



Seagrass distribution in relation with aquaculture development areas in the Argolic Gulf

Layman's Report



THESSALONIKI 2026

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GLOSSARY/ACRONYMS



Endemic species: Species found in a geographically restricted area, while not occurring elsewhere

Native species: Species that were originally found in an area but have evolved elsewhere

Invasive species: As invasive are characterised alien species that significantly modify or disrupt the ecosystems they colonise. As alien are characterised non-native species (plants and animals), with respect to a particular ecosystem, living outside of their natural range/distribution

MSP: Marine Spatial Planning

Validation points: Field collected locations taken to verify the observed habitat

POAY: Areas of Organized Development of Aquaculture Activities

PAY: Aquaculture Development Area

EIA: Environmental Impact Assessment

LEK: Local Ecological Knowledge

Aol: Area of Interest

Ha: hectares

AREAS OF INTEREST

Aol 1: Coastal area extending from Arkadiko Chorio to Cape Trikeri

Aol 2: Coastal area extending from Cape Bournias to Cape Fokiano

Aol 3: Coastal area extending south of Cape Thyni

Aol 4: Coastal area located adjacent to Vourlias Bay

Aol 5: Plateia island

AREAS OF INTEREST

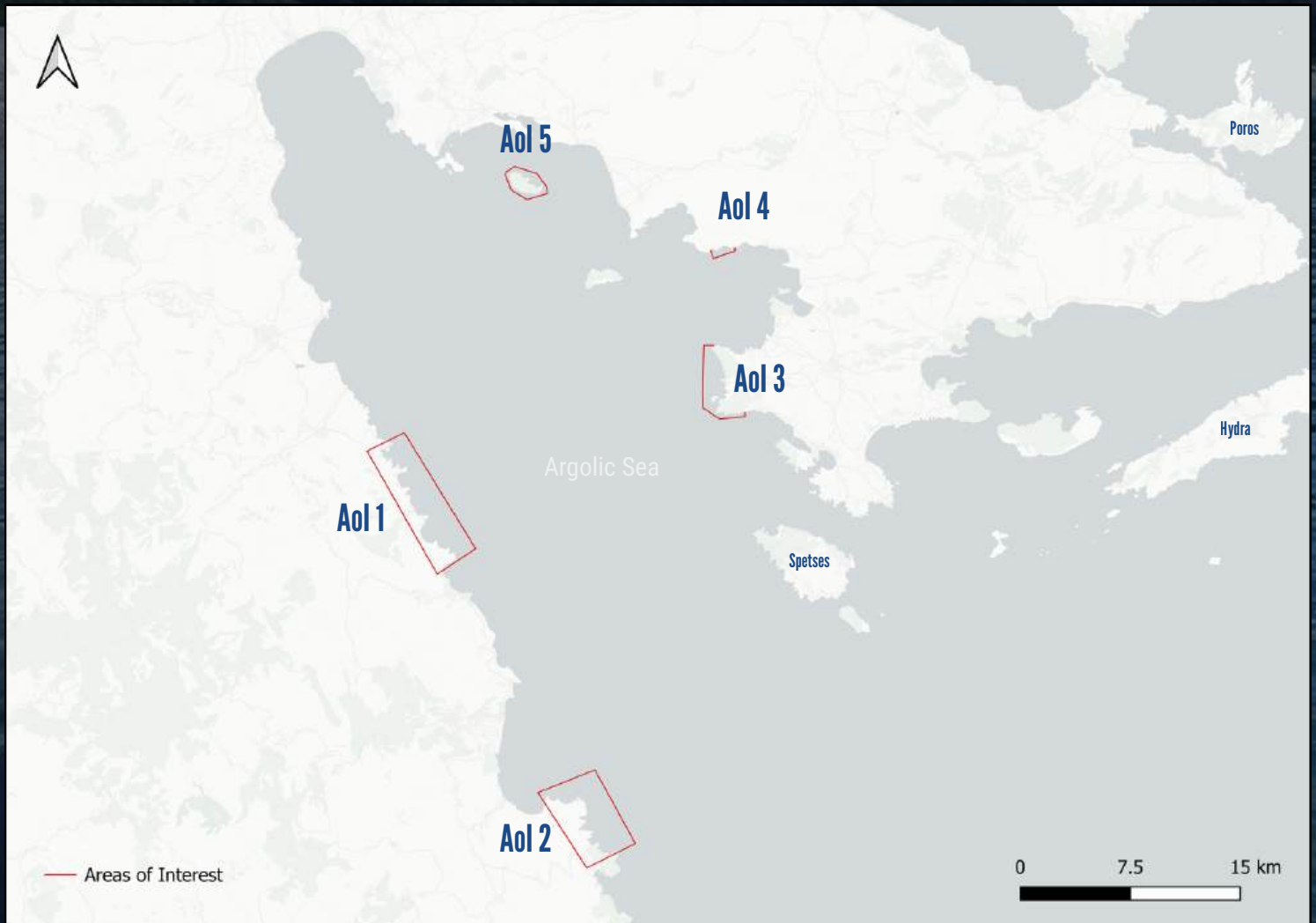


Figure 1. Visualization of the five Areas of Interest (Aol) in the Argolic Gulf.

EXECUTIVE SUMMARY



In this project, we aimed to map the distribution of seagrasses in the Argolic Gulf specifically focusing on areas of aquaculture operation. In total, five areas were assessed, for which mapping was conducted for three (Aol 2, Aol 3, Aol 4) using the combination of multiple satellite imagery sources, high-resolution satellite imagery (only in Aol 3), and validation points collected from the field (all). This resulted in **18.29 ha** of seagrass meadows (*Posidonia oceanica*, *Cymodocea nodosa*), while for the areas Aol 1 and Aol 5, detailed habitat mapping was not completed because of not meeting the mapping criteria with available satellite images (Aol 1) and the given data (Aol 5). However, it was identified through validation points that *Cymodocea* is present in area Aol 1. *Posidonia* was only found at Aol 2 and Aol 3.

Absence of seagrasses (sparse distribution) in areas on the Aol 1 and Aol 2 can be attributed to the slope and oceanographic conditions, which would not allow for the establishment of seagrasses. However, regarding Vourlias Bay (near Aol 4), where oceanographic conditions allow for the distribution of the species, the absence of seagrass could possibly be attributed to the long-term operation of the aquaculture, considering the evidence of the historic distribution of this report. Exploring the historic presence of seagrasses was done through combining results from historic aeroimages and data collected in the field.

Aquaculture is a known stressor for seagrass species. This report has shown that when looking at the proposed aquaculture expansion plans, the results of the present study suggest that at least two facilities (Aol 2 and Aol 3) could affect seagrass health, considering their distance to live meadows. Indeed, in the Aol 3, **0.11 ha** are within the **400m** range and 2.89 ha within the 800m range. In Aol 2, a patch of **0.13 ha** was found **within the limits**, close to propose cage and land facilities placement. For areas with no habitat mapping (Aol 1, Aol 5), it is expected that seagrass meadows observed through site validation data at the sites could potentially be further affected, considering the close association with proposed facilities.

Consequently, it is evident that in the Argolic, the inappropriate planning in the early 2000's has already caused severe degradation of *Cymodocea* seagrass areas (Aol 1, Aol 4). In light of further increases in production, it is important to identify the correct status of the area and avoid any further damage to surviving seagrass meadows, key to supporting wild fish populations. Considering the known impacts, the closed characteristics of the Argolic, demands from local community, alternatives should be addressed.

AIM

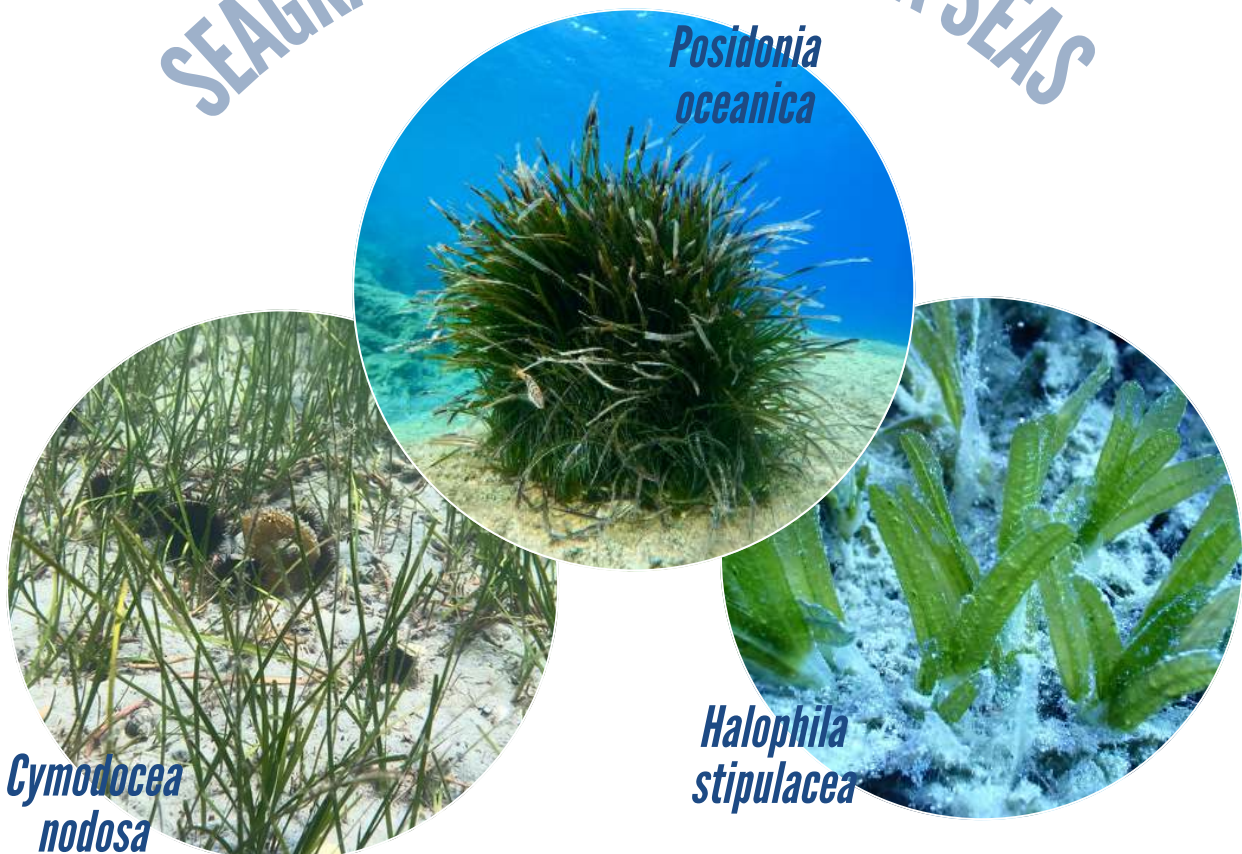


Contribute to increasing knowledge on seagrasses' extent in the Argolic Gulf, specifically in association with aquaculture operation areas.

