoea (C).*

AoI 1- Arkadiko Chorio to Cape Trikeri

AoI 1, includes the **PAY areas A4.1 and A4.2** and corresponds to the area extending from Cape Trikeri (37°15'33.86"N 22°51'16.46"E) until Avlaki beach (37°22'30.32"N 22°47'09.08"E), where a total of 72 validation points were recorded (Figure 4). The majority of the coastline here was characterised by rocky shores and steep cliffs. Of these, 17 points were indicating ***C. nodosa*** with additional 4 points representing mixed habitats with Cymodocea. Further, 34 points corresponded to rocky, sandy, pebble, or mixed substrates of these, while 17 points were taken for depth clarification.

Within this area, the **seagrass species** observed was **Cymodocea**, with a total **absence of Posidonia** traces. Considering the oceanographic characteristics of the site and freshwater input, it followed the prediction by Topouzelis et al. (2018) [24] and Panayotidis et al. (2022) [23]. Cymodocea was found sporadically in the entire area, not in a good state, but forming meadows, was confirmed at the location of Zaritsi beach, characterised by a sparse distribution, especially near the coastline, and often mixed with other habitat types (sand, pebbles, macro algae, *Halophila stipulacea*). Also, outside AoI 1, the distribution of Cymodocea meadow was observed near the beach of Agios Andreas, where the freshwater input source is located. Other habitats observed were sandy-soft substrates, rocky substrates and pebbles, while there was a mix of these surfaces.

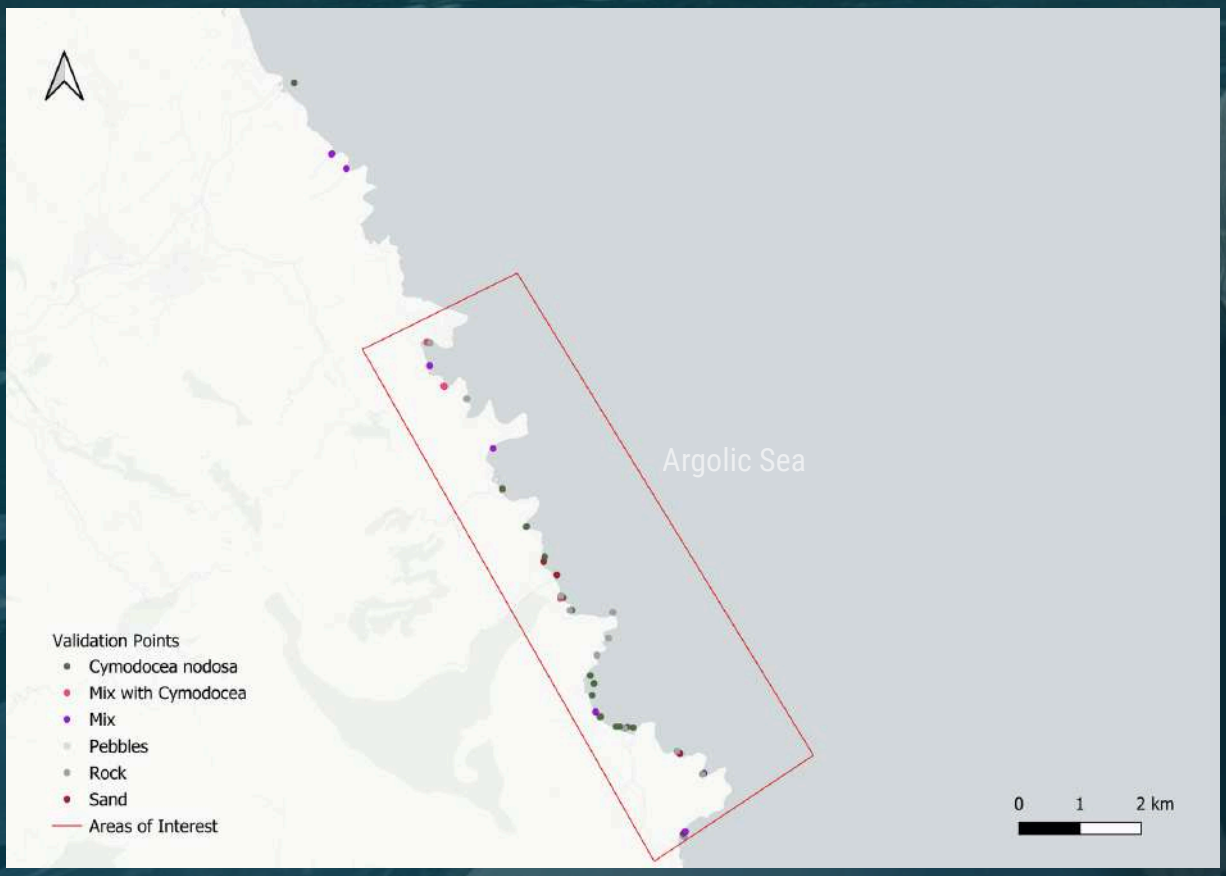


Figure 4. *Habitat classification points in AoI 1.*

AoI 2- Cape Bournias to Cape Fokiano

AoI 2, relates to the remaining area **PAY A4.2** and refers to the area extending from Cape Bournias to Cape Fokiano (37°07'00.83"N 22°55'37.24"E to 37°05'04.63"N 22°59'05.42"E), where a total of 25 points were recorded (Figure 5). Of these, 6 points were indicating the presence of **Posidonia** as a meadow or patches. 11 points corresponded to rocky or sandy habitats, while the remaining 8 points were taken for depth clarification. **Posidonia** was observed but limited to the north limit of the AoI (Figure 5). The remaining area was predominantly characterised by deep waters and steep drops, where seagrass species are unable to grow and establish. Other habitats observed were sandy-soft substrates and rocky surfaces.

Figure 5. *Habitat classification points in the AoI 2.*

AoI 3- Southern of Cape Thyni

AoI 3, relates to **PAY area A5** and refers to the southern area of Cape Thyni, extending from 37°23'34.83"N 23°03'52.16"E to 37°21'05.00"N 23°05'18.20"E, where a total of 90 points were recorded (Figure 6). The increased number of points was necessary in order to ensure that the points taken would be accurate for the prediction model, as the satellite images showed an unclear habitat separation. Regarding seagrass species, 13 points indicated **Posidonia presence** and 1 point showed Posidonia mixed with dead matte while 9 points corresponded to **Cymodocea** and 2 points represented Cymodocea mixed with other non seagrass habitats. All the remaining points were other habitats observed, more specifically soft substrates like sandy and muddy, rocky surfaces and pebbles. Additionally, a mix of these habitats was recorded.

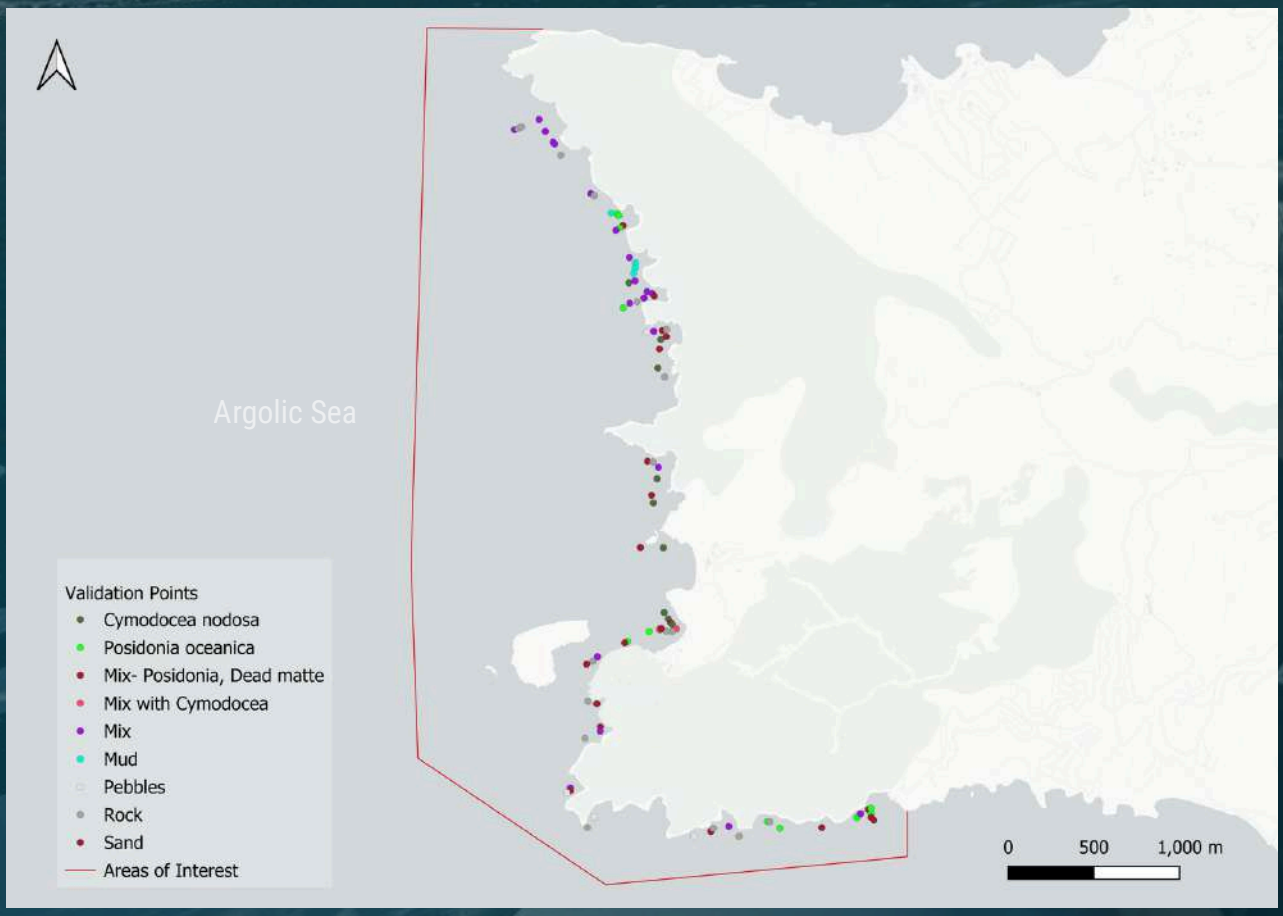


Figure 6. *Habitat classification points in AoI 3.*

AoI 4- Adjacent to Vourlias bay

AoI 4 relates to the northern **PAY area A5** and refers to the area south of Vourlias bay (37°27'02.87"N 23°03'55.07"E to 37°27'09.09"N 23°04'59.60"E), where a total of 18 validation points were taken within and adjacent to the areas of interest (Figure 7). Regarding **seagrass species** observed, 4 points indicated **Cymodocea**, forming meadows or patchy distributions, while the remaining points were associated other habitats (the majority of the observations) like soft substrates (sand and mud), rocky surfaces, and mix of these. Cymodocea was only found within the limits of the AoI, and not in the nearby bay.

Figure 7. *Habitat classification points in AoI 4.*

AoI 5- Plateia Island

The AoI 5 includes the **PAY A6** area, and refers to Plateia Island (37°29'37.59"N 22°55'18.56"E). It was not fully explored due to the proximity of the cages to the coast, where the sites for verification, and for safety precautions. In this area, only one point was taken, representing sandy and muddy substrate, while rocky substrate was observed shallower of the taken point (Figure 8).

