Received: 21 June 2023 | Revised: 21 November 2023 | Accepted: 18 December 2023

DOI: 10.1002/ppp3.10486

OPINION

Plants People Planet PPP Open Access

# One hundred priority questions for advancing seagrass conservation in Europe

Lina Mtwana Nordlund[1] | Richard K. F. Unsworth[2,3] | Sieglind Wallner-Hahn[1] | Lavenia Ratnarajah[4,5] | Pedro Beca-Carretero[6] | Elmira Boikova[7] | James C. Bull[2] | Rosa M. Chefaoui[8] | Carmen B. de los Santos[9] | Karine Gagnon[10] | Joxe Mikel Garmendia[11] | Francesca Gizzi[12] | Laura L. Govers[13] | Camilla Gustafsson[14] | Elitsa Hineva[15] | Eduardo Infantes[16] | João Canning-Clode[12] | Marlene Jahnke[17] | Periklis Kleitou[18] | Hilary Kennedy[19] | Stefania Klayn[20] | Tiia Moller[21] | João Monteiro[12,22] | Nerea Piñeiro-Juncal[23] | Emanuele Ponis[24] | Vasillis Papathanasiou[25] | Dimitris Poursanidis[26] | Riccardo Pieraccini[27] | Oscar Serrano[28] | Ana. I. Sousa[23] | Susanne Schäfer[12] | Francesca Rossi[29] | D. Sebastian Storey[30] | Marieke M. van Katwijk[31] | Dave Wall[32] | Emma A. Ward[33] | Robert Wilkes[34]

**Correspondence**

Richard K. F. Unsworth Biosciences, Faculty of Science and Engineering, Swansea University, Wales UK.

Email: r.k.f.unsworth@swansea.ac.uk

**Funding information**

Natural Environment Research Council, Grant/Award Numbers: RESOW, NE/V016385/1; United Nations Educational, Scientific and Cultural Organization; European Union, Grant/Award Number: 862626; FCT, Grant/Award Number: CEECIND/00962/2017; MCTES

**Societal Impact Statement**

Seagrass ecosystems are of fundamental importance to our planet and wellbeing. Seagrasses are marine flowering plants, which engineer ecosystems that provide a multitude of ecosystem services, for example, blue foods and carbon sequestration. Seagrass ecosystems have largely been degraded across much of their global range. There is now increasing interest in the conservation and restoration of these systems, particularly in the context of the climate emergency and the biodiversity crisis. The collation of 100 questions from experts across Europe could, if answered, improve our ability to conserve and restore these systems by facilitating a fundamental shift in the success of such work.

**Summary**

Seagrass meadows provide numerous ecosystem services including biodiversity, coastal protection, and carbon sequestration. In Europe, seagrasses can be found in shallow sheltered waters along coastlines, in estuaries & lagoons, and around islands, but their distribution has declined. Factors such as poor water quality, coastal modification, mechanical damage, overfishing, land-sea interactions, climate change and

For affiliations refer to page 12

disease have reduced the coverage of Europe's seagrasses necessitating their recovery. Research, monitoring and conservation efforts on seagrass ecosystems in Europe are mostly uncoordinated and biased towards certain species and regions, resulting in inadequate delivery of critical information for their management. Here, we aim to identify the 100 priority questions, that if addressed would strongly advance seagrass monitoring, research and conservation in Europe. Using a Delphi method, researchers, practitioners, and policymakers with seagrass experience from across Europe and with diverse seagrass expertise participated in the process that involved the formulation of research questions, a voting process and an online workshop to identify the final list of the 100 questions. The final list of questions covers areas across nine themes: Biodiversity & Ecology; Ecosystem services; Blue carbon; Fishery support; Drivers, Threats, Resilience & Response; Monitoring & Assessment; Conservation & Restoration; Governance, Policy & Management; and Communication. Answering these questions will fill current knowledge gaps and place European seagrass onto a positive trajectory of recovery.

**KEYWORDS**
aquatic environment, biodiversity, blue carbon, communication, Delphi method, ecosystem services, eelgrass, monitoring

## 1 | INTRODUCTION

Seagrass occurs all around the globe, except Antarctica, forming meadows that provide a broad range of ecosystem services such as enhanced biodiversity, coastal protection, and carbon sequestration (Campagne et al., 2015; Nordlund et al., 2016). They are marine flowering plants that increase the habitat complexity of the seascape over a variety of local and regional spatial scales and can be present as fragmented patches or continuous extended meadows. In Europe, seagrasses occupy a wide variety of environmental settings, from deep clear water embayments in the West of Ireland to turbid enclosed lagoons in the Mediterranean Sea, and are subject to extremes of tidal range, temperature, light, and salinity (Green & Short, 2003; McKenzie et al., 2020).

European seagrass distribution has been declining, with a net loss of around 35,000 ha between 1869 and 2016, which is approximately 1/3 of the historically mapped area (de los Santos et al., 2019). This decline is caused by the cumulative action of multiple factors, including water quality degradation, disease, coastal modification, mechanical damage, overfishing, land-sea interactions, and climate change (de los Santos et al., 2019).

Seven marine seagrass species occur in Europe, namely *Cymodocea nodosa*, *Posidonia oceanica*, *Zostera marina*, *Z. noltei*, *Ruppia maritima*, *Ruppia cirrhosa*, *Halophila decipiens*, and *H. stipulacea*. The latter species is considered non-indigenous of Indo-Pacific origin (Gerakaris et al., 2020; Winters et al., 2020), and some taxonomists do not consider the genus *Ruppia* to be seagrass because of differences in morphological traits such as rhizomes and root system, and its presence in low-salinity waters (Green & Short, 2003). However, we have included both in the present study as they are ecologically and functionally similar to the other species, living in similar and often the same environments.

Research efforts on seagrass ecosystems in Europe are biased both with respect to particular species and their spatial extent/distribution. Only a few areas are well-mapped or with updated spatial distribution data, while some areas have scattered data covering mainly the Natura 2000 network (i.e.,(Huber et al., 2022; Poursanidis et al., 2023) and others have been mapped but the data are not open access or out of date (Dunic et al., 2021; McKenzie et al., 2020), or exist only as web services (Web Map Services [WMS]) in local languages without easy access. Because of this lack of consistent spatiotemporal data and metrics, the gains and losses of the seagrass meadows in Europe are currently not tracked accurately enough.

Two of the seagrass species, *Z. marina* and *P. oceanica*, are more widely studied than other species likely because of their dominant character on the European coasts. Furthermore, there is traditionally more research originating from the western coasts of Europe and the Mediterranean Sea compared with more eastern-located seas such as the Black Sea, which likely biases our knowledge about the geographical distribution of the different species, as well as their ecology (Figure 1).

While our knowledge of the presence, ecology, and functions of European seagrass species and their many and varied environmental settings are growing, there is an increasing recognition that management of these systems is urgent. However, at the same time, many knowledge gaps still exist and limit our attempts to successfully conserve and restore seagrass meadows (Unsworth, McKenzie,

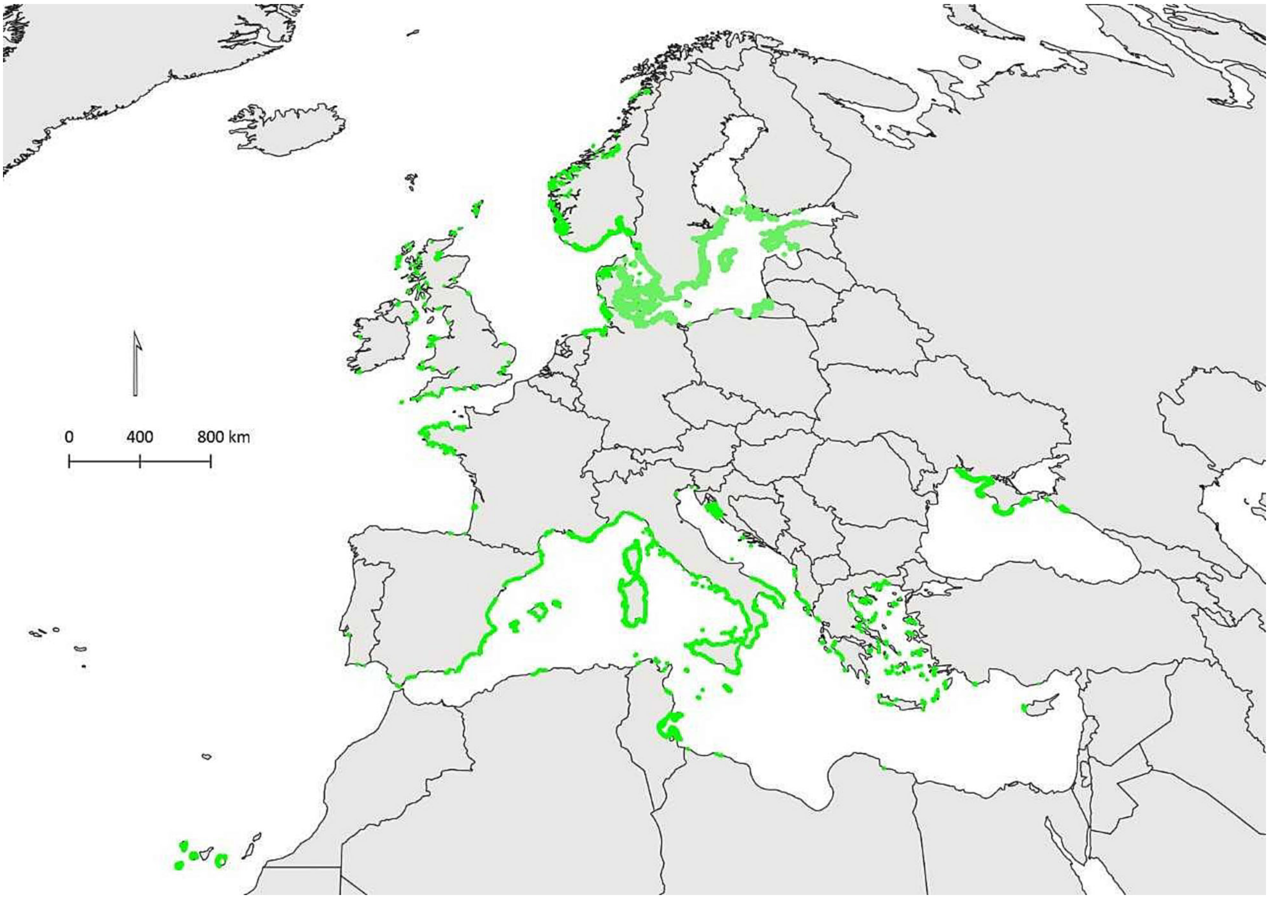


**FIGURE 1** Seagrass distribution across continental Europe. The distribution data is from the UN environment Programme world conservation monitoring Centre (UNEP-WCMC) and Helsinki commission (HELCOM).

et al., 2019). In addition to political drivers, a growing interest in climate change mitigation and adaptation, fisheries and biodiversity has resulted in an increasing focus on seagrass ecosystems (Unsworth et al., 2022). Seagrass was, for a long time, considered the 'ugly duckling' of conservation (Duarte et al., 2008), but improvements in nature conservation policy have begun to take place across Europe, particularly within the context of marine spatial planning (Qiu & Jones, 2013). In addition, there is increasing interest in utilizing seagrass as a nature-based solution to climate change (Macreadie et al., 2021; Unsworth et al., 2022) maximizing so-called "Blue Carbon" (Greiner et al., 2013) and a push to include it in national/regional carbon budgets (Jacquemont et al., 2022).

Seagrasses are identified as an Essential Ocean Variable (EOV) because of their relevance, feasibility, and cost-effectiveness for monitoring to support and develop our understanding of ocean health (Miloslavich et al., 2018; Duffy et al., 2019). Each EOV is associated with a series of recommendations on measurements, observational options, and data management practices in order to coordinate monitoring and provide comparable data across the globe (Miloslavich et al., 2018). Furthermore, European seagrass is considered a key Biological Quality Element (BQE) for coastal and transitional waters under the European Union Water Framework Directive (WFD) (Foden & Brazier, 2007) and is part of several environmental descriptors under the Marine Strategy Framework Directive (MSFD). Monitoring of seagrass across the globe as well as in Europe is not sufficiently coordinated nor interoperable, which results in inadequate delivery of critical information and limits science-based decision-making (Moersberger et al., 2022; Révelard et al., 2022). However, seagrass is becoming more often included in management and conservation, and several management actions such as improvement of water quality, reduction of industrial sewage, and anchoring and trawling regulations have been shown to support seagrass recovery (de los Santos et al., 2019). Despite these efforts, seagrass is still in decline, and more and stronger action is urgently needed (Cullen-Unsworth & Unsworth, 2018).

