

PRIORITISING POSIDONIA OCEANICA MEADOWS IN THE IONIAN SEA



**BLUE MARINE
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Foreword



Marcial Bardolet,
Co - founder of the Mediterranean Posidonia Network

For ages, the Mediterranean and the Ionian Sea have been connected through an amazing marine ecosystem in need of preservation: The *Posidonia oceanica* seagrass.

Posidonia is **a vital marine forest**, teeming with life and biodiversity, and an integral part of our Mediterranean heritage. In an era marked by climate change, *Posidonia oceanica* assumes even greater significance. It acts as a substantial **carbon sink** and plays a pivotal role in **mitigating coastal erosion** by reducing the wave energy, **producing organic sand**, and keeping **the dune systems safe with its fallen leaves**. These **natural treasures** face **mounting challenges**, including **coastal urbanization, anchor damage, and rising temperatures** due to the **climate crisis**. Thus, **protecting these meadows is more crucial than ever, offering a crucial pillar of hope for oceanic health**.

This report, "**Prioritising Posidonia Oceanica Meadows in the Ionian Sea**," confronts the urgency of preserving these marine ecosystems. It **emphasizes the vital role of *Posidonia oceanica* in maintaining the health of our oceans and its crucial contribution to coastal resilience**. We highlight the indispensable role of organizations like iSea in conserving these marine spaces, especially within **Natura 2000 sites**. Their dedication to **research and stakeholder collaboration** is **fundamental** for the **long-term management and safeguarding of *Posidonia oceanica*** and so, the rest of the **ecosystemic benefits**.

The collective efforts of communities, governments, and scientific bodies illustrate that unified and coordinated actions can significantly impact positively. Posidonia is a shared responsibility, And this document is not just an academic study of *Posidonia oceanica*; it is a call for action for protecting the Ionian Sea.

In collaboration with **iSea and the Mediterranean Posidonia Network**, we can make a substantial difference in preserving these marine ecosystems through a **holistic approach** that merges **research, education, and public engagement in conservation**. Together, we can safeguard these vital ecosystems, essential for the sustenance of life in the **Mediterranean and in our planet**.



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Glossary

Alien species: As alien are characterised non-native species (plants and animals), with respect to a particular ecosystem, living outside of their natural range/distribution.

Blue Carbon: Blue carbon refers to organic carbon that is captured and stored by the oceans and coastal ecosystems, particularly by vegetated coastal ecosystems such as mangroves, tidal marshes and seagrass meadows.

Ecological Quality Ratio: The ratio that represents the relation between the values of the observed biological parameters with their respective values in a reference system, and is used to determine the ecological water quality status.

Ecosystem services: Ecosystem services are defined as the direct and indirect contributions of ecosystems to human well-being and have an impact on our survival and quality of life. There are four types of ecosystem services: provisioning, regulating, cultural and supporting services.

Endemic: A species whose range is restricted to a limited geographical area.

Functional extinction: Functional extinction is the extinction of a species such that: it disappears from the fossil record, or historic reports of its existence cease; the reduced population no longer plays a significant role in the ecosystem function; or the population is no longer viable.

Invasive species: As invasive are characterised alien species that significantly modify or disrupt the ecosystems they colonise.

Kyoto protocol: An international treaty committing UN country members to limit and reduce greenhouse gas emissions according to their agreed individual targets.

Macroalgae: Macroalgae, or seaweeds, are macroscopic photosynthetic marine organisms that possess plant-like structural features and are visible to the naked eye.

Macrophytes: Macrophytes, or seagrasses (in respect to the marine environment), are vascular marine plants that are visible to the naked eye.

Matte: a special structure formed by the horizontal and vertical grow of the *Posidonia oceanica* rhizomes.

Paris Agreement: An international treaty concerning Climate Change, and covering Climate Change mitigation, adaptation, and finance.

Rhizome: a horizontal underground plant stem capable of producing the shoot and root systems of a new plant.

Abbreviations

EQR: Ecological Quality Ratio

ES: Ecosystem Services

GES: Good Ecological Status

IPCC: Intergovernmental Panel on Climate Change

MPAs: Marine Protected Areas

MPN: Mediterranean Posidonia Network

MSFD: EU Marine Strategy Framework Directive

SES: Special Environmental Study

SRES: Special Report on Emissions Scenarios

WFD: Water Framework Directive



Dive into *Posidonia oceanica*

The endemic species *Posidonia oceanica* is the most extensive seagrass in the Mediterranean Sea and its ecological role is similar to the forests in terrestrial environments. *Posidonia* forms lush and extensive meadows from the shoreline up to 45m depth, covering approximately 25% of the Mediterranean Sea [1].

Morphologically, this seagrass comprises of roots, rhizomes and leaves, it has an annual cycle like other plants, and beneath its rhizomes it forms mattress-like banks that are called "mattes".

The three-dimensional habitat it forms is of pivotal importance, providing >20 Ecosystem Services (ES) [2].