Figure 8. *Habitat classification points in AoI 4.*

A2. Seagrass habitat mapping

Seagrass habitat mapping

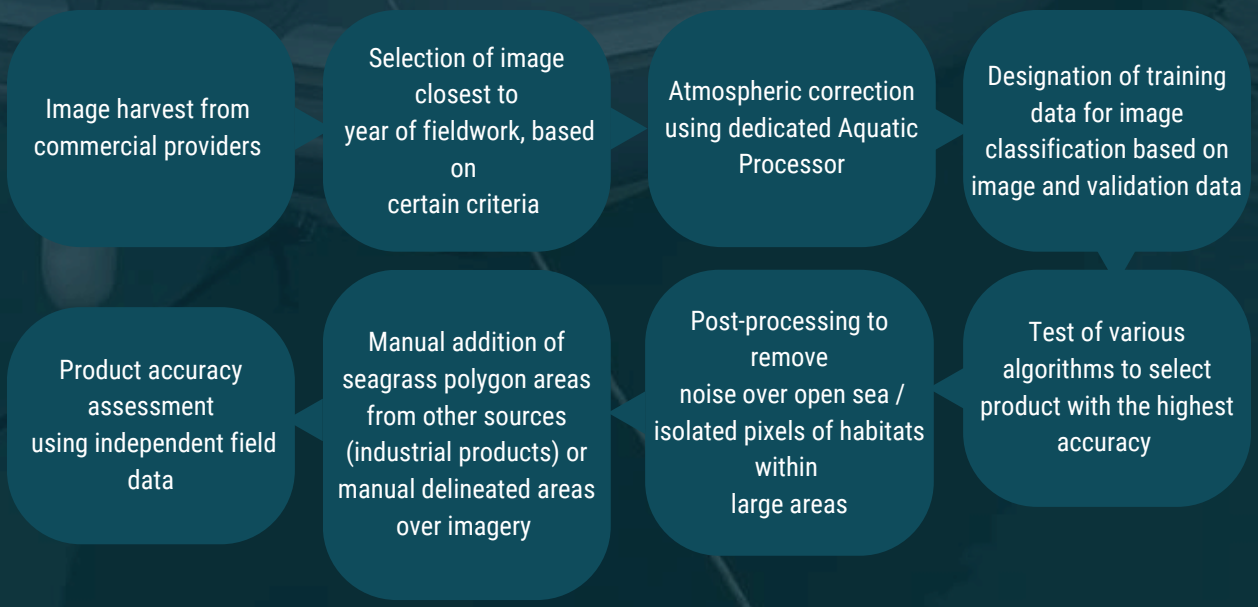
Habitat mapping is the process of identifying, classifying, and spatially delineating on a map where habitats occur and what type they are. For seagrass meadows, it combines **field validation data** (mentioned above) with **high resolution satellite** or drone images. It can also include acoustic surveys (sonar, multibeam) for deeper areas, which results in near 100% accuracy but comes however at a higher cost. Bathymetry data is also taken into account to improve accuracy. However, seagrass mapping using satellite imagery is difficult or impossible in deep water (where light doesn't reach), very turbid or muddy waters, rough sea conditions, under clouds, or where seagrass is very sparse or mixed with algae or rock, because these factors reduce detection accuracy and can cause overestimation or underestimation of seagrass area. Considering this, there are a number of criteria sites need to meet in order to allow for seagrass mapping with high accuracy (over 80%) when using satellite image and field data. The product validation was based on the point-based dataset (ground truthing points), collected by iSea during November 2025. A radius of 5m was used to compensate for the GPS accuracy. According to the current work, the meadows cover an area of 0.182 km^2 (18.21 hectares) for AoI 2, AoI 3 and AoI 4, with an overall accuracy of the final products as 91%.

Criteria to meet eligibility for accurate habitat mapping

- available high-resolution imagery
- absence of sun glint/reflection, waves, sedimentation, shadows in imagery
- a good pool of field validation points and deep limit points (the deepest part of the meadow)
- dense seagrass meadows (non-mix habitats)
- seagrass species of *Posidonia oceanica* (Cymodocea harder to map due to natural sparsity)

ANALYSIS WORKFLOW

Developed methodology for seagrass mapping

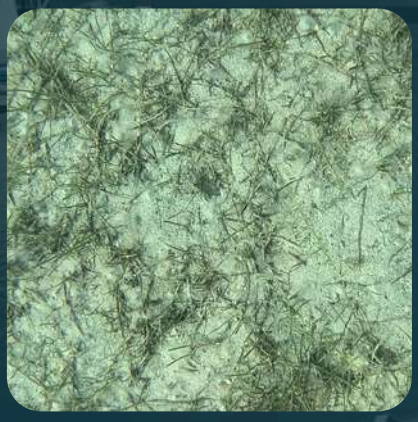


AoI 1- Arkadiko Chorio to Cape Trikeri

Considering the results presented in the previous section, along with the absence of high-resolution satellite imagery for AoI 1, seagrass habitat mapping and seagrass surface area calculation could not be completed. At the Agios Christoforos (Zaritsi beach) site, an approximate distribution was produced based on the validation points collected in this study, in combination with the previous seagrass mapping efforts of Topouzelis et al. (2018) and Panayotidis et al. (2022). The **possible Cymodocea area** (Figure 9) does not provide an accurate spatial distribution with precise boundaries. It should also be noted that in this bay, Cymodocea was found to be mixed with the invasive species Halophila in some locations as well.

***Figure 9**. Indicative distribution of Cymodocea nodosa (Habitat 1110) in Zaritsi beach without an accurate spatial distribution or precise boundaries.*

In AoI 1, two invasive species were recorded, the yellow spotted puffer fish (Torquigener flavimaculosus) in the bay of Arkadiko Chorio and in the bay of Zaritsi beach, Cymodocea was mixed with the invasive species Halophila stipulacea on the shallow limit, as you can see in the section below (Figure 10). Additionally, evidence of fishing and spearfishing activities was documented in the area.



Zaritsi Beach
37°16'35.4"N 22°50'36.4"E
Cymodocea nodosa

Zaritsi Beach
37°16'35.4"N 22°50'36.4"E
Cymodocea nodosa, Halophila stipulacea

Near Arkadiko Chorio
37°19'37.9"N 22°48'43.7"E
Sparse *Cymodocea nodosa*
on muddy substrate

Near Arkadiko Chorio
37°16'35.4"N 22°50'36.4"E
Muddy substrate

Arkadiko Chorio
37°20'01.3"N 22°48'32.7"E
Very sparse *Cymodocea nodosa*

Arkadiko Chorio
37°20'01.3"N 22°48'32.7"E
Torquigener flavimaculosus

Figure 10. *Invasive species and habitat of different sites of the AoI 1.*

AoI 2- Cape Bournias to Cape Fokiano

For the mapping of Posidonia in AoI 2, multiple satellite sources were used, and hand delineation was applied due to the absence of high-resolution satellite imagery and wave action, clouds, sedimentation, and terrestrial shadow effect, attributed to the oceanographic and geographic characteristics of the study area. The total area of **Posidonia** calculated was **3.13 ha**, where the 0.13 ha falls within the limits of the POAY (Figure 11).

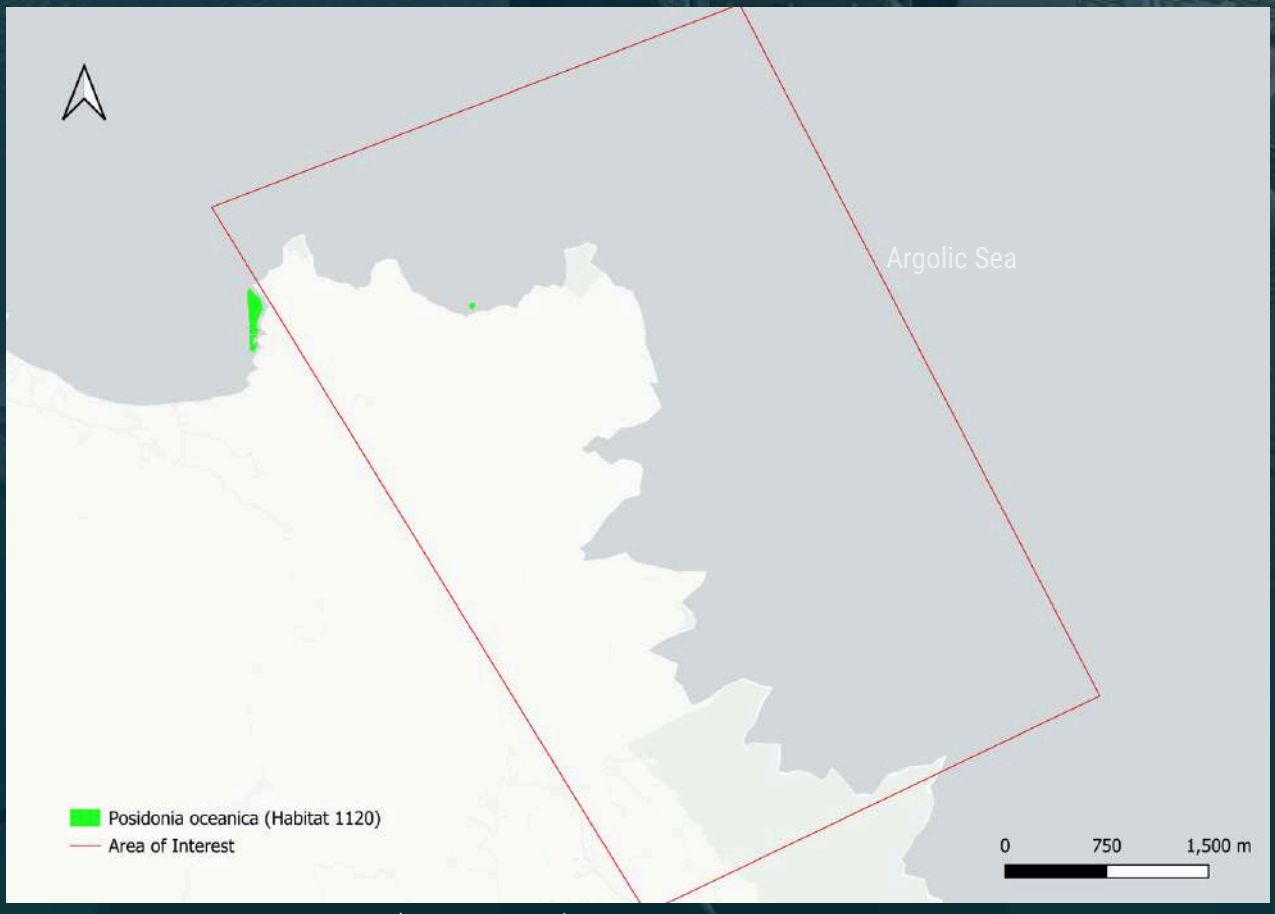


***Figure 11**. Posidonia oceanica (Habitat 1120) distribution in AoI 2.*

AoI 3- Southern of Cape Thyni

For the mapping of AoI 3, high-resolution satellite imagery (13/12/2024, image ID: 10300500F9F8B900) along with manual delineation was completed due to some areas without bottom reflectance information affected by wave action, clouds, sedimentation, and terrestrial shadow effect. The total area of **Posidonia** mapped was **13.61 ha** (Figure 12). The Cymodocea presence couldn't be mapped due to the natural sparse distribution of this seagrass, making it difficult to be portrayed within limits.