OBJECTIVES

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

SEAGRASSES OF THE GREEK SEAS



INTRODUCTION



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].

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 Paronias 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.

PROPOSED AQUACULTURE PLANS IN THE ARGOLIC GULF AND THE STUDY SITES

Due to the lack of a **Marine Spatial Planning (MSP) Framework** in Greece, aquaculture historically operated in areas provided through set-term, leasing-like contracts. Based on the MSP [European Directive 2014/89/EU](#), in order to regulate maritime spatial planning, protect the environment and promote socio-economic balance, Greece is obligated to establish marine areas as **Areas of Organized Development of Aquaculture (hereafter POAY)**. According to data from the Ministry of Environment and Energy (2023) and the 2024 Annual Aquaculture Report of the Hellenic Aquaculture Producers Organisation, **25 POAY proposals** have been submitted across the entire Greek territory. **15** of these **proposals** are located in areas **that have been specifically designed for aquaculture**, and have already registered a significant number of existing aquaculture units [Aquaculture Development Area (PAY) type A]. These 15 proposals include proposed expansions in **area coverage** and **annual productivity**. The proposed plans and zones were carried out back in **2011**, however they have suffered extensive delays related to their finalisation and establishment, which would allow for the legal recognition of them as aquaculture-utilisation sites.

To date, only 8 out of 25 POAY proposals have been established, while POAY proposals within PAY A have received an extension until 2025 to be completed. Due to this delay, many of these plans are considered severely out-of-date, while they have been criticized for the validity of their Environmental Impact Assessment (EIA) information. Aside from this, many local communities and municipal authorities express a strong disagreement with these plans and refer to a lack of bottom-up approaches in the review phase of these.

Recently, the plan related to **Poros island** has been retracted for review as a result of consistent evidence-based pressure from the local community and organisations.

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). 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, including Kynouria region (Area of Interest - Aol 1), Bournias Cape (Aol 2), southern of Cape Thyni (Aol 3), Vourlias bay (Aol 4), and Plateia island (Aol 5).

PRESENCE / ABSENCE DATA

Presence/Absence data represent field data (GPS points) of the actual habitat types that are observed at a given location, known as **validation points**. For each validation point, coordinates are taken using a GPS device (Garmin 22x) with a minimum accuracy of 3m. To ensure accuracy due to GPS's error, each habitat recorded covered at least a 9m² area. All activities were planned, consulting expert advice to identify expected areas of seagrass, considering:

- 1) national level mapping of seagrasses in the Greek seas [11]
- 2) bathymetry
- 3) available satellite imagery from Google Earth
- 4) local ecological knowledge reports on presence of seagrasses

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.

VALIDATION POINT COLLECTION

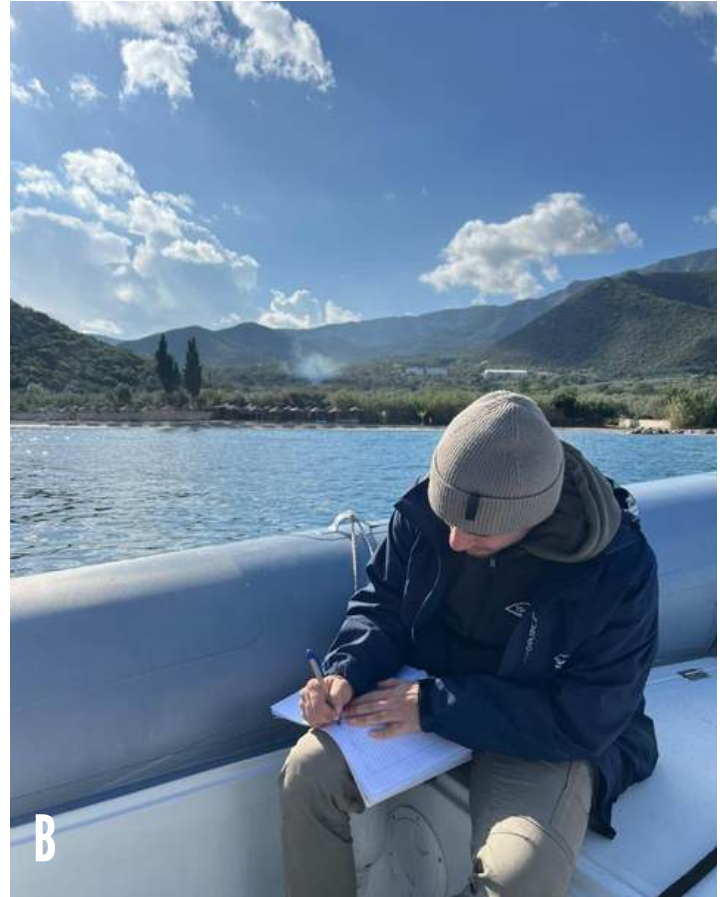


Figure 2. Collection of validation points from the boat using a bottom scope (A,B) and apnoea (C).

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. 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 images and field data.

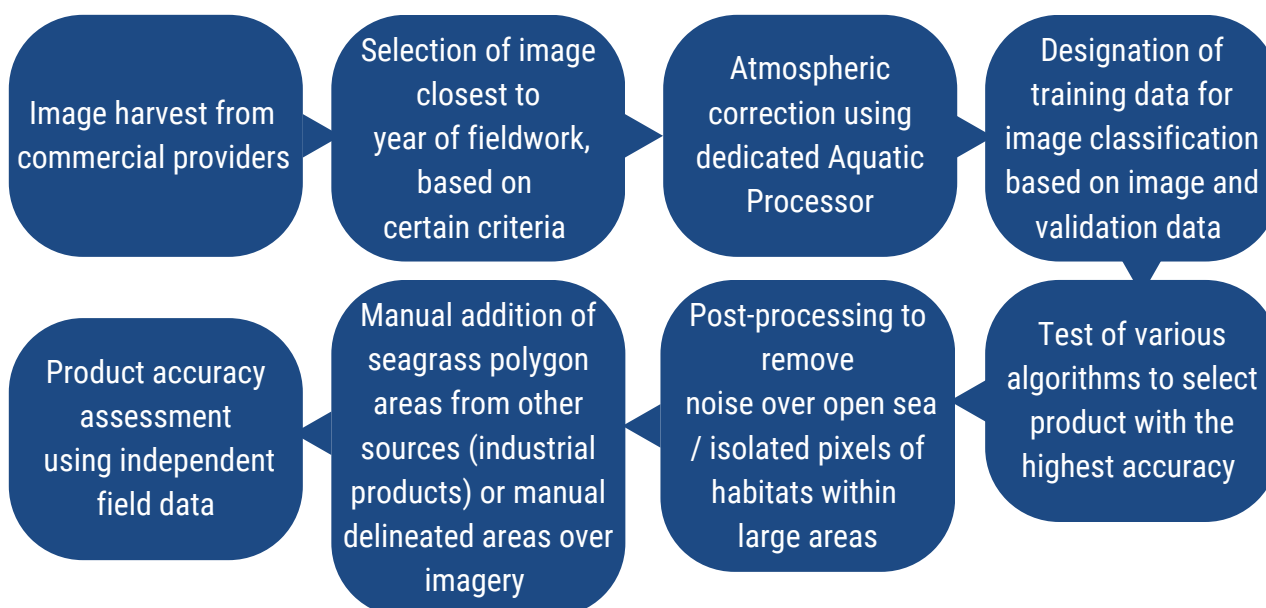
CRITERIA TO MEET ELIGIBILITY FOR ACCURATE HABITAT MAPPING

- 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



SEAGRASS DISTRIBUTION IN POAY

Here, 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 *Cymodocea* seagrass meadows. *Cymodocea nodosa* has shown degraded growth and mortality **100m** from fish-farms [30], while studies undertaken in Aol 4, compared two *Cymodocea* meadows 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 Aol.

EXPLORING HISTORIC SEAGRASS DISTRIBUTION

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. 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 an indication for the visible shallow limits (where the difference between seagrass and deep water starts to become unclear). The historic imagery cannot be shared due to the provider's copyright restrictions and has 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 provider's website. For each of the analysed photographs, an estimated area of historic seagrass is presented and compared with the current distribution, if present.

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.

RESULTS



Fieldwork was carried out under the research permit Prot. No: ΥΠΕΝ/ΔΠΔ/26906/1818; ΑΔΑ: ΨΩΝ64653Π8-ΞΔΧ

Fieldwork dates: **05/11/25 – 9/11/25**

Collected field validation points: **206**

(25 of which were recorded for depth observation alone)

Table 1. Number of validation points per habitat observed

***Mix habitat refers to a combination of non-seagrass habitats.**

Habitat type	Mix*	Rock	<i>Cymodocea nodosa</i>	Sand	<i>Posidonia oceanica</i>	Pebbles	Mix with <i>Cymodocea</i>	Mud	Mix <i>Posidonia</i> , dead matte
Number of points	44	40	30	28	19	8	6	5	1

The majority of habitats were identified and verified using apnoea, as the visibility in the area was poor and the identification from the boat could not be fully trusted. The identification from the boat (using a bottom glass scope) could be performed only up to a maximum of 10m depths and in some locations, less than 5m due to high water turbidity and lack of visibility. Most of the habitat types were classified as mixed, meaning that the point represented more than 1 habitat type (Table 1). The mixed habitats were combinations of rock, sand, mud, and pebbles.

Regarding the seagrass species observed (Figure 3), as expected, the majority related to *Cymodocea nodosa* sparse meadows, accounting for 30 points. *Posidonia oceanica* was largely absent in most locations, while it was found only in the southern areas (Aol 2, Aol 3), where 19 points were recorded, mainly indicating patchy formations. For the areas where seagrass mapping was conducted, the final distribution achieved an overall accuracy of 91%.

