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► To cite this version:

Denis Bailly, Laura Recuero Virto, Isabelle Perret, Pierre Scemama. The Underwater Forest of *Posidonia oceanica*: Recent Developments. 2025, pp.12. <hal-05341061>

HAL Id: hal-05341061

<https://hal.science/hal-05341061v1>

Submitted on 31 Oct 2025

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The Underwater Forest of *Posidonia oceanica*: Recent Developments



Figure 1. *P. oceanica* meadows (© Samuel Jeglot, NaturDive)

SUMMARY

In recent years, increasing attention has been given to the conservation of *Posidonia oceanica*, a vital Mediterranean seagrass species. This policy brief presents a review of the most recent scientific knowledge, along with ongoing efforts to protect and restore its meadows - primarily illustrated through research and experimental work carried out in France. *P. oceanica* meadows, often called the "underwater forests", form dense, leafy habitats that support rich marine biodiversity. Like their terrestrial counterparts, they provide shelter and food for numerous species, stabilise coastlines, and sequester significant amounts of carbon, contributing to climate change mitigation. Slow-growing and long-lived some clonal meadows are thousands of years-old, they are also highly vulnerable to human pressures such as anchoring, pollution, and coastal development. Protective measures include anchoring bans, eco-mooring systems, and marine protected area zoning, though enforcement remains uneven across regions. Innovative financing mechanisms, including blue carbon credit schemes, are emerging to support long-term conservation and sustainable local livelihoods.



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ACKNOWLEDGEMENTS:

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The EU Nature Restoration Law, which entered into force in August 2024, sets binding restoration targets for ecosystems, including marine habitats like *P. oceanica* meadows. Yet national implementation faces key challenges. Due to the species' exceptionally slow growth and sensitivity to disturbance, passive restoration, focused on reducing human pressures, is scalable and cost-effective, but demands sustained regulatory enforcement and long-term monitoring. In contrast, active restoration remains resource-intensive and experimental, with seed-based approaches aligning with natural reproduction, while segment transplantation offers an immediately operational solution.

The Law's emphasis on measurable ecological recovery may incentivise active restoration approaches, despite their technical and ecological limitations. This could lead to strategic imbalances if national plans prioritise visibility over viability. Moreover, variations in technical capacity, ecological baselines, and financing across Member States risk creating uneven implementation. Among the overlooked yet consequential pressures is the systematic removal of *Posidonia* banquettes from beaches, a practice that, despite its costly ecological and economic implications, receives far less attention than other threats. Often motivated by political or commercial assumptions about beach aesthetics, this removal undermines both biodiversity and shoreline stability, and stands at odds with restoration objectives.

Aligning policy ambition with ecological realism, recognising the unique biology of *P. oceanica* and the limits of current active restoration science, will be essential to ensure effective and scientifically grounded application of the Nature Restoration Law across the EU.

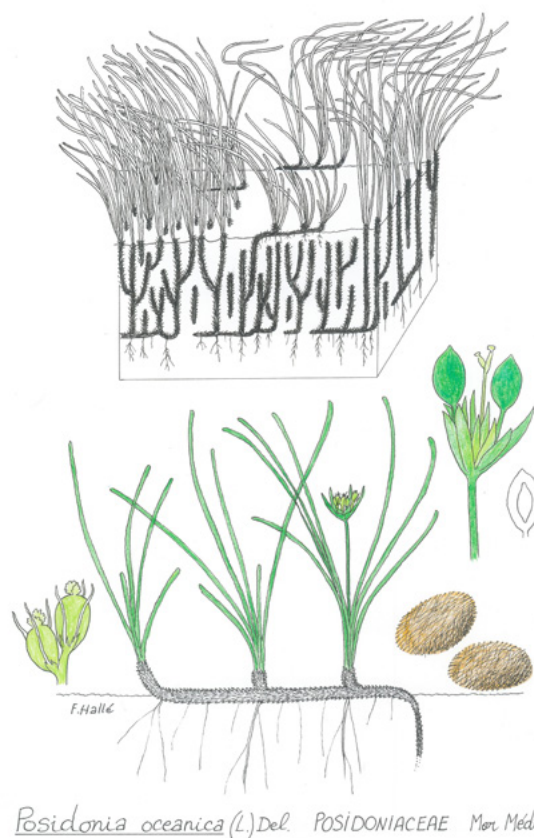
What is *Posidonia oceanica*?