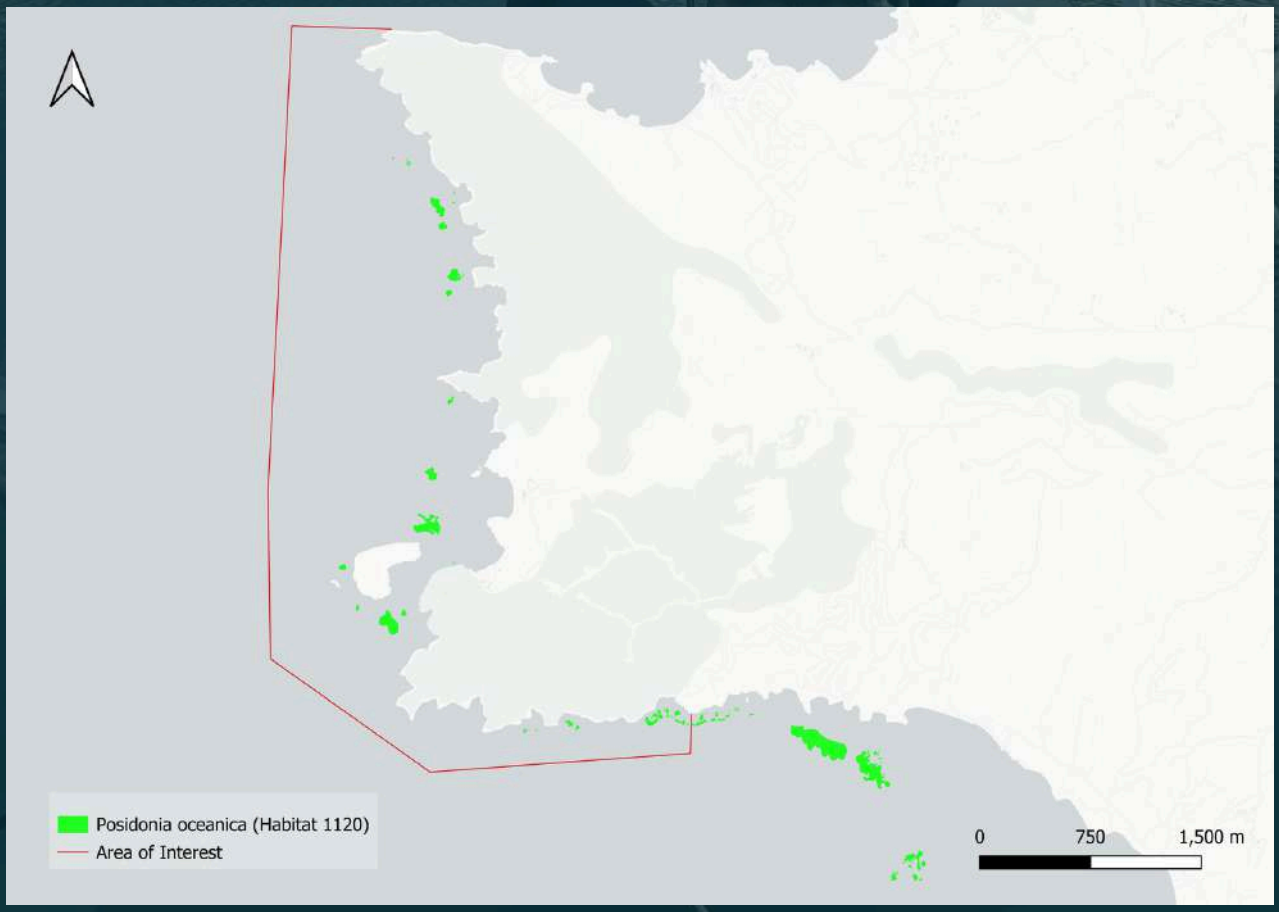


***Figure 12**. Posidonia oceanica (Habitat 1120) distribution in AoI 3.*

Aol 4- Adjacent to Vourlias bay

Considering the results of the validation points, seagrass was only mapped in the south-eastern limit of the study area. For the mapping of seagrass in the Aol 3, aerial imagery (orthophotography) was captured using a drone on 8/11/2026, and some recent satellite sources were used for the analysis; due to the absence of high-resolution satellite imagery and wave action, clouds, sedimentation, and terrestrial shadow effect. The total area of **Cymodocea** calculated was **1.55 ha** (Figure 13).

***Figure 13**. Cymodocea nodosa (Habitat 1110) distribution in Aol 4.*

AoI 5- Plateia Island

Considering the national-level mapping from Panayotidis et al. [11], there is no seagrass meadow found on the island. Despite this, evidence from LEK and open source sattelite imagery suggests the existence of patchy Cymodocea meadows. No high-accuracy seagrass mapping was completed here due to the lack of field validation points and the lack of high-resolution satellite imagery for the location. Instead, an **approximate seagrass covered area** (~0.45 ha) was estimated (at an unknown seagrass density) considering Google Earth imagery of 19/01/2024 (Figure 14).

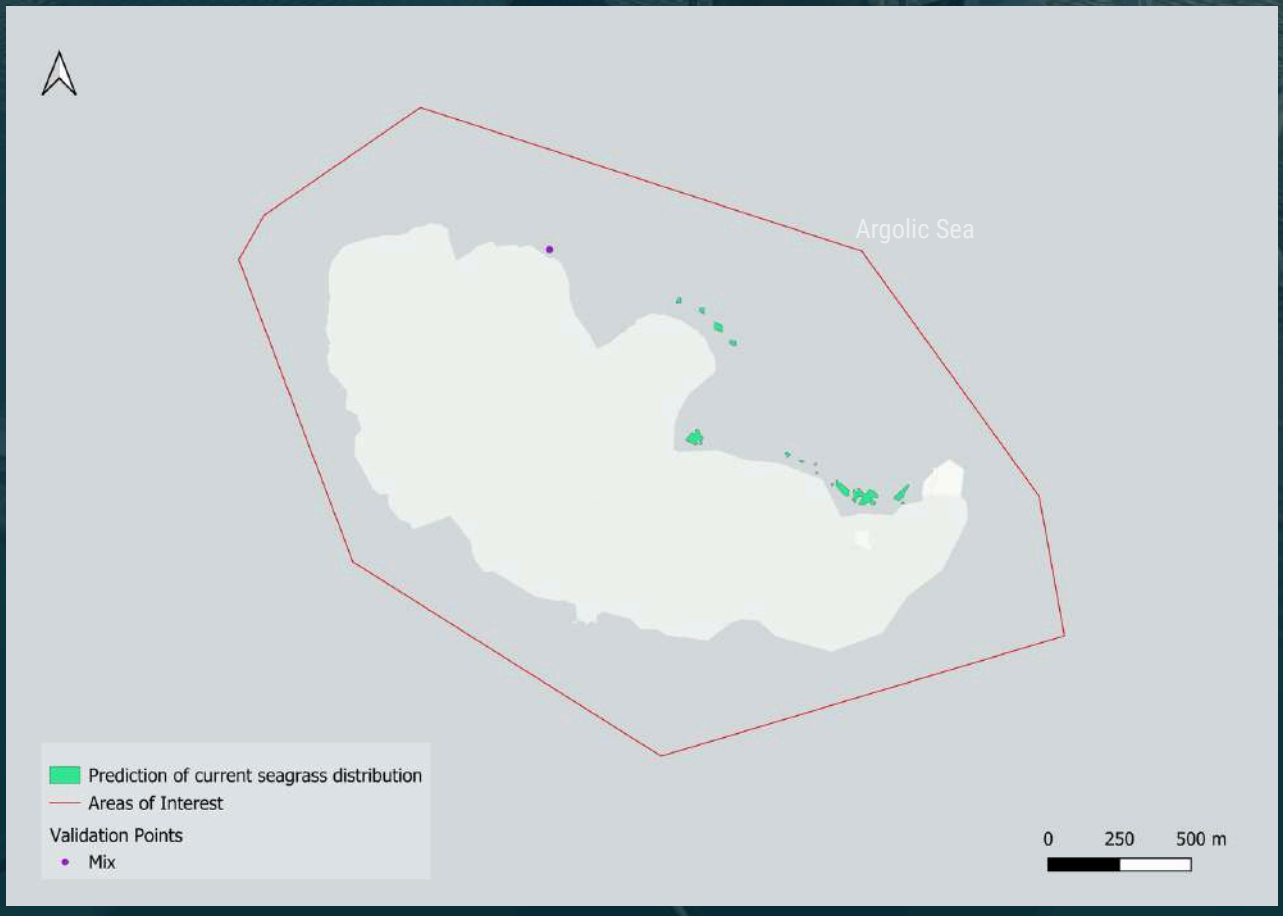


Figure 14. *Current approximate seagrass covered areas at AoI 5 from Google Satellite imagery from 2024.*

A3. Seagrass distribution in POAY

The association of **seagrass meadows** with **aquaculture facilities** is discussed in the context of the possible current and future impacts on the meadows, considering their **distance to operating** and proposed facilities. The availability of studies on the impacts of aquaculture on seagrass species in the Mediterranean differs between species, with more available for Posidonia meadows and limited for Cymodocea.

Regarding **Posidonia meadows**, there is a suggested distance of more than 400m from any new aquaculture facility from Posidonia meadows (following the recommendations produced from the MedVeg European project) [26]. However, according to Karakassis et al. (2013) [27], 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 [35] refers to studies on the impacts of aquaculture that report a 150m effect radius. However, studies addressing Posidonia meadows sensitivity show that aquaculture runoff effluents possibly extend to significant distances [28] and have an impact on Posidonia meadows even at a distance of 3km [29].

Cymodocea is generally recognised as resilient (especially to light deprivation); however, it is sensitive to hydrodynamic forces and major disturbances (dredging, water pollution) that can cause extensive damage. There is limited research on the effects of aquaculture on nearby Cymodosea seagrass meadows. *Cymodocea nodosa* has shown degraded growth and mortality 100m from fish-farms [30], while studies undertaken in AoI 4, compared two Cymodocea medows located at 440m and 780m distance from the fish-farms, found that the meadow nearest to the fish farm showed significant evidence of impaired growth and stress-related characteristics [31].

Several studies are showing that the greatest effects of fish-farming on the suspended sections of the water column in the Mediterranean are between 100m and 500m depending on current velocity [32, 33, 34], however, there are no guidelines in place to protect *C. nodosa* from fish farming, unlike the *P. oceanica* which has narrow protection, such as the 400m safety buffer recommendation between fish-cages and seagrass beds [26].

Taking the above into consideration, as well as the cumulative impact of multiple fish farms and the enclosed profile of the bays in our study, three buffer zones were created that extended for **400m (assumed high impact zone), 800m (high and intermediate impact zone)**, and an additional **3km (assumed total effect zone for areas with Posidonia meadows)** from the existing and proposed aquaculture facilities. The seagrass meadows present in each buffer zone are calculated and reported per AoI.