CHARACTERISTIC VALIDATION POINTS OBSERVED



Figure 3. Indicative habitats observed during data collection: a) *Cymodocea nodosa*, b) *Posidonia oceanica*, c) Rocky beds and d) Sandy substrate.

RESULTS



Aol 1 (Arkadiko Chorio - Cape Trikeri)

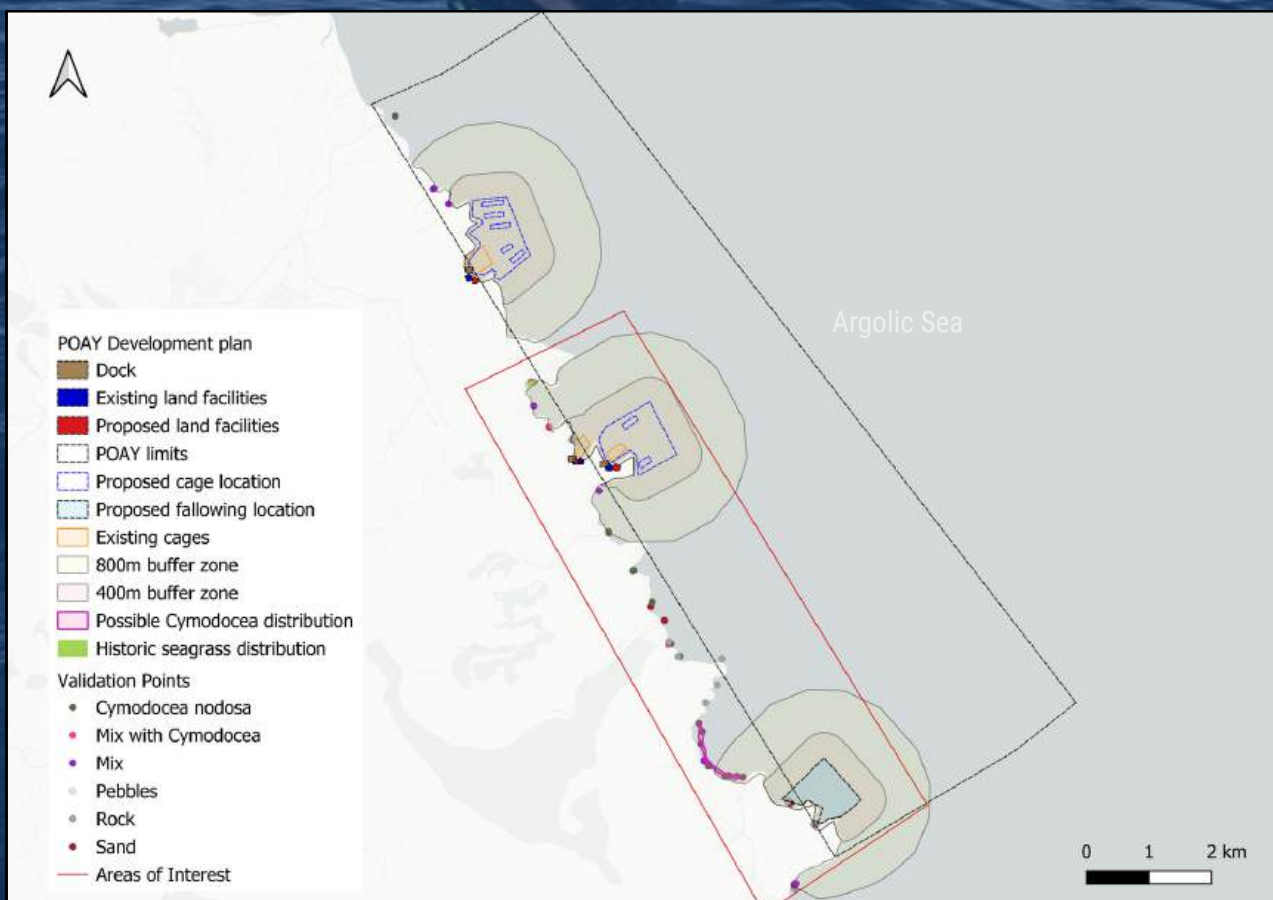


Figure 4. Visualisation of all layers within the discussed section of Area of Interest 1.

PRESENCE / ABSENCE DATA

Aol 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.

Aol 1 (Arkadiko Chorio - Cape Trikeri)

PRESENCE / ABSENCE DATA

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*) (Figure 5). Also, outside Aol 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.

Considering the above, along with the absence of high-resolution satellite imagery for Aol 1, seagrass habitat mapping and seagrass surface area calculation could not be completed. In this area, the presence/absence of seagrass species is confirmed through validation point data.

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 6) **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.

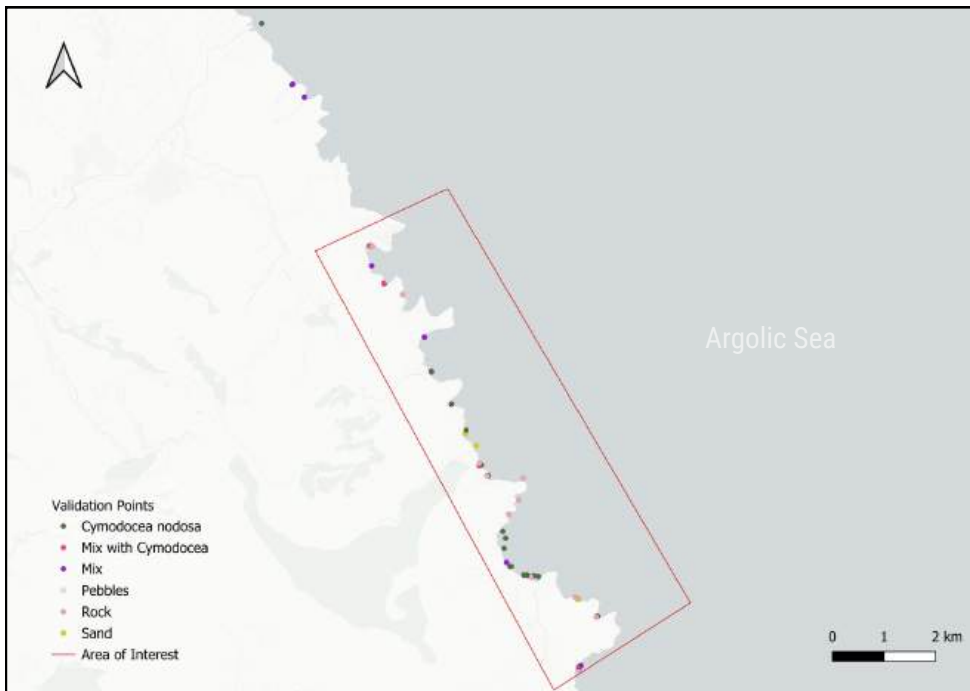


Figure 5. Validation points taken in Aol 1.

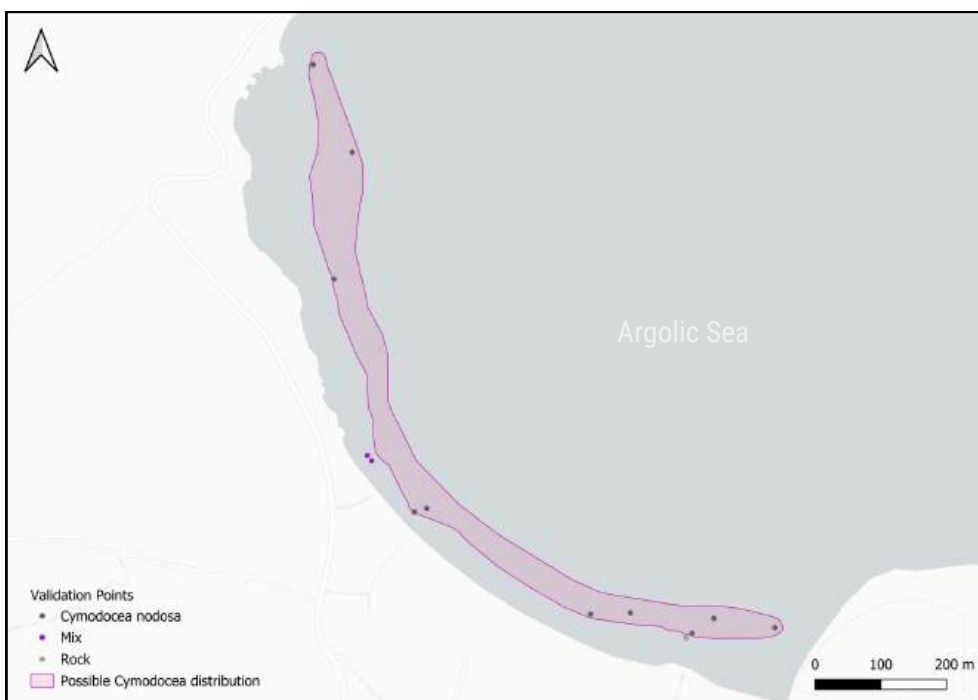
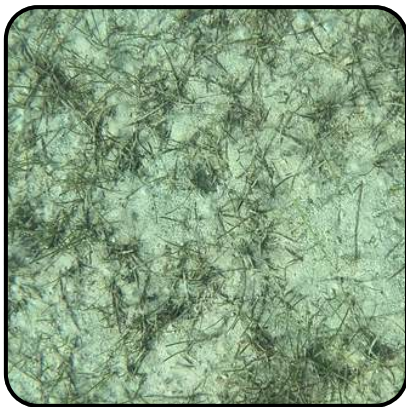


Figure 6. Indicative distribution of *Cymodocea* meadows in Zaritsi beach without an accurate spatial distribution and precise boundaries.

OTHER OBSERVATIONS

In Aol 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 7). Additionally, evidence of fishing and spearfishing activities was documented in the area.

HABITATS OBSERVED



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 7. Invasive species and habitat of different sites of the Aol 1.

SEAGRASS DISTRIBUTION IN POAY

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 8). 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.