Seagrass meadows are salt-water flowering plants found in coastal areas across 159 countries, ranging from the Arctic Circle to the tropics (UNEP, 2020). Amongst the roughly 60 known seagrass species, *P. oceanica* is the most abundant in the Mediterranean Sea, where it forms extensive meadows covering 25% of the seabed and can extend up to 40 meters in depth (Borum et al., 2004; see Figure 1). Like all flowering plants, *P. oceanica* possesses leaves, stems, roots, seeds, and flowers - traits that distinguish it from algae. Its flat, ribbon-like leaves typically range from 30 centimetres to 1 metre in length, and it produces flowers every 3 to 10 years, followed by fruits known as "sea olives" (Balestri et al., 2009; Buia et al., 2000; see Figure 2). A single clonal individual can span nearly 15 kilometres in diameter and may be over 100,000 years old, making *P. oceanica* one of the largest and oldest living organisms on Earth (Guerrero-Meseguer et al., 2018; see Figure 3).

Why should we care about *P. oceanica*?

P. oceanica is widely regarded as the most critical shallow-water coastal habitat in the Mediterranean (Abadie et al., 2018), owing to its foundational role in maintaining coastal ecological balance (Gobert et al., 2006). Its meadows are biodiversity hotspots, known for exceptional primary productivity and a capacity to support approximately 20-25% of all marine species in the Mediterranean (Boudouresque et al., 2012). These underwater meadows also provide other essential ecological and geological functions. They stabilise sediments, produce oxygen, sequester carbon, contribute to the nutrient cycle, host nursery areas, produce enhanced fisheries, contribute to water purification and coastal erosion control, serve as key indicators of marine ecosystem health, and are referred to as "sand factories" (Boudouresque et al., 2021; Boudouresque et al., 2024; Vasarri et al., 2021).

Often referred to as "the lungs of the Mediterranean", *P. oceanica* is one of the most important natural sources of oxygen in coastal marine waters. A study by the Mediterranean Institute for Advanced Studies (IMEDEA) and the BBVA Foundation estimates that *P. oceanica* meadows produce between 14 and 20 litres of oxygen per square metre each day (Campagne et al., 2015). Given that over half of the oxygen we breathe originates from the ocean, the ecological contribution of *P. oceanica* is both locally vital and globally significant.



Posidonia oceanica (L.) Del. POSIDONIACEAE Mer. Méditerranée.

Figure 2. *P. oceanica* drawing (© Hallé 2025).



Figure 3. A *P. oceanica* clonal individual, aged between 80,000 and 200,000 years old, spanning up to 15 kilometers in the Mediterranean (© San Felix & Arnaud-Haond et al., 2012).

In addition to the ecological value of *P. oceanica* for the Mediterranean marine environment, this species has been used in the past in the construction, industrial, and commercial sectors, as well as in the pharmacological field. Twenty-five ecosystem services ranging from provision, regulating and maintenance, to cultural services are provided by *P. oceanica* meadows. A French judge recently estimated an economic value of about 90 000 €/ha/year (Tribune, 2024). For Mediterranean countries, there is an estimated regression between 10% and 30% over 100 years (Telesca et al., 2015). This estimate does not account for several goods and benefits which need more data to be evaluated from an economic standpoint. The economic value of these meadows is estimated to be 3 times greater than that of coral reefs, 10 times greater than that of tropical forests and 100 times greater than that of a terrestrial meadow (Boudouresque et al., 2012).

Why is *P. oceanica* under pressure?

Globally, seagrass meadows are in decline (Orth et al., 2006) and are considered among the most endangered ecosystems on Earth (Waycott et al., 2009), with area losses estimated to range from 13% to 38% between 1842 and 2009 (Marbà et al., 2014). This vulnerability is especially acute in the Mediterranean Sea, a semi-

enclosed basin subject to intense demographic, urban, and industrial pressures, compounded by significant climate change impacts (Bianchi and Morri, 2004).

The main environmental pressures impacting *P. oceanica* in the Mediterranean today, at least within the European Union, come from anchoring particularly large vessels, bottom trawling, pollution, coastal artificialisation, and the introduction of non-native species (Erftemeijer and Lewis, 2006). Additionally, the removal of dead *Posidonia* leaves from beaches, often done in the name of tourist comfort, is a serious ecological and economic drawback (Boudouresque et al., 2024).

The removal of banquettes: A silent ecological problem

In the Mediterranean, the natural accumulation of dead *P. oceanica* leaves, known as banquettes, plays a vital role in preventing erosion, supporting dune formation, and enriching marine ecosystems (Boudouresque et al., 2017; Boudouresque et al., 2025; see Figure 4). Yet, motivated by the pursuit of artificially “clean” beaches, many local authorities -83% of those surveyed across eight Mediterranean sites have removed *P.* banquettes, contributing to biodiversity loss, and heightened coastal vulnerability (IUCN Centre for Mediterranean Cooperation, 2021). This shift, often based more on political or commercial assumptions than actual tourist demand, has caused ecological harm and significant economic costs. Indeed, surveys show it is less the users than the managers and tour operators who demand beaches without banquettes (Oudin and Boudouresque, 2023). Promoting ecologically managed *Posidonia*-compatible beaches may now be essential to preserving biodiversity, protecting shorelines, and sustaining Mediterranean tourism, particularly as the removal of banquettes incurs very high costs by accelerating *Posidonia* degradation, intensifying coastal erosion, and requiring repeated artificial beach replenishment. As part of the European Union’s InterregMed programme, the POSBEMED2 project introduced an innovative Charter of Commitment aimed at promoting environmentally responsible management practices for *P. oceanica* banquettes (Oudin and Boudouresque, 2023; see act4posidonia.eu).