To fast-track seagrass conservation, we recognize that there exists a range of knowledge gaps that need to be filled to advance this field (Unsworth, McKenzie, et al., 2019). With this present paper, we aim to identify the necessary research to fill these gaps by using expert opinion to priorities a list of the 100 most important questions for seagrass conservation in Europe. If these questions were to be addressed, it would strongly advance seagrass monitoring, research and conservation in Europe towards rich and resilient seagrass ecosystems that would benefit both people and the planet. Our goal is to inspire research, policy and management, and contribute towards more resilient seagrass ecosystems.

## 2 | METHODS

This list of 100 questions (Figure 2) was created using the Delphi method, a technique developed by the United States Air Force and the RAND Corporation in the 1950s as a military tool to engage with the community (Dalkey & Helmer, 1963). Using a structured group communication process, this qualitative approach is designed to get the most reliable consensus from a group of experts on a particular problem (Hasson et al., 2000). The Delphi method uses several rounds or iterations between the facilitator(s) and the expert community to review information (see also methods used in (Sutherland et al., 2009)). This study was inspired by previous similar exercises to identify priority questions related to conservation (Ockendon et al., 2018; Sutherland et al., 2013). In our exercise, participants signed up with their names, affiliations and email addresses during the steps of sending in questions and voting. However, the participants were not able to see the contributions from other authors, until the voting round and votes were sent in individually (the participants did not see any votes other than their own). The participants did engage and discuss the proposed questions with each other during the workshop stage. Further, all participants were invited to contribute to the writing process and produced this paper collaboratively with the facilitators.

### 2.1 | Participants

Researchers, practitioners, and policymakers with seagrass experience over all of continental Europe were contacted via email in order to introduce this study and ask for their voluntary participation in the exercise. Participants were sought that covered the complete geographical spread of European countries with a coastline and from as many areas of seagrass expertise as possible. Further, information about this study was spread through social media (Facebook, Twitter and LinkedIn).

The aim of the exercise was introduced to participants by asking them to identify, formulate and compile priority questions for the conservation, monitoring and research of seagrass ecosystems in Europe.

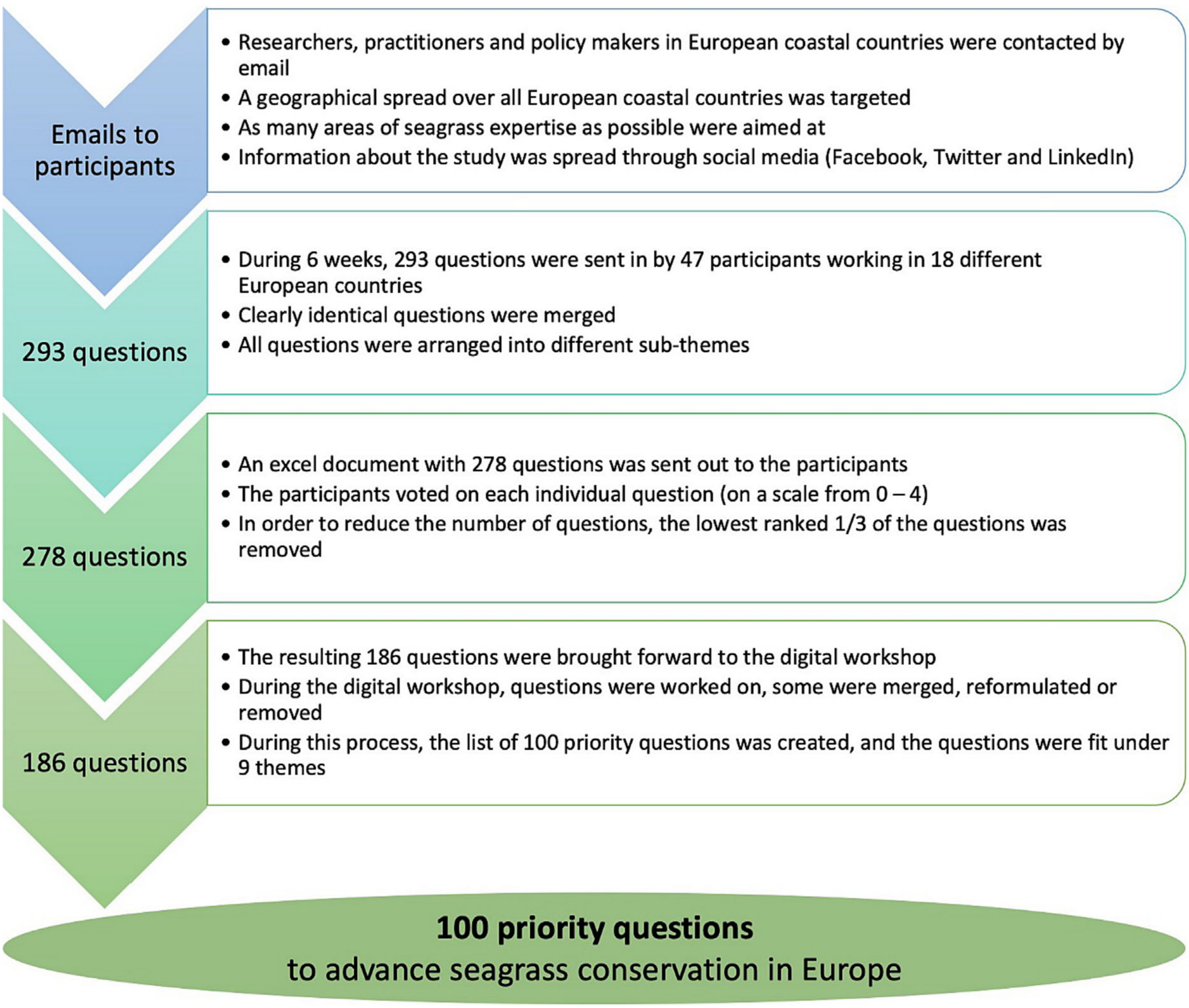


FIGURE 2 Flowchart of the steps involved in the iterative collaborative process, which was used to produce the 100 priority questions for advancing seagrass research, monitoring and conservation in Europe.

It was considered that, if answered, the output would strongly advance seagrass conservation in Europe towards rich and resilient seagrass ecosystems that would benefit both people and the planet. The four main steps of this common exercise were explained in the initial email: i) the formulation of research questions; ii) a voting process to identify the most important questions; iii) the online workshop in order to identify the final list of the 100 most urgent questions; and iv) the participation in the writing process of this paper.

## 2.2 | Formulation of research questions and voting

The participating experts were asked to submit one or more questions that, if answered, would strongly advance seagrass conservation in Europe. The participants were encouraged to consult with colleagues and within their networks to identify such questions. Questions were submitted within the following themes (but were not limited to them): Biodiversity and Ecology; Ecosystem Services and Communication; Blue Carbon; Fisheries support; Drivers and Threats; Monitoring and Assessment; Conservation and Restoration; and Governance, Policy and Management.

Instructions were provided that the questions should fulfill the following criteria to: i) address important knowledge gaps; ii) be relevant for continental Europe; iii) be answerable with a realistic research design and funding; iv) not be too limited in their spatial and/or temporal scope; and v) not be too general (each question should be possible to answer within an acceptable time frame).

Over a period of six weeks, 293 questions were submitted by 47 participants working in 18 European countries. Thereafter, clearly identical questions were merged, questions were arranged into nine sub-themes and an Excel document with the resulting 278 questions (without author information) was created (see Table S1). The Excel document was then redistributed to all participants for a subsequent voting process, and the participants were also encouraged to add any critical questions they considered missing from the list.

For the voting process, the participants were asked to read through the questions and to add a vote from 0 to 4 (0 = this question is not important, to 4 = this question is of highest importance) to each individual question. The participants were not able to see the votes of others. After all the individual votes were received, a list with all questions and the votes' calculated means and medians was created. In order to reduce the number of questions, the lowest ranked ⅓ of questions was calculated, resulting in a voting mean of 2.35, and all questions below this threshold were removed prior to the digital workshop. This resulted in a list of 186 questions across the nine themes: Biodiversity & Ecology; Ecosystem services & Communication; Blue carbon; Fishery support; Drivers & Threats; Monitoring & Assessment; Conservation & Restoration; Governance, Policy & Management; and Cross discipline. These questions were brought forward to be considered and discussed during the online workshop.

In Table S1, the full list of originally suggested questions, sorted after the original categories is presented.

## 2.3 | The workshop

A workshop was held online using Zoom for three days between March 22nd and 24th 2022, with 35 expert participants (of 49 who submitted questions) working in 18 countries. The workshop was the final step in the Delphi process with the aim to collaboratively produce a list of the most important 100 questions from the list of 186 questions brought forward from initial voting. Participants were divided into breakout groups that tackled the nine different themes. Before the groups were formed, the Delphi method was presented to the participants.

The questions were thoroughly discussed in the workshop by the 35 participants to ensure clarity. Some questions were combined with others to ensure broader coverage, and some were moved to better-fitting themes. Several questions were removed because they were too similar to others or were deemed to be not within the top 100 priority questions. To further ensure that the expert community was engaged and had active input in selecting all the priority questions, working groups were mixed between the discussion sessions, and the final session combined all participants into one common discussion.

# 3 | RESULTS

The 100 priority questions for seagrass conservation in Europe are presented under nine themes:

## 3.1 | Biodiversity & ecology

Seagrasses are ecosystem engineers that enhance marine biodiversity by providing food, shelter, and essential nursery areas for species, with important implications for ecosystem stability and productivity (Duffy et al., 2003; McHenry et al., 2021; van der Heide et al., 2012). Extensive and varied research has been undertaken regarding the biodiversity of seagrass ecosystems in the last decades (Duffy et al., 2005, 2022; York et al., 2018). This research has helped to understand the role seagrasses play in determining the processes that characterize biodiversity at every level, from individual genes to higher taxa and ecological assemblages, and from functional groups to communities and landscapes.

However, knowledge gaps exist both on a local and regional scale, mainly due to the limited spatial and temporal extent of most seagrass studies (Loh et al., 2019). Many aspects of the ecology of seagrass species and the biodiversity of seagrass habitats on the levels of genes, species, and ecosystems are still unknown. Further research is needed to investigate how non-indigenous seagrass species are expanding along European coasts (Wesselmann et al., 2021). Gaining a better understanding of the patterns and relationships between seagrass habitats, biodiversity, and environmental conditions is vital in designing successful management and conservation strategies.

1. How does the seascape context affect biodiversity, ecosystem functions and services provided by seagrass meadows?
2. What is the ecological contribution of seagrass detrital accumulation to coastal ecosystems?
3. What are the genetic population structure and connectivity of seagrass, especially in under-studied species and regions?
4. How do seagrasses and their associated food web interactions contribute to ecosystem functions (e.g., nutrient and carbon cycling, biodiversity, and ecosystem stability)?
5. How do intertidal and subtidal seagrass species respond to anthropogenic and natural change, and should their responses be considered separately?
6. How do non-indigenous seagrass species interact with native seagrasses?
7. How do non-indigenous seagrass species expand and affect native biodiversity and ecosystem functions and processes (e.g., *Halophila stipulacea* in the Mediterranean Sea)?
8. How are seagrass communities affected by non-indigenous species (e.g., wedge clam in the Baltic Sea)?
9. How can early signs of physiological and molecular stress and its source in a seagrass meadow be used to predict degradation?
10. How do changes in environmental factors influence phenology and reproduction in seagrass species?
11. What feedbacks and environmental and ecological factors facilitate the recovery of seagrass meadows from disturbances (e.g., water quality, food web)?
12. What is the role of community-wide biodiversity and feedback for the stability and resilience of seagrass meadows?
13. How do spatial distribution and connectivity of seagrass meadows affect resilience on a local and regional scale?
14. How does functional diversity within seagrass meadows influence ecosystem processes (e.g., growth, nutrient cycling)?
15. What is the role of intra- and interspecific variability in seagrass functional traits for seagrass resilience?
16. How do we quantify ecological feedbacks (e.g., sediment-light interactions) in seagrass ecosystems to inform conservation?
17. How does herbivory, particularly by large herbivores, influence seagrass community structure, functioning and resilience?
18. How does the presence of seagrass influence sediment?
19. How do wading birds and seabirds benefit from the biodiversity associated with seagrass meadows?
20. How do macro- and microplastic accumulation in seagrass meadows affect the associated fauna and ecosystem functioning?