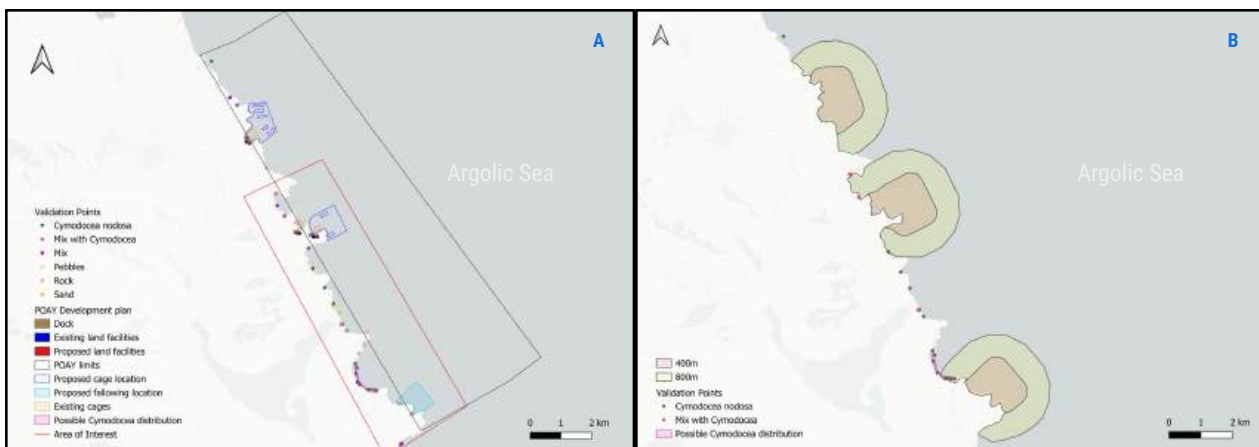


Figure 8. Resulting habitat classification points and aquaculture development plans (A) the impact (buffer) zones (B) of the proposed facilities in Aol 1 and beyond.

EXPLORING HISTORIC DISTRIBUTION

Within Aol 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.

EXPLORING HISTORIC DISTRIBUTION

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 9D, based on 1985 imagery) and 0.92 ha (Figure 9E, based on 2017 imagery).

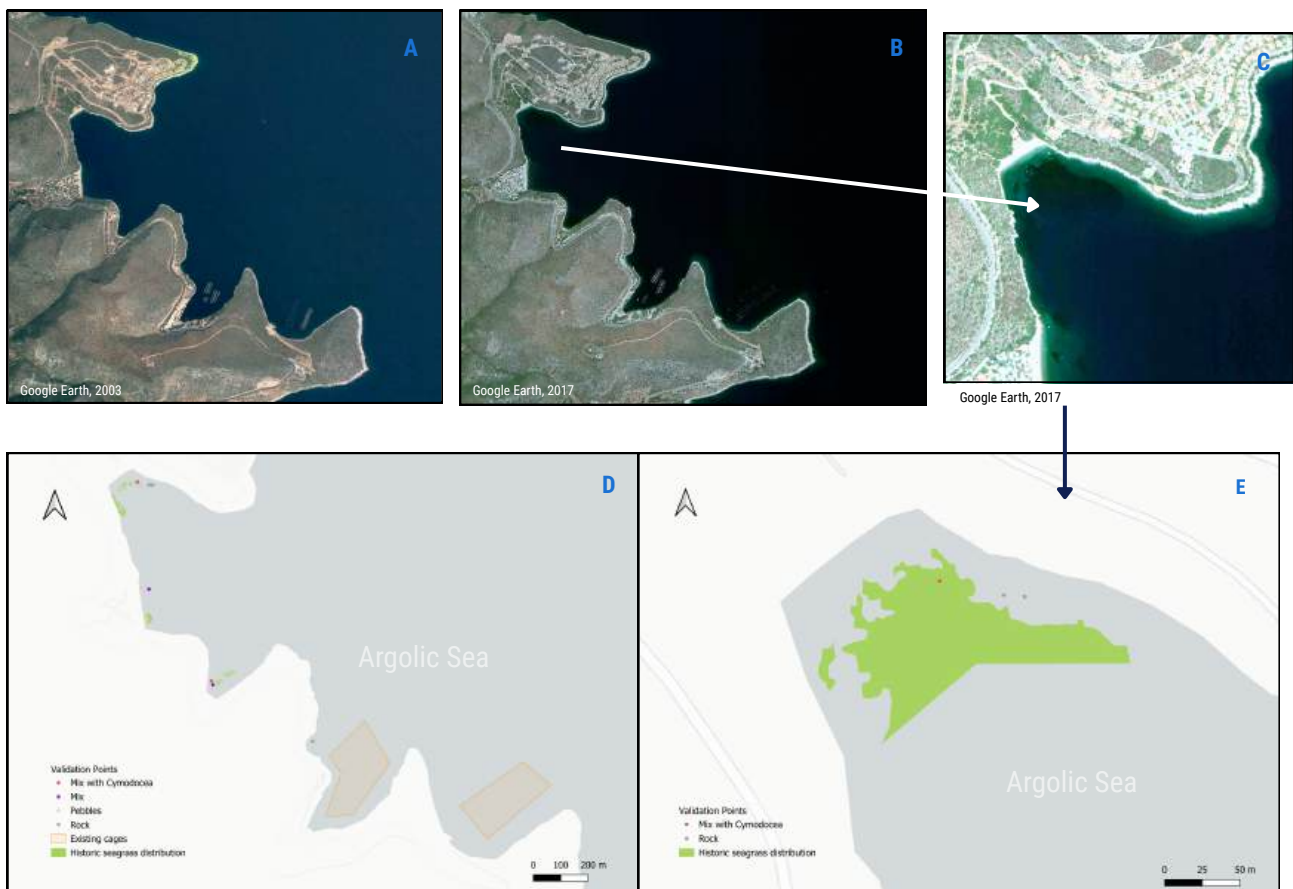


Figure 9. A: Earliest satellite imagery with visible facilities (2003). B,C: Last evident satellite imagery with visible seagrass meadow (2017). D: Historic seagrass meadow, derives from historic aerophoto (1985). E: Historic seagrass meadow, derives from Google Earth imagery (2017).

Aol 2 (Cape Bournias-Cape Fokiano)

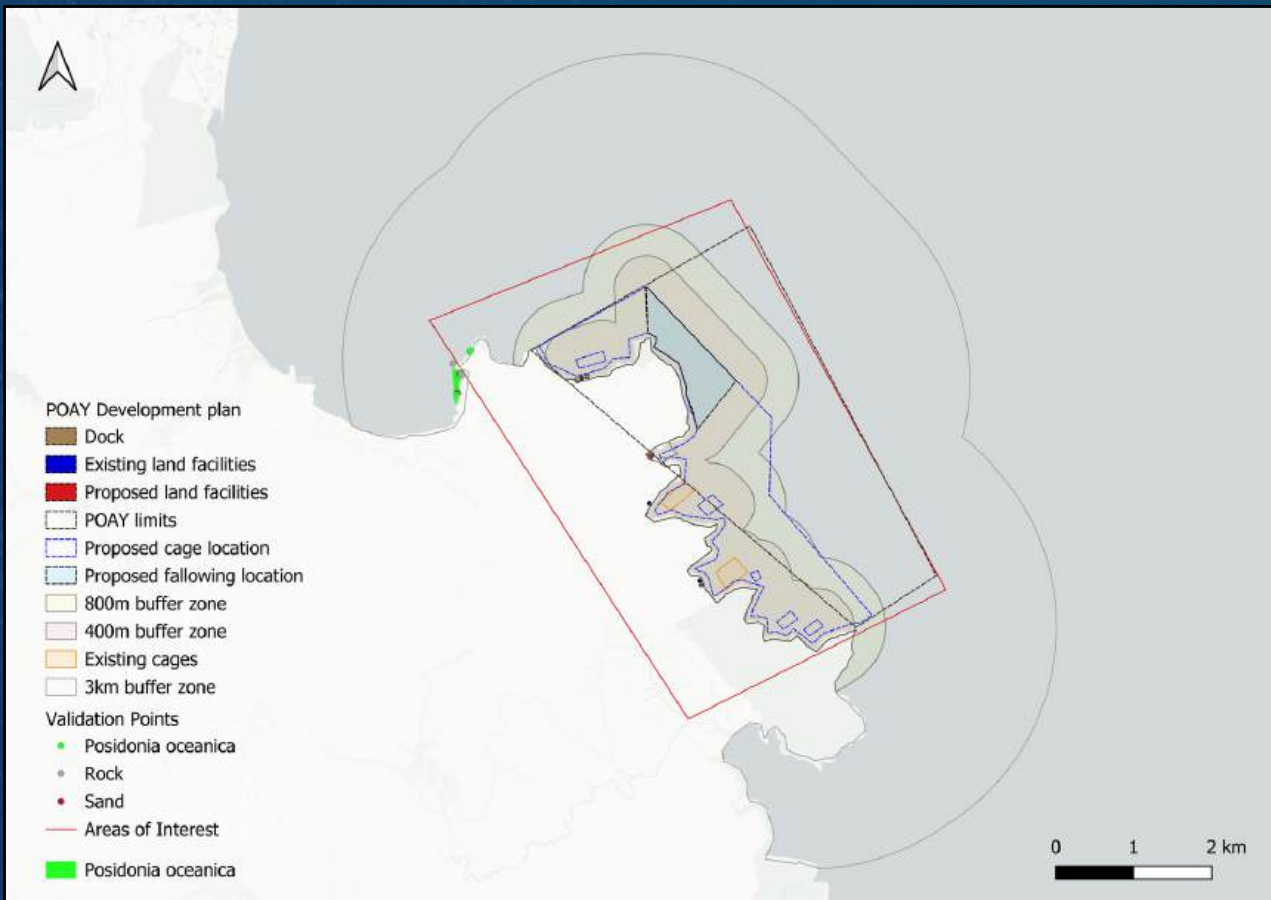


Figure 10. Visualization of all layers within the discussed section of Area of Interest 2.

PRESENCE / ABSENCE DATA

Aol 2, relates to the remaining area **PAY A4.2** and refers to the area extending from Cape Bournias to Cape Fokiano ($37^{\circ}07'00.83''\text{N}$ $22^{\circ}55'37.24''\text{E}$ to $37^{\circ}05'04.63''\text{N}$ $22^{\circ}59'05.42''\text{E}$), where a total of **25** points were recorded (Figure 10). **Posidonia** was observed but limited to the north limit of the Aol (Figure 11A). 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.