BOX 1: MEDITERRANEAN POSIDONIA NETWORK (MPN)

In 2019, the MPN was established following a EU conference addressing the impacts of ship anchors. The network brings together approximately sixty members, including the European Union, twelve Mediterranean countries, and major international environmental organisations. Coordinated by the French Biodiversity Agency (OFB), the MPN aims to protect 100% of threatened *P. oceanica* across the Mediterranean by 2030. Its objectives also include completing comprehensive mapping of seagrass beds and assessing the associated pressures they face, thereby implementing effective conservation measures.





Figure 4. The banquette of dead *P. oceanica* leaves on Stagnolu beach (Corsica) (© Boudouresque et al., 2023).

Where do we stand in terms of its protection?

Over the past two decades, *P. oceanica* has emerged as a key focus for the protection and management of the Mediterranean marine environment. It is designated as a priority habitat under the European Union's 1992 Habitats Directive (Boudouresque et al., 2012) and benefits from protection through several international agreements, including the RAMSAR Convention, the Bern Convention, and the Barcelona Convention, which lists *P. oceanica* as a priority species (Vasarri et al., 2021; UNEP/MED, 2013; UNEP/MED, 2022). Furthermore, the 2008 EU Marine Strategy Framework Directive (MSFD) identifies *P. oceanica* as a representative species for the angiosperm quality elements within the Mediterranean marine environment (EU Directive, 2008). Its conservation is further supported by the EU Water Framework Directive and the EU Common Fisheries Policy (EU Directive, 2000; EU Regulation, 2013). In addition, France has set the objective of placing 100% of its Mediterranean *P.* seagrass meadows under strong protection by 2030 (National Strategy for the Sea and Coastline 2024–2030 and National Strategy for Biodiversity 2030), marking a major national commitment to seagrass conservation. In recent years, the continuity of major international and regional commitments has reinforced this protective framework, including the Kunming-Montreal Global Biodiversity Framework, the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol), the Post-2020 Strategic Action Programme for Biodiversity (SAPBIO), and the "Action Plan for the Conservation of Marine Vegetation in the Mediterranean." Within this context, the forthcoming Mediterranean Strategy for Sustainable Development 2026–2035 under the Barcelona Convention, introduces a new flagship initiative aiming at promoting the protection and conservation of seagrass/Posidonia meadows as crucial ecosystems, adopted by the Mediterranean

Commission for Sustainable Development (June) and slated for adoption by the 21 Contracting Parties plus the EU in December 2025. Partners include the French Biodiversity Agency (OFB), the IUCN Centre for Mediterranean Cooperation, WWF Mediterranean, the Mediterranean Posidonia Network, and the countries France, Tunisia, Spain, Malta, Cyprus, Algeria, Türkiye, Italy, and Greece. Moreover, the Mediterranean Posidonia Network has emerged as a key platform for translating these commitments into coordinated strategies, bringing together Mediterranean countries and environmental organisations to implement effective protection measures aligned with these evolving legal and policy frameworks (see Box 1).

What actions are engaged to protect *P. oceanica*?

Such communication strategies need to be complemented with specific measures such as zoning regulations, anchoring regulations, control actions, customized actions at marine protected areas, as well as actions to raise awareness, the development of adapted tools as such light equipment zones and support to research on adapted mooring facilities. Moreover, establishing country-level networks, locally managed and involving both public and private actors on a voluntary basis, is essential to advancing the implementation of concrete actions.

Eco-mooring systems

To protect *P. oceanica* meadows from the mechanical damage caused by traditional anchoring, many Mediterranean countries have adopted eco-mooring systems, a key element within designated light equipment zones (see Figure 5). Unlike conventional anchors, which can rip through seagrass beds and leave long-lasting scars, eco-moorings use floating buoys attached to the seabed by elastic or screw-in systems that avoid contact with the meadow. These systems allow boats to moor safely without impacting the fragile substrate. Eco-moorings are increasingly installed in marine protected areas and popular anchoring zones near *P.* habitats, particularly in France, Spain, and Italy. Their implementation not only reduces direct damage but also supports sustainable tourism and boating practices, aligning with broader conservation goals and EU marine directives.