AoI 1- Arkadiko Chorio to Cape Trikeri

Regarding the presence of seagrass species in relation to the proposed aquaculture operation areas, it is evident that Cymodocea is found within the POAY limits (Figure 15). Considering the buffer zones, in the 400m buffer zone, no seagrass point or meadow is observed. However, the **800m buffer zone** includes two sites (37°16'39.3"N 22°50'28.0"E; 37°19'37.9"N 22°48'43.7"E) with **live Cymodocea**. Among the spots where Cymodocea was observed near facilities (current or proposed), the distance ranged between 0.5km and 2km.

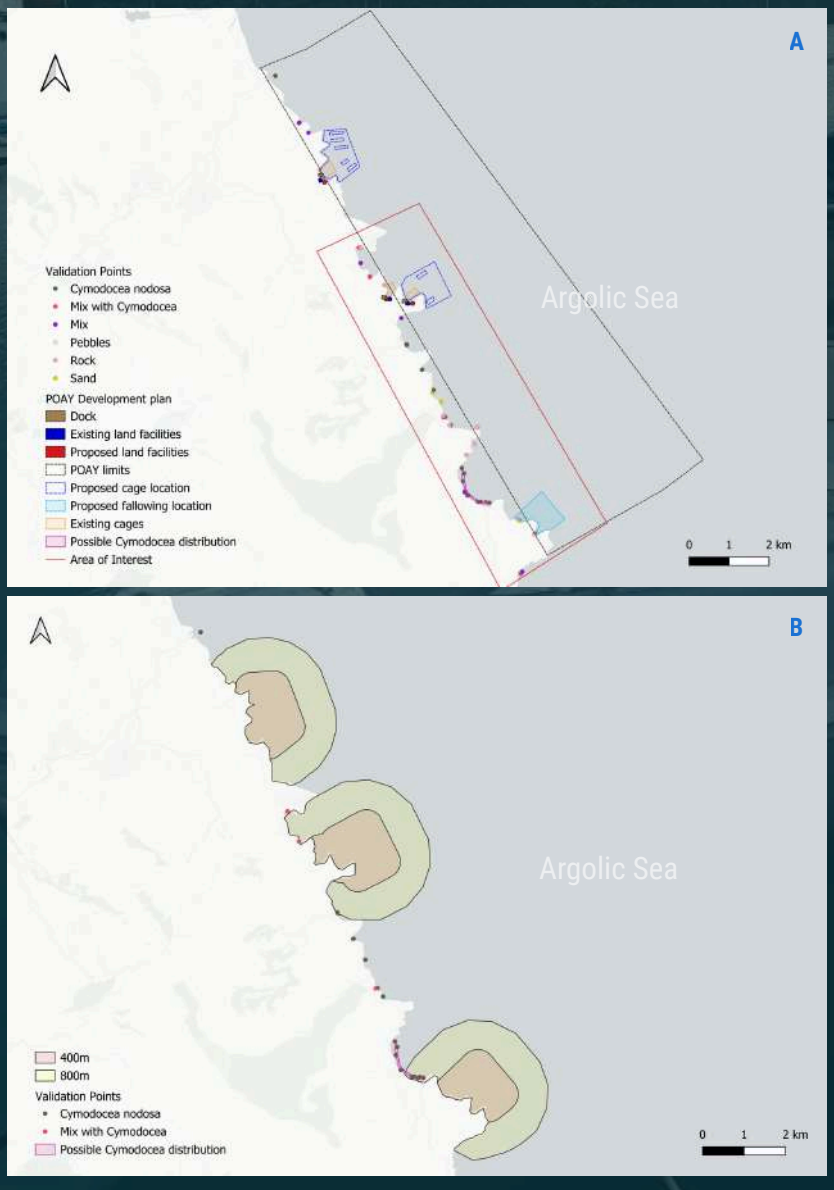


***Figure 15**. Resulting habitat classification points and aquaculture development plans (A) the impact (buffer) zones (B) of the proposed facilities in AoI 1 and beyond.*

AoI 2- Cape Bournias to Cape Fokiano

Based on the buffer zones of **400m, 0.13 ha of Posidonia** would be impacted, while in the 800m buffer, there was no presence of any seagrass species. A total of **3.13 ha of Posidonia** lies within the **3km zone**, however the level of impact would **highly depend on oceanographic conditions**, and is expected to be minimal due to the geological isolation of the meadow from the aquaculture run-off (Figure 16). Additionally, the Posidonia patch that is found within the limits, is located right in front of proposed facilities (land and cage) were the wastewaters would have a significant impact on the meadows' condition [25].

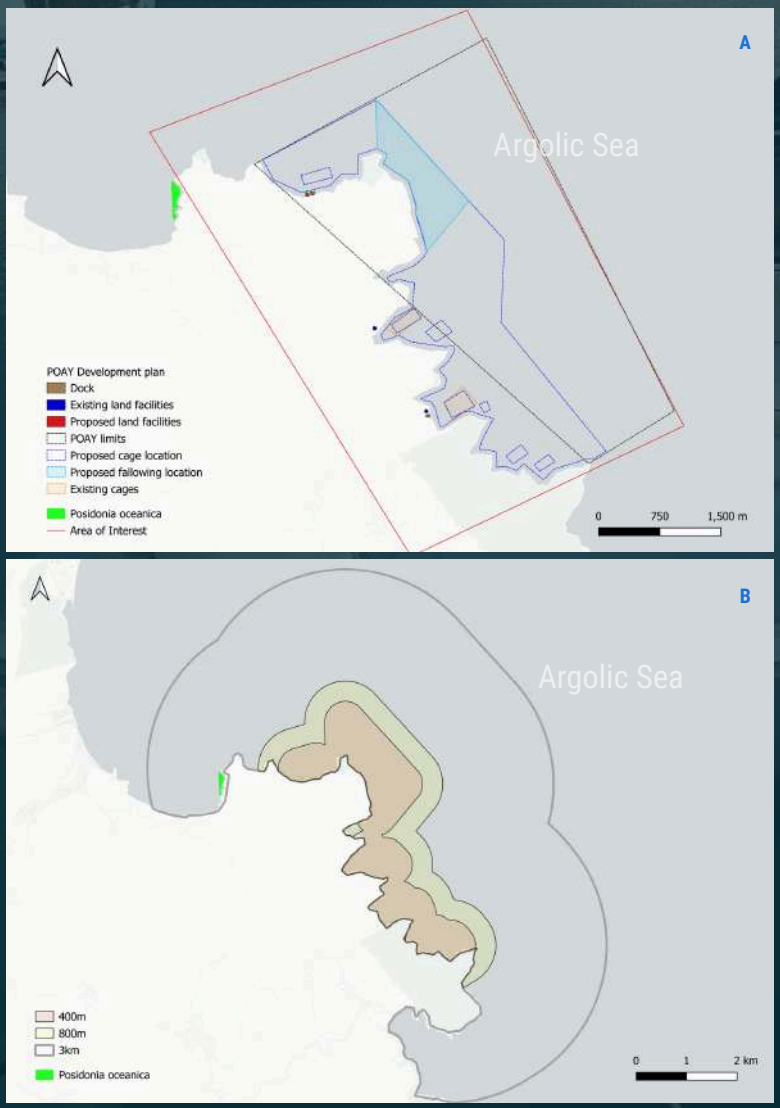


Figure 16. *Resulting habitat classification points and aquaculture development plans (A) the impact (buffer) zones (B) of the proposed facilities in AoI 2 and beyond.*

Aol 3- Southern of Cape Thyni

According to the buffer zones of 400m, the Posidonia patches fall within the limits of the impactful zone of cages, where this distance is also mentioned in the POAY plan as a minimum distance that the facilities must be placed at [35]. The total area that is located within the **400m zone** was **0.11 ha of Posidonia**, while in the **800m 2.89 ha**. Then, considering the **3km** impact range, **13.28 ha** could be affected, indicating some effect on almost all the mapped meadows (Figure 17).

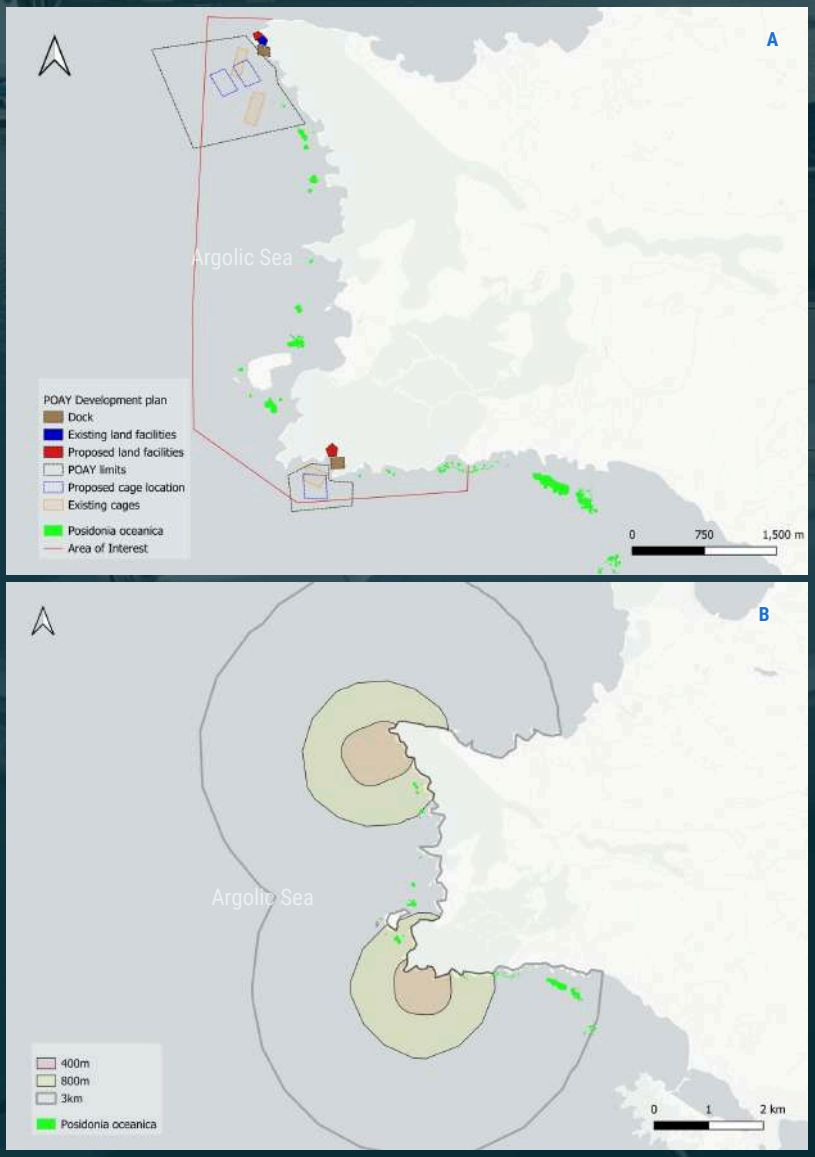


***Figure 17**. Posidonia oceanica (Habitat 1120) distribution in accordance with the development plans (A) and the impact (buffer) zones (B) of the facilities in Aol 3 and beyond.*

AoI 4- Adjacent to Vourlias bay

In Vourlias bay, there is no seagrass species found and based on this study is located outside, on the south-eastern side of the POAY. For this area, within the buffer zones of 400m, there is no presence of the observed seagrass, whereas within the **800m zone,** acting as an intermediate impact zone, almost the entire mapped **Cymodocea**, with **1.48 ha**, is found (Figure 18).