SEAGRASS HABITAT MAPPING & SEAGRASS DISTRIBUTION IN POAY

For the mapping of Posidonia in Aol 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.

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 11C). Additionally, the Posidonia patch that is found within the limits, is located right in front of proposed facilities (land and cage) where the wastewaters would have a significant impact on the meadows' condition [25].

EXPLORING HISTORIC DISTRIBUTION

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.

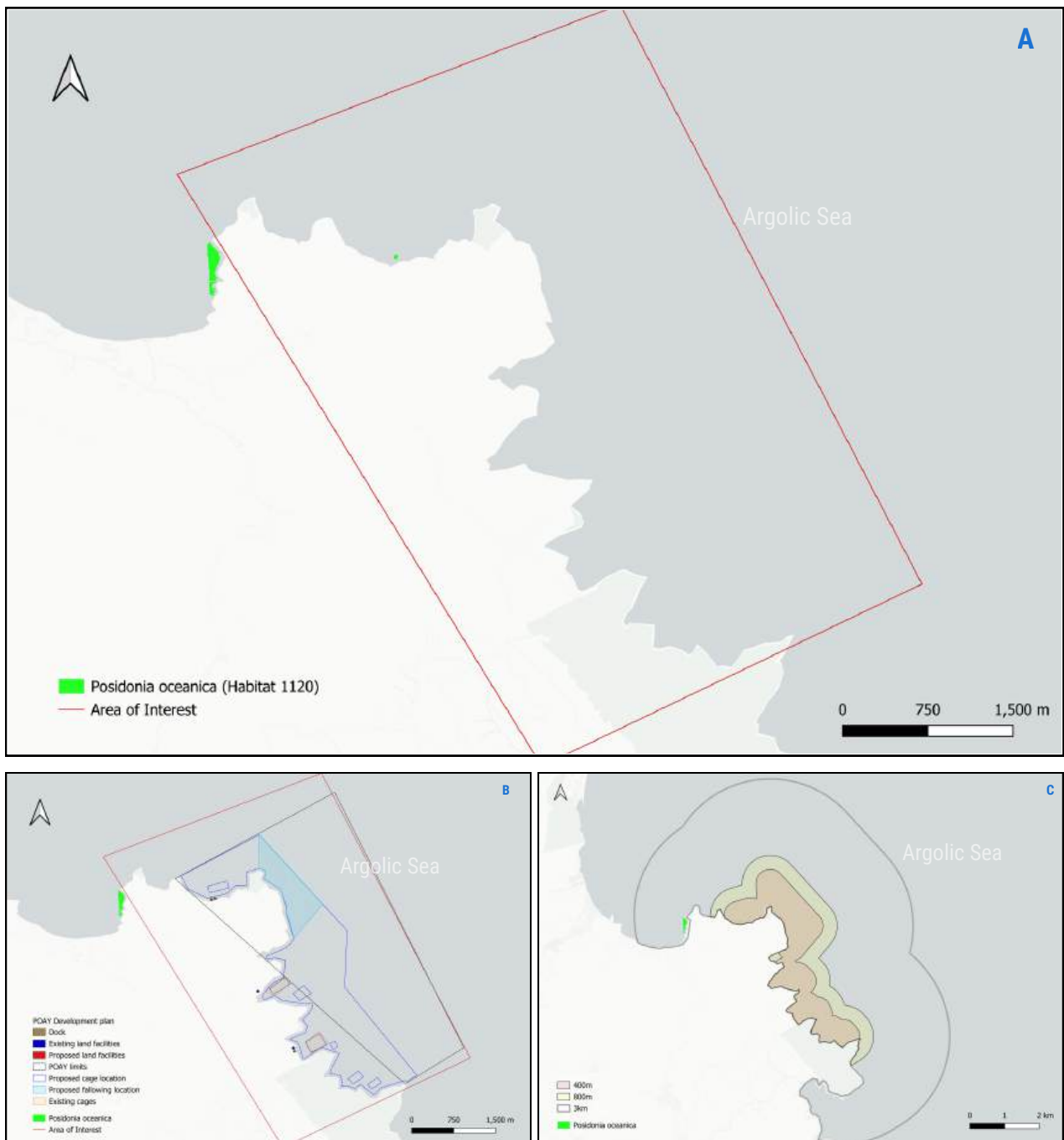


Figure 11. *Posidonia oceanica* (Habitat 1120) distribution in Aol 2 (A) *Posidonia* meadows in relation to facilities (B) and buffer zones (C).

Aol 3 (Southern of Cape Thyni)

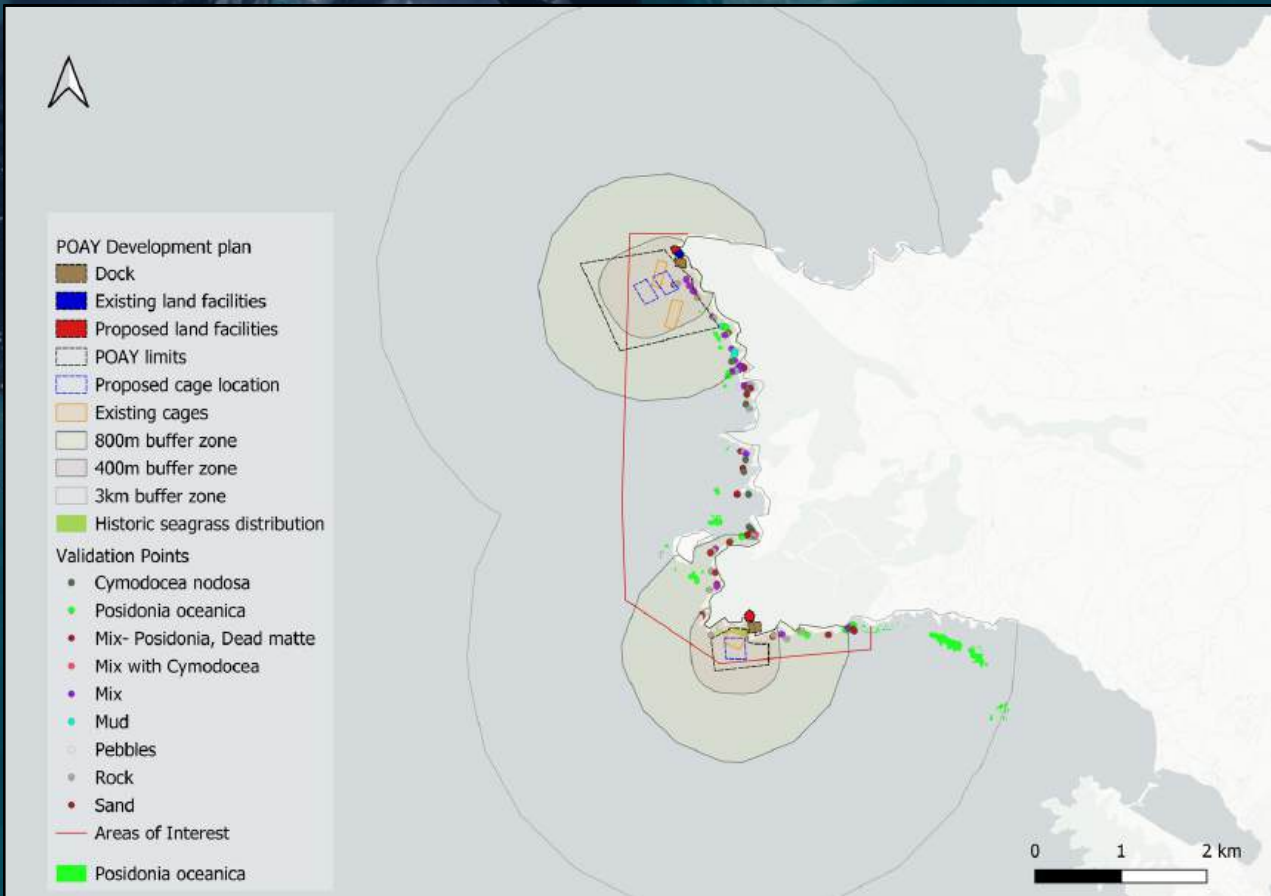


Figure 12. Visualization of all layers within the discussed section of Area of Interest 3.

PRESENCE / ABSENCE DATA

Aol 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 12). 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 observed, the presence of both **Posidonia** and **Cymodocea** was confirmed in the form of meadows or patches. Cymodocea was not as widespread as observed in other areas. In the very southern part of the site, Posidonia distribution was wider while Cymodocea was absent. Apart from seagrasses, other habitats observed were soft substrates like sandy and muddy, rocky surfaces and pebbles. Additionally, a mix of these habitats was recorded.

SEAGRASS HABITAT MAPPING

For the mapping of Aol 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 13). The *Cymodocea* presence couldn't be mapped due to the natural sparse distribution of this seagrass, making it difficult to be portrayed within limits.