>3% of total catches in the Mediterranean are related to *P. oceanica* meadows [3]



> 1,400 species live in this habitat

P. oceanica meadows constitute a permanent habitat and serve as a nursery, spawning and hunting ground, hosting >400 different plant species and >1,000 animal species making these underwater meadows a biodiversity hotspot [4, 5, 6].

“5.6 million tonnes of CO₂ emissions are fixed annually & 21% of this carbon will be stored in *P. oceanica* mattes for millennia [7].

“Total estimated economic value from ES of *P. oceanica* yields up to 514 €/ha/year [2]

They produce up to 14L of O₂ per m² per day and it is estimated that they fixate up to 5,681,206 tonnes of CO₂ emissions annually in the Mediterranean Sea [7].

Posidonia oceanica is one of our most crucial allies in Climate Crisis mitigation, as it's one of the most efficient carbon sinks compared to other Blue Carbon ecosystems [8].

Furthermore, *P. oceanica* serves as a purifier as it **improves the water quality** by trapping particle loads including harmful **particles of heavy metals** and, as recently discovered, **microplastics** [9].

It is an “**ecosystem engineer**” acting as a natural barrier and wave braker; **stabilising the sediment in the seafloor and protecting the coasts from erosion** [2].



As a temperate species, *P. oceanica* **leaves fall in autumn**, these are then washed by the currents to adjacent beaches forming a new habitat; the “**banquettes**”, who also serve as **wave brakers; temporal carbon storages, trap plastic debris and export nutrients towards the terrestrial dune ecosystem** [10].

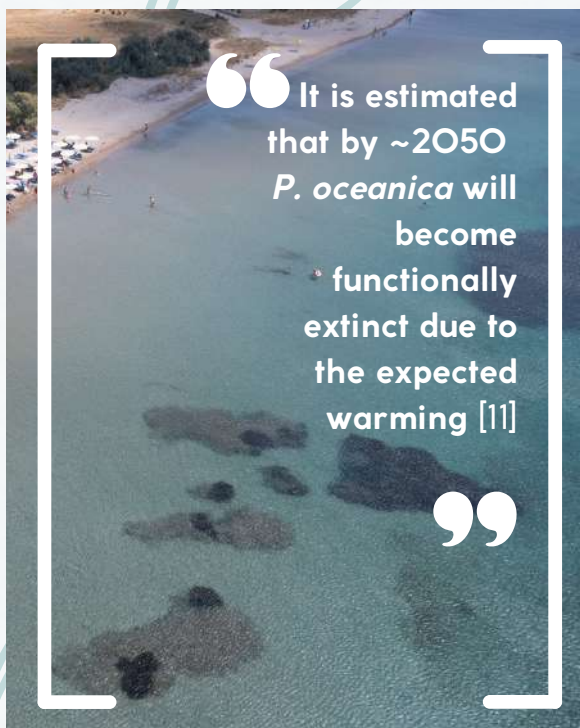
Due to the importance of *P. oceanica*, the species is protected by the **Barcelona Convention (Annex II; List of the endangered or threatened species)**, the **Bern Convention (Appendix 1; Strictly protected flora species)**, while it is also considered a priority habitat by the **EU Habitats Directive (92/43/EEC; Annex I)** and therefore the EU parties are obliged to protect it. Following that designation, it is included in the **EU Regulation (1967/2006/EC)** regarding the management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, which **prohibits fishing with dynamic gears** (trawls, dredges, beach trawls, etc.) on vegetated bottoms especially those with *P. oceanica*.

Finally, the species serves as a **biological indicator** for coastal waters and habitats and its monitoring is required by all member states according to the **Water Framework Directive (2000/60/EC)** and the **Marine Strategy Framework Directive (2008/56/EC)**, while actions to preserve it are required to achieve and maintain **Good Ecological Status (GES)**.

Pressures on Posidonia meadows

P. oceanica is a particularly fragile species with **slow growth rate**.

A variety of **localised pressures** can affect the meadows' health, such as fluctuations of salinity, turbidity and increased flow of sediments **which can cause irreparable damage** [7].



Currently, estimations on **loss of its areal extent in the Mediterranean range between 13% and 50%** since the 1960s [12] related to various reasons. However, new studies project its **functional extinction by the middle of the century (2049 +/-10)** due to **Climate Crisis warming even under a relatively mild greenhouse-gas emissions scenario** [11].

One of the main pressures to *P. oceanica* is **mechanical damage** which causes a) uprooting of the rhizomes, b) cut leaves and, c) meadow fragmentation.