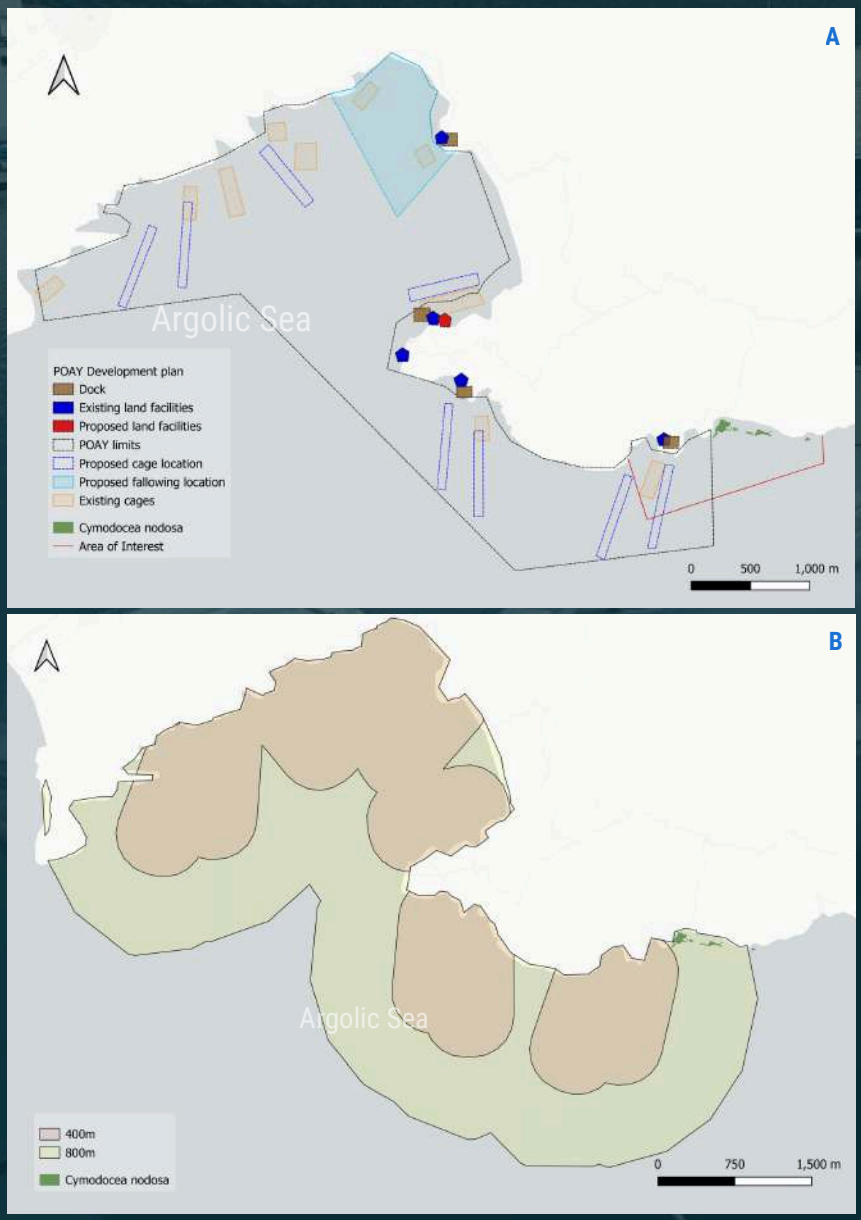


***Figure 18**. Cymodocea nodosa distribution (A) in accordance with the development plans (B) and the impact (buffer) zones of the facilities in AoI 4 and beyond.*

AoI 5- Plateia Island

Based on the approximate seagrass covered area (~0.45 ha) that was estimated (at an unknown seagrass density), the closest visible seagrass area can be seen distanced 200m away from the currently operating facilities. According to the buffer zone of **400m**, **all the possible seagrass** fall within this zone, meaning it is and would be highly impacted (Figure 19).

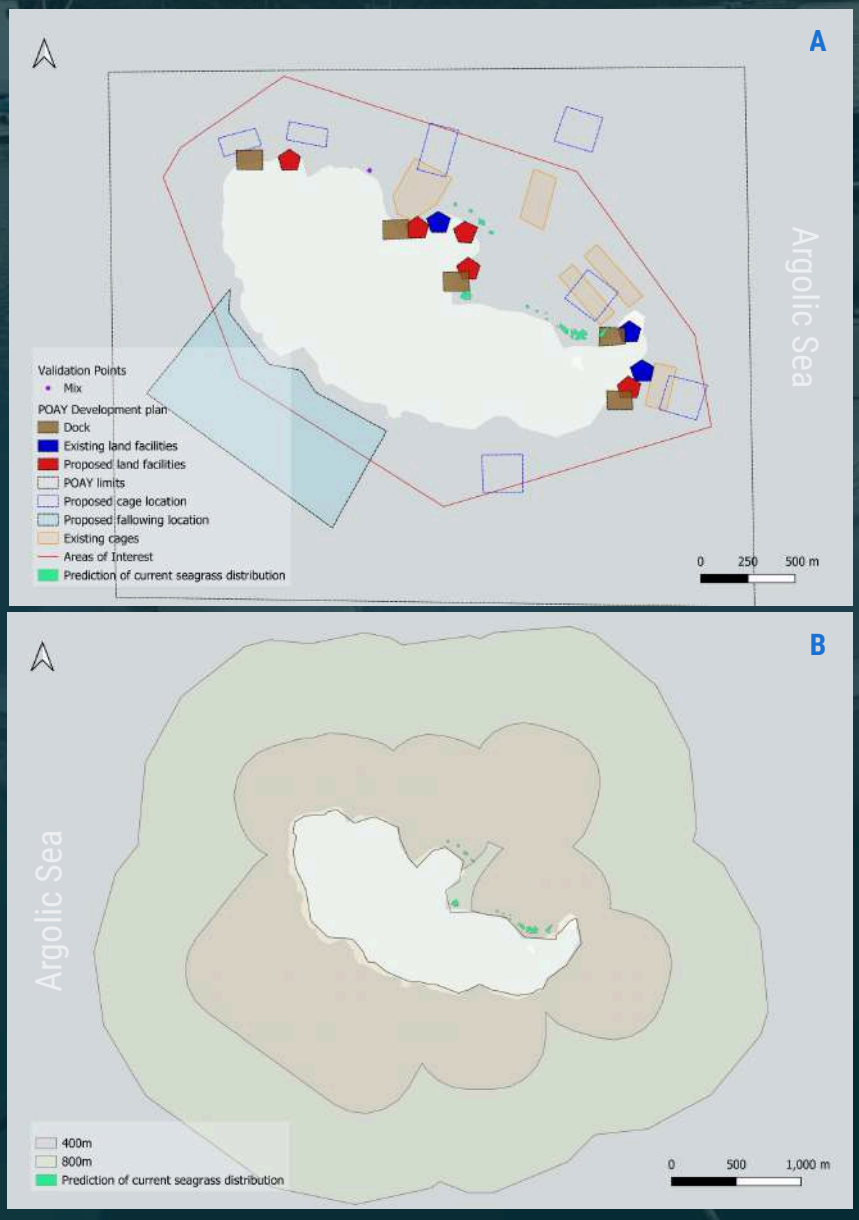


Figure 19. *Possible seagrass distribution (A) in accordance with the development plans (B) and the impact (buffer) zones of the facilities in AoI 4 and beyond.*

B. Past presence/absence of meadows adjacent to the aquaculture facilities

The use of **historical images** and **local ecological knowledge** (LEK), when available, can be utilised to assess the distribution of Posidonia meadows (and other seagrass species) pre-aquaculture establishment. This is the only source of data available for the specific time period (pre-2000's) and although poor in quality, can be combined with field observations and give evidence, and even a rough extent, of shallow seagrass loss due to intensive anthropogenic activities.

Historic aero-photographs from the National Cadastre's archive (https://gis.ktimanet.gr/gis/apr/) were searched, and images for the areas of interest with good coverage, minimal sun glint/reflection and indication of seabed characteristics were obtained. For the analysis, the image was georeferenced in QGIS (version: 3.36.0) and the created vector was reclassified with values representing the darker pixels (seagrass) and cropped to a selected area of interest. The area of interest excluded the locations where seagrass 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 and iv) the image quality. It is important to note that due to this, the analysis does not assess the historic distribution of the meadows in its deeper limits and only gives indication for the visible shallow limits (where the difference of seagrass and deep water start to become unclear). The historic imagery cannot be shared due to the provider's copyright restrictions and so have been removed from the present report but can be shared upon request. Instead the codes of the used images have been provided and can be viewed directly from the providers website. For each of the analysed photograph an estimate area of historic seagrass is presented and compared with current distribution, if present.

The historic aeroimages available on the website National Cadastre's archive were examined for all the five AoI's. Initially, the selection resulted in 150 photos, where only seven of them were actually suitable for the analysis. It must be noted that no aeroimages were found for the AoI 5 (Plateia Island). Upon further examination of seven images purchased, one picture was excluded due to the insufficient quality and only six were used for the analysis, corresponding to the AoI 1, AoI 3 and AoI 4. Moreover, **Google Earth historic imagery** was examined in order to obtain additional suitable images for the historic exploration. The Google Earth images used dated back approximately a decade, and were utilised for the AoI 1 and AoI 5. Unfortunately, no historic imagery could be found in both sources for the AoI 2.

These 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.

AoI 1- Arkadiko Chorio to Cape Trikeri

Within AoI 1, the only area with evidence of the past presence of seagrass meadows and available historic images was **Arkadiko Chorio bay**. Here, two facilities have been operating for at least **two decades**, while LEK indicated the once extensive presence of seagrass in the bay. Two analyses were completed for this site, the first using historic imagery from **1985** (Y_BW_85_181853) that covered three bays, while the second image derived from Google Earth Imagery (**2017**) and only focused in Arkadiko Chorio bay.

Currently, the seagrass meadow, once present, is likely completely vanished. Validation points confirm some presence of poor Cymodocea shoots, very sparse, and with the substrate mainly covered with mud. Considering the almost complete lack of live seagrass meadows in all three bays, it is likely that this could be the result of the operating aquaculture facility distanced 1.2km away from the historic meadow. The historic extent of seagrass was estimated as **0.31 ha** (Figure 20D, based on 1985 imagery) and **0.92 ha** (Figure 20E, based on 2017 imagery).

