Priorities for Conservation, Monitoring and Research of Seagrass Ecosystems in Europe

Workshop Report

22 - 24 March 2022

Posidonia oceanica (Image by: Dimitris Poursanidis)

Report prepared by:
Lavenia Ratnarajah (Global Ocean Observing System of IOC/UNESCO)
Richard Unsworth (Swansea University, United Kingdom)
Lina Mtwana Nordlund (Uppsala University, Sweden)
Sieglind Wallner Hahn (Uppsala University, Sweden)

Table of Contents

Summary	3
Importance of seagrasses in Europe	4
Aims of the workshop	5
Expected outputs and outcome	6
Methods: The 100 questions approach	7
Workshop participants	10
Workshop output	13
Conclusion and steps forward	14
Reflections on the workshop	15
Acknowledgements	16
References	16
Appendix 1 GoogleForm outline	18
Appendix 2 Workshop Agenda	28
Appendix 3 Workshop participant review	31

Summary

Seagrasses are flowering marine plants that can be found in tropical, temperate, and polar waters. As their rhizomes weave together under the seabed, seagrasses stabilise the sand and mud they grow in. They are also an important source of diet and nursery habitats for a range of marine animals and play a role in marine carbon sequestration. In Europe, seagrass research and monitoring are undertaken to understand how these critical ecosystems are changing and to meet national and regional policy requirements, however there is still a lot of work to be done. This workshop aimed to bring the seagrass community together to formulate, identify and compile important questions that, if answered, would strongly advance seagrass conservation in Europe towards rich and resilient seagrass ecosystems that would benefit both nature and people. Through a series of question development and subsequent voting using the Delphi method, the seagrass community within the European region identified 293 questions across 9 themes (Monitoring & Assessment, Biodiversity & Ecology, Drivers & Threats, Conservation & Restoration, Fisheries support, Ecosystem services & Communications, Blue carbon, Governance, Policy & Management and Cross-discipline). Workshop discussions synthesised these 293 questions to the top 100 priority questions for conservation, monitoring and research of seagrass ecosystems in Europe. The workshop brought together seagrass researchers, managers, and other practitioners for an opportunity to discuss the future need of seagrass science to be able to advance seagrass conservation in Europe. The possibility to collaborate on a way forward, gaining insight from countries across Europe and deliver the priority questions together to the wider community will strengthen the output.

Importance of seagrasses in Europe

Seagrasses are flowering plants adapted to life in the oceans and are the only angiosperms able to withstand a saline existence (Hemminga and Duarte, 2000). These prolific plants that exist on the continental shelf of all continents except Antarctica are not a diverse group, with only 72 recognised species arising from 4 families of the mostly aquatic plant order Alismatales (Green and Short, 2003). Despite the comparatively low global and local diversity of seagrasses, there is an abundance of diverse organisms that occupy the highly productive meadow ecosystems which these plants create. Seagrasses form biogenic habitats that extend from small $1m^2$ patches to extensive continuous meadows of many thousands of hectares in area. Seagrass meadows are commonly monospecific but may consist of multispecies communities, sometimes with up to 12 species present within one location.

Just like terrestrial flowering plants, seagrasses flower fruit and seed, recent evidence has found how this sexual reproduction is facilitated (pollination and movement of seeds and propagules) by animals as well as the movements of water currents (van Tussenbroek et al., 2016). Although sexual reproduction is key to maintaining diversity and adaptation seagrasses also utilise asexual reproduction, this is commonly thought to be very important for the growth of seagrass meadows.

Seagrass meadows are of great ecological importance providing high biodiversity and production of both plants and animals, including many commercially important species (Lefcheck et al., 2019; Unsworth et al., 2019). Numerous fish and invertebrate species prefer seagrass meadows relative to unvegetated habitats because of high provision of food and shelter (Whalen et al., 2020).

Increasingly seagrasses are being recognised for a range of other ecological roles and values they have in the coastal environment, such as for carbon storage, nitrogen cycling and coastal defense (Nordlund et al., 2016), and the interest in these values are growing as a result of the greater appreciation being given to Nature based Solutions to climate change (Chausson et al., 2020) and coastal protection.

In Europe, there exists an abundance of seagrass that is estimated to extend to cover an area of approximately $15600km^2$ (McKenzie et al., 2020), but many areas are yet to be mapped. Across Europe, seagrasses grow from the intertidal and down to a depth of 5-15 m in North European waters (*Zostera marina, Z. noltii*), but seagrasses may be found even deeper than 50 m in clear Mediterranean waters *(Cymodocea nodosa* and *Posidonia oceanica*) (Borum et al., 2004). In the Mediterranean Sea, *P. oceanica* beds cover between 25,000 and 50,000 km^2 of the coastal areas corresponding to 25% of the sea bottom at depths between 0 and 40 m (Borum et al., 2004). Hence, seagrasses are extremely important components of coastal European waters.

Seagrass meadows are sensitive to environmental change making them highly vulnerable to loss. Key anthropogenic risks to seagrass include eutrophication, chemical pollutants, coastal development, bottom fishing and poor boating practice (Grech et al., 2012). In addition, in some parts of the world climate change is rapidly altering the composition and viability of some seagrass species (Turschwell et al., 2021). In Europe there is extensive evidence that seagrasses have declined substantially (Airoldi and Beck, 2007) with recent modeling and re-examination of estimates from the UK placing loss at potentially up to 92% (Green et al., 2021). Although long term loss has been widely reported across the continent of Europe, there has also been some recent recovery, particularly within intertidal seagrass populations (de los Santos et al., 2019), the cause of which is unclear.

Some countries within Europe have national legislation and regulations to protect seagrass meadows from anthropogenic disturbance. Within the Water Framework Directive of the European Union member states have established a mutual platform and obligation to ensure a "good ecological status" corresponding to conditions with minimal anthropogenic impact of all surface waters (Borum et al., 2004). This directive along with the Marine Strategy Framework Directive (MSDF) and the Habitats Directive in the EU have led to improved widespread monitoring of seagrasses, however the coverage of such activity is not ubiquitous and there remain many gaps. Some countries beyond the EU do not have such targeted activities to monitor seagrass and data is less available.