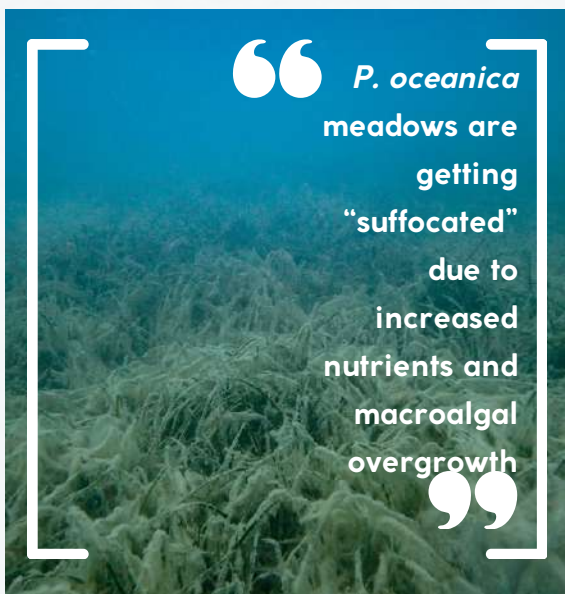


After the EU regulation banning fishing with dynamic gears on top of *P. oceanica* meadows, **the primary cause for mechanical damage is uncontrolled anchorage**. Uncontrolled anchorage is the most documented impact of recreational boating, impacting all Mediterranean coasts.

Another activity causing direct mechanical damage is **illegal fishing with explosives and/or dynamic gears**.



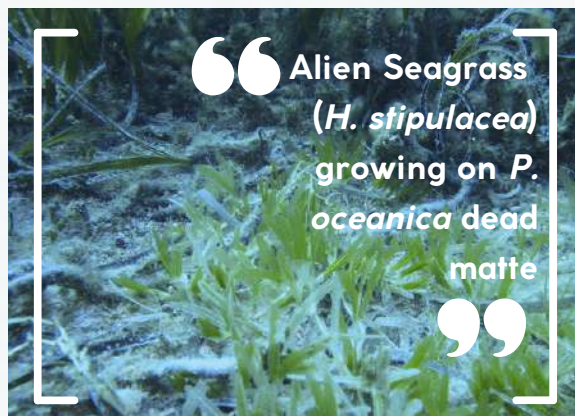
Another documented pressure is coastal development (e.g., harbour construction, beach filling, land reclamation, construction of pipelines/cables, dams and breakwaters, river diversions and other coastal works). Such activities cause changes in environmental parameters (i.e., fluctuations of salinity, turbidity and increased sedimentation) which as a result impact the meadows' health by disrupting vital functions of the plant (i.e., photosynthesis, respiration, etc.).



P. oceanica is a biological index for achieving GES, as it is sensitive to water quality degradation. This pressure includes overflow of nutrient input and organic matter, which can also trigger eutrophication phenomena and macroalgal growth, damaging the meadows' health. These are caused by activities such as aquaculture and urban/ industrial sewage input.

As mentioned above Climate Crisis is one of the main threats to *P. oceanica* with extreme phenomena such as heat waves, storms and heavy rainfalls, and flood stressing vital mechanisms of the plant and in some cases causing mortality. The latter, in combination with the introduction of Alien and Invasive species (macroalgae, macrophytes), that are more adapted to warmer climates, increases the competition for space and resources.

Alien species documented to pose a threat to *P. oceanica* are: *Caulerpa* spp., *Halophyla stipulacea*, *Acrothamnion preissii*, *Womersleyella setacea*.



All the aforementioned pressures work in combination, with some being interconnected. As such, activities that pose one threat are affecting and strengthening the impact of the others.