Anchoring regulations in marine protected areas

Across several Mediterranean countries, anchoring regulations have been established within Marine Protected Areas to safeguard *P. oceanica* meadows from physical damage. These measures commonly include prohibiting anchoring directly on seagrass beds and providing eco-friendly mooring buoys as



Figure 5. Eco-mooring system (© Parc Marin de la Côte Bleue)

alternatives to prevent anchor drop impacts. For example, in France's Calanques National Park near Marseille, anchoring is banned in *P.* habitats with mooring buoys installed for boats. Similarly, many Italian marine protected areas, such as the Tavolara-Punta Coda Cavallo reserve, enforce strict anchoring prohibitions supported by fines and surveillance to ensure compliance. In the Balearic Islands of Spain, anchoring on *P.* meadows is forbidden, with enforcement through regular patrols and extensive mooring infrastructure. Croatia and Greece also implement comparable regulations within their coastal marine protected areas, promoting the use of designated mooring zones and applying variable enforcement measures to limit illegal anchoring activities. Collectively, these efforts contribute to reducing direct mechanical pressures on *P.* meadows, though enforcement and awareness levels vary across regions.

Decrees prohibiting anchoring of vessels over 24 metres

Anchoring by large vessels in *P.* meadows is prohibited only in France and the Balearic Islands. Areas of very high anchoring pressure on *P.* meadows in the Mediterranean have nevertheless been identified (Bockel et al., 2024; see Figure 6). In France, at least 17 prefectural decrees (2020–2023) have banned

anchoring of vessels over 24 metres, and in some areas over 20 metres, within *P.* zones, such as along the Côte d'Azur, Corsica, and the Calanques. These regulations are marked on nautical charts and enforced with substantial fines and legal consequences. More than 100 verbal reports have been reported per year, triggering administrative fines and legal action.

In one notable case, a yacht captain was fined €20,000 for illegally anchoring a 26-metre yacht on a *P. oceanica* meadow along the French Côte d'Azur, specifically near Cannes in 2021 and Saint Tropez in 2022. He was also subject to a 12 month ban from French territorial waters. Beyond the administrative penalty, the captain was also held civilly liable for ecological damage, with the court ordering the payment of almost €100,000 in reparations. These damages were calculated based on the extent of destruction inflicted on the seagrass habitat the ecosystem services provided by the plant and the time of recovery reflecting its protected status under multiple national and international conventions.

Two complementary approaches were used to assess ecological damage caused to *P. oceanica* meadows. The first, an ecosystem services valuation, estimated the value of the seagrass habitat at €86,676 per hectare per year, assuming a 25-year recovery period to restore ecological efficiency. The second, a restoration cost approach, calculated expenses at €170 per square metre for propagation and transplantation techniques, with an additional €80,105 allocated for long-term monitoring. This case set a precedent by clearly establishing that the destruction of *Posidonia* is not only an ecological concern but also carries significant legal and financial repercussions. It also marked a turning point in how authorities quantify and enforce biodiversity protection in the Mediterranean.

What financing for the protection of *P. oceanica*?

The protection of *P. oceanica* in the Mediterranean has historically relied on a mix of public funding, and project-based initiatives. Key support has come from European programmes (e.g. LIFE, INTERREG,



Figure 6. Areas of very high anchoring pressure on *P. oceanica* meadows

Horizon), national and regional budgets. NGOs and scientific institutions have also played a critical role through donor-backed conservation and awareness projects. In recent years, new mechanisms have emerged, including eco-mooring systems financed through multiple revenue streams, and pilot initiatives exploring blue carbon credits under schemes like France's Label Bas-Carbone. As carbon represents less than 10% of the ecosystem services, biodiversity credits are currently under process. Moreover, while carbon finance remains limited in scale, combining regulatory tools with innovative funding models offers growing potential to sustain long-term protection efforts.

Certification schemes for voluntary carbon offset projects

The Label Bas-Carbone is France's official certification scheme for voluntary carbon offset projects. By certifying and monetising carbon savings, the scheme enables public or private actors to financially support climate-positive actions within France, through the purchase of certified carbon credits. A methodology was recently developed to identify and preserve carbon stocks stored in *P. oceanica* meadows that are currently at risk of degradation (Comte et al., 2025). It supports the implementation of additional conservation measures that improve the environmental and ecological conditions of these seagrass habitats.

The methodology outlines eligibility criteria, defines how additionality must be demonstrated, addresses the risk of non-permanence, and provides procedures for calculating net reductions in greenhouse gas emissions. It enables project developers to secure funding by carrying out and monitoring actions that protect vulnerable carbon stocks. In some cases, these initiatives may also lead to enhanced carbon sequestration through passive restoration, increasing carbon stored in both the sediment and plant biomass.