## 3.2 | Ecosystem services

Seagrass ecosystems provide a wide array of services to humanity and the planet. They have a pivotal role in providing food and habitat, sustaining biodiversity, and helping to establish and maintain complex food webs (Heck et al., 2008). The abundance of different life forms associated with seagrass protects and provides food to many organisms at various life stages, including commercially exploited fish and invertebrates, thus supporting small- and large-scale fisheries (Jackson et al., 2001; Lilley & Unsworth, 2014; Nordlund et al., 2018; Unsworth et al., 2018). Seagrass roots, rhizomes and canopy protect coastal sediments from erosion (Infantes et al., 2022; Koch et al., 2009) and filter excess nutrients, pollutants and sediment. In addition, the uptake of carbon contributes to global biogeochemical cycles and the buffering of ocean acidification (Barbier et al., 2011; Potouroglou et al., 2017; Unsworth et al., 2012; Van Dam et al., 2021). Seagrass meadows also help control marine pathogens (Lamb et al., 2017; Reusch et al., 2021) and store carbon, both in living biomass and in the underlying sediments, making them a critical ecosystem for climate change mitigation and adaptation (Fourqurean et al., 2012; Röhr et al., 2018). Seagrasses also provide cultural services such as tourism and a sense of place (Nordlund et al., 2016).

Ecosystem services, direct and indirect contributions to human wellbeing, are an efficient way to communicate the benefits of seagrass to policymakers, practitioners, and the general public. A better understanding of seagrass services and their value provides a better basis for seagrass conservation and management, including economic incentives. Although our knowledge of seagrass ecosystem service provisioning is growing, we still have significant gaps in our understanding, especially among different seagrass species across latitudinal ranges and in terms of their economic valuation. A better understanding of these changing features of seagrass meadows and the drivers of this variation is needed to provide a baseline for more reliable estimates and targeted coastal management and conservation (Nordlund et al., 2016, 2018). There are few comprehensive seagrass valuation studies, most of them use indirect methods based on proxy measures which often leads to an underestimation, and very few consider seagrass non-use and existence value (Clifton et al., 2014; Dewsbury et al., 2016). There is also a bias towards provisioning and regulating services, while cultural services are understudied, as are the economic and social aspects of seagrass service provision (Nordlund et al., 2016; Ruiz-Frau et al., 2017).

21. What are the ecosystem services and their economic value provided by seagrass ecosystems?
22. What mechanisms are needed to implement a holistic approach to evaluate the provisioning, regulating, supporting and cultural ecosystem services of seagrass ecosystems?
23. To what extent do seagrass ecosystem services contribute to nature-based solutions across Europe (e.g., coastal erosion prevention, wastewater treatment, carbon sequestration)?
24. What is the role of seagrass cultural ecosystem services across Europe (e.g., in history, folklore, traditions)?
25. How is the provision of ecosystem services influenced by intra- and inter-specific variation, meadow traits, and environmental conditions?
26. How do seascape configuration and connectivity influence seagrass ecosystem service provisioning?
27. How do anthropogenic pressure and climate change (e.g., temperature increase, acidification) affect ecosystem services provisioning, nutrient cycling and sediment-water fluxes in seagrass ecosystems?

28. Which seagrass ecosystem services are at the highest risk of being altered or disappearing because of climate change and anthropogenic pressure, and what are the consequences?
29. How could we avoid or mitigate against the potential loss of ecosystem services provided by seagrass meadows in the future?

## 3.3 | Blue carbon

Blue Carbon is the carbon captured and stored by the world's oceans and coastal ecosystems, including seagrass meadows (Pendleton et al., 2012). Recognition and application of this concept within seagrass management offer a promising strategy to finance seagrass conservation and restoration projects while contributing to climate change mitigation (Oreska et al., 2020; Pendleton et al., 2012) and the array of other ecosystem services provided by seagrass. While global agreements for climate change mitigation include seagrass meadows alongside mangroves and tidal marshes (Macreadie et al., 2021) their integration into this policy falls behind the other coastal vegetated ecosystems (principally because of a lack of knowledge about their location and changes in areal extent). However, it has been reported that the protection of seagrass ecosystems could result in avoided emissions and enhanced carbon sequestration, estimated at about 200 million tons per year worldwide (Macreadie et al., 2021). There are also still important gaps in our understanding of the role of seagrasses as a carbon sink. The blue carbon sink capacity can be counteracted by emissions of other potent greenhouse gases (GHG) such as $CH_4$ and $N_2O$ (Roth et al., 2023). In fact, high temporal and spatial variability in GHG emissions from blue carbon ecosystems can make it more difficult to produce reliable estimates of climate mitigation when, for example, restoring blue carbon ecosystems (Rosentreter et al., 2021; Schorn et al., 2022).

Science and policy barriers still preclude the uptake and scalability of seagrass-based blue carbon initiatives. To maximize these opportunities for seagrass-based climate mitigation, we need to more fully understand the processes controlling carbon storage and the balance of GHG emissions and removals. This improved understanding is not just needed in a biological context but in a policy and socio-economic context (Unsworth et al., 2022). Important knowledge gaps also exist regarding temporal, spatial, anthropogenic and environmental factors influencing this balance.

30. What are the net GHG emissions (sources) and removals (sinks) across spatial and temporal scales?
31. What are the drivers of variation in carbon sequestration and storage across the depth and biogeographic range of European seagrass species?
32. How do disturbance, fragmentation, and loss of seagrass meadows affect the burial and the fate of Blue Carbon?
33. What are the compounding effects of multiple threats on the carbon storage and GHG emissions and removals from seagrass ecosystems?
34. What data do we need to model future GHG emissions and removals from seagrass meadows based on the IPCC scenarios?
35. How does the balance between allochthonous and autochthonous organic content in seagrass meadows vary with species and environment?
36. What are the GHG emissions and removals in restored seagrass meadows and how do they change with time?
37. What knowledge gaps persist in calculating GHG emissions and removals in seagrass meadows and what are the consistent methodologies to support it?
38. How can we convince policymakers to include seagrass in national inventories to make the conservation and restoration of seagrass meadows eligible for NDCs towards climate change mitigation?

## 3.4 | Fisheries support

Seagrass meadows are used as key fishery grounds on a global scale, for subsistence, recreational and commercial fisheries (Cullen-Unsworth et al., 2014; Nordlund et al., 2018; Unsworth et al., 2018). With their extremely high primary and secondary productivity, and complex habitat structure, seagrass meadows support diverse fish and invertebrate communities, and supply adjacent and even deep-water habitats with plant and animal biomass, organic matter and detritus (Gillanders, 2006; Heck et al., 2008; Lilley & Unsworth, 2014). Many commercially important species use seagrass at different stages of their life history, although few are strictly associated with seagrass throughout their life cycle (Beck et al., 2001; Lefcheck et al., 2019). Other species find refuge and foraging grounds in seagrass meadows (Jackson et al., 2001).

Despite the often-cited role of seagrass meadows as nursery habitats for commercial fisheries species, the extent of this function can be species-specific, and should be evaluated on a case-by-case basis (Beck et al., 2001; Lilley & Unsworth, 2014). There are clear knowledge gaps in the understanding of the basic biology and ecological interactions of many target fisheries species, especially invertebrates. The links between seagrass meadows and other coastal and marine habitats are also poorly known, for example, larval sources, transport pathways, larval biology, ecology and behaviour, and contribution to adult fish and invertebrate stocks.

From a policy perspective, the role of seagrass meadows as fishing grounds is still insufficiently acknowledged in fisheries management and seagrass conservation. Because of the lack of data, it is difficult to assess the impact of seagrass fisheries on fish stocks, as well as the indirect effect of fishing on seagrass communities. As a result, many stakeholders that are directly or indirectly dependent on these resources remain unaware of the role of seagrass meadows in fisheries support.

39. Which fisheries species are associated with seagrass meadows, during which life stages and to what extent?

40. What is the potential for European seagrass meadows to support commercially important fisheries stocks (e.g., fish, shellfish)?
41. How does habitat and nursery quality for fisheries species differ between seagrass meadows and other coastal and marine vegetated areas?
42. How can we communicate the importance of seagrass meadows for fisheries to stakeholders, policy makers and the general public more effectively?
43. How can we develop new and modify existing fisheries technology to be less damaging to seagrass ecosystems?

### 3.5 | Drivers, threats, resilience and response

There has been a global decline in the areal extent of seagrass meadows since 1880. The underlying factors driving this trend are manifold, locally diverse, and need to be better elucidated (Dunic et al., 2021; Green et al., 2021; Waycott et al., 2009). In Europe, it is estimated that about 1/3 of the seagrass area has been lost since the 19th century because of water quality deterioration, coastal development, eutrophication and wasting disease, with losses peaking in the 1970s and 1980s (de los Santos et al., 2019). Threats to seagrass meadows remain spatially extensive, cumulative, multifaceted and, in many cases, poorly understood (Turschwell et al., 2021). There is also high inter- and intraspecific variability in response to threats in different environments and with differing associated communities (Brown et al., 2013; Chefaoui et al., 2016). For example, projected climate warming may lead to significant loss of native seagrass in the Mediterranean Sea (Chefaoui et al., 2018), while it may favor the expansion of non-native seagrass species (Beca-Carretero et al., 2020).

How seagrass species respond to diverse and multiple climate and anthropogenic cumulative threats strongly depends on a complex interplay between ecological and physico-chemical factors that drive feedbacks between seagrasses, the organisms they support, and the environment (Maxwell et al., 2017). The resilience of the system and its capacity to adapt and withstand shocks and disturbance is important, and the system can buffer the effect of a disturbance until the latter becomes too intense and the system collapses (Montefalcone et al., 2007; Unsworth et al., 2015). For instance, mesograzers – especially amphipods – have been found to play an important role in protecting seagrasses from eutrophication by grazing on epiphytes (Duffy et al., 2015).

The complex impacts of the cumulative threats to seagrass meadows and how these impacts are intensified by increasing levels and duration of threats remain poorly understood. Thus, further research is urgently needed to underpin the decisions required to set informed impact thresholds for conservation management.

44. What are the impacts of climate change on seagrass meadows?
45. What are the impacts of the current and predicted changes in intensity, frequency and duration of different types of extreme events on seagrass meadows?
46. What role do pathogens play in influencing current and future seagrass populations?
47. What are the cumulative effects of multiple stressors on seagrass meadows and their associated species?
48. What are the tipping points for anthropogenic threats to seagrass ecosystems?
49. What are the effects of land use change and other terrestrial activities on seagrass ecosystems?
50. How do anthropogenic activities (e.g., aquaculture, physical disturbance) in the seascape influence/impact seagrass ecosystems?
51. What are the impacts of emerging and increasing contaminant threats to seagrass ecosystems (e.g., microplastics, chemical pollutants, metals)?
52. How and to what extent can seagrass ecosystems contribute to climate change adaptation and mitigation?
53. How does genetic diversity within seagrass ecosystems influence responses to environmental change?
54. Which seagrass species have the highest potential to adapt to environmental change in European waters?
55. Can seagrasses genetically, epigenetically and/or biochemically adapt to environmental change, and if so, how?

### 3.6 | Monitoring & assessment

The monitoring and assessment of seagrass ecosystems is essential to detect changes such as early signs of degradation due to local and global human impacts, or recovery following, for example, restoration or management actions. Although the EU Water Framework Directive (WFD 2000/60/EC, 2000) included seagrass species as indicators (García-Marín et al., 2013; Romero et al., 2007; Wilkes et al., 2017), there are no common monitoring protocols. Another main challenge is that there is no central information system that provides adequate information on the spatial and temporal extent of marine monitoring programs and associated data within Europe, or globally (Miloslavich et al., 2018), but see GOOS BioEco Metadata Portal (https://bioeco.goosocean.org/). The largest gap in our knowledge relates to habitat distribution and change in extent over time, especially from places such as coastal Sweden, Scotland and the Black Sea (Green et al., 2021).