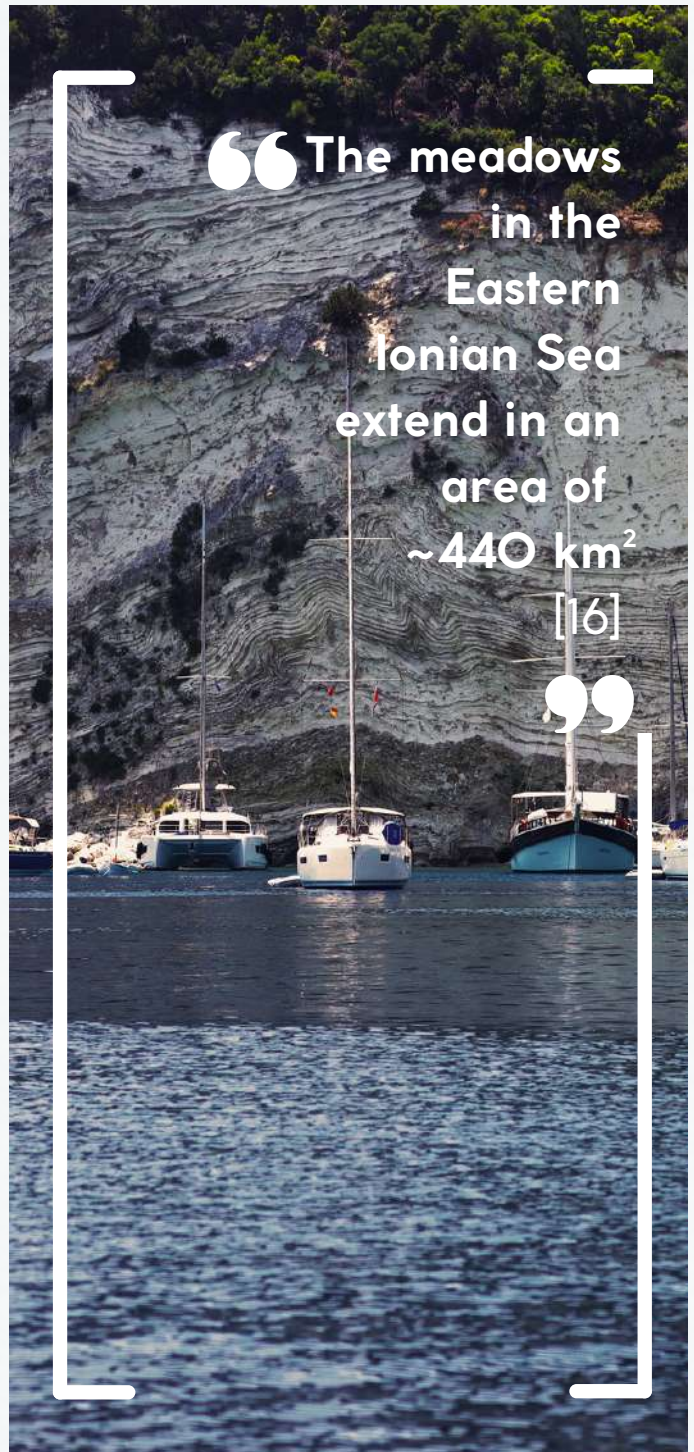
Posidonian Sea

Posidonia meadows can be found along the majority of the Greek coastline (~70%), constituting the most dominant seagrass [13]. However, its meadows are still not sufficiently mapped [12], and thus the available data regarding their extent and distribution is ambiguous.

iSea, together with the Ionian Environment Foundation and the Blue Marine Foundation, joined forces to identify priority Posidonia meadows in the Eastern Ionian Sea.

The project “**Prioritising Posidonia oceanica meadows in the Ionian Sea**” aims to map the key pressures the meadows face in the Ionian Sea by combining existing data and **prioritise the meadows according to the threats they face.**

The results of the latter will be used as **a decision tool to focus future efforts and highlight gaps of knowledge.**



Eastern Ionian Sea

The Eastern Ionian Sea presents a narrow continental shelf with steep reliefs which largely account for deep and oligotrophic coastal water masses [14], while large rivers outflows (e.g., Kalamas, Acheloos, Evrotas) are relatively limited and locally restricted. In this marine area, which is therefore generally characterised by exceptional water transparency (down to 40m) [15]. This allows the meadows of the Ionian Sea to reach deeper while in general their shoot density is higher than elsewhere in Greece [14]. After the South Aegean Sea, the islands in the Eastern Ionian Sea have the most extended meadows (~440 km²) [16].²For most of the Ionian Sea, the Posidonia meadows habitat is poorly documented with Natura 2000 not being an exception.

Threats

Posidonia is known to be susceptible to a variety of pressures, affecting its distribution, density, and physiology. To gather information on the local pressures in the Ionian Sea, we considered factors such as uncontrolled **anchorage**, **sewage discharges**, **aquaculture**, and **coastal development activities**.

Pressures considered for the spatial prioritisation



Anchorage

Aquaculture



Sewage

Coastal development



Sport, tourism & leisure activities

The geospatial data for the aforementioned activities derived from available online sources, with the exception of anchorage which was compiled by leveraging high-resolution open-source satellite imagery provided by Google Earth Pro of anchored boats observed in the area during the summer months of 2022.

To run the prioritisation model each identified pressure received a ranking, regarding the qualitative damage it poses, using experts' knowledge.

Anchorage was attributed the highest score with the most direct, extensive and seasonally intensive pressure on Posidonia meadows and it is vast practise that even within Natura 2000 sites it is unregulated [17, 18, 19], while **aquaculture** and **sewage discharges** also have a significant impact on the meadows of the Ionian Sea.



Figure 1: P. oceanica distribution in the Eastern Ionian Sea based on data acquired from various sources, sensors and methods that cover the coastal zone of Greece [13]. The map is adjusted and upscaled to 1x1 km grid.

All the layers gathered were upscaled to 1x1 km grid and a prioritisation model was applied using the zonation algorithm [20, 21]. To identify meadows of priority, previous Posidonia mapping efforts were compiled in one map and similarly to the pressures, upscaled in a reference grid 1X1 km². The Posidonia meadows occupy the majority of the Eastern Ionian Sea (Figure 1).

[1] <https://emodnet.ec.europa.eu/en>

[2] <https://geonode.epm-maps.gr/maps/3497/view#/>

Areas of priority

The prioritisation analysis ranked high values with *Posidonia* meadows, while “avoiding” areas where human activities act as pressure. The priority index ranges from 0 to 1, indicating the least and the most important areas, in respect to conservation (giving priority to apparently undisturbed areas) [22].

We classified these values in 4 categories indicating the scale of threats to the meadows (Figure 2).

The meadows classified as “Least threatened” are found in 8 distinct locations, namely in the southeastern part of **Kefalonia (Lixouri-Argostoli)**, the eastern part of **Zakynthos (Planos)**, the **northwestern coasts of the Peloponnese (Kyllini)**, parts of the **north and southern coasts of Corfu Island**, the coasts around **Aktio**, a tiny patch west to **Messolonghi** and a tiny patch in the **Messenian Gulf**.