To illustrate how carbon credits can support marine conservation, the Port-Cros National Park has established a mooring zone with light infrastructure (ZMEL) to protect 176 hectares of seagrass meadows. In this area, specifically the Bagaud channel between the islands of Port-Cros and Bagaud, anchoring is prohibited, and recreational boaters are required to use designated mooring buoys. This initiative shall be partly financed through carbon credits, which contribute to safeguarding the site's ecological integrity by preventing anchor damage and preserving these vital carbon-storing habitats.

Blue carbon financing model for eco-mooring zones

In 2022, BlueSeeds collaborated with the Blanes Centre for Advanced Studies and the consultancy Biosfera to pioneer a methodology for assessing the

ecological and economic value of carbon preserved by *P. oceanica* meadows protected through eco-mooring systems (BlueSeeds, 2024). Their findings suggest that a single eco-mooring buoy can help safeguard approximately 18 tonnes of CO₂ over a 40-year period. However, the low market value of voluntary carbon credits currently limits the feasibility of using them as the sole funding source for such installations.

In response, the 2023 BlueOasis programme reimagined eco-moorings not only as conservation tools but as drivers of sustainable local development. Through the BlueMooring digital platform, recreational boaters can book moorings and access additional services, ranging from guided ecotours and local cuisine to waste collection and maintenance, directly from their vessels. The model creates multiple revenue streams for coastal communities and marine protected areas, including mooring fees, service commissions, and potential carbon credit earnings, while also contributing to the protection of critical seagrass habitats.

When to restore and how?

Ecological restoration refers to efforts aimed at facilitating the recovery of ecosystems that have suffered degradation, damage, or complete loss. Within the framework of the European Union's restoration strategy, this process encompasses both passive and active measures to guide ecosystems, habitats, and species back toward a healthier state (EC, 2022; Atkinson and Bonser, 2020). In particular, the European Council adopted Regulation 2024/1991, commonly referred to as the Nature Restoration Law, in June 2024, with the legislation entering into force two months thereafter (European Council, 2024). Under this new legal framework, all EU member states are mandated to develop and initiate national restoration plans by July 2026, allowing a two-year window for preparation, coordination, and the launch of restoration activities. Whatever the nature of projects, they will need to account for a variety of general and climate-related uncertainties, including human pressures like macro-waste discharged by boats, and lost fishing gear, or environmental disturbances such as storms and sea-level rise (Comte et al., 2024).

Passive restoration

Passive restoration relies on reducing or removing anthropogenic pressures to enable natural regeneration, particularly in areas where the ecosystem's inherent recovery potential remains high, making it a cost-efficient strategy. Effective restoration must begin by passive actions through the removal or reduction of existing pressures (Pergent-Martini et al., 2024).

Active restoration

Active restoration involves more direct interventions, such as reintroducing species or reconstructing habitats, to accelerate or enhance recovery where natural processes alone are insufficient. While technical methods for transplanting *P. oceanica* exist and can yield high survival rates, especially in France, true restoration success, meaning full ecological recovery, has not yet been demonstrated and should still be considered experimental and research-oriented (Cunha et al., 2012; Pergent-Martini et al., 2024).

P. oceanica indeed exhibits extremely slow growth rates, ranging from approximately 100 to 1,000 centimetres per century. According to Boudouresque et al., (2021), active restoration is recommended when a set of conditions are fulfilled: (i) the restoration is not planned in connection with a development; (ii) *P. oceanica* should have existed in the site in the past; (iii) an human impact should be at the origin of the damage and this impact should have ceased to operate; (iv) a natural expansion is happening and/or natural cutting are observed; (v) the restoration does not threaten natural meadows; and (vi) there is a monitoring programme (over five years). Most importantly, assisted recolonization must be faster than natural recolonization. Natural regeneration of seagrass meadows was once considered impossible on a human timescale, but this view has since been revised: regeneration appears to occur more rapidly than previously thought. The cost of relocation must be compared to an equivalent investment in improving environmental conditions (e.g., eco-friendly anchoring, sewage treatment, ban on the creation or expansion of harbors and marinas, ban on the removal of *P. oceanica* banquettes on beaches). Pergent-Martini et al. (2021) have developed detailed guidelines for active restoration of *P. oceanica*.

There are three main approaches to the active restoration of *P. oceanica* meadows: (i) using seeds; (ii) using sods or clumps of seagrass including the surrounding sediment; and (iii) using cuttings. **Restoration using seeds** is considered the most environmentally sustainable approach for *P. oceanica* meadows, as it avoids physical disturbance to donor sites and supports the species' natural reproductive cycle. It also aligns with nature-based solutions by minimizing sediment disruption, reducing carbon release, and fostering ecosystem integrity. As such, it represents a low-impact, ecologically sound method for restoring degraded seagrass habitats.