There is greater interest in seagrass conservation and with this an increasing recognition of the major knowledge gaps within these systems that create bottlenecks to improving the status and coverage of these habitats across Europe. Effective management of seagrass ecosystems requires the scientific and management communities to work together to understand the status, trends and challenges for seagrass conservation. This aligns to a strategic vision to form a global monitoring network for seagrasses (Duffy et al., 2019) and to integrate monitoring across Europe into this vision. One approach to coordinate the global ocean observing community is through the biology and ecosystem Essential Ocean Variables (EOVs) - of which seagrass canopy cover and composition is one. In response to this vision and the need to fill knowledge gaps and progress the conservation and management of seagrass ecosystems in Europe, a workshop was conducted by the Biology and Ecosystems panel of the Global Ocean Observing System (GOOS) and EuroSea. This workshop, co-chaired by Dr Lina Mtwana Nordlund (Uppsala University) and Dr Richard Unsworth (Swansea University) brought together expert witnesses across Europe to help define 100 questions for seagrass conservation for Europe.

Aims of the workshop

This workshop aims to:

1. Formulate, identify, and compile important questions that, if answered, would strongly advance seagrass conservation in Europe towards rich and resilient seagrass ecosystems that would benefit both nature and people
2. Increase cross-collaboration between seagrass researchers and practitioners in Europe
3. Develop a framework that can guide the development and continuation of seagrass monitoring programs within Europe
4. Address knowledge gaps in seagrass conservation, monitoring and research in Europe
5. Improve communication between researchers, managers, and policy makers
6. Inspire the global seagrass research and conservation community to strategically conserve the gaps and key questions for their seagrass ecosystems

Expected outputs and outcome

- A scientific manuscript that outlines the '100 Questions: Priorities for Conservation, Monitoring and Research of Seagrass Ecosystems in Europe' (Aim 1, 2, 3 and 4)
- The 100 questions will be communicated to a wide range of stakeholders via Project Seagrass, World Seagrass Association, and social media outlets (Aim 1, 5 and 6)
- Presentation of methodology and results at the European Ocean Observing System (EOOS) which is represented by the European Marine Board, the European Global Ocean Observing System (EuroGOOS), and JPI Oceans (Aim 5)
- Development of similar 100 questions in other regions where constraints on seagrass conservation, monitoring and research are different from that experience in Europe (Aim 6)

Methods: The 100 questions approach

The workshop used the Delphi method, a technique developed by the United States Air Force and the RAND Corporation, to engage with the community. This qualitative approach is designed to get the most reliable consensus from a group of experts on a particular problem. The Delphi method uses a series of rounds or iterations between the facilitator and the expert where to review information (Figure 1). Participants work anonymously, and do not know who the other participants are. Through multiple steps outlined below, we demonstrate how we have used the Delphi method to reach consensus amongst the seagrass community in Europe.

Figure 1: The Delphi Method (credit: University of Phoenix)

Following weeks of discussion to identify the different themes that should be covered, we developed a GoogleForm (Appendix 1) that detailed the Delphi process and sought questions across 9 different themes:

1. Monitoring & Assessment
2. Biodiversity & Ecology
3. Drivers & Threats
4. Conservation & Restoration
5. Fisheries support
6. Ecosystem services & Communications
7. Blue carbon
8. Governance, Policy & Management
9. Cross-discipline

All those participating in the survey were asked to develop questions based on these criteria's:

- Are answerable through a realistic research design
- Address important gaps in knowledge
- Are relevant within continental Europe
- Are at an appropriate spatial and temporal scale and scope
- Not too general (i.e., a research programme could make progress towards answering each question within an acceptable time frame)
- Not too limited in scope: i.e., answering a question should have a significant impact on the effectiveness of seagrass conservation, monitoring and/or research
- Answering the questions should be doable, not just desirable
- Fall within the scope of the exercise

The GoogleForm was targeted to seagrass stakeholders (e.g., researchers, managers, policy makers) in Europe via email, and highlighted on social media platforms (e.g., Twitter, Facebook, and LinkedIn). The goal was to achieve a balance in expertise and geographical coverage. Over the 6-week period, a total of 293 questions were received from the community across these 9 themes. Identical questions were merged and a total of 285 unique questions were then populated onto a GoogleSheet under these 9 themes. Where appropriate, sub themes (e.g., Mapping, Communication, Climate change, Citizen science, Genetic Diversity, Ecosystem services etc.) were identified and questions were pooled into the different sub themes (Figure 2).

QUESTION ID	PLEASE ADD YOUR VOTING HERE (0-4)	QUESTIONS
		CLIMATE CHANGE
BE1		How will climate change affect the distribution of seagrass habitats?
BE2		How could local adaptation secure the future of seagrasses under climate change?
BE3		What are the most urgent climate change threats to seagrass meadows across Europe?
BE4		How will sea level rise affect seagrass ecosystems?
BE5		Does genetic diversity of the seagrass or the entire ecosystem matter in response to climate change?
BE6		What is the role of intra-species and inter-species variability in functional traits for seagrass resilience under climate change?
BE7		How will seagrass species and/or habitats adapt to ocean acidification and warming?
BE8		Should warm-adapted seagrass populations be mixed with cold-adapted populations to increase their resilience to predicted warming conditic
BE9		Should southern and warm-adapted species, such as Cymodocea nodosa be transplanted in those areas where they are not native but they ma
BE10		How are seagrass species (e.g. Zostera noltii and Zostera marina) affected by water and/or air temperature?
BE11		Are local seagrass genotypes able to cope with the temperature changes that can be expected in the near and further future?
BE12		Is climate change affecting the biochemical composition of seagrasses, and thus its nutritional value, consequently affecting seagrass' herbivor
BE13		How could climate change induced changes in seagrass habitat types (e.g., regression of Posidonia oceanica versus expansion of halophila stip
BE14		Which factors influence the resilience of the different seagrass species in the Mediterranean to climate change (i.e. temperature, storms..), foc
		GENETIC DIVERSITY
BE15		What is the genetic structure and connectivity of seagrass populations, especially in under-studied regions (e.g. Black Sea)?
BE16		Are epigenetic diversity and somatic mutations replacing the important role of genetic diversity in clonal seagrass?
BE17		How does functional and genomic diversity of seagrass species influence their growth, tolerance and conservation?
BE18		What drives sexual reproduction in seagrasses?