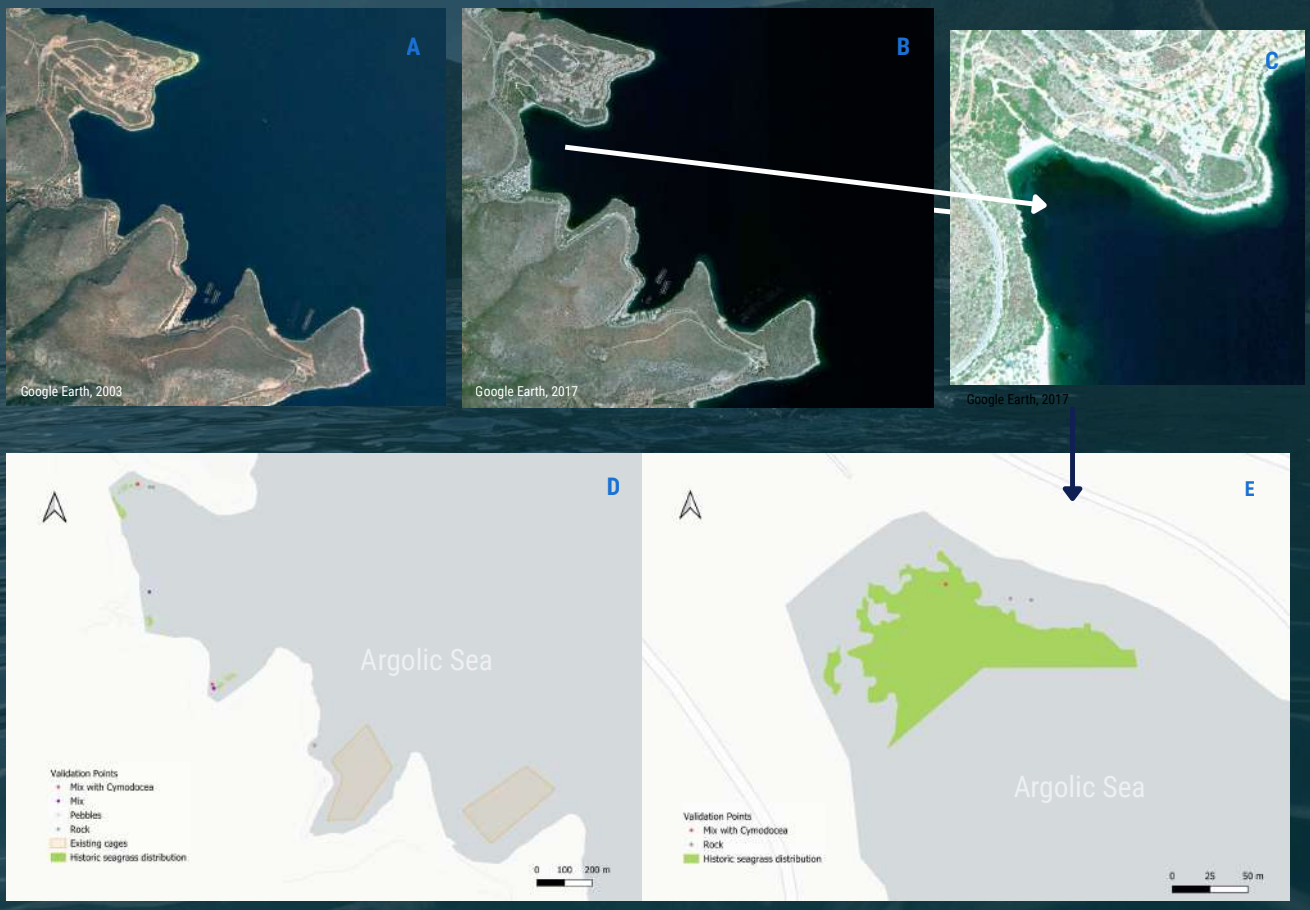


***Figure 20**. A: Earliest satellite imagery with visible facilities (2003). B,C: Last evident satellite imagery with visible seagrass meadow (2017). D: Historic seagrass meadow, derives from historic aerophoto (1985). E: Historic seagrass meadow, derives from Google Earth imagery (2017).*

Aol 2- Cape Bournias to Cape Fokiano

Regarding the historic seagrass presence in areas of current aquaculture facilities in Fokiano (37°06'01.4"N 22°57'31.1"E and 37°05'29.1"N 22°57'57.4"E), considering: i) absence of seagrass evidence in historic imagery (image code: Y_BW_72_950538) and ii) bathymetric profiles at the locations, the possibility of the pre-aquaculture presence of seagrass was rejected.

AoI 3- Southern of Cape Thyni

Within AoI 3, a few candidate bays to explore pre-aquaculture seagrass distribution were identified, considering favourable oceanographic, geological conditions, and long-term operation of existing facilities. Specifically at 37°21'04.7"N 23°04'18.2"E the image Y_BW_72_950988, dated from **1972**, was analysed. This photo supports a strong possibility of the past presence of seagrass beds at the aquaculture site. Analysis of the image showed at least a meadow of **1.68 ha** (only accounting for the shallow limit of the meadow) (Figure 21). Unfortunately, it was not possible to collect validation points due to the proximity of the cages. However, a validation point was collected further away from the cages, in the former meadow, but only pebbles were found with no trace of seagrass or dead matte.

Figure 21. *AoI 3 with the historic meadows shown in green, habitats indicated by coloured dots, and aquaculture cages visible.*

AoI 4- Adjacent to Vourlias bay

For the majority of shallow bays found along the area of **Vourlias**, evidence suggested the extensive historic presence of seagrass pre-aquaculture operation. Firstly, at location 37°27'05.6"N 23°04'15.3"E (Agios Nikolaos), considering the historic image (Y_BW_72_950959) dated from **1972**, two seagrass meadows were detected near (300m) the current aquaculture facilities with a total area of **0.88 ha** (Figure 22A). Three validation points confirm the presence of these two Cymodocea meadows, which still remain alive but form a sparse distribution.

Furthermore, at location 37°27'20.4"N 23°03'03.5"E (Akra Vourlia) considering the historic image (Y_BW_72_950963) also dated from **1972**, another pre-aquaculture seagrass meadow can be suspected, with an area of **0.093 ha** (Figure 22B). No validation points could be taken here due to the proximity of the cages (150m). Similarly, at 37°28'07.0"N 23°00'48.3"E the analysis of the image Y_BW_72_950941 (dated from **1972**) resulted in a historic meadow near a now-relocated aquaculture facility that operated 240m away until at least 2017. The analysis resulted in an area of **0.11 ha** (Figure 22C). Validation points show that aquaculture activities have caused the meadow to disappear completely, with the substrate now characterised by the exclusive presence of mud and sand.

Finally, at 37°28'36.4"N 23°02'45.4"E (north of Katsigianneika beach), analysis of the imagery Y_BW_72_950955 from **1972**, results in the discovery of a large (**2.6 ha**) seagrass meadow, located between three current aquaculture facilities (Figure 22D) distanced 350m and 450m away. The validation points in this former meadow recorded only sand and rock. This suggests that the longstanding intensive aquaculture activities, combined with the enclosed profile of the area, have possibly led to the complete disappearance of the meadows.

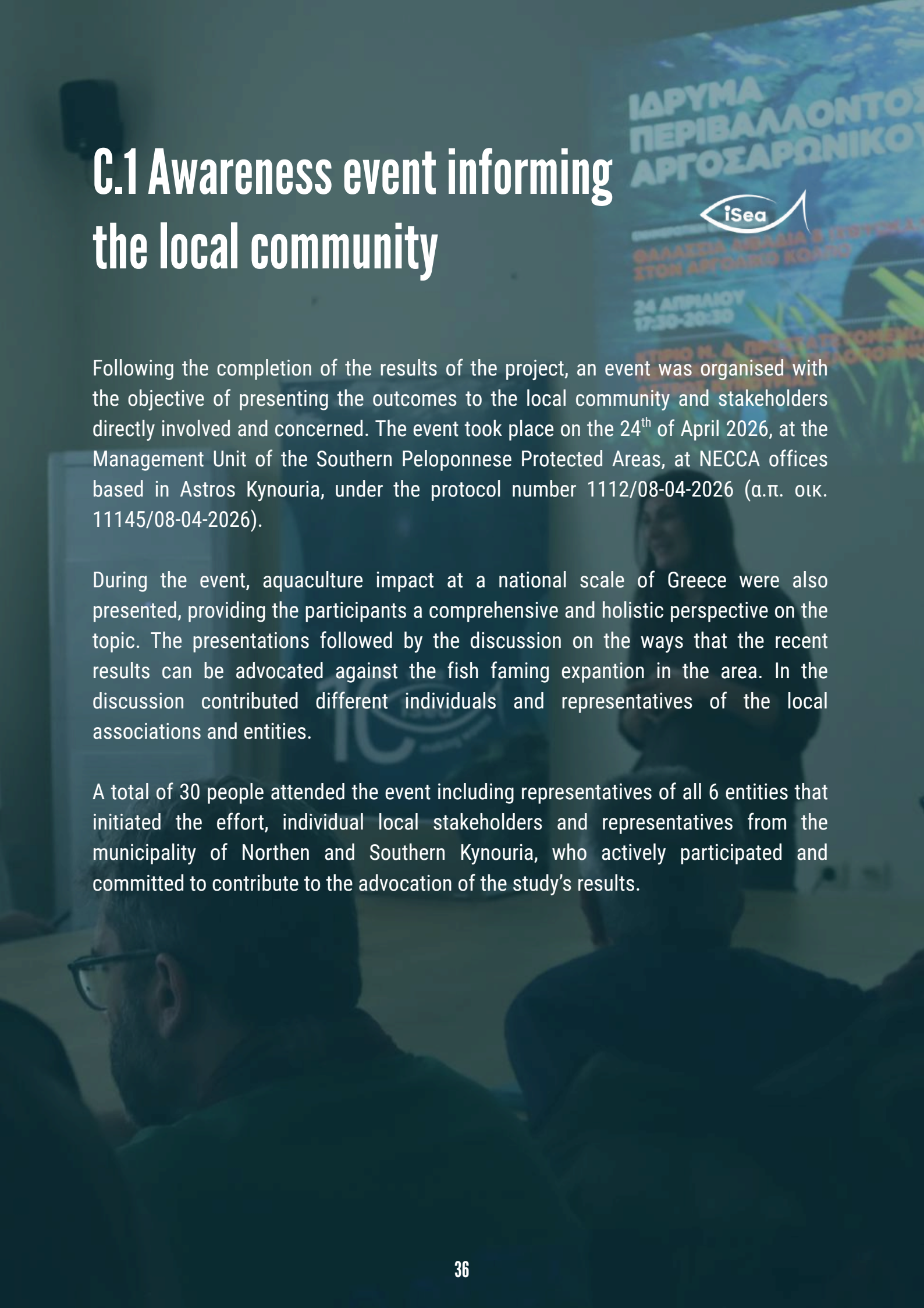
Figure 22. *Close to AoI 4 with the historic meadows shown in green polygons, habitats indicated by coloured dots, and aquaculture cages visible.*

AoI 5- Plateia Island

Within Plateia Island, no imagery pre-aquaculture settlement is available from the National Resource. Instead, Google Satellite historic imagery was available for the site, and given the shallow distribution of seagrass, this was visible in multiple imagery. The earliest imagery clear enough to distinguish seagrass distribution was dated from **2013** (Google Earth, 09/08/2013). This photo supports a strong possibility of the past presence of seagrass beds at the aquaculture site, distanced from 60-200m. Analysis resulted in a segrass coverage area of **1.52 ha** (Figure 23). Comparing this with the current approximate estimate of 0.45 ha, it is evident that the majority of the shallow seagrass here has been eradicated.