This method depends however on the availability of fruit, an unpredictable resource. *P. oceanica* does not flower annually; instead, flowering events occur irregularly, roughly every 3 to 11 years. Moreover, some flowerings are highly localized and occur in very limited quantities. According to GIS Posidonia, viable fruiting events remain relatively infrequent. Large-scale flowering episodes have only been documented in

specific years: 1961, 1971, 1975, 1982, 1985, 1993, 2003, 2012, and most recently, in 2022. It was precisely in response to this recent large-scale reproductive event that GIS Posidonia launched an ecological restoration initiative using seeds collected from naturally dispersed fruits in two sites where anchoring is forbidden, Bouches de Bonifacio in Corsica, and Prado bay, CorseRade Sud in Marseille with low survival rates (see Box 2).

Restoration using cuttings has been developed since 2019 to restore degraded *P. oceanica* meadows damaged by anchoring (see Figure 8). Under the REPIC programme (*REstaurer la Posidonie Impactée par l'anCrage*), annual initiatives in Golfe-Juan, Beaulieu-sur-Mer, and Villefranche-sur-Mer involve gathering floating fragments, either naturally detached or dislodged by anchors during the summer months and transplanting them into degraded seabeds using biodegradable metal staples. Between 2019 and 2023, the project's initial research and development phase focused on optimising restoration protocols to enhance the survival and growth of transplanted fragments, and on developing robust monitoring tools to assess restoration outcomes. The programme now in its implementation phase, aims to restore approximately 1,500 square metres of *P. oceanica* meadows annually. Currently, 3,800 square metres have been already re-established (see Figure 8). Certain sites exhibit high survival rates but there is an absence of comparison with a control site.

Restoration using seeds and restoration based on rhizome transplants from impacted areas present distinct benefits. Seed-based restoration is generally less costly, more natural, and promotes high genetic diversity, as each seed carries a unique genome. This diversity enhances the range of ecosystem services provided. However, seed availability is limited, typically occurring only once every ten years. In contrast, restoration using rhizome fragments offers the advantage of being available year-round, making it more immediately operational.



Figure 8. A restoration programme in Spain where floating fragments of *P. oceanica* are transplanted them into degraded seabeds (©IMEDEA (CSIC-UIB)/I.Castejón-Silvo, J.Terrados).

BOX 2: RESTORATION USING SEEDS ENABLED BY THE “FLOWERING OF THE CENTURY”

Following the remarkable flowering of *P. oceanica* in 2022 (André et al., 2023), renamed by GIS Posidonie as potentially the “flowering of the century”, a significant fruiting phase occurred over the winter months. From spring 2023 onward, numerous fruits and seeds were observed both floating at the sea surface and stranded along the coastline. Since of these fruits eventually become stranded on beaches, GIS Posidonie initiated the REPOSEED programme (REStoration of the *P. Oceanica* meadow by SEEDs), a nature-based active restoration action focused on replanting *P. oceanica* meadows using seeds gathered from these naturally stranded fruits. Fruit collection sites were required to be located no more than 100 km from the restoration areas, to respect the natural maximum dispersal distance of the fruits. The seeds were then planted following two different methods: either embedded within a coconut fiber mat or directly sown into the dead seagrass rhizome layer (matte). Additionally, two seed densities were tested, with either 100 or 200 seeds per square meter. According to the latest reports from the Marseille seed sowing sites, healthy seedlings have already been observed just a few weeks after planting the seeds although survival rates are low (see Figure 7).



Figure 7. Growth of *Posidonia* seeds planted into the dead matte) after one month in Marseille (© Gis Posidonie)

Is communication important to protect *P. oceanica*?

Communication plans can be a relevant vehicle to trigger action for the protection of *P. oceanica* in the Mediterranean. The OFB has commissioned a study to analyze the most appropriate communication strategies to protect the species depending on the typology of boater (OFB, 2022). Such strategies seek (i) to underscore the urgency through a wide range of medias; (ii) to motivate action, for instance, via physical devises such as maps, digital applications for navigation or augmented reality experiences, and educational underwater pathways; (iii) to facilitate action through fines, bonus-penalty systems for parking, reminders at sea, and social recognition depending on practices; and (iv) to motivate influential stakeholders as a tool for action (socioeconomic actors such as boaters, renters, clubs, ports, professional associations... and other partner organizations such as local and central administrations, local and national environmental associations, marine protected areas...).