There is ongoing development and innovation of seagrass and associated species monitoring and assessment (Martin et al., 2019). For example, the use of new remote mapping techniques (Huber et al., 2022; Traganos & Reinartz, 2018) is promising in order to update seagrass distribution maps at national and supra-national levels using satellite images. However, many limitations of these methods remain in deeper and turbid waters, and in areas where seagrass is mixed with extensive algal communities. Even though there is a great improvement in both mapping and monitoring of seagrass meadows, there are still many knowledge gaps. There are ongoing efforts by the Global Ocean Observation System (GOOS) to address this globally by developing specification sheets that aim to facilitate the collection of comparable seagrass data supporting Findable, Accessible, Interoperable, and Reusable (FAIR) principles (Miloslavich et al., 2018; Ratnarajah et al., 2022). Further improvements in seagrass monitoring and assessment and a willingness to adopt comparable and transparent methods are needed in order to improve seagrass monitoring and assessments across Europe and beyond.

56. What are the past, present and predicted changes in seagrasses distribution and condition in Europe because of various pressures and management actions?
57. How do we efficiently map seagrass habitat at scale to fill the gaps in existing distribution maps of European seagrass species?
58. What are the ways forward to make seagrass data more FAIR (findable, accessible, interoperable, reusable) across Europe, and can available platforms be used more efficiently and collaboratively?
59. How can traditional and emerging techniques for assessing seagrasses distribution and health (e.g., field data, drones, remote sensing and Machine Learning/Artificial Intelligence) be integrated to increase confidence in mapping and monitoring results?
60. How can we further improve and develop standardized seagrass monitoring protocols that also have the capacity to include and build on historical data?
61. How should we cost-efficiently measure the quality and extent of seagrass meadows to meet local, national and European targets?
62. What is the relative contribution of natural vs anthropogenic causes of seagrass temporal trends in Europe?
63. How can Citizen Scientists be engaged to map and monitor seagrass meadows at sufficient scales to improve conservation?
64. How can temporal genetic monitoring be used to enhance conservation of seagrass meadows?
65. How can we ensure that monitoring data is regularly analysed to assess and act on trends in seagrass status?
66. How does the concept of Essential Ocean Variables link to the monitoring of seagrass ecosystems across Europe?

## 3.7 | Conservation & restoration

Currently, a diverse array of conservation and restoration strategies are being deployed to prevent further declines of seagrass ecosystems across Europe and to maintain connectivity with other ecosystems. However, effective conservation of seagrass ecosystems is a challenging prospect requiring a good understanding of the ecology, status, and threats to seagrass meadows, as well as interdisciplinary cooperation at scientific, stakeholder and political scales (Unsworth, McKenzie, et al., 2019). Management interventions, mostly at the local and regional scales, such as improvement of water quality, may explain some of the recovery of seagrass meadows across Europe (de los Santos et al., 2019).

However, management interventions that have led to improvement in environmental conditions have not necessarily translated to seagrass recovery, mostly because of complex feedbacks and interactions (Maxwell et al., 2017; Valdez et al., 2020). In addition, seagrass restoration projects, using a variety of methods, have been attempting to restore lost seagrass meadows across Europe (van Katwijk et al., 2016) with mixed success thus far. Generally, seagrass restoration is challenging and expensive (Bayraktarov et al., 2016), but because of persistent trials, knowledge exchange and methodological advancements, there are more and more successful examples, along with the recovery of associated ecosystem services (Govers et al., 2022). Despite these hopeful indications of recovery, seagrass meadows across Europe are still facing multiple challenges as a result of continued environmental degradation and accelerating climate change — as an especially pressing threat. Furthermore, the recovery of slow-growing species such as *Posidonia oceanica* takes decades or more, so despite recent advances in restoration methods and success rates (Pansini et al., 2022; Terrados et al., 2013), restoration simply cannot replace conservation for this species (Boudouresque et al., 2021). Even for fast-growing species such as *Z. marina*, where local recovery can occur within a decade, and species can quickly colonize the restored areas (Gagnon et al., 2023), it will take many decades to regenerate fully functional ecosystems at the regional scale. There is especially a need to effectively upscale restoration efforts (Unsworth et al., 2019) and to consider genetic diversity (Pazzaglia et al., 2021, 2021), connectivity (Jahnke et al., 2020) and life history traits (van Katwijk et al., 2021), while tailoring restoration strategies for different seagrass species (Bekkby et al., 2020). The development of an effective and scalable seagrass restoration methodology arises as a great challenge for the 21st century. Thus, for healthy and abundant seagrass meadows in the future both conservation of existing seagrass meadows and restoration efforts of degraded and lost seagrass meadows across Europe need to be urgently improved and optimized.

67. What are the potential roles and perceptions of different stakeholders in current and future seagrass conservation and restoration and how do they influence project success?
68. Which conservation measures have been proven to be most effective in protecting seagrasses, and how can we implement these on a local level?
69. What approaches, criteria and tools are best used to identify priority seagrass sites for conservation as well as to ensure connectivity?
70. Which new or existing quantifiable criteria can be used for improving and implementing conservation policies of seagrass ecosystems when areal extent and rate of change are not available?
71. How should intraspecific genetic variability be considered in the management and conservation of seagrass ecosystems?
72. What are the best approaches, criteria and tools for identifying priority areas for the restoration of seagrass ecosystems in order to increase restoration success rate?
73. What is needed to successfully and efficiently upscale seagrass restoration and aid recovery?

74. At what temporal and spatial scales do seagrass ecosystems recover functionality, connectivity and services after a successful restoration program?
75. How and to what extent should seascape considerations be taken into account when planning active restoration actions of seagrass ecosystems?
76. How do we forecast the potential success of transplantations (incl. sites and procedures) based on multiple indicators?
77. How does the genetic makeup of donor material affect the restoration success of seagrasses?
78. In what way can we use knowledge of seagrass-microbiome relationships to improve seagrass transplantation (or restoration in general)?
79. How do the method and spatial arrangement of transplant units affect seagrass restoration success?
80. What is the impact of transplanting different genetic ramets on the resilience of local seagrass populations?
81. How do we make decisions about the most appropriate conservation and/or restoration activities in order to ensure healthy and functioning seagrass meadows both locally and regionally?
82. How can the public be involved and contribute to the conservation and restoration of seagrass habitats?

## 3.8 | Governance, Policy & Management

There is no single policy or set of policies to manage the marine environment on the European continent (Grip, 2017). The Water Framework Directive (WFD) (2000/60/EC) was adopted in 2000 to achieve 'good status' for all water bodies by 2015, including marine/coastal waters up to one nautical mile from shore, but because of implementation challenges, it is now extended to 2027 (Carvalho et al., 2019; Voulvoulis et al., 2017). The EU adopted the Marine Strategy Framework Directive (MSFD) (2008/56/EC) in 2008, to protect the marine environment and natural resources while also establishing a framework for the sustainable use of European marine waters. Effective governance of seagrass meadows entails the implementation of conservation policies and management strategies across terrestrial catchments, the coastline and the deep ocean. The location of seagrass ecosystems at the land-sea interface implies that multiple threats including agriculture, land clearance, urban and industrial sewage, fishing practices and climate change need to be properly managed to ensure the preservation of seagrass meadows and the ecosystem services they provide. These threats act at different spatial and temporal scales, adding complexity to the effective management of seagrass ecosystems (O'Brien et al., 2018). Overcoming science and policy knowledge gaps, including how to effectively restore seagrasses at scale and the implementation of national and transboundary conservation strategies, are crucial to foster large-scale recovery of seagrass ecosystems.

The involvement of stakeholders, policymakers, government and non-government agencies and scientists in delineating effective seagrass governance, policy and management mechanisms across Europe and beyond is crucial to achieve the desired conservation and restoration goals. The valuation of seagrass ecosystem services, including Payments for Ecosystems Services (PES) and carbon credits, appears as a crucial step to finance and promote seagrass conservation and restoration activities.

83. How can we better integrate management on land and at sea to prevent further loss and degradation of seagrass ecosystems?
84. What strategy can be devised in seagrass conservation to scale up, connect and absorb small-scale interventions into broader and potentially more impactful ones at larger scales?
85. How can marine protected area (MPA) planning enhance the connectivity and resilience of seagrass meadows?
86. How can existing policy and management be used to prioritize seagrass restoration sites and areas with large potential for recovery?
87. How can seagrass management be improved at different spatial scales in the face of global and local stressors?
88. How can we bring stakeholders together to address drivers of seagrass loss and advance restoration and conservation on a regional scale?
89. What are the specific features of dynamic seagrass meadows, which vary in space and time, that should be considered to provide effective conservation policies and assessment methods?
90. How do we deal with different context-dependent responses (inter- and intraspecific) in seagrass management and decision-making?
91. How can we integrate faunal species that use seagrass as a critical habitat into management and policy?
92. What are the best ways that European seagrass researchers work together to develop long-term research and conservation programs with common goals and sustainable funding?
93. How can we change policy to make conservation and restoration of seagrass meadows eligible for financial instruments (e.g., carbon credits)?
94. How can the inclusion of seagrass meadows into adaptation and mitigation plans of the Nationally Determined Contributions (NDCs) of European countries, and similar initiatives, be promoted?

## 3.9 | Communication

Communication is needed across planning scales, nations, and stakeholders to improve conservation, monitoring and research of seagrass meadows. Communication involves the co-operation among researchers from different disciplines to adopt integrated approaches in order to overcome present seagrass conservation challenges (Unsworth et al., 2019). Another essential aspect of communication in the need of improvement is the exchange of scientific, local and/or traditional knowledge as well as experience between researchers, managers, policymakers and fishers in order to learn from each other, to better transfer knowledge, and to identify and communicate needs. A seagrass-literate society is vital for the sustainability of seagrass ecosystems (Cullen-Unsworth & Unsworth, 2018). While some progress has been made in the last decade regarding seagrass awareness in society (Cullen-Unsworth & Unsworth, 2018), full recognition has not been reached among all stakeholder groups (UNEP, 2020), which remains one of the global challenges in seagrass conservation (Unsworth et al., 2019). The cooperation of educators and scientists to create a seagrass-literate society is needed to raise awareness of seagrasses. In some European regions, seagrass-literacy is improving (Barracosa et al., 2019). Recently, the key principles and concepts in relation to seagrasses that a seagrass-literate person should know have been defined (Apostoloumi et al., 2021). Communication is now needed to ensure we achieve a far greater level of seagrass literacy in the population in order to ensure seagrass ecosystem persistence and resilience. To achieve this a better understanding of environmental education and ocean literacy is needed.

95. How can we improve communication for a better understanding using interdisciplinary skills and partnerships to further seagrass conservation and restoration?
96. How can we optimize knowledge sharing among and between different seagrass professionals and stakeholders such as researchers, managers, educators and policy makers?
97. How could ocean literacy on seagrass ecology become widespread, from science programs at school to awareness by the wider public?
98. What are the socio-ecological values of seagrass meadows (from cultural values to climate change mitigation and adaptation) for communities including citizens, fishers, boat users, politicians and governments and how can they be communicated?
99. What are the mechanisms and levers to best communicate the diverse and multiple benefits of seagrass ecosystems to raise more awareness of their ecological importance to all relevant stakeholders?
100. How can we better communicate research and monitoring findings to stakeholders and policy makers to drive seagrass conservation and restoration actions on the ground?

## 4 | DISCUSSION

European seagrass meadows face ongoing degradation, and our ability to make effective and large-scale improvements is limited by numerous knowledge gaps in the ecology, functioning and management of these systems (Unsworth, McKenzie, et al., 2019). However, there is an unprecedented political and media interest in seagrass ecosystems in Europe in recent years. While historically the financing of research and conservation has been limited for these ecosystems (Unsworth, McKenzie, et al., 2019), there is now evidence of increased funding opportunities to achieve an improved understanding of seagrass meadows. In the present paper, we propose 100 key questions, predicated on expert knowledge, that if answered would fill many current knowledge gaps and place European seagrass onto a positive trajectory of recovery. We believe that this targeted list of questions, spanning *Biodiversity & Ecology; Ecosystem services; Blue carbon; Fishery support; Drivers, Threats, Resilience & Response; Monitoring & Assessment; Conservation & Restoration; Governance, Policy & Management; and Communication* will assist in directing opportunities towards evidence-based action appropriate for European seagrass conservation. The 100 questions do not only succinctly cover the key knowledge gaps but also reflect a growing maturity and understanding of seagrass science, enabling scientists to propose meaningful questions in the context of developing applied actions for advancing seagrass research, monitoring and conservation.