Figure 23. *Estimated historic seagrass covered areas within AoI 5 from Google Satellite imagery from 2013*

C.1 Awareness event informing the local community



Following the completion of the results of the project, an event was organised with the objective of presenting the outcomes to the local community and stakeholders directly involved and concerned. The event took place on the 24th of April 2026, at the Management Unit of the Southern Peloponnese Protected Areas, at NECCA offices based in Astros Kynouria, under the protocol number 1112/08-04-2026 (α.π. οικ. 11145/08-04-2026).

During the event, aquaculture impact at a national scale of Greece were also presented, providing the participants a comprehensive and holistic perspective on the topic. The presentations followed by the discussion on the ways that the recent results can be advocated against the fish faming expantion in the area. In the discussion contributed different individuals and representatives of the local associations and entities.

A total of 30 people attended the event including representatives of all 6 entities that initiated the effort, individual local stakeholders and representatives from the municipality of Northen and Southern Kynouria, who actively participated and committed to contribute to the advocation of the study's results.

C.2 Communication of project on SoMe and news outlets

A communication strategy was developed in collaboration with all the project partners in order to effectively highlight the targets and goals of the project. The campaign resulted in a total number of five posts and one press release, elaborating on different topics. More specifically:

Social Media

Post 1: 20th of April
Topic: Launch of the layman's report
Views: >4000

Post 2: 21st of April
Topic: Invitation to the event
Views: >28000

Post 3: 22nd of April
Topic: POAY and seagrass overlapping in the Argolic Gulf
Views: >4000

Post 4: 23rd of April
Topic: *Cymodocea nodosa* in the Argolic
Views: >5200

Post 5: 4th of May
Topic: Event highlights
Views: >2150

Mass Media

The relevant Press Released was published on the 17th of April. It was sent to the national and local press and also available on iSea's website.

A total number of >390 users read the Press Release from iSea's website and a total number of 15 articles we published in the local and nationl press based on the information circulated from the corresponding Press Release that was sent. In addition, local press also circulated the invitation to the event as a separate publication from the Layman's report results for the area.

An interview was also provided to a local TV channel, Mesogeios TV, which was broadcasted live. Its recording was also broadcasted by 2 more local channels. In addition, it was also shared in all the Social Media platforms of these channels.

Radio channels are also a powerfull media to spread the message in a local scale. An interview was thus also provided to a local radio channel, the day of the event, with the aim to discuss the results of iSea's recent study in the area and also invite more people to the event.

C.3 Production of a Layman's Report

With the aim to encourage bottom-up management approaches, the project outcomes were compiled and presented in a report for non-scientific audience, in the form of a Layman's Report. This report was produced both in Greek and English, and was dissiminated with the local stakeholders, relevant municipalities and event participants.

Alongside this action, the habitat seagrass mapping and the associated habitat groundtruthing points have been made publicly available through Zenodo website.

Validation points

Seagrass mapping

D.1 Monitoring the project actions, ensuring high-quality deliverables, and reporting

A project manager has been assigned to the project who is closely monitoring the projects actions and ensures the timeline, and the actions of the project are being met. While a broader team is involved in the implementation of various actions of the project. The project manager works with the team and coordinates the implementation of the project.

D.2 Financial monitoring

The project manager, the financial officer and financial assistant are following the finances of the project, ensuring that the expenses follow the budget. All original receipts are kept in iSea's headquarters and copies can be given to the funder upon request.

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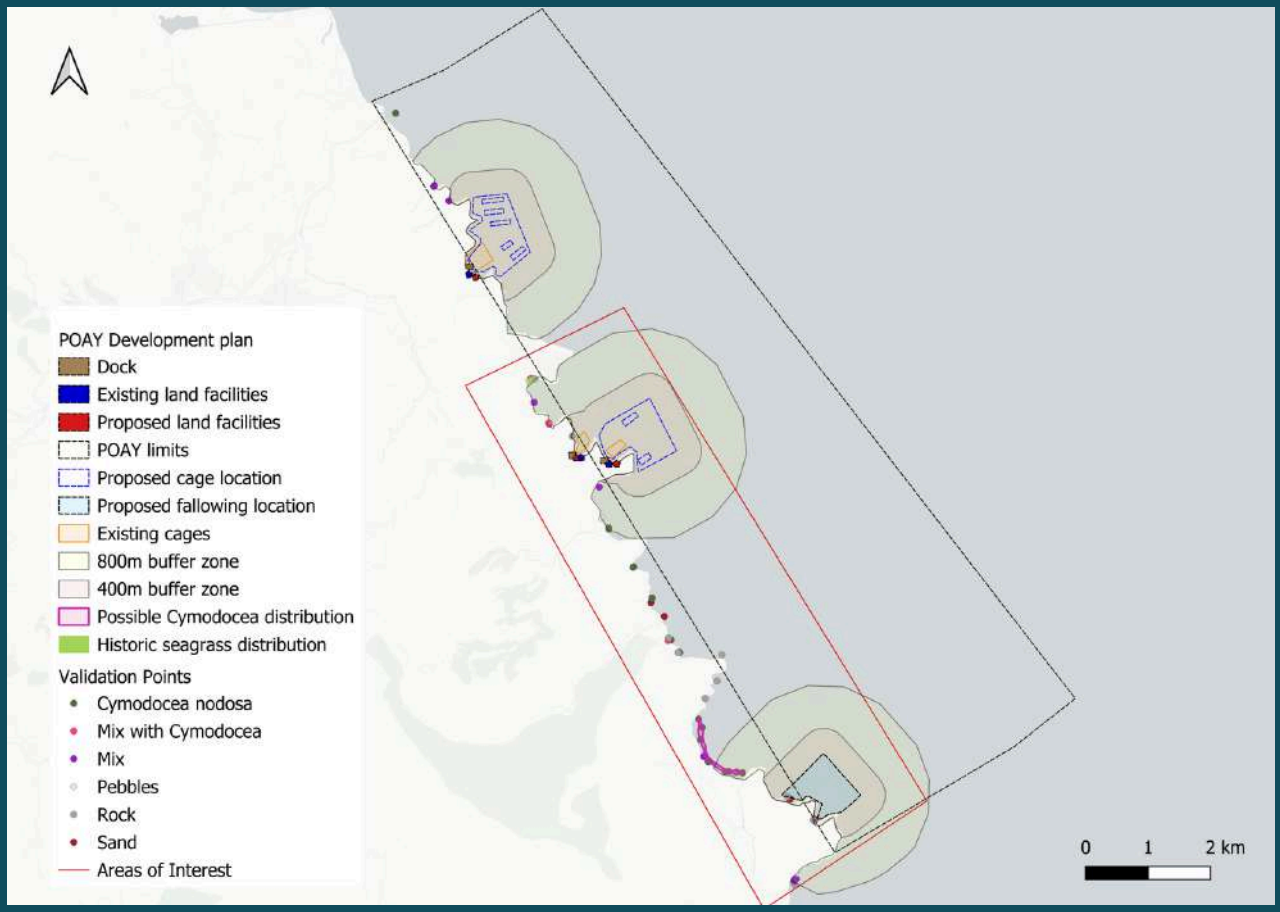
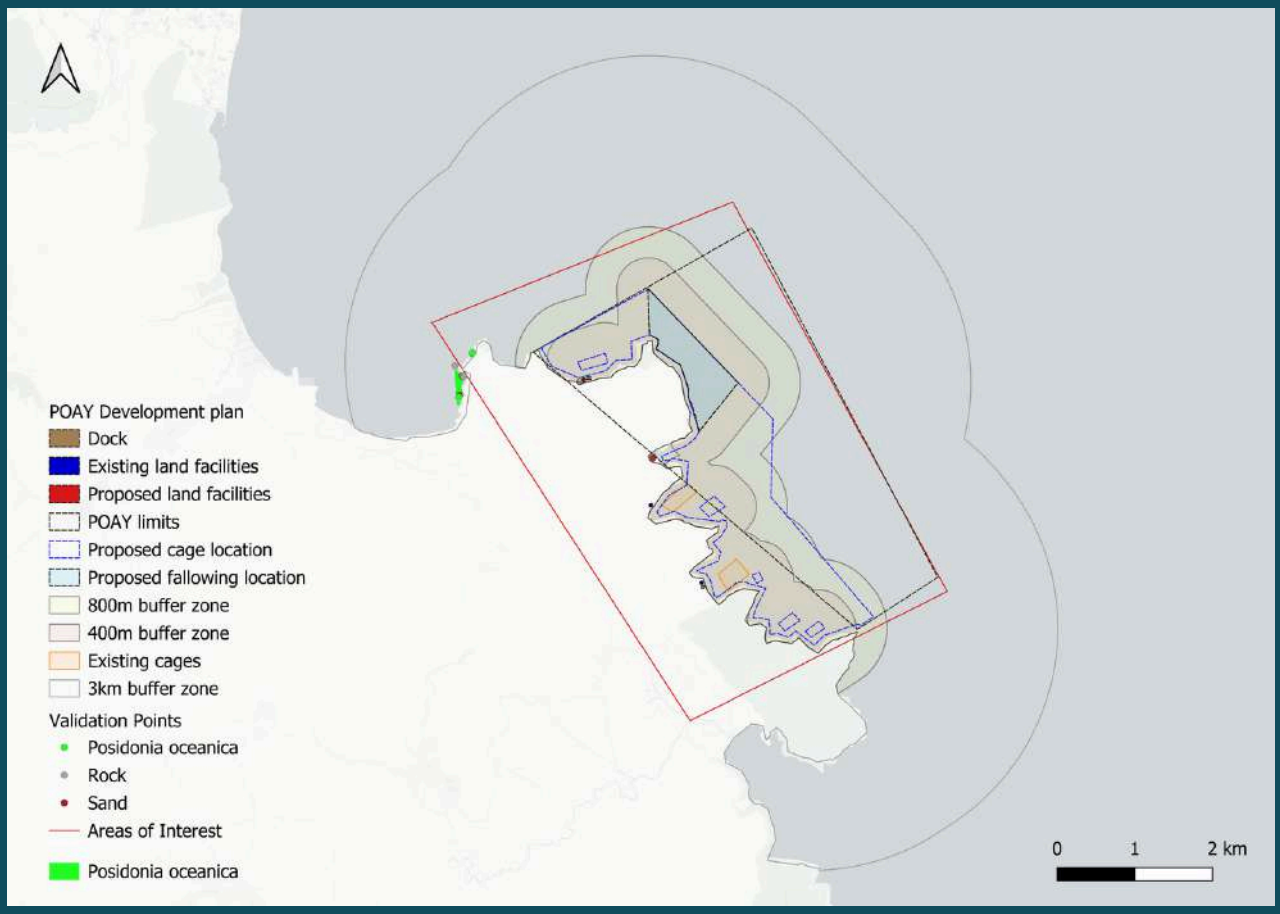
Appendix