Free applications: Allies for *P. oceanica*

Donia, Nav&Co and Navionics are increasingly popular tools designed to assist seafarers and conservation practitioners in avoiding damage to sensitive marine habitats in the Mediterranean region. They provide real-time, high-resolution maps of seagrass meadows and other critical habitats in the Mediterranean, including *P. oceanica*. By using GPS positioning, these applications allow recreational boaters, divers, and professionals to navigate without

anchoring on protected seagrass beds, promoting sustainable marine activities. They serve as a scientific and management tool. They can support marine protected area managers, environmental agencies, and researchers by providing spatial data on habitat distribution, identifying areas at risk, and helping track changes over time. This functionality is particularly valuable in the context of EU directives, such as the Marine Strategy Framework Directive, and the broader framework of regional protection strategies. While they are well known among environmental managers, marine protected area authorities, NGOs, and certain boating communities, their adoption among the broader population of recreational boaters is still growing. The use of these applications should be generalized. Donia, for instance has been downloaded by only 26% of boaters, with just 18% using it regularly.

Why research is key?

Distance to maritime structures

The DREAL Provence-Alpes-Côte d’Azur has recently assessed whether the minimum distance between *P. Oceanica* and maritime structures should be reconsidered (Schohn et al., 2025). The construction of maritime structures on shallow coastal areas has caused significant declines in *P.* meadows in recent decades given direct destruction by physical coverage and impacts during both the construction and the operational phases. Often, a zone of dead matte -dead seagrass rhizomes- forms adjacent to maritime structures. In their study, they find that the current

minimum distance of 10 metres, based on the work of Boudouresque et al. (2006) within the framework of the RAMOGE agreement, appears insufficient. The results clearly show significant impacts beyond 10 metres, extending up to 20 metres (see Figure 9). These conclusions contribute to the ongoing update of the RAMOGE guide, on the preservation and conservation of *P. oceanica* meadows.

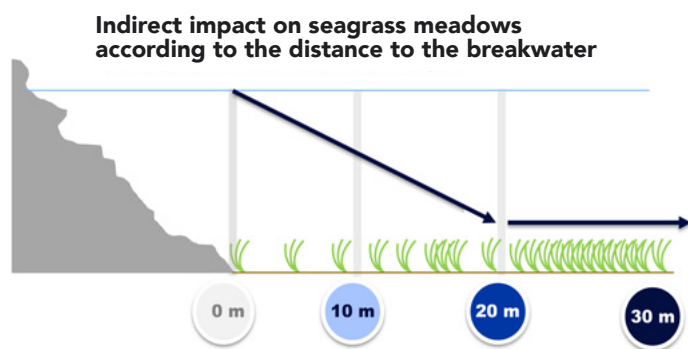


Figure 9. Indirect impacts on *Posidonia* meadows according to the distance from the breakwater (© Schohn et al., 2025)

Implementing an ecosystem services approach

Implementing ecosystem services approach in marine policy has long been challenged by the complexity of socio-ecological systems and their dynamic nature. A recent study focused on *P. oceanica* in Provence and the French Riviera to better understand how different pressures, such as overfishing, habitat fragmentation, pollution, and invasive species, alter their ecological states and the services they provide (Scemama et al., 2024). Using a state-and-transition model, the research identifies how bundles of ecosystem services change across different degradation stages of the meadows. Scientific expertise and field data -evaluated using the Ecosystem-Based Quality Index and aligned with the ecosystem-based approach promoted by the European Marine Strategy Framework Directive (MSFD, 2010/477/EU)- were combined to define the ecosystem states and assess their conservation status.

Findings reveal that provisioning services, particularly sea urchin and commercial fish production, are the most sensitive to degradation. Once the meadows reach a critical threshold and shift to a “dead mat” state, they cease to deliver any significant ecosystem services. The study offers a simplified, yet ecologically grounded framework that helps communicate these complex dynamics to policymakers and stakeholders, supporting more informed, adaptive, and ecosystem-based coastal management decisions.

Other seagrasses in the Mediterranean region

Among the seven seagrass species found in the Mediterranean (Boudouresque et al., 2009;

Boudouresque et al, 2021), *P. oceanica* is the only species endemic to the Mediterranean and stands out as the most ecologically significant, forming dense, long-lived meadows with individual shoots living up to 50 years and clones aged several millennia, with exceptional structural and functional roles. However, it is vulnerable to disturbance and recovers slowly, ranking among the slowest growing (1–6 cm per year) plants (Marbà, et al., 2014), with recolonisation taking centuries or more. In contrast, species like *Cymodocea nodosa*, *Ruppia* spp., and *Zostera* spp. exhibit higher tolerance to environmental fluctuations and anthropogenic pressures but offer less in terms of ecosystem services such as carbon sequestration and habitat complexity (see Figure 10 on *Cymodocea nodosa*). Moreover *Halophila stipulacea*, a non-native species, is spreading quickly in degraded environments, raising questions about long-term impacts on native assemblages. The loss of *P. oceanica* meadows is therefore not functionally compensated by the presence of other seagrasses, making their conservation an urgent priority.