Traditionally seagrass research has been mostly focused on biology and ecology but in the last decade there has been a boost in seagrass related social-ecological, social, cultural, management and governance research, along with more frequent inter- and transdisciplinary studies. This is also reflected in the questions presented in this paper. In the case of ecological research on seagrass, it was for many decades focused on describing the ecological communities present within these productive meadows. While the questions in this paper shows how ecological thinking and research within this area have moved toward understanding ecological processes and drivers, particularly within an applied context. These advances have also highlighted how many larger gaps in ecological understanding still remain on this issue. Furthermore, the present paper poses questions about how an improved understanding of seagrass community interactions and processes relates to food webs, ecosystem functions, and feedbacks (Moreira-Saporiti et al., 2023). It also confirms the need to better understand genetics, traits, the impact of non-indigenous species, changing phenology and the critical nature of reproduction. Questions about prioritizing sites and effective upscaling for conservation and restoration, the role of connectivity, seascape and MPA planning all point to the increasing need to effectively integrate seagrass conservation in (international) urban and landscape planning. Moreover, in such planning, not only conservation but also assignments of new sites for seagrass culture or rewilding could be considered to further benefit from seagrass ecosystem services (van Katwijk et al., 2021). However, such efforts should not be 'traded' as compensation for deliberate damage to extant meadows (Boudouresque et al., 2021; Cunha et al., 2012). In many cases more holistic, integrated and applied approaches are needed to answer these questions to better understand seagrass ecosystems and its future sustainability.

Understanding where seagrass meadows occur remains a European as well as a global challenge for seagrass conservation (McKenzie et al., 2020) as we cannot conserve and improve what we do not know exists. Although this gap is an age-old problem, it has never been such a pressing one. The questions here grapple with this problem both from a monitoring and a mapping perspective and highlight the need to maximize our use of technological innovation. Furthermore, many studies have demonstrated the long-term loss and decline in the health of seagrass ecosystems in Europe and beyond (Airoldi & Beck, 2007), but this only applies to the seagrass that we are aware of, again highlighting the importance of mapping and monitoring. Seagrasses remain under threat across the continent, despite increased efforts (Turschwell et al., 2021). Tied to these problems are large gaps in our knowledge of how these threats act independently, synergically and cumulatively and the implications for maintaining the resilience of seagrass ecosystems. Without filling these gaps, we will struggle to undertake the most appropriate management actions for conserving and restoring these habitats across Europe.

A key theme that arises from the proposed questions on seagrass ecosystem services is the ever-increasing realization that what we measure today will not apply in the future as the forcing of climate change increases. Furthermore, the questions in this paper reflect both the need to broaden the understanding and the interconnectedness among ecosystem services as well as a focus on Fishery support (Food, Tourism, Recreation) and Blue carbon (Carbon sequestration and storage). The fishery support questions are mostly focusing on the potential and the importance of seagrass for fisheries. Blue carbon is an ever-expanding part of the discussions around seagrass science. The questions posed here rightly move beyond the inventory as scientists recognize more human activities that negatively affect seagrass blue carbon sequestration and stocks. What we see in the proposed questions is an increasing need to understand the mechanisms behind the accumulation of carbon and the balance between GHG removals and emissions linked to conservation and restoration actions. Answering these questions will ultimately provide the best management options to enhance the role of seagrass meadows in climate change mitigation.

Successful conservation of seagrass requires strong governance, policy and management to guide and support the process, furthermore, monitoring and assessment are essential to understand change (UNEP, 2020). The questions reflect the need for the integration of different types of data but also the need for long-term understanding that can support our understanding, as well as to develop potential future scenarios. The questions also reflect the need to evaluate and compare different approaches to identify more effective conservation. There are multiple active seagrass monitoring programs across Europe, but the data is often not publically available nor comparable because of different parameter being measures (Ratnarajah et al., 2022). To overcome many of these challenges it is key that seagrass monitoring is interoperable and comparable across regions and countries using FAIR principles to enhance our understanding of change. Learning from change (both positive and negative) is key to successful conservation, it is important to understand which governance, policy and management actions are working, and in which settings.

In conclusion, to make the political and societal case for action on seagrass research, monitoring, conservation and restoration, it is essential to provide evidence of their value to nature and human well-being and effectively communicate their importance. Our work has identified 100 priority questions relevant to seagrass conservation in Europe and demonstrates the huge gaps we still have in our understanding of these diverse and productive ecosystems. These questions will probably not be easily and quickly answered, but would allow large advancements in our understanding. We encourage a collective effort – researchers, managers, politicians, research funders, and others – to add these questions to the agenda as we believe this knowledge would greatly advance seagrass research, monitoring and conservation.

## AUTHOR CONTRIBUTIONS

RU and LMN developed the original idea for this MS. LMN, RU, LR & SWH planned and designed the research. LMN, RU and SWH drafted the manuscript. All authors (LMN, RU, SWH, LR, PBC, EB, JCB, RMC, CBS, KG, JMG, FG, LLG, CG, EH, EI, JCC, MJ, PK, HK, SK, TMR, JM, NP, EP, VP, DP, RP, OS, AS, SS, FR, SDS, MvK, DW, EAW, RW) jointly contributed to conducting the research and editing the manuscript. Final edits were made by RU & LMN. All authors have approved the final version.

## AFFILIATIONS

[1]Natural Resources and Sustainable Development, Department of Earth Sciences, Uppsala University, Sweden
[2]Biosciences, Faculty of Science and Engineering, Swansea University, Wales, UK
[3]Bracka Industrial Estate, Bridgend, Wales, UK
[4]Integrated Marine Observing System, Hobart, Tasmania, Australia
[5]Global Ocean Observing System, International Oceanographic Commission, UNESCO, Paris, France
[6]Instituto de Investigaciones Marinas, Consejo Superior de Investigaciones Cientificas (IIM-CSIC), Vigo, Spain
[7]Institute of Biology, University of Latvia, Latvia
[8]Universidad Rey Juan Carlos, Area of Biodiversity and Conservation, Instituto de Investigación en Cambio Global (IICG-URJC), Spain
[9]Centre of Marine Sciences of Algarve (CCMAR), Portugal
[10]Institute of Marine Research (IMR), His, Norway
[11]AZTI- BRTA (Marine Research), Pasaia, Spain
[12]MARE – Marine and Environmental Sciences Centre/ARNET - Aquatic Research Network, Agência Regional para o Desenvolvimento da Investigação, Tecnologia e Inovação (ARDITI), Portugal
[13]Conservation Ecology Group, GELIFES, The Netherlands AND Department of Coastal Systems, University of Groningen, Royal Netherlands Institute for Sea Research (NIOZ), The Netherlands
[14]Tvärminne Zoological Station, Faculty of Biological and Environmental Sciences, University of Helsinki, Finland
[15]Institute of Oceanology, Bulgarian Academy of Sciences, Bulgaria
[16]Department of Biology and Environmental Sciences, University of Gothenburg, Kristineberg, Sweden
[17]Department of Marine Sciences – Tjärnö Marine Laboratory, University of Gothenburg, Strömstad, Sweden
[18]Marine and Environmental Research (MER) Lab, Limassol, Cyprus
[19]School of Ocean Sciences, Bangor University, Anglesey, UK
[20]Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Bulgaria
[21]Estonian Marine Institute, University of Tartu, Tallinn, Harjumaa, Estonia
[22]Faculty of Life Sciences, University of Madeira, Portugal
[23]ECOMARE – Laboratory for Innovation and Sustainability of Marine Biological Resources, CESAM – Centre for Environmental and Marine Studies, Department of Biology, University of Aveiro, Aveiro, Portugal
[24]ISPRA - Italian Institute for Environmental Protection and Research, Chioggia, Italy
[25]Fisheries Research Institute, Greece

[26]Foundation for Research and Technology Hellas, Institute of Applied and Computational Mathematics, The Remote Sensing Lab, Heraklion, Greece
[27]Department of Biology, Marine Biology Research Group, Ghent University, Ghent, Belgium
[28]Centro de Estudios Avanzados de Blanes, Consejo Superior de Investigaciones Cientificas (CEAB-CISC), Blanes, Spain
[29]Dipartimento di Ecologia Marina IntegrataGenoa Marine Centre (GMC), Stazione Zoologica Anton Dohrn, Genoa Marine Center, Genoa, Italy
[30]Carl von Ossietzky Universität Oldenburg, Institute for Chemistry and Biology of the Marine Enviroment (ICBM), Germany
[31]Department of Environmental Science, Radboud Institute of Biological and Environmental Sciences, Radboud University, Nijmegen, The Netherlands
[32]National Biodiversity Data Centre, Carriganore, Co. Waterford, Ireland
[33]Institute of Marine Sciences, School of Biological Sciences, University of Portsmouth, UK
[34]Environmental Protection Agency, Castlebar, Co., Mayo, Ireland

## ACKNOWLEDGMENTS

This project was initiated and carried out under the EuroSea project using funding from the United Nations Educational, Scientific and Cultural Oragnisation. Additional support was from the UK Natural Environment Research Council RESOW grant to Swansea University (NE/V016385/1). The EuroSea project is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 862626. Thanks to Toste Tanhua and Emma Heslop for their supporting this process. Thanks are due to FCT/MCTES for the financial support to CESAM (UIDB/50017/2020 + UIDP/50017/2020 + LA/P/0094/2020), through PT national funds. Financial support from Fundacao para a Ciencia e a Technologia was also provided through the research contract to A.I. Sousa (CEECIND/00962/2017). We would like to thank the following people for their contributions during the Delphi-process: Teresa Alcoverro, Johnny Berglund, Tobias Börger, Dick de Jong, Ventzi Karamfilov, Dorte Krausen-Jensen, Søren Laurentius Nielsen, Ana Lillebø, Rory O'Callaghan, Jordi Pagès, Joanne Preston, Sara Pruckner, Thorsten Reusch, Javier Romero, and Hendrik Schubert.

## CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest with respect to any of the content, funding or implications of the study findings.

## DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

## ORCID

*Lina Mtwana Nordlund* https://orcid.org/0000-0002-4450-2331
*Richard K. F. Unsworth* https://orcid.org/0000-0003-0036-9724
*Sieglind Wallner-Hahn* https://orcid.org/0000-0003-0010-745X
*Pedro Beca-Carretero* https://orcid.org/0000-0002-4000-6912
*James C. Bull* https://orcid.org/0000-0002-4373-6830
*Carmen B. de los Santos* https://orcid.org/0000-0002-7013-494X
*Karine Gagnon* https://orcid.org/0000-0002-0971-7740
*Joxe Mikel Garmendia* https://orcid.org/0000-0002-9403-1777
*Francesca Gizzi* https://orcid.org/0000-0001-9447-8694
*Camilla Gustafsson* https://orcid.org/0000-0001-7308-3802
*Elitsa Hineva* https://orcid.org/0000-0002-9540-5267
*Eduardo Infantes* https://orcid.org/0000-0002-9724-9237
*João Canning-Clode* https://orcid.org/0000-0003-2143-6535
*Marlene Jahnke* https://orcid.org/0000-0001-7262-315X
*Periklis Kleitou* https://orcid.org/0000-0002-9168-4721
*Hilary Kennedy* https://orcid.org/0000-0003-2290-2120
*Stefania Klayn* https://orcid.org/0000-0003-3610-8155
*Tiia Moller* https://orcid.org/0000-0003-2445-9978
*João Monteiro* https://orcid.org/0000-0002-3401-6495
*Emanuele Ponis* https://orcid.org/0000-0001-6109-3931
*Vasillis Papathanasiou* https://orcid.org/0000-0002-1899-6972
*Dimitris Poursanidis* https://orcid.org/0000-0003-3228-280X
*Riccardo Pieraccini* https://orcid.org/0000-0002-6122-5807
*Oscar Serrano* https://orcid.org/0000-0002-5973-0046
*Ana. I. Sousa* https://orcid.org/0000-0003-0783-5177
*Susanne Schäfer* https://orcid.org/0000-0002-0344-0541
*Francesca Rossi* https://orcid.org/0000-0003-1928-9193
*D. Sebastian Storey* https://orcid.org/0009-0005-4396-7494
*Marieke M. van Katwijk* https://orcid.org/0000-0002-4482-5835
*Robert Wilkes* https://orcid.org/0000-0002-2943-9020

## REFERENCES

Airoldi, L., & Beck, M. W. (2007). Loss, status and trends for coastal marine habitats of Europe. *Oceanography and Marine Biology: an Annual Review*, *45*, 345–405.