Figure 2: An example of the GoogleSheet showing questions under different sub themes.

The GoogleSheet was then redistributed to all the participants for voting. At this stage, participants were also encouraged to add more questions if they find a particular question is missing. Participants could vote from 0 to 4.
0 - This question is not important and does not need to be included in the workshop/paper
1 - This question is of low importance
2 - This question is important
3 - This question is very important
4 - This question is of highest importance

All votes were then tabulated, and the mean and median votes were calculated. Questions were then ranked by order of importance. To reduce the number of questions from 285 to 100, the lowest ranked ⅓ of questions from all themes were removed prior to the workshop. The remaining ⅔ of questions were then extensively discussed in the workshop by the 35 participants within breakout rooms to reduce the questions to the top 100. Questions were thoroughly discussed to ensure clarity, combined with other questions to ensure broader coverage and/or removed if deemed to be not within the top 100 priority questions. To further ensure that the community was engaged and had active input into selecting all the priority questions, working groups were mixed between discussions and the final session combined all participants into one discussion.

Workshop participants

A total of 35 participants attended the workshop and an additional 14 individuals participated in developing the questions but did not attend the workshop.

No.	Name	Organization
1	Richard Unsworth (co-chair)	Swansea University
2	Lina Mtwana Nordlund (co-chair)	Uppsala University
3	Sieglind Wallner Hahn	Uppsala University
4	Lavenia Ratnarajah	Global Ocean Observing System
5	Laura Govers	University of Groningen
6	João Canning-Clode	MARE - Marine and Environmental Sciences Centre
7	Oscar Serrano	Centro de Estudios Avanzados de Blanes (CEAB-CSIC)
8	Marlene Jahnke	Gothenburg University
9	Nerea Piñeiro Juncal	University of Santiago de Compostela, University of Aveiro
10	Dimitris Poursanidis	terraSolutions marine environment research
11	Emma A Ward	University of Portsmouth
12	Joxe Mikel Garmendia	AZTI-BRTA
13	Stefania Klayn	Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences
14	Carmen Barrena de los Santos	Centro de Ciências do Mar do Algarve
15	Pedro Beca-Carretero	IIM-CSIC
16	Ana Sousa	University of Aveiro, Portugal
17	Dave Wall	National Biodiversity Data Centre
18	Elmira Boikova	Institute of Biology, University of Latvia
19	Tiia Möller-Raid	University of Tartu, Estonian Marine Institute
20	Camilla Gustafsson	University of Helsinki
21	Rosa M. Chefaoui	Universidad Rey Juan Carlos
22	Karine Gagnon	Norwegian Institute of Marine Research
23	Robert Wilkes	EPA

24	Hilary Kennedy	Bangor University
25	Marieke van Katwijk	Radboud University
26	James Bull	Swansea University
27	Emanuele Ponis	Italian Institute for Environmental Protection and Research
28	Vasillis Papathanasiou	Fisheries Research Institute, GR
29	Riccardo Pieraccini	Ghent University
30	Periklis Kleitou	Marine and Environmental Research (MER) Lab
31	Francesca Gizzi	MARE-Madeira, ARDITI
32	Susanne Schäfer	MARE Madeira
33	João Gama Monteiro	MARE-Madeira
34	Sebastian Storey	University of Oldenburg, ICBM
35	Eduardo Infantes	Gothenburg University

Additional participants who contributed questions but did not attend the workshop:

No.	**Name**	**Organization**
1	Johnny Berglund	Lansstyrelsen
2	Teresa Alcoverro	Centro de Estudios Avanzados de Blanes (CEAB-CSIC)
3	Sara Pruckner	UNEP-WCMC
4	Dick de Jong	Retired
5	Dorte Krause-Jensen	Department of Ecoscience, Aarhus University
6	Ventzi Karamfilov	Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences
7	Francesca Rossi	CNRS, University of Côte d'Azur
8	Hendrik Schubert	University Rostock
9	Thorsten Reusch	GEOMAR Kiel
10	Joanne Preston	University of Portsmouth
11	Javier Romero	University of Barcelona
12	Jordi Pagès	Universitat de Barcelona
13	Ana Lillebø	University of Aveiro
14	Søren Laurentius Nielsen	Ocean Institute
15	Tobias	