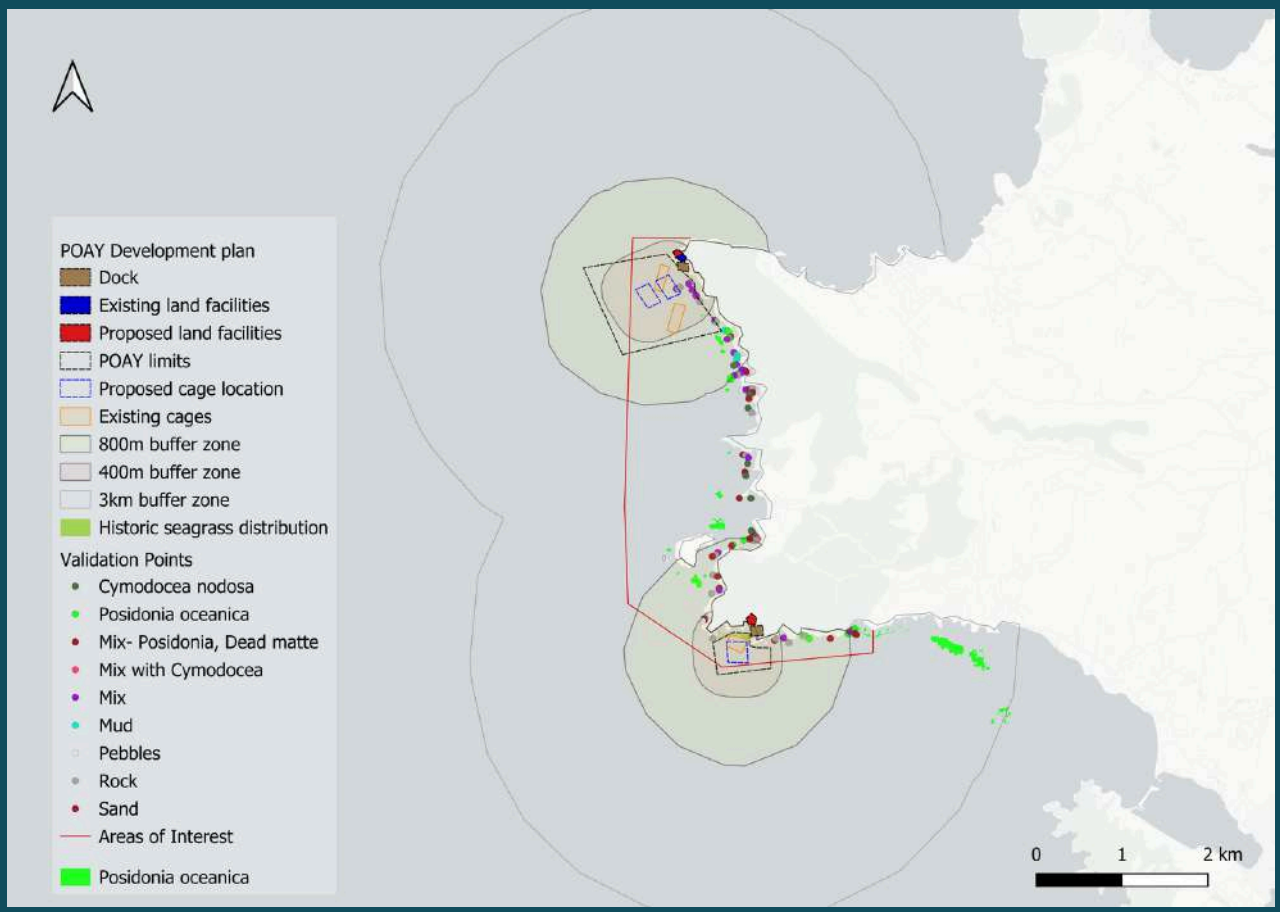
Appendix 1. Visualization of all layers combined discussed within all sections for area of interest 1.



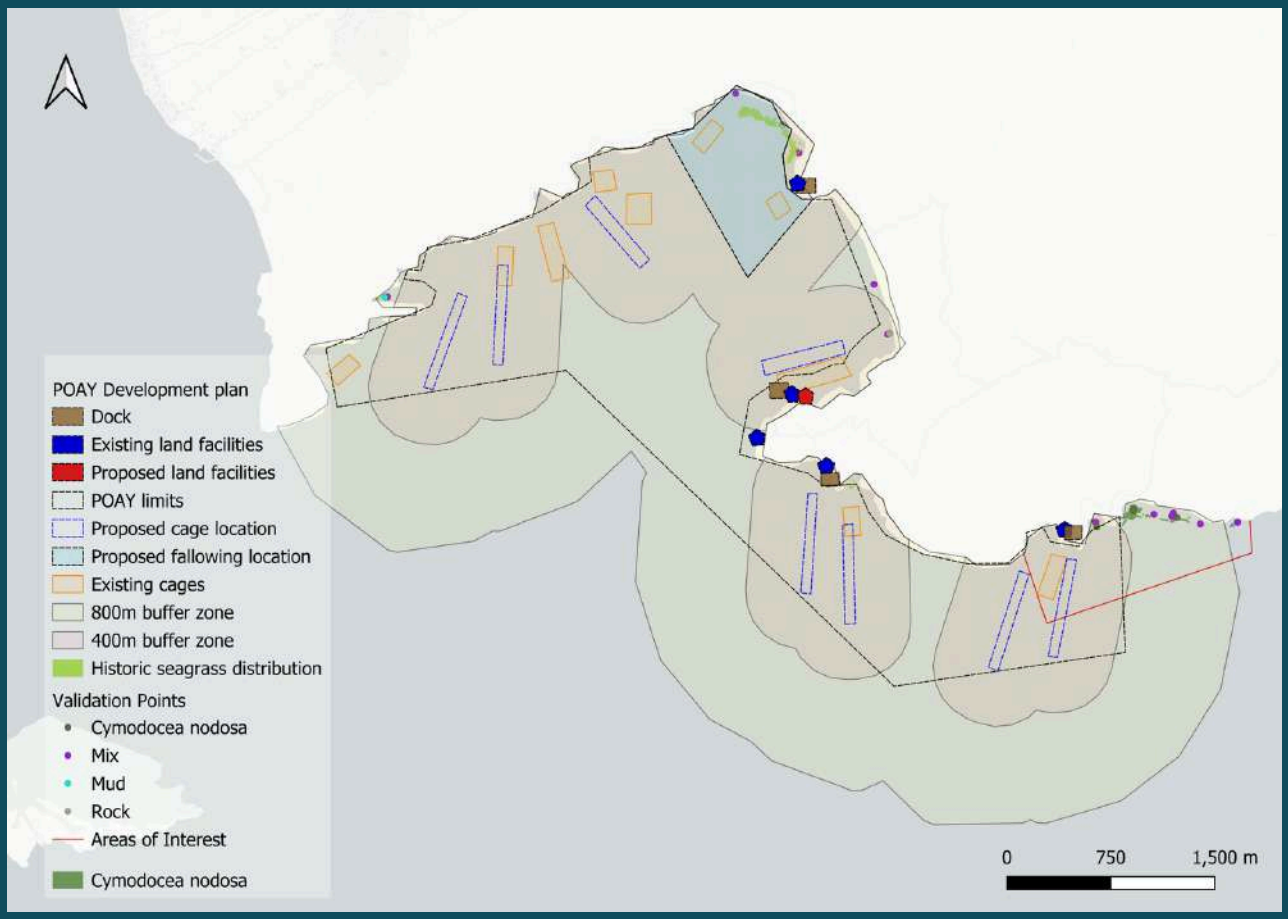
Appendix 2. Visualization of all layers combined discussed within all sections for area of interest 2.



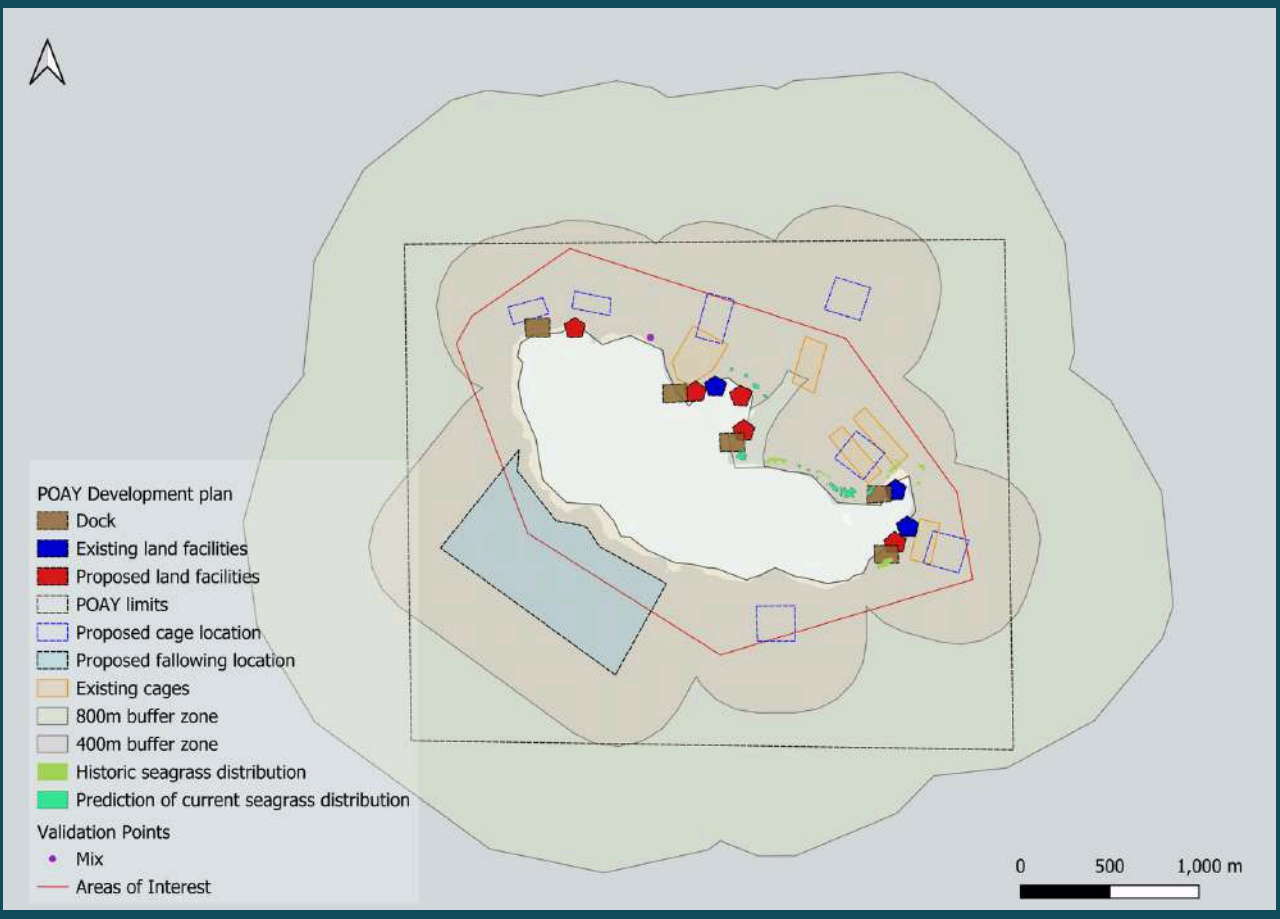
Appendix 3. Visualization of all layers combined discussed within all sections for area of interest 3.



Appendix 4. Visualization of all layers combined discussed within all sections for area of interest 4.



Appendix 5. Visualization of all layers combined discussed within all sections for area of interest 5.

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