Apostoloumi, C., Malea, P., & Kevrekidis, T. (2021). Principles and concepts about seagrasses: Towards a sustainable future for seagrass ecosystems. *Marine Pollution Bulletin*, *173*, 112936. https://doi.org/10.1016/j.marpolbul.2021.112936

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs*, *81*(2), 169–193. https://doi.org/10.1890/10-1510.1

Barracosa, H., De los Santos, C. B., Martins, M., Freitas, C., & Santos, R. (2019). Ocean literacy to mainstream ecosystem services concept in formal and informal education: The example of coastal ecosystems of southern Portugal. *Frontiers in Marine Science*, *6*. https://doi.org/10.3389/fmars.2019.00626

Bayraktarov, E., Saunders, M. I., Abdullah, S., Mills, M., Beher, J., Possingham, H. P., Mumby, P. J., & Lovelock, C. E. (2016). The cost and feasibility of marine coastal restoration. *Ecological Applications*, *26*(4), 1055–1074. https://doi.org/10.1890/15-1077

Beca-Carretero, P., Teichberg, M., Winters, G., Procaccini, G., & Reuter, H. (2020). Projected rapid habitat expansion of tropical seagrass species in the Mediterranean Sea as climate change progresses. *Frontiers in Plant Science*, *11*. https://doi.org/10.3389/fpls.2020.555376

Beck, M. W., Heck, K. L., Able, K. W., Childers, D. L., Eggleston, D. B., Gillanders, B. M., Halpern, B., Hays, C. G., Hoshino, K., Minello, T. J., et al. (2001). The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. *Bioscience*, *51*(8), 633–641. https://doi.org/10.1641/0006-3568(2001)051[0633:TICAMO]2.0.CO;2

Bekkby, T., Papadopoulou, N., Fiorentino, D., McOwen, C. J., Rinde, E., Boström, C., Carreiro-Silva, M., Linares, C., Andersen, G. S., Bengil, E. G. T., et al. (2020). Habitat features and their influence on the restoration potential of marine habitats in Europe. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.00184

Boudouresque, C.-F., Blanfuné, A., Pergent, G., & Thibaut, T. (2021). Restoration of seagrass meadows in the Mediterranean Sea: A critical review of effectiveness and ethical issues. *Watermark*, *13*(8), 1034. https://doi.org/10.3390/w13081034

Brown, C. J., Saunders, M. I., Possingham, H. P., & Richardson, A. J. (2013). Managing for interactions between local and global stressors of ecosystems. *PLoS ONE*, *8*(6), e65765. https://doi.org/10.1371/journal.pone.0065765

Campagne, C. S., Salles, J.-M., Boissery, P., & Deter, J. (2015). The seagrass Posidonia oceanica: Ecosystem services identification and economic evaluation of goods and benefits. *Marine Pollution Bulletin*, *97*(1), 391–400. https://doi.org/10.1016/j.marpolbul.2015.05.061

Carvalho, L., Mackay, E. B., Cardoso, A. C., Baattrup-Pedersen, A., Birk, S., Blackstock, K. L., Borics, G., Borja, A., Feld, C. K., Ferreira, M. T., Globevnik, L., Grizzetti, B., Hendry, S., Hering, D., Kelly, M., Langaas, S., Meissner, K., Panagopoulos, Y., Penning, E., … Solheim, A. L. (2019). Protecting and restoring Europe's waters: An analysis of the future development needs of the water framework directive. *Science of the Total Environment*, *658*, 1228–1238. https://doi.org/10.1016/j.scitotenv.2018.12.255

Chefaoui, R. M., Assis, J., Duarte, C. M., & Serrão, E. A. (2016). Large-scale prediction of seagrass distribution integrating landscape metrics and environmental factors: The case of *Cymodocea nodosa* (Mediterranean–Atlantic). *Estuaries and Coasts*, *39*(1), 123–137. https://doi.org/10.1007/s12237-015-9966-y

Chefaoui, R. M., Duarte, C. M., & Serrão, E. A. (2018). Dramatic loss of seagrass habitat under projected climate change in the Mediterranean Sea. *Global Change Biology*, *24*(10), 4919–4928. https://doi.org/10.1111/gcb.14401

Clifton, J., Cullen-Unsworth, L. C., & Unsworth, R. K. F. (2014). Valuing and evaluating marine ecosystem services: Putting the right Price on marine environments. *Environment and Society: Advances in Research*, *5*(1), 66–85. https://doi.org/10.3167/ares.2014.050105

Cullen-Unsworth, L. C., Nordlund, L. M., Paddock, J., Baker, S., McKenzie, L. J., & Unsworth, R. K. F. (2014). Seagrass meadows globally as a coupled social–ecological system: Implications for human wellbeing. *Marine Pollution Bulletin*, *83*(2), 387–397. https://doi.org/10.1016/j.marpolbul.2013.06.001

Cullen-Unsworth, L. C., & Unsworth, R. (2018). A call for seagrass protection. *Science*, *361*(6401), 446–448. https://doi.org/10.1126/science.aat7318

Cunha, A. H., Marba, N. N., van Katwijk, M. M., Pickerell, C., Henriques, M., Bernard, G., Ferreira, M. A., Garcia, S., Garmendia, J. M., & Manent, P. (2012). Changing paradigms in seagrass restoration. *Restoration Ecology*, *20*(4), 427–430. https://doi.org/10.1111/j.1526-100X.2012.00878.x

Dalkey, N., & Helmer, O. (1963). An experimental application of the DELPHI method to the use of experts. *Management Science*, *9*(3), 458–467. https://doi.org/10.1287/mnsc.9.3.458

de los Santos, C. B., Krause-Jensen, D., Alcoverro, T., Marbà, N., Duarte, C. M., van Katwijk, M. M., Pérez, M., Romero, J., Sánchez-Lizaso, J. L., Roca, G., et al. (2019). Recent trend reversal for declining European seagrass meadows. *Nature Communications*, *10*(1), 3356. https://doi.org/10.1038/s41467-019-11340-4

Dewsbury, B. M., Bhat, M., & Fourqurean, J. W. (2016). A review of seagrass economic valuations: Gaps and progress in valuation approaches. *Ecosystem Services*, *18*, 68–77. https://doi.org/10.1016/j.ecoser.2016.02.010

Duarte, C. M., Dennison, W. C., Orth, R. J. W., & Carruthers, T. J. B. (2008). The charisma of coastal ecosystems: Addressing the imbalance. *Estuaries and Coasts*, *31*(2), 233–238. https://doi.org/10.1007/s12237-008-9038-7

Duffy, J. E., Benedetti-Cecchi, L., Trinanes, J., Muller-Karger, F. E., Ambo-Rappe, R., Boström, C., Buschmann, A. H., Byrnes, J., Coles, R. G., Creed, J., Cullen-Unsworth, L. C., Diaz-Pulido, G., Duarte, C. M., Edgar, G. J., Fortes, M., Goni, G., Hu, C., Huang, X., Hurd, C. L., … Yaakub, S. M. (2019). Toward a coordinated global observing system for seagrasses and marine macroalgae. *Frontiers in Marine Science*, *6*. https://doi.org/10.3389/fmars.2019.00317

Duffy, J. E., Reynolds, P. L., Boström, C., Coyer, J. A., Cusson, M., Donadi, S., Douglass, J. G., Eklöf, J. S., Engelen, A. H., Eriksson, B. K., Fredriksen, S., Gamfeldt, L., Gustafsson, C., Hoarau, G., Hori, M., Hovel, K., Iken, K., Lefcheck, J. S., Moksnes, P. O., … Stachowicz, J. J. (2015). Biodiversity mediates top–down control in eelgrass ecosystems: A global comparative-experimental approach. *Ecology Letters*, *18*(7), 696–705. https://doi.org/10.1111/ele.12448

Duffy, J. E., Richardson, J. P., & Canuel, E. A. (2003). Grazer diversity effects on ecosystem functioning in seagrass beds. *Ecology Letters*, *6*(9), 881–881.

Duffy, J. E., Richardson, J. P., & France, K. E. (2005). Ecosystem consequences of diversity depend on food chain length in estuarine vegetation. *Ecology Letters*, *8*, 301–309. https://doi.org/10.1111/j.1461-0248.2005.00725.x

Duffy, J. E., Stachowicz, J. J., Reynolds, P. L., Hovel, K. A., Jahnke, M., Sotka, E. E., Boström, C., Boyer, K. E., Cusson, M., Eklöf, J., Engelen, A. H., Eriksson, B. K., Fodrie, F. J., Griffin, J. N., Hereu, C. M., Hori, M., Hughes, A. R., Ivanov, M. V., Jorgensen, P., … Olsen, J. L. (2022). A Pleistocene legacy structures variation in modern seagrass ecosystems. *Proceedings of the National Academy of Sciences*, *119*(32), e2121425119. https://doi.org/10.1073/pnas.2121425119

Dunic, J. C., Brown, C. J., Connolly, R. M., Turschwell, M. P., & Côté, I. M. (2021). Long-term declines and recovery of meadow area across the world's seagrass bioregions. *Global Change Biology*, *27*(17), 4096–4109. https://doi.org/10.1111/gcb.15684

Foden, J., & Brazier, D. P. (2007). Angiosperms (seagrass) within the EU water framework directive: A UK perspective. *Marine Pollution Bulletin*, *55*(1–6), 181–195. https://doi.org/10.1016/j.marpolbul.2006.08.021

Fourqurean, J. W., Duarte, C. M., Kennedy, H., Marba, N., Holmer, M., Mateo, M. A., Apostolaki, E. T., Kendrick, G. A., Krause-Jensen, D., McGlathery, K. J., et al. (2012). Seagrass ecosystems as a globally significant carbon stock. *Nature Geoscience*, *5*(7), 505–509. https://doi.org/10.1038/ngeo1477

Gagnon, K., Bocoum, E.-H., Chen, C. Y., Baden, S. P., Moksnes, P.-O., & Infantes, E. (2023). Rapid faunal colonization and recovery of biodiversity and functional diversity following eelgrass restoration. *Restoration Ecology*, *31*(4), e13887. https://doi.org/10.1111/rec.13887

García-Marín, P., Cabaço, S., Hernández, I., Vergara, J. J., Silva, J., & Santos, R. (2013). Multi-metric index based on the seagrass Zostera noltii (ZoNI) for ecological quality assessment of coastal and estuarine systems in SW Iberian Peninsula. *Marine Pollution Bulletin*, *68*(1), 46–54. https://doi.org/10.1016/j.marpolbul.2012.12.025

Gerakaris, V., Lardi, P.-I., & Issaris, Y. (2020). First record of the tropical seagrass species Halophila decipiens Ostenfeld in the Mediterranean Sea. *Aquatic Botany*, *160*, 103151. https://doi.org/10.1016/j.aquabot.2019.103151

Gillanders, B. M. (2006). Seagrasses, fish, and fisheries. In A. W. Larkum, R. J. Orth, & C. M. Duarte (Eds.). *Seagrasses: Biology* (pp. 503–536). Springer. https://doi.org/10.1007/1-4020-2983-7_21

Greiner, J. T., McGlathery, K. J., Gunnell, J., & McKee, B. A. (2013). Seagrass restoration enhances “blue carbon” sequestration in coastal waters. *PLoS ONE*, *8*(8), e72469. https://doi.org/10.1371/journal.pone.0072469

Govers, L. L., Heusinkveld, J. H. T., Gräfnings, M. L. E., Smeele, Q., & van der Heide, T. (2022). Adaptive intertidal seed-based seagrass restoration in the Dutch Wadden Sea. *PLoS ONE*, *17*(2), e0262845. https://doi.org/10.1371/journal.pone.0262845

Green, E. P., & Short, F. T. (2003). *World atlas of seagrasses*. University of California Press.