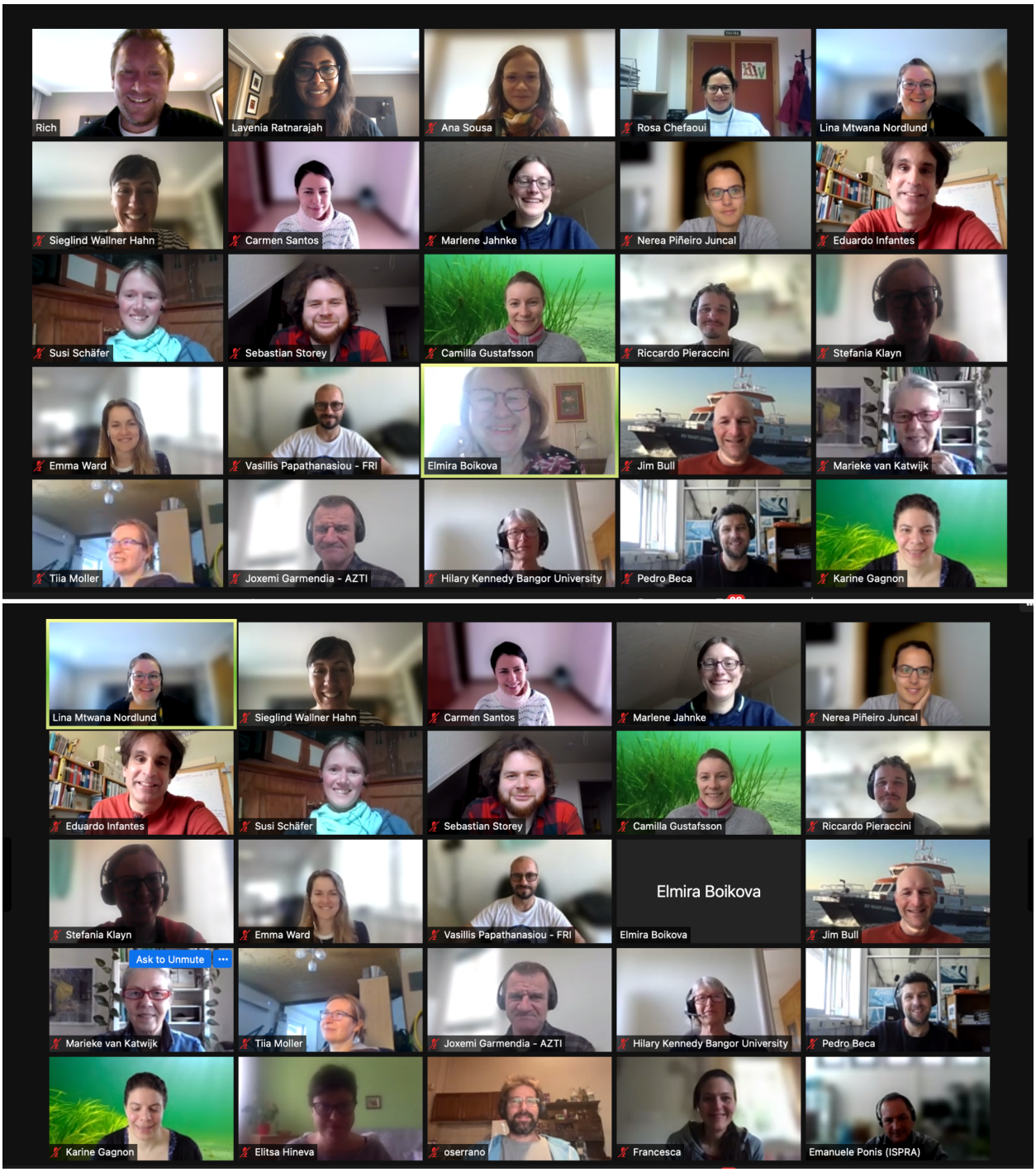


Figure 3: Workshop participants

Workshop output

The workshop involved 3 breakout groups that tackled the 9 different themes. Each theme was discussed over 2 x 45-minute sessions, to engage the participants to synthesise the number of questions within each field. Breakout sessions were then grouped into multiple themes to further ensure the questions were being synthesised down to the top 100. From the initial 293 questions gathered across the 9 different themes, the workshop participants identified the top 100 priority questions across 8 themes, with the 'Cross-discipline' theme being disregarded.

Whilst we are unable to provide the exact questions identified at present because a manuscript is being prepared for submission in May 2022. Thus, we provide a brief overview of all the questions identified across the 8 themes:

Ecosystem services & Communication:
15 questions were identified in this theme largely around quantifying the value of seagrass ecosystems, implications of anthropogenic pressures and climate change, knowledge sharing and communication to various stakeholders.

Drivers & Threats
12 questions were identified in this theme that sought to answer the impacts of extreme events, climate change, anthropogenic activities, contaminants, and pathogens on seagrass response, and how factors such as species, and genetic diversity influence resilience.

Monitoring & Assessment
11 questions were identified that covered seagrass abundance and distribution, data availability, methodology, and citizen science programs to quantify seagrass status.

Biodiversity & Ecology
19 questions were identified here that focuses on the response of seagrass to pressure, importance of seagrass in under-studied regions like the Black Sea, ecosystem services, food web interactions, impact of non-native species, herbivory, and ecological feedbacks (e.g., sediment-light interactions).

Conservation & Restoration
15 questions were identified around seagrass restoration and aid recovery, conservation measures, spatial and temporal scales, transplantations, genetic makeup of donor material, genetic variability, and public involvement.

Blue carbon
9 questions were identified that sought to answer the effects of seagrass meadows on greenhouse gas emissions and removals, carbon sequestration capacity, effects of multiple threats and engagement with policymakers

Fisheries support
5 questions were identified under fisheries support largely around the fisheries species associated with seagrass communities, development of new fisheries techniques and communication to various stakeholders (e.g., scientist, managers, policymakers, and general public)

Governance, Policy & Management
12 questions were identified around improved and integrated management to prevent seagrass degradation and loss, stakeholder engagement to advance restoration and conservation, methods to deal with context-dependent responses and collaboration amongst European seagrass researchers.

At the end of the workshop, 98 questions were identified, and the participants are currently developing a further 2 questions based on the pool of 'reserve' questions. These questions that were identified by the seagrass community will set the scene for seagrass research, monitoring and conservation in Europe. Whilst this is not all-encompassing, it should instead be seen as a way to engage with researchers across various subfields in an effort to promote more cross-collaborative research and monitoring. Moving forward, this workshop can be used as a prototype to develop regional workshops that strongly engage and provide the community with a voice in directing the future of research and conservation strategies for their region. This is particularly important as factors that impede research and monitoring efforts can differ by region.

Conclusion and steps forward

Seagrass ecosystems provide critical resources for both marine and human life. The Water Framework Directive, the MSFD and the Habitat Directive have led to improved widespread monitoring of seagrasses, however the coverage of such activity is not ubiquitous and there remain many gaps. This workshop outlined the priority questions that if answered would significantly advance the conservation, monitoring and research of seagrass ecosystems in Europe. Moving forward, these 100 questions can be used as the backbone to develop indicators to monitor and assess the state of the marine environment. Additionally, the development of a global monitoring network for seagrasses that engages various stakeholders (scientists, managers, policy makers etc.) can strengthen the scientific understanding of the status and trends

of seagrass ecosystems at different places around the world and highlight key gaps (e.g., the data needed to inform policies of nations to sustain seagrass ecosystems).

Reflections on the workshop

This was a hybrid (in-person and virtual) workshop where the co-chairs and facilitators are in one central location and the participants join via zoom. We undertook a survey in the last session of the workshop to gain feedback from the participants. In reflecting on the workshop, we outline some positives and negatives that can guide future workshop preparations. Further results from the workshop participant survey are in Appendix 3.