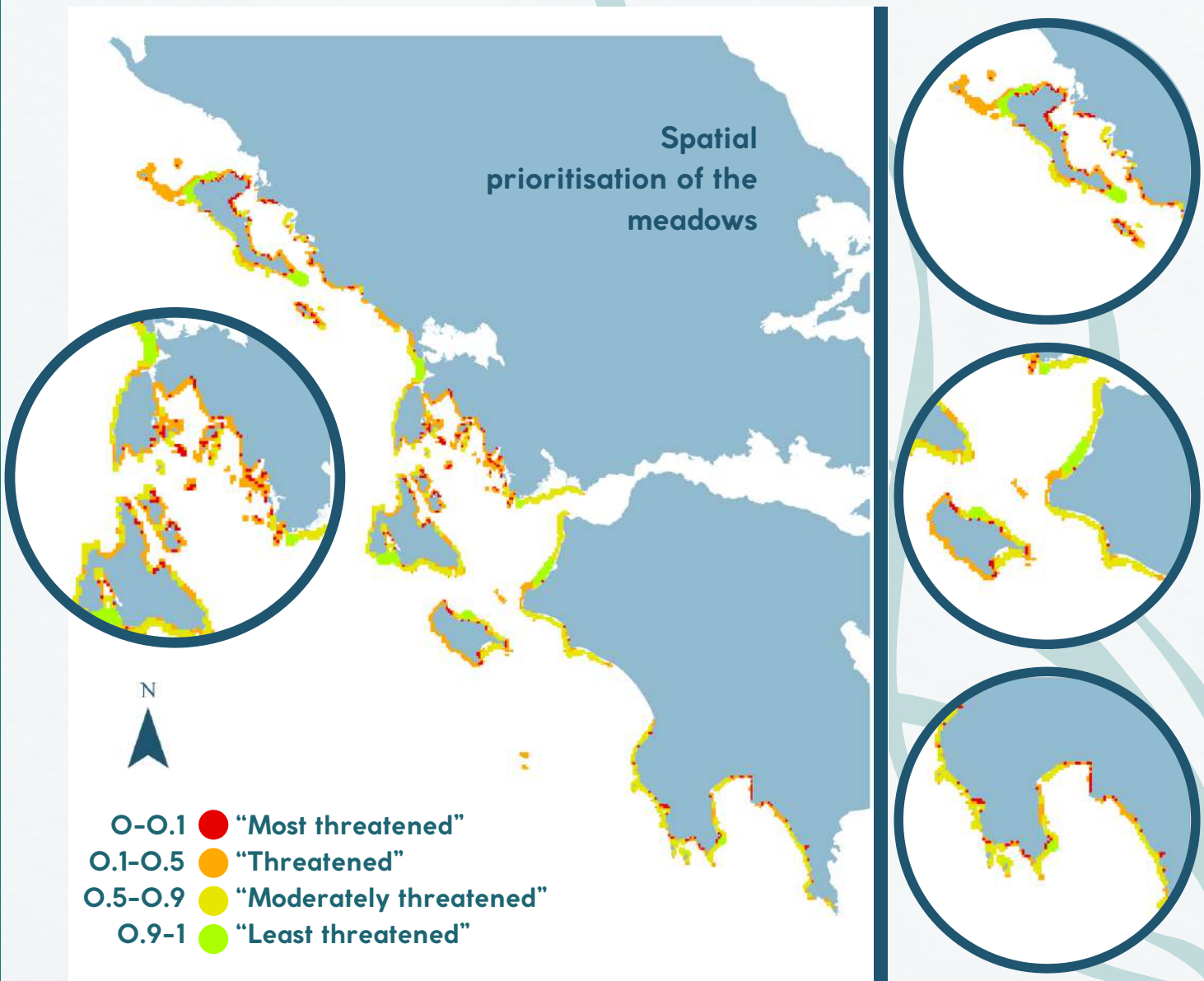
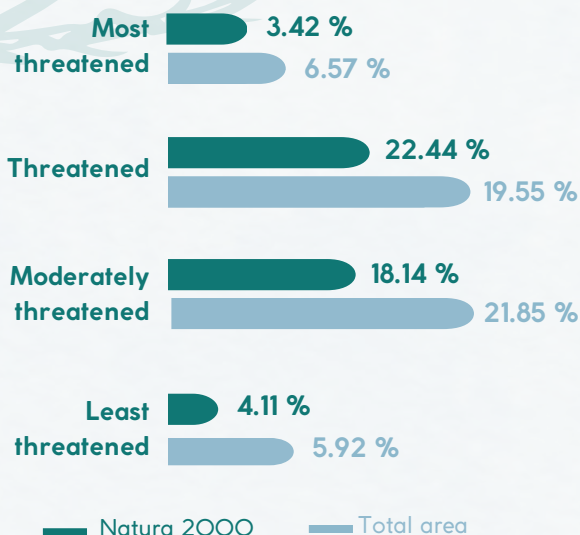


Figure 2: Priority areas in the Eastern Ionian Sea (1x1 km)

On the contrary, the “**Most threatened**” meadows are more **dispersed** and include, the ones in the **Inner Ionian Archipelago**, the **islands of Paxoi**, the **Eastern and North Corfu Island**, **Zakynthos** and several patches in the coasts of **Messenia** (Peloponnese). These **results align with previous studies** that identified the **Inner Ionian Archipelago** (GR2220003), the islands of **Paxoi and Antipaxoi** (GR2230004) and the **Marine region of Messenia** (GR2550010) to be the **most impacted Natura 2000 sites in Greece** [20].