Green, A. E., Unsworth, R. K. F., Chadwick, M. A., & Jones, P. J. S. (2021). Historical analysis exposes catastrophic seagrass loss for the United Kingdom. *Frontiers in Plant Science*, *12*. https://doi.org/10.3389/fpls.2021.629962

Grip, K. (2017). International marine environmental governance: A review. *Ambio*, *46*(4), 413–427. https://doi.org/10.1007/s13280-016-0847-9

Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing*, *32*(4), 1008–1015. https://doi.org/10.1046/j.1365-2648.2000.t01-1-01567.x

Heck, K. L., Carruthers, T. J. B., Duarte, C. M., Hughes, A. R., Kendrick, G., Orth, R. J., & Williams, S. W. (2008). Trophic transfers from seagrass meadows subsidize diverse marine and terrestrial consumers. *Ecosystems*, *11*, 1198–1210. https://doi.org/10.1007/s10021-008-9155-y

Huber, S., Hansen, L. B., Nielsen, L. T., Rasmussen, M. L., Sølvsteen, J., Berglund, J., Paz von Friesen, C., Danbolt, M., Envall, M., Infantes, E., & Moksnes, P. (2022). Novel approach to large-scale monitoring of submerged aquatic vegetation: A nationwide example from Sweden. *Integrated Environmental Assessment and Management*, *18*(4), 909–920. https://doi.org/10.1002/ieam.4493

Infantes, E., Hoeks, S., Adams, M. P., van der Heide, T., van Katwijk, M. M., & Bouma, T. J. (2022). Seagrass roots strongly reduce cliff erosion rates in sandy sediments. *Marine Ecology Progress Series*, *700*, 1–12. https://doi.org/10.3354/meps14196

Jackson, E. L., Rowden, A. A., Attrill, M. J., Bossey, S., & Jones, M. (2001). The importance of seagrass beds as a habitat for fishery species. *Oceanography and Marine Biology*, *39*, 269–304.

Jacquemont, J., Blasiak, R., Le Cam, C., Le Gouellec, M., & Claudet, J. (2022). Ocean conservation boosts climate change mitigation and adaptation. *One Earth*, *5*(10), 1126–1138. https://doi.org/10.1016/j.oneear.2022.09.002

Jahnke, M., Moksnes, P.-O., Olsen, J. L., Serra Serra, N., Nilsson Jacobi, M., Kuusemäe, K., Corell, H., & Jonsson, P. R. (2020). Integrating genetics, biophysical, and demographic insights identifies critical sites for seagrass conservation. *Ecological Applications*, *30*(6), e02121. https://doi.org/10.1002/eap.2121

Koch, E. W., Barbier, E. B., Silliman, B. R., Reed, D. J., Perillo, G. M. E., Hacker, S. D., Granek, E. F., Primavera, J. H., Muthiga, N., Polasky, S., Halpern, B. S., Kennedy, C. J., Kappel, C. V., & Wolanski, E. (2009). Non-linearity in ecosystem services: Temporal and spatial variability in coastal protection. *Frontiers in Ecology and the Environment*, *7*, 29–37. https://doi.org/10.1890/080126

Lamb, J. B., JAJM, V. D. W., Bourne, D. G., Altier, C., Hein, M. Y., Fiorenza, E. A., Abu, N., Jompa, J., & Harvell, C. D. (2017). Seagrass ecosystems reduce exposure to bacterial pathogens of humans, fishes, and invertebrates. *Science*, *355*(6326), 731–733. https://doi.org/10.1126/science.aal1956

Lefcheck, J. S., Hughes, B. B., Johnson, A. J., Pfirrmann, B. W., Rasher, D. B., Smyth, A. R., Williams, B. L., Beck, M. W., & Orth, R. J. (2019). Are coastal habitats important nurseries? A meta-analysis. *Conservation Letters*, *12*(4), e12645. https://doi.org/10.1111/conl.12645

Lilley, R. J., & Unsworth, R. K. F. (2014). Atlantic cod (Gadus morhua) benefits from the availability of seagrass (Zostera marina) nursery habitat. *Global Ecology and Conservation*, *2*, 367–377. https://doi.org/10.1016/j.gecco.2014.10.002

Loh, T.-L., Archer, S. K., & Dunham, A. (2019). Monitoring program design for data-limited marine biogenic habitats: A structured approach. *Ecology and Evolution*, *9*(12), 7346–7359. https://doi.org/10.1002/ece3.5261

Macreadie, P. I., Costa, M. D. P., Atwood, T. B., Friess, D. A., Kelleway, J. J., Kennedy, H., Lovelock, C. E., Serrano, O., & Duarte, C. M. (2021). Blue carbon as a natural climate solution. *Nature Reviews Earth & Environment*, *2*(12), 826–839. https://doi.org/10.1038/s43017-021-00224-1

Martin, B. C., Alarcon, M. S., Gleeson, D., Middleton, J. A., Fraser, M. W., Ryan, M. H., Holmer, M., Kendrick, G. A., & Kilminster, K. (2019). Root microbiomes as indicators of seagrass health. *FEMS Microbiology Ecology*, *96*(2). https://doi.org/10.1093/femsec/fiz201

Maxwell, P. S., Eklöf, J. S., van Katwijk, M. M., O'Brien, K. R., de la Torre-Castro, M., Boström, C., Bouma, T. J., Krause-Jensen, D., Unsworth, R. K. F., van Tussenbroek, B. I., & van der Heide, T. (2017). The fundamental role of ecological feedback mechanisms for the adaptive management of seagrass ecosystems – A review. *Biological Reviews*, *92*(3), 1521–1538. https://doi.org/10.1111/brv.12294

McHenry, J., Rassweiler, A., Hernan, G., Uejio, C. K., Pau, S., Dubel, A. K., & Lester, S. E. (2021). Modelling the biodiversity enhancement value of seagrass beds. *Diversity and Distributions*, *27*(11), 2036–2049. https://doi.org/10.1111/ddi.13379

McKenzie, L. J., Nordlund, L. M., Jones, B. L., Cullen-Unsworth, L. C., Roelfsema, C., & Unsworth, R. K. F. (2020). The global distribution of seagrass meadows. *Environmental Research Letters*, *15*(7), 074041. https://doi.org/10.1088/1748-9326/ab7d06

Miloslavich, P., Bax, N. J., Simmons, S. E., Klein, E., Appeltans, W., Aburto-Oropeza, O., Andersen Garcia, M., Batten, S. D., Benedetti-Cecchi, L., Checkley, D. M. Jr., Chiba, S., Duffy, J. E., Dunn, D. C., Fischer, A., Gunn, J., Kudela, R., Marsac, F., Muller-Karger, F. E., Obura, D., & Shin, Y. J. (2018). Essential Ocean variables for global sustained observations of biodiversity and ecosystem changes. *Global Change Biology*, *24*(6), 2416–2433. https://doi.org/10.1111/gcb.14108

Moersberger, H., Martin, J. G. C., Junker, J., Georgieva, I., Bauer, S., Beja, P., Breeze, T. D., Brotons, L., Bruelheide, H., Fernández, N., et al. (2022). Europa biodiversity observation network: User and policy needs assessment. *EuropaBON/German Centre of Biodiversity Research (iDiv), Leipzig*. https://doi.org/10.3897/arphapreprints.e84517

Montefalcone, M., Morri, C., Peirano, A., Albertelli, G., & Bianchi, C. N. (2007). Substitution and phase shift within the Posidonia oceanica seagrass meadows of NW Mediterranean Sea. *Estuarine, Coastal and Shelf Science*, *75*(1), 63–71. https://doi.org/10.1016/j.ecss.2007.03.034

Moreira-Saporiti, A., Teichberg, M., Garnier, E., Cornelissen, J. H. C., Alcoverro, T., Björk, M., Boström, C., Dattolo, E., Eklöf, J. S., Hasler-Sheetal, H., Marbà, N., Marín-Guirao, L., Meysick, L., Olivé, I., Reusch, T. B. H., Ruocco, M., Silva, J., Sousa, A. I., Procaccini, G., & Santos, R. (2023). A trait-based framework for seagrass ecology: Trends and prospects. *Frontiers in Plant Science*, *14*. https://doi.org/10.3389/fpls.2023.1088643

Nordlund, L. M., Cullen-Unsworth, L. C., Unsworth, R. K. F., & Gullstrom, M. (2018). Global significance of seagrass fishery activity. *Fish and Fisheries*, *19*, 399–412. https://doi.org/10.1111/faf.12259

Nordlund, L. M., Koch, E. W., Barbier, E. B., & Creed, J. C. (2016). Seagrass ecosystem services and their variability across genera and geographical regions. *PLoS ONE*, *11*(10), e0163091. https://doi.org/10.1371/journal.pone.0163091

O'Brien, K. R., Waycott, M., Maxwell, P., Kendrick, G. A., Udy, J. W., Ferguson, A. J. P., Kilminster, K., Scanes, P., McKenzie, L. J., McMahon, K., et al. (2018). Seagrass ecosystem trajectory depends on the relative timescales of resistance, recovery and disturbance. *Marine Pollution Bulletin*, *134*, 166–176. https://doi.org/10.1016/j.marpolbul.2017.09.006

Ockendon, N., Thomas, D. H. L., Cortina, J., Adams, W. M., Aykroyd, T., Barov, B., Boitani, L., Bonn, A., Branquinho, C., Brombacher, M., Burrell, C., Carver, S., Crick, H. Q. P., Duguy, B., Everett, S., Fokkens, B., Fuller, R. J., Gibbons, D. W., Gokhelashvili, R., … Sutherland, W. J. (2018). One hundred priority questions for landscape restoration in Europe. *Biological Conservation*, *221*, 198–208. https://doi.org/10.1016/j.biocon.2018.03.002

Oreska, M. P. J., McGlathery, K. J., Aoki, L. R., Berger, A. C., Berg, P., & Mullins, L. (2020). The greenhouse gas offset potential from seagrass restoration. *Scientific Reports*, *10*(1), 7325. https://doi.org/10.1038/s41598-020-64094-1

Pansini, A., Bosch-Belmar, M., Berlino, M., Sarà, G., & Ceccherelli, G. (2022). Collating evidence on the restoration efforts of the seagrass Posidonia oceanica: Current knowledge and gaps. *Science of the Total Environment*, *851*, 158320. https://doi.org/10.1016/j.scitotenv.2022.158320

Pazzaglia, J., Nguyen, H. M., Santillán-Sarmiento, A., Ruocco, M., Dattolo, E., Marín-Guirao, L., & Procaccini, G. (2021). The genetic component of seagrass restoration: What we know and the way forwards. *Watermark*, *13*(6), 829. https://doi.org/10.3390/w13060829

Pazzaglia, J., Reusch, T. B. H., Terlizzi, A., Marín-Guirao, L., & Procaccini, G. (2021). Phenotypic plasticity under rapid global changes: The intrinsic force for future seagrasses survival. *Evolutionary Applications*, *14*(5), 1181–1201. https://doi.org/10.1111/eva.13212

Pendleton, L., Donato, D. C., Murray, B. C., Crooks, S., Jenkins, W. A., Sifleet, S., Craft, C., Fourqurean, J. W., Kauffman, J. B., Marbà, N., Megonigal, P., Pidgeon, E., Herr, D., Gordon, D., & Baldera, A. (2012). Estimating global "blue carbon" emissions from conversion and degradation of vegetated coastal ecosystems. *PLoS ONE*, *7*(9), e43542. https://doi.org/10.1371/journal.pone.0043542

Potouroglou, M., Bull, J. C., Krauss, K. W., Kennedy, H. A., Fusi, M., Daffonchio, D., Mangora, M. M., Githaiga, M. N., Diele, K., & Huxham, M. (2017). Measuring the role of seagrasses in regulating sediment surface elevation. *Scientific Reports*, *7*(1), 11917. https://doi.org/10.1038/s41598-017-12354-y

Poursanidis, D., Mylonakis, K., Christofilakos, S., & Barnias, A. (2023). Mind the gap in data poor Natura 2000 sites and how to tackle them using earth observation and scientific diving surveys. *Marine Pollution Bulletin*, *188*, 114595. https://doi.org/10.1016/j.marpolbul.2023.114595

Qiu, W., & Jones, P. J. S. (2013). The emerging policy landscape for marine spatial planning in Europe. *Marine Policy*, *39*, 182–190. https://doi.org/10.1016/j.marpol.2012.10.010