Positives	Negatives
With co-chairs and facilitators (total of 4 people) in one location, we were able to discuss workshop demands and questions in person over the breaks (breakfast, coffee, lunch and dinner), make amendments to the program, and discuss any issues immediately and in person.	Meetings were short → 2 x 2.25-hour sessions per day to prevent zoom fatigue but led to discussions being cut short. Full in person meetings allow for continued engagement throughout the day.
In person workshops can be incredibly expensive to host particularly if many participants are required to travel, thus limiting the number of participants. Having a hybrid workshop allows for greater participation from the community. In this workshop we engaged ~35 people around Europe with a total budget of ~USD10k.	Networking would have been better in person
Discussions were held in parallel using the Breakout room function in zoom.	
Meetings were short → 2 x 2.25-hour sessions per day so people could continue undertaking normal duties (e.g., teaching, research etc.) and they were allowed to join and leave when possible.	
Efficiency would improve if 2 people facilitated, one to write and one to lead the discussion and check the chat+hands.	

Acknowledgements

This work was organized in the framework of the Global Ocean Observing System (GOOS) Biology and Ecosystems panel and funded through the EU Horizon 2020 EuroSea action (grant no. 862626). We would like to sincerely thank the workshop participants, as they have been through this multi-step process to identify the top 100 priority questions for conservation, monitoring and research of seagrass ecosystems in Europe. Richard Unsworth was supported by Swansea University and Lina Mtwana Nordlund and Sieglind Wallner-Hahn were supported by Uppsala University.

References

Airoldi, L., Beck, M., 2007. Loss, status and trends for coastal marine habitats of Europe. https://doi.org/10.1201/9781420050943.ch7

Borum, J., Duarte, C.M., Krause-Jensen, D., Greve, T.M. (Eds.), 2004. European seagrasses: an introduction to monitoring and management. The M&MS project, S. l.

Chausson, A., Turner, B., Seddon, D., Chabaneix, N., Girardin, C.A.J., Kapos, V., Key, I., Roe, D., Smith, A., Woroniecki, S., Seddon, N., 2020. Mapping the effectiveness of nature-based solutions for climate change adaptation. Global Change Biology 26, 6134–6155. https://doi.org/10.1111/gcb.15310

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., Jankowska, E., Pérez-Lloréns, J.L., Fournier, J., Montefalcone, M., Pergent, G., Ruiz, J.M., Cabaço, S., Cook, K., Wilkes, R.J., Moy, F.E., Trayter, G.M.-R., Arañó, X.S., de Jong, D.J., Fernández-Torquemada, Y., Auby, I., Vergara, J.J., Santos, R., 2019. Recent trend reversal for declining European seagrass meadows. Nature Communications 10, 3356. https://doi.org/10.1038/s41467-019-11340-4

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., Johnson, C., Konar, B., Krause-Jensen, D., Krumhansl, K., Macreadie, P., Marsh, H., McKenzie, L.J., Mieszkowska, N., Miloslavich, P., Montes, E., Nakaoka, M., Norderhaug, K.M., Norlund, L.M., Orth, R.J., Prathep, A., Putman, N.F., Samper-Villarreal, J., Serrao, E.A., Short, F., Pinto, I.S., Steinberg, P., Stuart-Smith, R., Unsworth, R.K.F., van Keulen, M., van Tussenbroek, B.I., Wang, M., Waycott, M., Weatherdon, L.V., Wernberg, T., Yaakub, S.M., 2019. Toward a Coordinated Global Observing System for Seagrasses and Marine Macroalgae. Front. Mar. Sci. 6. https://doi.org/10.3389/fmars.2019.00317

Grech, A., Chartrand-Miller, K., Erftemeijer, P., Fonseca, M., McKenzie, L., Rasheed, M., Taylor, H., Coles, R., 2012. A comparison of threats, vulnerabilities and management approaches in global seagrass bioregions. Environmental Research Letters 7, 024006. https://doi.org/10.1088/1748-9326/7/2/024006

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.
Green, E.P., Short, F.T., 2003. World Atlas of Seagrasses. University of California Press.
Hemminga, M.A., Duarte, C.M., 2000. Seagrass Ecology. Cambridge University Press.
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, e12645. https://doi.org/10.1111/conl.12645
McKenzie, L., Nordlund, L.M., Jones, B.L., Cullen-Unsworth, L.C., Roelfsema, C.M., Unsworth, R., 2020. The global distribution of seagrass meadows. Environ. Res. Lett. https://doi.org/10.1088/1748-9326/ab7d06
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 2016. https://doi.org/10.1371/journal.pone.0163091
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. PNAS 118. https://doi.org/10.1073/pnas.2110802118
Unsworth, R.K.F., Nordlund, L.M., Cullen-Unsworth, L.C., 2019. Seagrass meadows support global fisheries production. Conservation Letters 12, e12566. https://doi.org/10.1111/conl.12566
van Tussenbroek, B.I., Villamil, N., Márquez-Guzmán, J., Wong, R., Monroy-Velázquez, L.V., Solis-Weiss, V., 2016. Experimental evidence of pollination in marine flowers by invertebrate fauna. Nat Commun 7, 12980. https://doi.org/10.1038/ncomms12980
Whalen, M.A., Whippo, R.D.B., Stachowicz, J.J., York, P.H., Aiello, E., Alcoverro, T., Altieri, A.H., Benedetti-Cecchi, L., Bertolini, C., Bresch, M., Bulleri, F., Carnell, P.E., Cimon, S., Connolly, R.M., Cusson, M., Diskin, M.S., D'Souza, E., Flores, A.A.V., Fodrie, F.J., Galloway, A.W.E., Gaskins, L.C., Graham, O.J., Hanley, T.C., Henderson, C.J., Hereu, C.M., Hessing-Lewis, M., Hovel, K.A., Hughes, B.B., Hughes, A.R., Hultgren, K.M., Jänes, H., Janiak, D.S., Johnston, L.N., Jorgensen, P., Kelaher, B.P., Kruschel, C., Lanham, B.S., Lee, K.-S., Lefcheck, J.S., Lozano-Álvarez, E., Macreadie, P.I., Monteith, Z.L., O'Connor, N.E., Olds, A.D., O'Leary, J.K., Patrick, C.J., Pino, O., Poore, A.G.B., Rasheed, M.A., Raymond, W.W., Reiss, K., Rhoades, O.K., Robinson, M.T., Ross, P.G., Rossi, F., Schlacher, T.A., Seemann, J., Silliman, B.R., Smee, D.L., Thiel, M., Unsworth, R.K.F., van Tussenbroek, B.I., Vergés, A., Yeager, M.E., Yednock, B.K., Ziegler, S.L., Duffy, J.E., 2020. Climate drives the geography of marine consumption by changing predator communities. Proceedings of the National Academy of Sciences 117, 28160–28166. https://doi.org/10.1073/pnas.2005255117