TOPICS FOR FUTURE RESEARCH

- **Advance knowledge on the distribution, status, and pressures affecting *P. oceanica* across the Mediterranean.** This includes, first, the comprehensive and up-to-date mapping of *P. oceanica* meadows, which remains incomplete or outdated in many coastal regions. Second, a systematic assessment of site-specific pressures -such as anchoring, illegal fishing, removal of banquettes, coastal artificialisation, pollution, and invasive species- is essential to understand local threats.
- **Enhancing local governance and societal engagement.** Research should also explore context-specific solutions to mitigate these pressures, including their technical and economic feasibility, governance requirements, and potential implementation barriers and opportunities. In parallel, there is a need to investigate strategies for public engagement and behavioral change, including the creation of local and national alliances and the organisation of regional cultural events.
- **Strengthening regulatory frameworks for *P. oceanica*.** There is a need to assess the effectiveness and enforcement potential of regulatory measures aimed at reducing direct physical impacts on *P. oceanica* meadows. This includes evaluating the ecological and socio-economic implications of prohibiting the removal of banquettes and anchoring by vessels over 20 meters in sensitive areas, as well as identifying best practices for integrating *P. oceanica* protection into the design and expansion of marine protected areas across the Mediterranean.

- **Monitoring and enforcement against illegal bottom trawling.** There is a pressing need to develop and implement effective monitoring systems -technological, legal, and institutional- to detect, prevent, and deter illegal bottom trawling activities impacting *P. oceanica* meadows. Research should assess the applicability of satellite tracking, remote sensing, enforcement protocols, and cross-border cooperation to ensure consistent protection of vulnerable areas.

- **Enhancing water quality in *P.* habitats.** Improving the ecological health of *P. oceanica* meadows requires targeted research into water quality upgrades, including the modernization of wastewater treatment infrastructure and pollution reduction strategies. Studies should focus on identifying priority pollution sources, evaluating the ecological benefits of improved treatment standards, and proposing cost-effective solutions adapted to the socio-economic context of Mediterranean coastal regions.

- **Eco-mooring effectiveness and adoption.** There is a need to assess the long-term effectiveness and durability of different eco-mooring technologies across varying seabed types and environmental conditions. Research should also explore the ecological benefits of these systems compared to traditional anchoring, their economic viability, and their acceptance by boaters. Furthermore, studies on user behaviour, governance models, and scaling strategies are essential to support the wider implementation of eco-mooring as a core tool for habitat conservation in the Mediterranean.

- **Assessing the impact of small boat anchoring on *P. Oceanica* meadows:** Assess the ecological impacts of anchoring by small boats (<12 m) in *P. oceanica* meadows. Although these vessels account for approximately 40% of anchoring events in such habitats, the extent, frequency, and severity of the resulting damage are still poorly quantified and require targeted investigation.

- **Development of innovative financing mechanisms.** Securing effective protection for *P.* meadows requires a robust mix of public and private funding, combining state resources with carbon markets, philanthropy, and other forms of impact finance. Moreover, there is a need to explore and design innovative, non-carbon-based financial instruments to support the conservation of *P. oceanica*, including the potential establishment of a dedicated P. Fund. Research should focus on identifying sustainable funding models, evaluating their governance structures, stakeholder engagement, legal feasibility, and potential to effectively channel resources toward priority conservation sites.

- **Restoration costs and governance frameworks:** A thorough evaluation of restoration costs -including banquettes removal costs (such as removal costs, beach nourishment, and the destruction of seagrass meadows carried away by storms)- is essential. This assessment must be accompanied by the development of suitable governance models, including their integration into Member States' climate policies, to determine when active restoration is both ecologically and economically viable.

- **Capacity building and spatial planning integration.** Research should support the development of practical toolkits for marine protected area managers, enabling more effective, science-based decision-making. Additionally, targeted training and guidance for maritime spatial planners are needed to better integrate *P. oceanica* and other blue carbon ecosystems into spatial planning processes. This includes embedding ecological value, carbon storage potential, and vulnerability assessments into spatial zoning and marine governance frameworks.

- **Advancement of restoration strategies.** Research is needed on both active and passive restoration approaches for *P. oceanica*, in alignment with the EU Nature Restoration Law. Among other factors, this includes assessing site-specific ecological effectiveness and costs compared to natural regeneration strategies.



Figure 10. *Cymodocea nodosa* seagrass meadow in the Bay of Pollensa, Mallorca (© Eduardo Infantes)

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OCEAN UNIVERSITY INITIATIVE

The Ocean University Initiative was initiated by the local authorities in Brittany. It is implemented by the University of Brest (UBO) with the aim of creating the conditions for establishing in France of an institute of the United Nations University dedicated to the ocean and the coasts, and with the means to carry out pioneering work in three areas: research, training and communication.

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