Natura 2000 sites represent 46% of the total area of Posidonia meadows distribution in the Ionian Sea.

It is indicative to the lack of management measures regarding known threats to Posidonia meadows, that all four classes were found within Natura 2000 sites; with 3.42% belonging to the “most threatened”, 20.44% to the “threatened”, 18.14% to the “moderately threatened” and 4.11% to the “least threatened” meadows.

Mechanical damage caused by anchoring is among the biggest threats to Posidonia meadows; being very well documented in the western Mediterranean, in sites frequently visited by boaters.

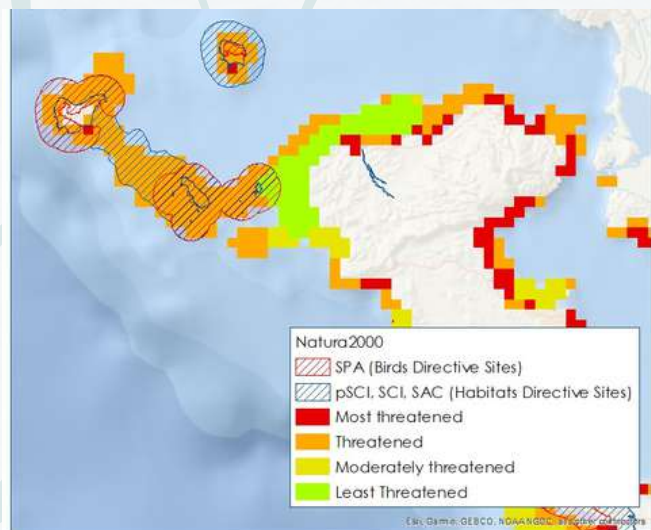
In the last decade, different strategies have been put into practice to reduce such impacts on seagrasses in different Marine Protected Areas (MPAs) across the Mediterranean, **by anchoring bans, fines, monitoring/ patrolling and establishment of mooring systems.**

However, Greece lacks the legal framework for the installation and maintenance of such mooring systems; even though this need is increasing in parallel with boat tourism in the Ionian Sea.

The spatial extend of this pressure is evident by this work, with its real impact going unseen under the legal gaps for the protection of this priority habitat.

In addition, the meadows near fish farms are not able to properly grow [23]; a fact that is of growing concern in the Ionian Sea. In particular, **61% of fish farming overlaps with the meadows' distribution**, challenging even further the areas that are classified as “most threatened” and “threatened”. In addition, approximately **1/5 of fish farming** is located inside Natura 2000 sites.

To further examine the results of this work, we decided to zoom in to two case studies: **Northern Corfu** and the **Inner Ionian Archipelago**. In both, we have Natura 2000 designations, anchoring of leisure boats and fish farms, while at the latter sewage discharges are also documented.



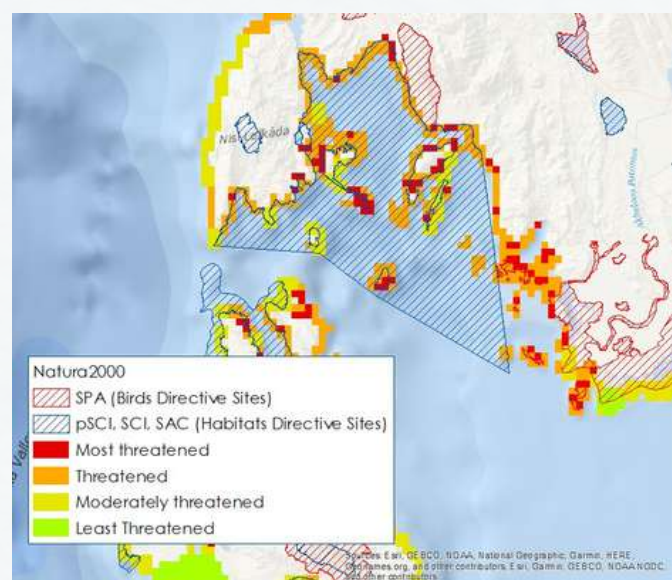
The case study of **Northern Corfu** extends over an area of 308 km² and in 44% of its Posidonia meadows are within the Natura2000 network. These meadows are classified by 5.5% as “most threatened”, 65.9% as “threatened” and 9.5% as “least threatened”.