Appendix 1 GoogleForm outline

Priorities for Conservation, Monitoring and Research of Seagrass Ecosystems in Europe

Dear experts and practitioners on European seagrass,

We are delighted to invite you to a process aiming to identify the Priorities for Conservation, Monitoring and Research of Seagrass Ecosystems in Europe as part of the EuroSea project*. This process is an exciting opportunity to bring together researchers, practitioners, and policymakers from across Europe and will culminate with an online workshop organized in collaboration with the Biology and Ecosystems Panel of the Global Ocean Observing System (GOOS), IOC/UNESCO. The process will consist of four steps and aims to formulate, identify, and compile important questions that, if answered, would strongly advance seagrass conservation in Europe towards rich and resilient seagrass ecosystems that would benefit both nature and people**. The final outputs of the process will be a report and a scientific paper summarizing the most urgent questions for future seagrass conservation in Europe, and you are invited to participate following your involvement in this process. The process is planned as follows:

1) Formulating questions - due on Friday 4th February, 2022

As a first step in the process, we kindly ask you to formulate questions that you think, if answered, could advance seagrass conservation in Europe. You may also consult with your colleagues and networks to identify such questions. We seek to include questions covering topics relating to any aspect of seagrass ecosystems including, but not limited to monitoring, policy, culture, economics, equity, sustainable development, governance, planning, connectivity, reintroductions, climate change and resilience, and ecosystem services, as well as practical questions about habitat management. The survey will need a bit of effort and thought, and more detailed instructions are presented in the survey. We kindly ask you (each participant) to submit 1-10 questions by the 4th of February 2022. It will be possible for you to change or add to your response by clicking the edit button in your confirmation email after your submission, so we encourage you to start as soon as possible. Please take part in the survey and submit your contribution here below.

Thereafter we will collate all questions, structure them after topics and merge similar questions.

2) Scaling down to key questions - February 21st until March 6th, 2022

In mid-February, we will send out the compiled list of questions to all participants. You will be asked to vote on the key questions to narrow down the list of questions. You will also have the opportunity to add pressing, new or missing questions that will be brought forward to the workshop. The deadline is March 6th, 2022.

3) The online workshop - March 22-24, 2022

We will organize an online workshop on March 22-24, with two sessions each day from 10-12:15 and 14-16:15 CET. Please note the dates and times in your calendars. During this workshop, we will work in smaller groups and collaboratively to discuss seagrass management, monitoring and research in Europe and decide on the priority questions which will be included in the final output.

4) Report & scientific paper

After the workshop, we (the people behind the survey) will compile a report for the European Commission under the terms of the EuroSea project. We also aim to write a scientific publication with a focus on the priority questions. See below for examples of papers with priority questions that have previously been undertaken for other topics. All participants following this process and supporting the writing are cordially invited to co-author this scientific paper led by Lina Mtwana Nordlund and Richard Unsworth.

We would very much appreciate your valuable expert input and sincerely hope that you will be able to take part in the process. May we suggest that you schedule a day after the holidays to formulate the questions. You confirm your participation by submitting the survey in step 1 by the 4th of February. If you have any questions please do not hesitate to contact us by responding to this email. We look forward to hearing from you.

Best wishes,

Lina Mtwana Nordlund, co-chair, Uppsala University, Sweden
Richard Unsworth, co-chair, Swansea University, UK
Lavenia Ratnarajah, Biology and Ecosystems panel of GOOS, IOC/UNESCO
Sieglind Wallner-Hahn, Uppsala University, Sweden

*This survey and upcoming workshop is part of the EuroSea project (https://eurosea.eu) and GOOS (https://www.goosocean.org). EuroSea is a European Union Innovation Action funded through the European Commission research funding programme Horizon 2020 under a call supporting the G7 Future of Seas and Oceans Flagship Initiative.

** Management of all data collected in this questionnaire will adhere to standards set out in the following: https://www.swansea.ac.uk/about-us/compliance/data-protection/

Example of papers with important questions (but for other topics):
-Sutherland et al 2013. Identification of 100 fundamental ecological questions.
https://besjournals.onlinelibrary.wiley.com/doi/epdf/10.1111/1365-2745.12025

-Sutherland et al 2009. One Hundred Questions of Importance to the Conservation of Global Biological Diversity.
https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/j.1523-1739.2009.01212.x

* Required
Email *
Cannot pre-fill email
Photo of seagrass research in Denmark

This survey will need a bit of effort and thought. Your participation in this survey is voluntary. You are encouraged to enquire about the project and your participation, and you can withdraw your participation at any time. We are collecting your name and email address to be able to invite you to the next step of this process and to the online workshop. It is only the research team behind the study that will see your name and contact information. The other participants will not be able to see who has submitted which question. Your questions posted here may be published in part or in full in a report and a scientific publication. *

I agree to participate in this survey
No thank you, I do not agree to participate

Please fill in your name as you would like it to be displayed (first name, surname).
Your answer

Please enter an URL of your affiliation (e.g. website of your company, LinkedIn)
Your answer

I agree to have my name published in a report, scientific publication and/or on social media (e.g., as a contributor, co-author or in acknowledgements), if applicable. It will not be possible to identify any person's specific answer or formulated questions from the survey. *
Yes
Yes, but only in a report and scientific publication (not on social media)
No
Other:

Gender
Female
Male
Non-binary / Third gender
Prefer not to say

Which of the following position/suggestion best suits your current work related to seagrass? (Tick all applicable boxes)
Desicion-maker / Governance
Policy maker
Manager
Technician
Adviser (e.g., policy and management)
PhD Student
Post-doc
Researcher (working at an academic institution)

Researcher (working at a non-academic institution)
Assistant/Associate professor
Professor
Prefer not to say
Other:

From which European country or countries do you have most experience with related to your work with seagrasses? Please add up to 3 countries/areas
Albania
Belgium
Bosnia and Herzegovina
Bulgaria
Croatia
Cyprus
Denmark
Estonia
Finland
France
Germany
Greece
Iceland
Ireland
Italy
Latvia
Lithuania
Malta
Monaco
Montenegro
Netherlands
Norway
Poland
Portugal
Romania
Russia
Slovenia
Spain
Sweden
United Kingdom
Ukraine
Other European Country
I work with European data
A European country but outside of continental Europe (e.g. La reunion, France)
I work with global data
Other:

Which seagrass species in Europe do you have the most experience with? (check all that apply)
Zostera marina
Zostera noltei
Posidonia oceanica
Cymodocea nodosa

Ruppia maritima
Mixed vegetation (seagrass and other underwater plants)
Other:

What methods do you use to communicate your seagrass related "findings"? (check all that apply)
Scientific research articles
Policy briefs
Reports for mandated monitoring (e.g., MSFD, Habitat Directive etc.)
Internal reports
Popular science articles (e.g. new paper, websites)
Research conference presentations (e.g. oral, poster)
International meetings (e.g. UN Biodiversity conference COP15)
Social media (e.g., blogs, Twitter, Facebook)
Databases (e.g., data submitted to a national or international database);
Other:

Is the data you gather about seagrass data publicly available? (i.e., stored in a public repository)
Yes
No
Part/components of it
I don't know

Where is the data stored? (e.g., National database, OBIS, EMODnet, private etc.)
Your answer

Formulating priority questions

Instructions for the formulation of priority questions for conservation, monitoring and research of seagrass ecosystems

In the following section we ask you to please add up to ten questions.

Criteria for Good Questions
- Are answerable through a realistic research design.
- Address important gaps in knowledge.
- Are relevant within continental Europe.
- Are at an appropriate spatial and temporal scale and scope.
- Not too general: i.e. a research programme could make progress towards answering each question within an acceptable timeframe.
- Not too limited in scope: i.e. answering a question should have a significant impact on the effectiveness of seagrass conservation, monitoring and/or research.
- Answering the questions should be doable, not just desirable.
- Fall within the scope of the exercise.

Minimum 1 and maximum 10 questions per person.

For each question please assign on of the following categories.

MONITORING & ASSESSMENT
Questions the covers all aspects of monitoring & assessment of seagrass ecosystems.

DRIVERS AND THREATS
Questions relating to drivers of change in seagrass ecosystems and threats to the seagrass ecosystems.

BIODIVERSITY & ECOLOGY
Questions relating to the ecology of seagrass ecosystems, including but not limited to reintroductions, species' interactions and ecological function.

ECOSYSTEM SERVICES & COMMUNICATION
Questions on the benefits and services provided by seagrass (services in general rather than a specific service) and communication of e.g. threats and benefits of seagrass to humans.

BLUE CARBON
Questions related to all aspects of blue carbon.

FISHERY SUPPORT
Questions related to all aspects of fishery support, including but not limited to e.g. fisheries, invertebrate stocks, nursery grounds.

GOVERNANCE, POLICY & MANAGEMENT
Questions related to how we could strengthen and improve governance, policy and management within Europe that reflect national, regional and European regulatory frameworks (e.g., MSFD, Water Framework Directive etc.). This category includes but is not limited to e.g. including seagrass in marine spatial planning, or management and enforcement of seagrass protection.

CONSERVATION & RESTORATION
Questions related to conservation and restoration of seagrass ecosystems.

CROSS DISCIPLINES
Questions that deals with several of the categories, or the intersection of suggested categories.

OTHER
If non of the categories fit, or you would like to suggest a new category please do so under other.

Example of papers with important questions (but for other topics):

Here are examples of papers (open access) with questions:
Sutherland et al 2013. Identification of 100 fundamental ecological questions.
https://besjournals.onlinelibrary.wiley.com/doi/epdf/10.1111/1365-2745.12025

Sutherland et al 2009. One Hundred Questions of Importance to the Conservation of Global Biological Diversity.
https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/j.1523-1739.2009.01212.x

zu Ermgassen et al 2020. Forty questions of importance to the policy and practice of native oyster reef restoration in Europe. Aquatic Conservation. https://doi.org/10.1002/aqc.3462

Lennox et al. 2019. One Hundred Pressing Questions on the Future of Global Fish Migration Science, Conservation, and Policy. Front. Ecol. Evol. https://doi.org/10.3389/fevo.2019.00286

Question 1

Please write your question (1)

Your answer

Under which category would you like to place your question (1)?

MONITORING & ASSESSMENT
BIODIVERSITY & ECOLOGY
DRIVERS & THREATS
ECOSYSTEM SERVICES & COMMUNICATION
BLUE CARBON
FISHERY SUPPORT
GOVERNANCE, POLICY & MANAGEMENT
CONSERVATION & RESTORATION
CROSS-DISCIPLINES
Other:

Question 2

Please write your question (2)

Your answer

Under which category would you like to place your question (2)?

MONITORING & ASSESSMENT
BIODIVERSITY & ECOLOGY
DRIVERS & THREATS
ECOSYSTEM SERVICES & COMMUNICATION
BLUE CARBON
FISHERY SUPPORT
GOVERNANCE, POLICY & MANAGEMENT
CONSERVATION & RESTORATION
CROSS DISCIPLINES
Other:

Question 3

Please write your question (3)

Your answer

Under which category would you like to place your question (3)?

MONITORING & ASSESSMENT
BIODIVERSITY & ECOLOGY
DRIVERS & THREATS
ECOSYSTEM SERVICES & COMMUNICATION
BLUE CARBON
FISHERY SUPPORT
GOVERNANCE, POLICY & MANAGEMENT
CONSERVATION & RESTORATION
CROSS DISCIPLINES
Other:

Question 4

Please write your question (4)

Your answer

Under which category would you like to place your question (4)?