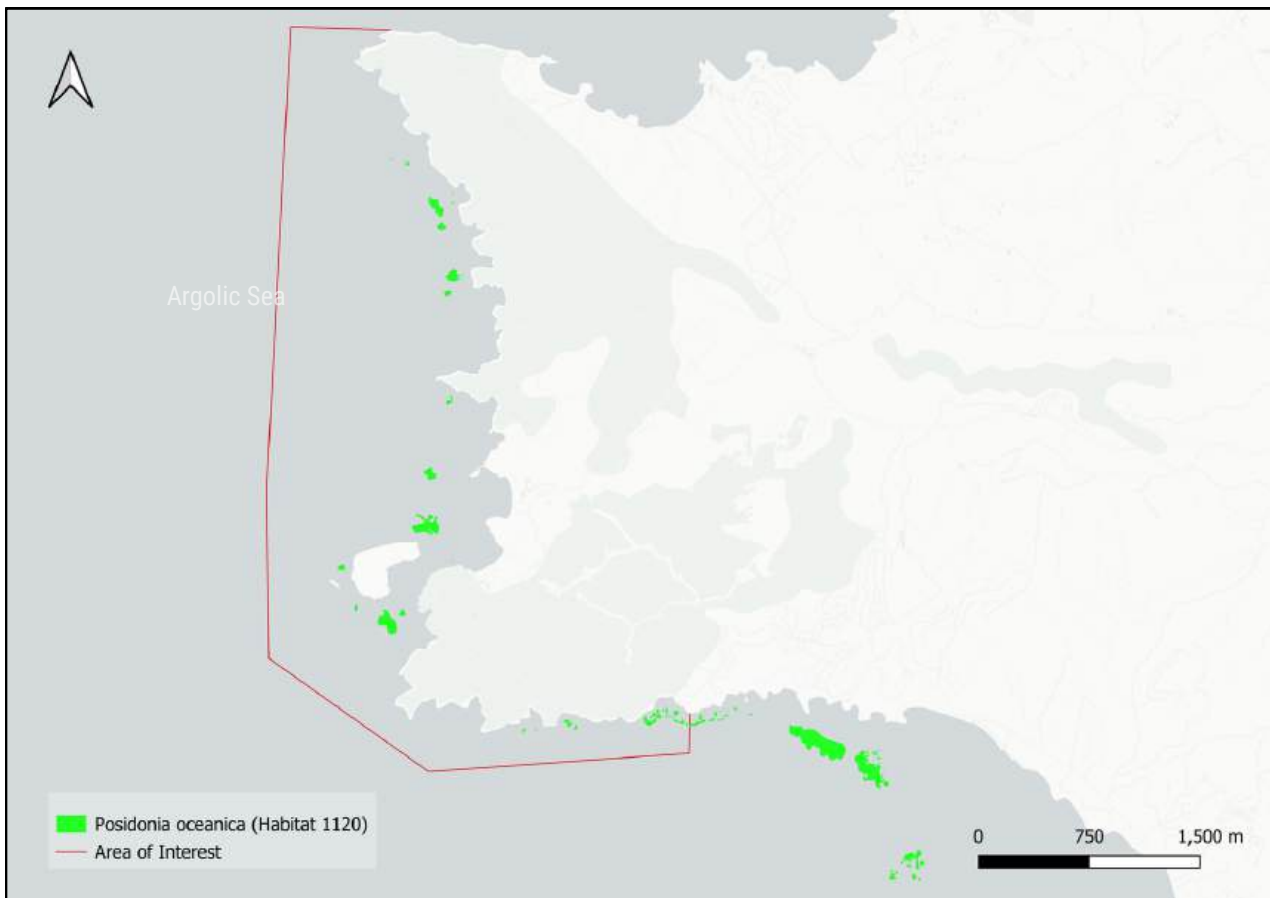


Figure 13. *Posidonia oceanica* (Habitat 1120) distribution in Aol 3.

SEAGRASS DISTRIBUTION IN POAY

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 14).

SEAGRASS DISTRIBUTION IN POAY

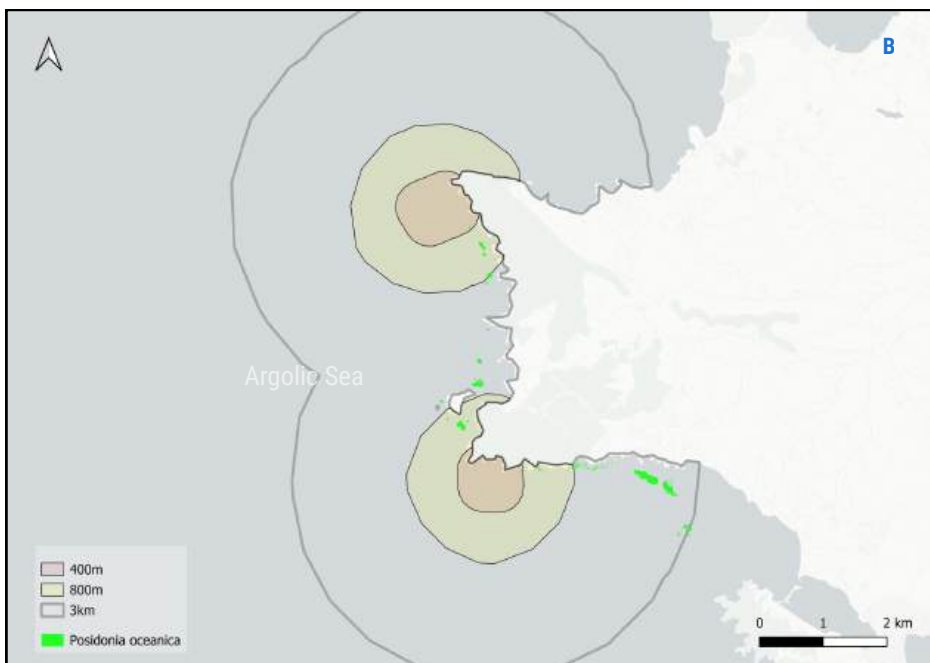
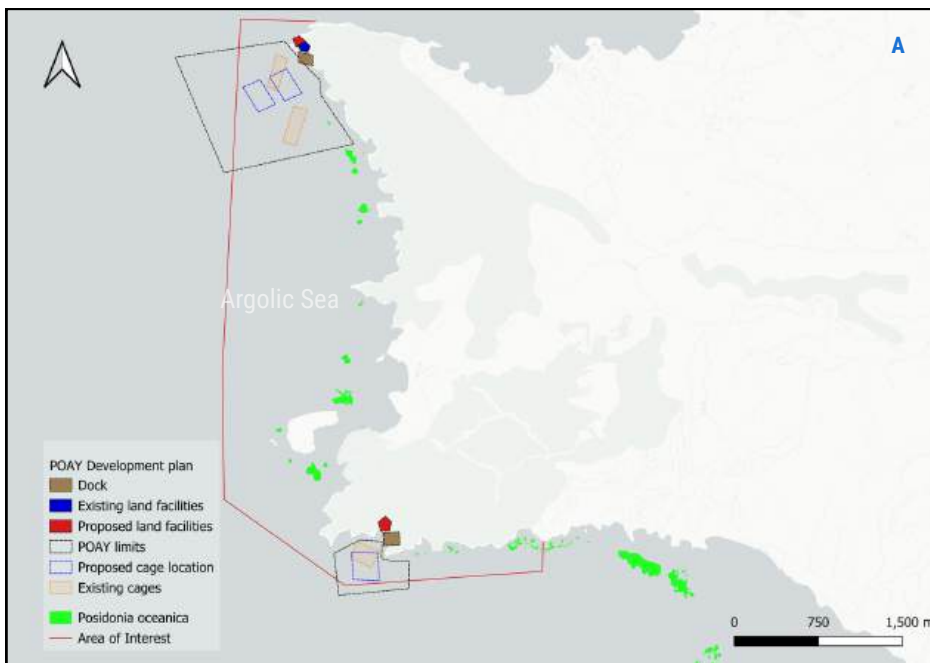


Figure 14. *Posidonia oceanica* (Habitat 1120) distribution in accordance with the development plans (A) and the impact (buffer) zones (B) of the facilities in Aol 3 and beyond.

EXPLORING HISTORIC DISTRIBUTION

Within **Aol 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 15). 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 matter.

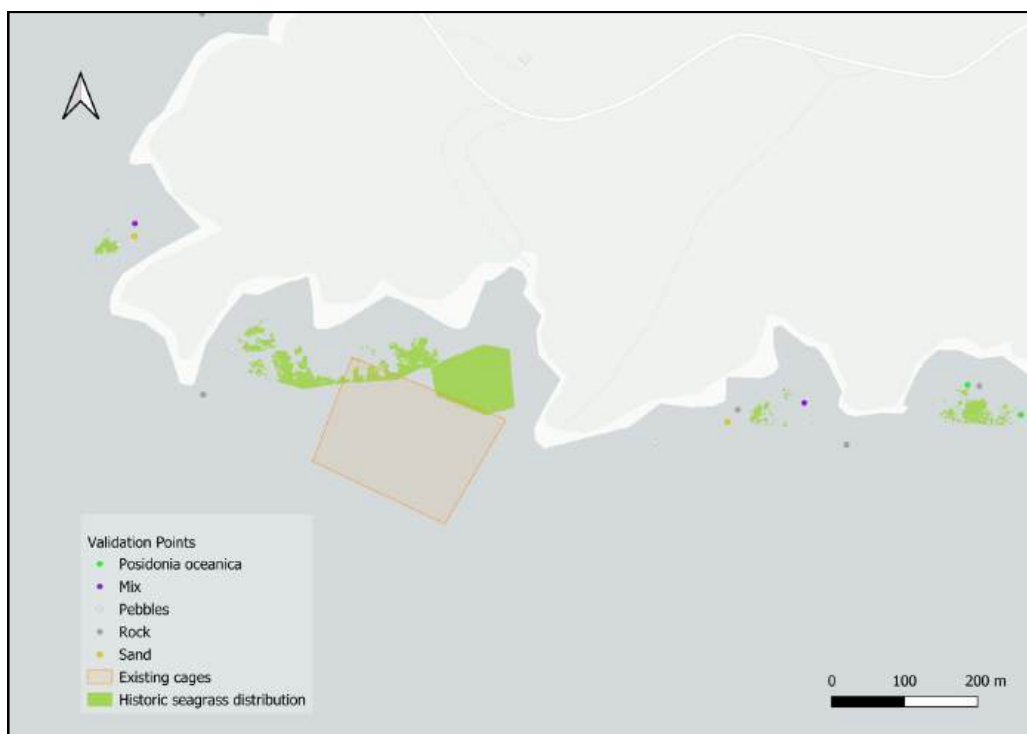


Figure 15. Aol 3 with the historic meadows shown in green, habitats indicated by coloured dots, and aquaculture cages visible.