Ratnarajah, L., Heslop, E., Lips, I., Simpson, P., Nordlund, L. M., Unsworth, R. K. F., Sousa-Pinto, I., & Benedetti-Cecchi, L. (2022). Report on the European BioEco observing system. *EuroSea Deliverable*, D1.4. EuroSea, 21 pp. https://doi.org/10.3289/eurosea_d1.4

Reusch, T. B. H., Schubert, P. R., Marten, S.-M., Gill, D., Karez, R., Busch, K., & Hentschel, U. (2021). Lower vibrio spp. abundances in Zostera marina leaf canopies suggest a novel ecosystem function for temperate seagrass beds. *Marine Biology*, *168*(10), 149. https://doi.org/10.1007/s00227-021-03963-3

Révelard, A., Tintoré, J., Verron, J., Bahurel, P., Barth, J. A., Belbéoch, M., Benveniste, J., Bonnefond, P., Chassignet, E. P., Cravatte, S., Davidson, F., deYoung, B., Heupel, M., Heslop, E., Hörstmann, C., Karstensen, J., le Traon, P. Y., Marques, M., McLean, C., … Williams, B. (2022). Ocean integration: The needs and challenges of effective coordination within the ocean observing system. *Frontiers in Marine Science*, *8*. https://doi.org/10.3389/fmars.2021.737671

Röhr, M. E., Holmer, M., Baum, J. K., Björk, M., Boyer, K., Chin, D., Chalifour, L., Cimon, S., Cusson, M., Dahl, M., Deyanova, D., Duffy, J. E., Eklöf, J. S., Geyer, J. K., Griffin, J. N., Gullström, M., Hereu, C. M., Hori, M., Hovel, K. A., … Boström, C. (2018). Blue carbon storage capacity of temperate eelgrass (Zostera marina) meadows. *Global Biogeochemical Cycles*, *32*(10), 1457–1475. https://doi.org/10.1029/2018GB005941

Romero, J., Martínez-Crego, B., Alcoverro, T., & Pérez, M. (2007). A multivariate index based on the seagrass Posidonia oceanica (POMI) to assess ecological status of coastal waters under the water framework directive (WFD). *Marine Pollution Bulletin*, *55*(1), 196–204. https://doi.org/10.1016/j.marpolbul.2006.08.032

Rosentreter, J. A., Borges, A. V., Deemer, B. R., Holgerson, M. A., Liu, S., Song, C., Melack, J., Raymond, P. A., Duarte, C. M., Allen, G. H., Olefeldt, D., Poulter, B., Battin, T. I., & Eyre, B. D. (2021). Half of global methane emissions come from highly variable aquatic ecosystem sources. *Nature Geoscience*, *14*(4), 225–230. https://doi.org/10.1038/s41561-021-00715-2

Roth, F., Broman, E., Sun, X., Bonaglia, S., Nascimento, F., Prytherch, J., Brüchert, V., Lundevall Zara, M., Brunberg, M., Geibel, M. C., Humborg, C., & Norkko, A. (2023). Methane emissions offset atmospheric carbon dioxide uptake in coastal macroalgae, mixed vegetation and sediment ecosystems. *Nature Communications*, *14*(1), 42. https://doi.org/10.1038/s41467-022-35673-9

Ruiz-Frau, A., Gelcich, S., Hendriks, I. E., Duarte, C. M., & Marbà, N. (2017). Current state of seagrass ecosystem services: Research and policy integration. *Ocean and Coastal Management*, *149*, 107–115. https://doi.org/10.1016/j.ocecoaman.2017.10.004

Schorn, S., Ahmerkamp, S., Bullock, E., Weber, M., Lott, C., Liebeke, M., Lavik, G., Kuypers, M. M. M., Graf, J. S., & Milucka, J. (2022). Diverse methylotrophic methanogenic archaea cause high methane emissions from seagrass meadows. *Proceedings of the National Academy of Sciences*, *119*(9), e2106628119. https://doi.org/10.1073/pnas.2106628119

Sutherland, W. J., Adams, W. M., Aronson, R. B., Aveling, R., Blackburn, T. M., Broad, S., Ceballos, G., Côté, I. M., Cowling, R. M., Da Fonseca, G. A., et al. (2009). One hundred questions of importance to the conservation of global biological diversity. *Conservation Biology*, *23*(3), 557–567. https://doi.org/10.1111/j.1523-1739.2009.01212.x

Sutherland, W. J., Freckleton, R. P., Godfray, H. C. J., Beissinger, S. R., Benton, T., Cameron, D. D., Carmel, Y., Coomes, D. A., Coulson, T., Emmerson, M. C., Hails, R. S., Hays, G. C., Hodgson, D. J., Hutchings, M. J., Johnson, D., Jones, J. P. G., Keeling, M. J., Kokko, H., Kunin, W. E., … Wiegand, T. (2013). Identification of 100 fundamental ecological questions. *Journal of Ecology*, *101*(1), 58–67. https://doi.org/10.1111/1365-2745.12025

Terrados, J., Marín, A., & Celdrán, D. (2013). Use of Posidonia oceanica seedlings from beach-cast fruits for seagrass planting. *Botanica Marina*, *56*(2), 185–195. https://doi.org/10.1515/bot-2012-0200

Traganos, D., & Reinartz, P. (2018). Mapping Mediterranean seagrasses with Sentinel-2 imagery. *Marine Pollution Bulletin*, *134*, 197–209. https://doi.org/10.1016/j.marpolbul.2017.06.075

Turschwell, M. P., Connolly, R. M., Dunic, J. C., Sievers, M., Buelow, C. A., Pearson, R. M., Tulloch, V. J. D., Côté, I. M., Unsworth, R. K. F., Collier, C. J., & Brown, C. J. (2021). Anthropogenic pressures and life history predict trajectories of seagrass meadow extent at a global scale. *Proceedings of the National Academy of Sciences*, *118*(45), e2110802118. https://doi.org/10.1073/pnas.2110802118

UNEP. (2020). *Out of the blue: The value of seagrasses to the environment and to people*. UNEP.

Unsworth, R. K. F., Bertelli, C. M., Cullen-Unsworth, L. C., Esteban, N., Jones, B. L., Lilley, R., Lowe, C., Nuuttila, H. K., & Rees, S. C. (2019). Sowing the seeds of seagrass recovery using hessian bags. *Frontiers in Ecology and Evolution*, *7*. https://doi.org/10.3389/fevo.2019.00311

Unsworth, R. K. F., Collier, C. J., Henderson, G. M., & McKenzie, L. J. (2012). Tropical seagrass meadows modify seawater carbon chemistry: Implications for coral reefs impacted by ocean acidification. *Environmental Research Letters*, *7*(2), 024026. https://doi.org/10.1088/1748-9326/7/2/024026

Unsworth, R. K. F., Collier, C. J., Waycott, M., McKenzie, L. J., & Cullen-Unsworth, L. C. (2015). A framework for the resilience of seagrass ecosystems. *Marine Pollution Bulletin*, *100*(1), 34–46. https://doi.org/10.1016/j.marpolbul.2015.08.016

Unsworth, R. K. F., Cullen-Unsworth, L. C., Jones, B. L. H., & Lilley, R. J. (2022). The planetary role of seagrass conservation. *Science*, *377*(6606), 609–613. https://doi.org/10.1126/science.abq6923

Unsworth, R. K. F., McKenzie, L. J., Collier, C. J., Cullen-Unsworth, L. C., Duarte, C. M., Eklöf, J. S., Jarvis, J. C., Jones, B. L., & Nordlund, L. M. (2019). Global challenges for seagrass conservation. *Ambio*, *48*(8), 801–815. https://doi.org/10.1007/s13280-018-1115-y

Unsworth, R. K. F., Nordlund, L. M., & Cullen-Unsworth, L. C. (2018). Seagrass meadows support global fisheries production. *Conservation Letters*, *12*(1), e12566. https://doi.org/10.1111/conl.12566

Valdez, S. R., Zhang, Y. S., van der Heide, T., Vanderklift, M. A., Tarquinio, F., Orth, R. J., & Silliman, B. R. (2020). Positive ecological interactions and the success of seagrass restoration. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.00091

Van Dam, B., Lopes, C., Zeller, M. A., Ribas-Ribas, M., Wang, H., & Thomas, H. (2021). Overstated potential for seagrass meadows to mitigate Coastal Ocean acidification. *Frontiers in Marine Science*, *8*. https://doi.org/10.3389/fmars.2021.729992

van der Heide, T., Eklof, J. S., van Nes, E. H., van der Zee, E. M., Donadi, S., Weerman, E. J., Olff, H., & Eriksson, B. K. (2012). Ecosystem engineering by seagrasses interacts with grazing to shape an intertidal landscape. *PLoS ONE*, *7*(8), e42060. https://doi.org/10.1371/journal.pone.0042060

van Katwijk, M. M., Thorhaug, A., Marbà, N., Orth, R. J., Duarte, C. M., Kendrick, G. A., Althuizen, I. H. J., Balestri, E., Bernard, G., Cambridge, M. L., Cunha, A., Durance, C., Giesen, W., Han, Q., Hosokawa, S., Kiswara, W., Komatsu, T., Lardicci, C., Lee, K. S., … Verduin, J. J. (2016). Global analysis of seagrass restoration: The importance of large-scale planting. *Journal of Applied Ecology*, *53*(2), 567–578. https://doi.org/10.1111/1365-2664.12562

van Katwijk, M. M., van Tussenbroek, B. I., Hanssen, S. V., Hendriks, A. J., & Hanssen, L. (2021). Rewilding the sea with domesticated seagrass. *Bioscience*, *71*(11), 1171–1178. https://doi.org/10.1093/biosci/biab092

Voulvoulis, N., Arpon, K. D., & Giakoumis, T. (2017). The EU water framework directive: From great expectations to problems with implementation. *Science of the Total Environment*, *575*, 358–366. https://doi.org/10.1016/j.scitotenv.2016.09.228

Waycott, M., Duarte, C. M., Carruthers, T. J. B., Orth, R. J., Dennison, W. C., Olyarnik, S., Calladine, A., Fourqurean, J. W., Heck, K. L., Hughes, A. R., et al. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(30), 12377–12381. https://doi.org/10.1073/pnas.0905620106

Wesselmann, M., Chefaoui, R. M., Marbà, N., Serrao, E. A., & Duarte, C. M. (2021). Warming threatens to propel the expansion of the exotic seagrass Halophila stipulacea. *Frontiers in Marine Science*, *8*. https://doi.org/10.3389/fmars.2021.759676

Wilkes, R., Bennion, M., McQuaid, N., Beer, C., McCullough-Annett, G., Colhoun, K., Inger, R., & Morrison, L. (2017). Intertidal seagrass in Ireland: Pressures, WFD status and an assessment of trace element contamination in intertidal habitats using Zostera noltei. *Ecological Indicators*, *82*, 117–130. https://doi.org/10.1016/j.ecolind.2017.06.036

Winters, G., Beer, S., Willette, D. A., Viana, I. G., Chiquillo, K. L., Beca-Carretero, P., Villamayor, B., Azcárate-García, T., Shem-Tov, R., Mwabvu, B., et al. (2020). The tropical seagrass Halophila stipulacea: Reviewing what we know from its native and invasive habitats, alongside identifying knowledge gaps. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.00300

York, P. H., Hyndes, G. A., Bishop, M. J., & Barnes, R. S. K. (2018). Faunal Assemblages of Seagrass Ecosystems. In A. W. D. Larkum, G. A. Kendrick, & P. J. Ralph (Eds.). *Seagrasses of Australia: Structure, ecology and conservation* (pp. 541–588). Springer International Publishing. https://doi.org/10.1007/978-3-319-71354-0_17

## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

**How to cite this article:** Nordlund, L. M., Unsworth, R. K. F., Wallner-Hahn, S., Ratnarajah, L., Beca-Carretero, P., Boikova, E., Bull, J. C., Chefaoui, R. M., de los Santos, C. B., Gagnon, K., Garmendia, J. M., Gizzi, F., Govers, L. L., Gustafsson, C., Hineva, E., Infantes, E., Canning-Clode, J., Jahnke, M., Kleitou, P., … Wilkes, R. (2024). One hundred priority questions for advancing seagrass conservation in Europe. *Plants, People, Planet*, 1–17. https://doi.org/10.1002/ppp3.10486