Within the area the main threat is anchoring especially in the Northeastern part which has very high traffic from leisure boats during the summer [24]. In the area there is also a 1 fish farm located close to Kassioyi.

What is very interesting in this case study is the “least threatened” meadows located just in the borders of the Natura 2000 site of Othonoi islands (Northwestern) which are classified as “least threatened”. This can be explained by the lack of documentation of pressures outside the Natura 2000 sites, plus the lack of measures regarding anchoring either in or outside the protected area; a practice that has proven to be detrimental for the priority habitat *Posidonia oceanica* constitutes.

As regards the **Inner Ionian Archipelago**, the whole area is a Natura 2000 site where Posidonia meadows cover ~43.7% of its extend. The meadows are classified by 42.1% as “most threatened”, 49% as “threatened”, 50.2% as “moderately threatened” and 6.5% as “least threatened”. **The site has been identified by previous studies as one of the most impacted by anchoring [25].**

The area is among the most popular destinations for new sailors as the sea is mostly calm and protected, while in the site there are 12 islands and islets of which 7 are uninhabited offering a rich natural landscape and attracting a very high number of boats [26], exceeding the capacity of the 15 port facilities which are constantly expanding to meet the needs of this growing activity [27]. Sewage discharges are observed in Vasiliki, Palairos and in the canal between Meganisi and Lefkada. Finally, in the site there are 3 fish farm clusters located in Palairos, Mytikas and Kalamos.



Again in this Natura 2000 site, which is 100% marine, there are no measures protecting this priority habitat and activities are unregulated as the new management measures are still under a consultation* state and expected to be in place after a long period let alone enforced.

*Special Environmental Study: <https://shorturl.at/pxLMQ>

In the context of the Water Framework Directive (WFD), *P. oceanica* meadows are used as a biological indicator of the ecological status of water bodies [28]. We compared four biotic indices that were computed in the past in the context of WFD and the requirements of Natura 2000 network and previous work of iSea, in the Eastern Ionian Sea, namely **PREI**, **Valencian CS**, **BiPo** and **CI**, with the results of this prioritisation.

The Ecological Quality Ratio (EQR) is characterised as “high” and “good”, coming in contrast with our ranking based on which most of the studied areas are in the range of “most threatened” to “moderately threatened” (Figure 3). However, this comparison is just to give us an idea as the majority of these indices in all but two areas were based on data prior 2015[28], and may not be representative of the current situation, while the ranking is regarding the threats not the state of the meadows.