Aol 4 (Adjacent to Vourlias bay)

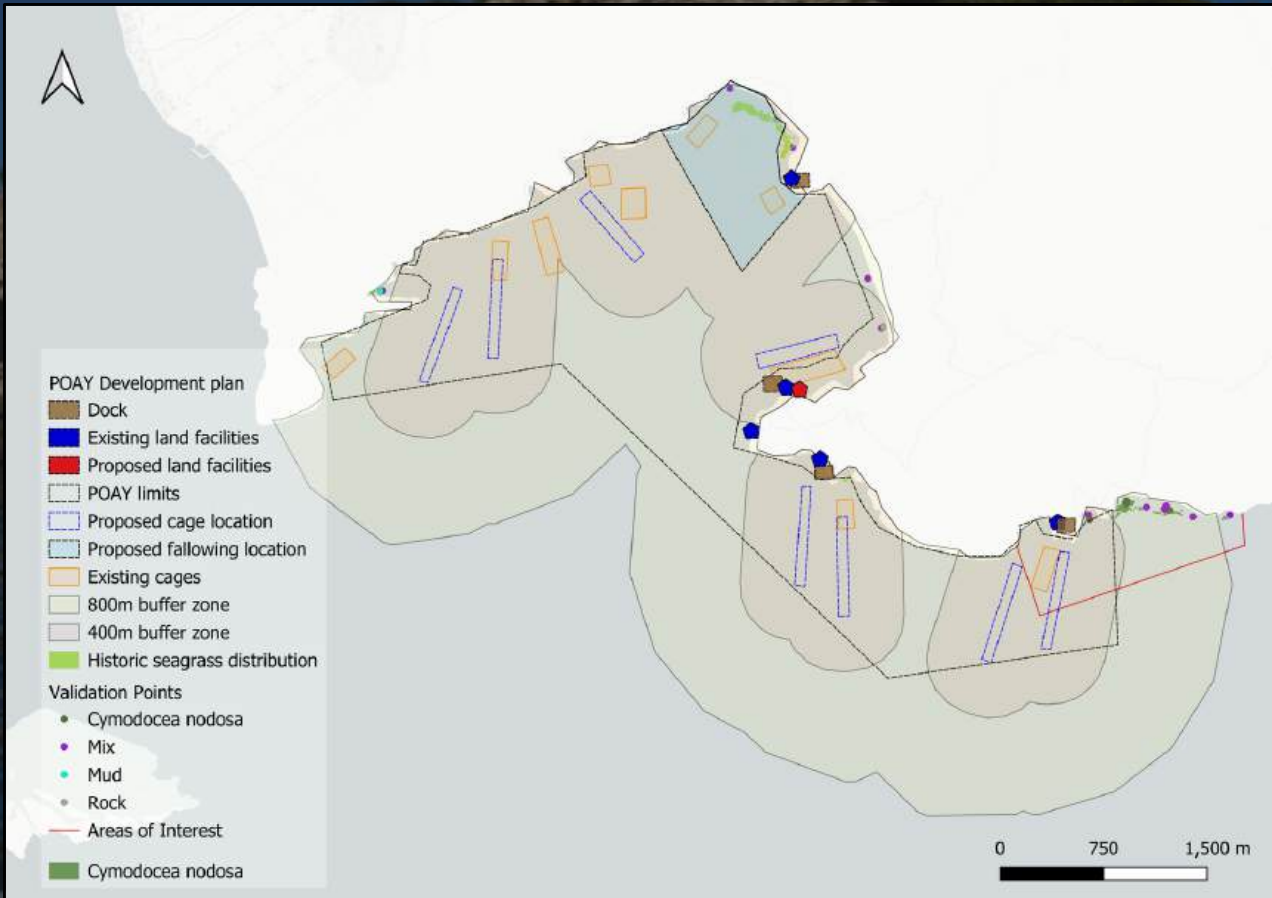


Figure 16. Visualization of all layers within the discussed section of Area of Interest 4.

PRESENCE / ABSENCE DATA

Aol 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 16). Regarding seagrass species observed, **Cymodocea** was **only** found within the study limits, and not in the nearby bay, forming meadows or patchy distributions, while other habitats observed (the majority of the observations) were characterised by soft substrates like sand and mud, and rocky surfaces.

SEAGRASS HABITAT MAPPING

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 seagrass calculated was **1.55 ha** (Figure 17A).

SEAGRASS DISTRIBUTION IN POAY

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 17C).

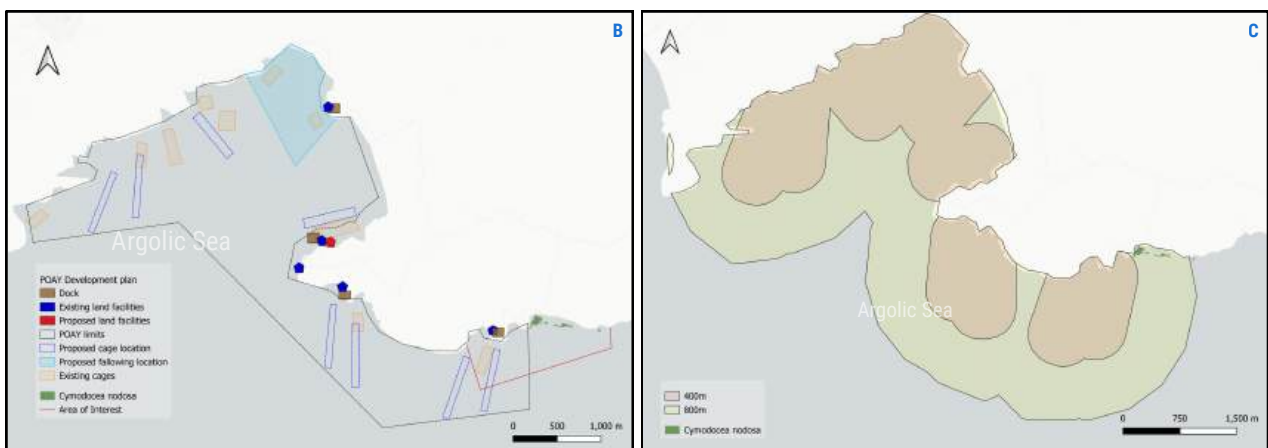


Figure 17. *Cymodocea nodosa* distribution (A) in accordance with the development plans (B) and the impact (buffer) zones (C) of the facilities in Aol 4 and beyond.

EXPLORING HISTORIC DISTRIBUTION

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 $37^{\circ}27'05.6''\text{N}$ $23^{\circ}04'15.3''\text{E}$ (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 18A). Three validation points confirm the presence of these two *Cymodocea* meadows, which still remain alive but form a sparse distribution.

Furthermore, at location $37^{\circ}27'20.4''\text{N}$ $23^{\circ}03'03.5''\text{E}$ (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 18B). No validation points could be taken here due to the proximity of the cages (**150m**). Similarly, at $37^{\circ}28'07.0''\text{N}$ $23^{\circ}00'48.3''\text{E}$ 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 18C). 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 $37^{\circ}28'36.4''\text{N}$ $23^{\circ}02'45.4''\text{E}$ (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 18D) 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.

EXPLORING HISTORIC DISTRIBUTION

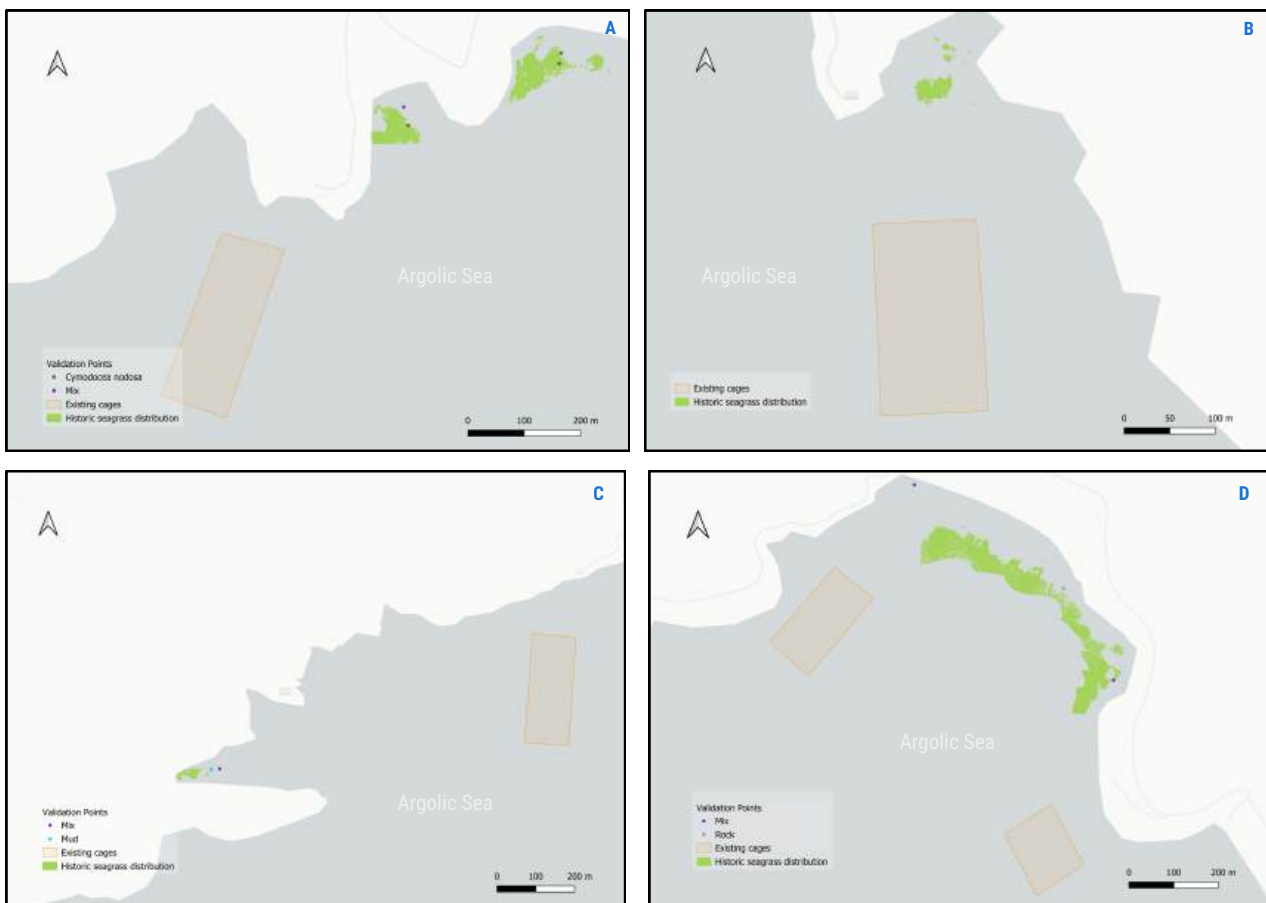


Figure 18. Close to Aol 4 with the historic meadows shown in green polygons, habitats indicated by coloured dots, and aquaculture cages visible.