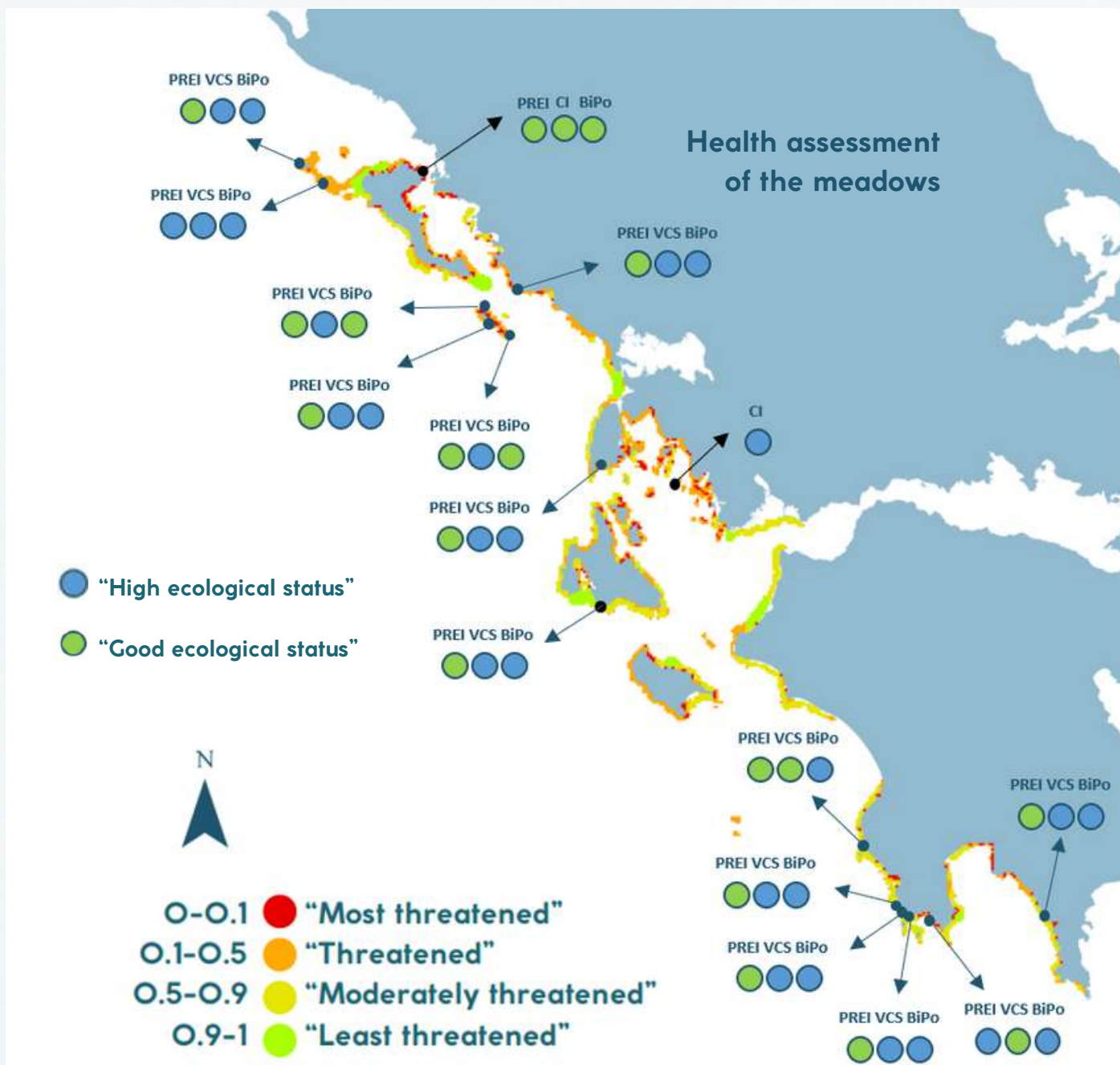


Figure 3: Priority areas (1x1 kilometre grid) and characterisation of their biotic indices.

Discussion

The existence of diverse pressures on the seagrass meadows growing in the Mediterranean Sea is undeniable [17]. In light of the newly discovered evidence of the impacts of Climate Crisis related events on the meadows, it is even more urgent to tackle localised pressures (i.e., anchoring, sewage, aquaculture, etc.).

However, it is easier said than done when **available cartography is ambiguous, and the legal framework is abstract.** While *P. oceanica* is protected under multiple conventions and regulations, concrete provisions on management and mitigation of specific pressures are absent. Even though the technical report of the European Commission for the Management of Natura 2000 habitats proposes specific measures [29], these are yet to be incorporated in EU and as far as Greek law is concerned; **the management plans for Natura 2000 sites are already past their deadline and currently still under public consultation state.**

The Special Environmental Study (SES) for the Ionian Sea [30] has specific measures regarding the Posidonia meadows habitat; including boat capacity and environmental studies for the installation of eco-moorings and prohibition of anchoring within the sites, however **these will not be enforced until the issue of a Presidential Degree** that is unknown when it will be enforced, let alone the implementation of the measures due to bureaucratic processes.

Finally, these measures will concern the extend of *P. oceanica* within the 62 marine Natura 2000 sites on a national level **covering just 8% of the Greek coastline [16] and in the case of the Ionian 46.11% of the total extent of the meadows.** Similarly to management measures, the same is true for monitoring requirements as the latter will be also limited in Natura 2000 sites and exclude specific measures regarding pressures' assessments.

Perhaps all the above are the aftermath of **lack of literacy** regarding the importance of this habitat from individuals working in the marine sector, national and local authorities, decision-makers, and nevertheless the general public. **The need to raise awareness about the matter is imperative to ensure its preservation and ecosystem services it offers.**

Case of the Balearics

- Regulatory framework on mooring/anchoring
- Installation & management of eco-moorings
- Monitoring of seagrasses in Natura 2000 sites
- Awareness & educational programs



Future steps

This preliminary work gave us the opportunity to identify the pressures to the Posidonia meadows in the Ionian Sea and the knowledge gaps regarding the cartography, pressures and monitoring.

To ensure the protection of *P. oceanica* meadows in the Ionian Sea, three priority actions have been identified.

1 Improve the knowledge regarding *Posidonia oceanica*

- Accurate and detailed mapping of *P. oceanica* meadows in the Ionian Sea
- Identification and quantitative assessment of the activities threatening the meadows
- Establishment of systematic monitoring of the habitat and the activities that affect its ecological status.

2 Awareness raising on the value of *P. oceanica*

- **National scale awareness raising and literacy campaign** on Posidonia meadows importance following the awareness objective of the Mediterranean Posidonia Network (MPN) by that Posidonia meadows are the “**Amazon Forest of the Mediterranean**”.
- Education and **training of boat tourism sector on correct practises regarding anchoring.**

3 Better-informed decision and policymaking

- Address of legal gaps by producing **specific and science-based local management measures using a precautionary approach** to ensure adequate protection for the species taking into consideration the activities taking place in the area within and outside the Natura 2000 network.
- Development of enforcement strategies to **minimise uncontrolled anchorage** by replicating models of Balearics and France (i.e. Remote monitoring systems, fines, etc).
- Development of **legally binding management plans setting specific goals** focused on protecting this crucial **blue carbon habitat** following the Intergovernmental **Panel on Climate Change (IPCC) report on Special Report on Emissions Scenarios (SRES)** and the goals set by **Kyoto protocol and Paris Agreement** [31, 32].
- Development of **legally binding management and monitoring actions plans** focused on restoration of degraded meadows, based on **current and future projections of change.**

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