Aol 5 (Plateia Island)

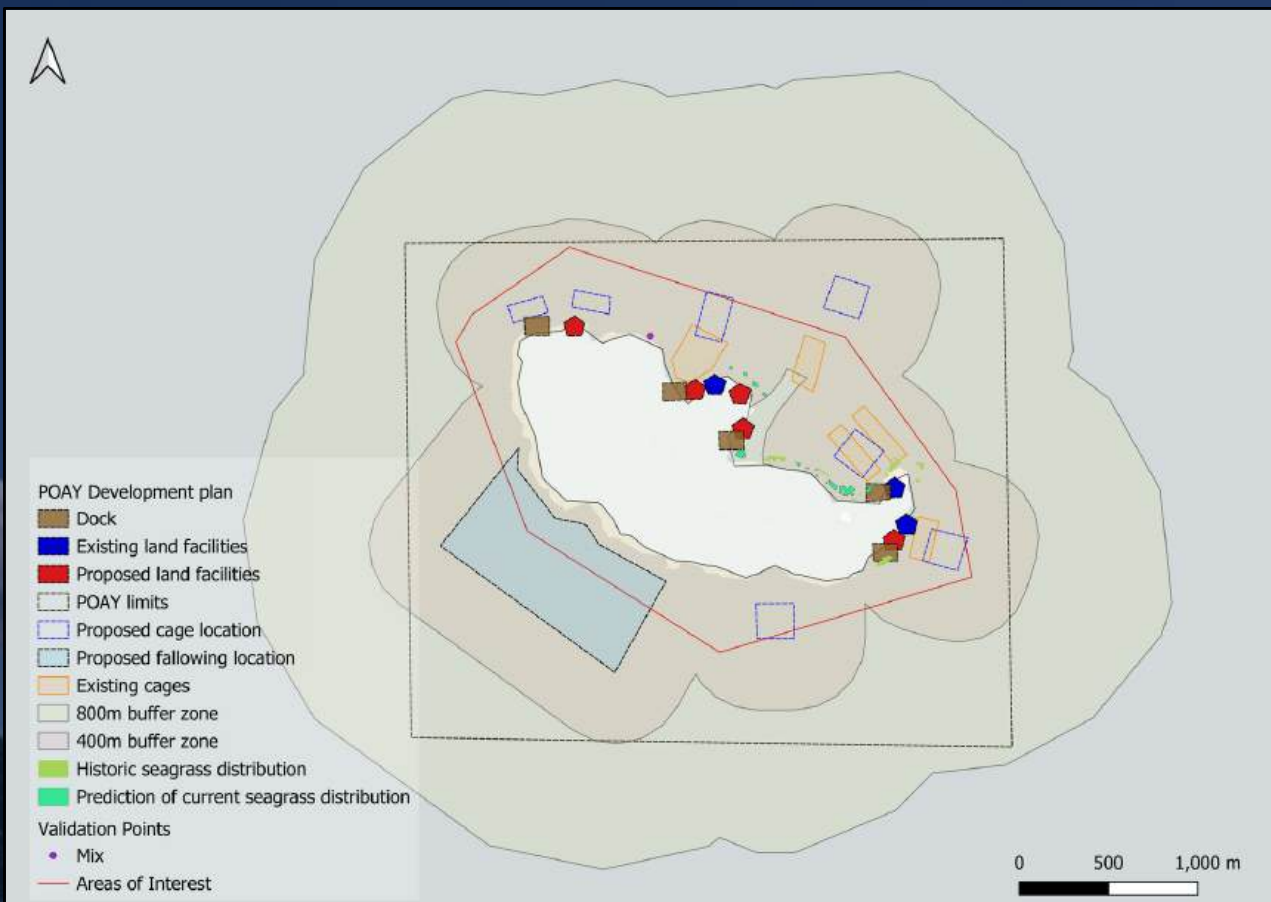


Figure 19. Visualization of all layers within the discussed section of Area of Interest 5.

PRESENCE/ABSENCE DATA, SEAGRASS HABITAT MAPPING & SEAGRASS DISTRIBUTION IN POAY

Aol 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 with field validation due to the proximity of the cages to the coast, 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 19).

PRESENCE/ABSENCE DATA, SEAGRASS HABITAT MAPPING & SEAGRASS DISTRIBUTION IN POAY

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 sat 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 20). 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 21).



Figure 20. Current approximate seagrass covered areas at Aol 5 from Google Satellite imagery from 2024.

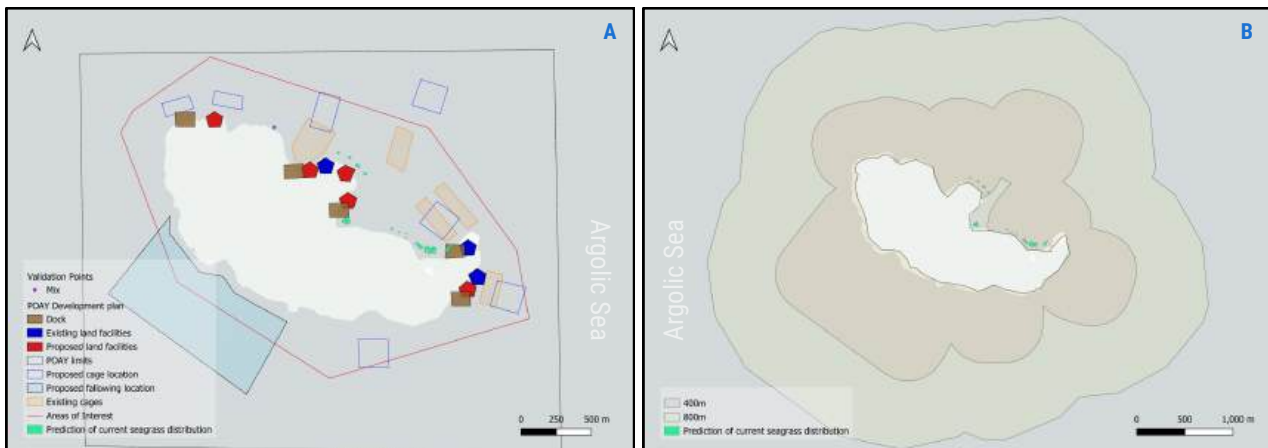


Figure 21. POAY development plan (A) and the impact buffer zones (B) of the facilities based on the plan.

EXPLORING HISTORIC DISTRIBUTION

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 seagrass coverage area of **1.52 ha** (Figure 22). 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 22. Estimated historic seagrass covered areas within Aol 5 from Google Satellite imagery from 2013

Legal Framework



Seagrass species are one of the most threatened species globally by previous and current human activities [16, 17], with the need for preservation.

The two species discussed in this report, *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.

Discussion



The results of this report showcase the presence of two seagrass species found within and adjacent to the areas of interest, *Posidonia oceanica* and *Cymodocea nodosa*. Based on the proposed development plan [35], the facilities must be placed more than 400m from a living *Posidonia* meadow, whereas other seagrass and *Cymodocea* meadows are not included. According to the current bibliography, aquaculture runoff effluents can extend to a significant area surrounding the cages [17] and have an impact on *Posidonia* meadows even at a distance of 3km [18]. The effects in most cases have to do with an increase in sedimentation level of hypertrophic particles, hence an increase of turbidity, which has a direct impact on the plant's functional mechanisms (i.e., photosynthesis), limits the growth of *Posidonia* leaves (e.g., length and width), and consequently decreases its growth and density [19].

Karakassis et al. (2013) [20] suggest that fish farming should not be permitted at least 800m from the boundaries of a *Posidonia* meadow, while facilities operating in proximity to these should either be relocated or at least not be permitted to increase production capacity. Part of *Posidonia*'s distribution in Aol 2 and Aol 3 falls within the POAY limits, where the 400m distance is not applicable, as in Aol 2, a patch of 0.13 ha is located approximately 100m away from a proposed cage location, while in Aol 3, 0.11 ha with the closest patch occurring approximately 300m away. For the 800m impact zone, the mapped seagrass area increased in Aol 3, whereas within the 3km zone, nearly the entire mapped seagrass was included.

Regarding *Cymodocea*, the impacts of aquaculture on this seagrass are not well studied, where, based on the available literature, the potential effects could extend up to 400-500m [31]. In this report, impacts were assessed using a 400m zone, together with an 800m zone defined as an intermediate impact zone. In Aol 1 and Aol 3, as the *Cymodocea* could not be mapped, no impact estimation was possible. In Aol 4, no mapped meadow occurred within the impact of the 400m, whereas in the 800m zone, almost the entire meadow was included, indicating that most of the habitat could possibly be affected. In the study area Aol 4, a previous study by Kock et al. [31] reported that the aquaculture effluents affected the meadow, where, closer to the facilities, the intensity of the impacts was increasing.

Additionally, adjacent to the Aol 4, Vourlias Bay is subjected to intensive aquaculture activity. The historical mapping of the bay documented the presence of seagrass that currently are totally absent, with no remaining traces of their existence. This loss may be associated with the long-term fish farm operation, potentially in combination with the enclosed profile of the area. For the areas where mapping was not completed, the seagrass close to the aquaculture facilities operation area could potentially be further affected.

Across the Aols, the absence of seagrass mapping was evident. Aquaculture activities may cause implications for the survival of these fragile habitats, and therefore, the actual distribution should be thoroughly assessed before their establishment. The abovementioned findings showcase that the Environmental Impact Assessment [35] for the study areas did not consider the presence of the surrounding seagrass habitats. Furthermore, the effluents may cause significant repercussions to the adjacent habitats, particularly through the increase of productivity in enclosed bays and nearby sensitive habitats. In the EIA, the selected sampling stations did not provide sufficient coverage to represent the entire area, exhibiting results that might not accurately reflect the conditions of this wide area. In addition, the absence of a detailed monitoring plan and management measures is evident [36], while it should be included to prevent further environmental decline.

Although the seagrass meadows presented in this report are not designated under any protection status (e.g. Natura2000 Network), their presence remains ecologically significant due to the important ecosystem services they provide. An incomplete management plan would affect local environmental conditions and therefore the associated habitats and life surrounding them. Before an aquaculture establishment, a comprehensive scientific assessment of other existing uses of the assessed area (e.g., fishing, eco-tourism) should be conducted to ensure the area's suitability and in order to mitigate conflict with other activities occurring in the area. Moreover, it is imperative to note that such activities should comply with the protocols and guidelines, occurring in areas where the environmental conditions (e.g., hydrodynamics, seagrass beds) could accommodate and potentially mitigate the impacts.

DATA AVAILABILITY



Validation points



Seagrass mapping



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