MONITORING & ASSESSMENT
BIODIVERSITY & ECOLOGY
DRIVERS & THREATS
ECOSYSTEM SERVICES & COMMUNICATION
BLUE CARBON
FISHERY SUPPORT
GOVERNANCE, POLICY & MANAGEMENT
CONSERVATION & RESTORATION
CROSS DISCIPLINES
Other:

Question 5

Please write your question (5)

Your answer

Under which category would you like to place your question (5)?

MONITORING & ASSESSMENT
BIODIVERSITY & ECOLOGY
DRIVERS & THREATS
ECOSYSTEM SERVICES & COMMUNICATION
BLUE CARBON
FISHERY SUPPORT
GOVERNANCE, POLICY & MANAGEMENT
CONSERVATION & RESTORATION
CROSS DISCIPLINES
Other:

Question 6

Please write your question (6)

Your answer

Under which category would you like to place your question (5)?

MONITORING & ASSESSMENT
BIODIVERSITY & ECOLOGY
DRIVERS & THREATS
ECOSYSTEM SERVICES & COMMUNICATION
BLUE CARBON
FISHERY SUPPORT
GOVERNANCE, POLICY & MANAGEMENT
CONSERVATION & RESTORATION
CROSS DISCIPLINES
Other:

Question 7

Please write your question (7)

Your answer

Under which category would you like to place your question (5)?

MONITORING & ASSESSMENT
BIODIVERSITY & ECOLOGY
DRIVERS & THREATS
ECOSYSTEM SERVICES & COMMUNICATION
BLUE CARBON
FISHERY SUPPORT
GOVERNANCE, POLICY & MANAGEMENT
CONSERVATION & RESTORATION
CROSS DISCIPLINES
Other:

Question 8

Please write your question (8)

Your answer

Under which category would you like to place your question (5)?

MONITORING & ASSESSMENT
BIODIVERSITY & ECOLOGY
DRIVERS & THREATS
ECOSYSTEM SERVICES & COMMUNICATION
BLUE CARBON
FISHERY SUPPORT
GOVERNANCE, POLICY & MANAGEMENT
CONSERVATION & RESTORATION
CROSS DISCIPLINES
Other:

Question 9

Please write your question (9)

Your answer

Under which category would you like to place your question (5)?

MONITORING & ASSESSMENT
BIODIVERSITY & ECOLOGY
DRIVERS & THREATS
ECOSYSTEM SERVICES & COMMUNICATION
BLUE CARBON
FISHERY SUPPORT
GOVERNANCE, POLICY & MANAGEMENT
CONSERVATION & RESTORATION
CROSS DISCIPLINES
Other:

Question 10

Please write your question (10)

Your answer

Under which category would you like to place your question (5)?

MONITORING & ASSESSMENT
BIODIVERSITY & ECOLOGY
DRIVERS & THREATS
ECOSYSTEM SERVICES & COMMUNICATION
BLUE CARBON
FISHERY SUPPORT
GOVERNANCE, POLICY & MANAGEMENT
CONSERVATION & RESTORATION
CROSS DISCIPLINES
Other:

Thank you for your participation in this survey!

Is there anything else you would like to add?

Your answer

Appendix 2 Workshop Agenda

Tuesday 22 March

0945 - 1000 Meeting room opens/technical check
1000 - 1215 CET
0945 - 1000 Meeting room opens/technical check
1000 - 1010 Welcome note from Lina and Rich
1000 - 1020 What is EuroSea?
1020 - 1040 Introductions
1040 - 1100 Instructions (how the workshop will be done) - 3 breakout groups. Test by going into the breakout rooms, returning to the main room. Time for questions.
1100 - 1115 Coffee Break
1115 - 1125 Questions from the attendees
1125 - 1215 Breakout session 1 (each breakout room highlights a different theme)
Group 1: Ecosystem services & Communication (Lina)
Group 2: Blue carbon (Rich)
Group 3: Governance, Policy & Management (Sieglind)

LUNCH BREAK

1400 - 1615 CET
1400 - 1410 Summary from morning session (tips/advice/questions etc.)
1410 - 1500 Breakout session 2
Group 1: Ecosystem services & Communication (Lina) *continued*
Group 2: Blue carbon (Rich) *continued*
Group 3: Governance, Policy & Management (Sieglind) *continued*
1500 - 1515 Coffee break
1515 - 1520 Summary from the earlier part of the afternoon
1520 - 1610 Breakout session 3
Group 4: Monitoring & Assessment (Lina)
Group 5: Drivers & Threats (Rich)
Group 6: Conservation & Restoration (Sigi)
1610-1615 Sum up where we are in the process

Wednesday 23 March

0945 - 1000 Meeting room opens/technical check
1000 - 1215 CET

1000 - 1010 Summary from Day 1
1010 - 1100 Breakout session 4
Group 4: Monitoring & Assessment (Lina) *continued*
Group 5: Drivers & Threats (Rich) *continued*
Group 6: Conservation & Restoration (Sieglind) *continued*
1100 - 1115 Coffee Break
1115 - 1215 Breakout session 5
Group 5: Drivers & Threats (Rich) *continued*
Group 6: Conservation & Restoration (Sieglind) *continued*
Group 7: Fisheries support (Lina)

LUNCH BREAK

1400 - 1615 CET
1400 - 1410 Summary from morning session (tips/advice/questions etc.)
1410 - 1500 Breakout session 6
Group 8: Cross-discipline (Sieglind)
Group 9: Biodiversity & Ecology (Rich)
Group 11: Combination of Monitoring & Assessment, Conservation & Restoration and Drivers and Threats (Lina)
1500 - 1515 Coffee break
1515 - 1520 Summary from the earlier part of the afternoon
1520 - 1610 Breakout session 7
Group 9: Biodiversity and Ecology (Rich) *continued*
Group 10: Combination of Governance, Policy & Management, Ecosystem services & Communication and Cross disciplines (Sieglind)
Group 11: Combination of Monitoring & Assessment, Conservation & Restoration and Drivers and Threats (Lina)
1610-1615 Sum up where we are in the process

Thursday 24 March

0945 - 1000 Meeting room opens/technical check
1000 - 1215 CET
1000 - 1015 Show attendees all the questions left
1015 - 1100 Breakout session 8
Group 12: Combination of Fisheries support, Blue carbon, Ecosystem services & Communication, Drivers & Threats, Monitoring & Assessment (Sieglind)

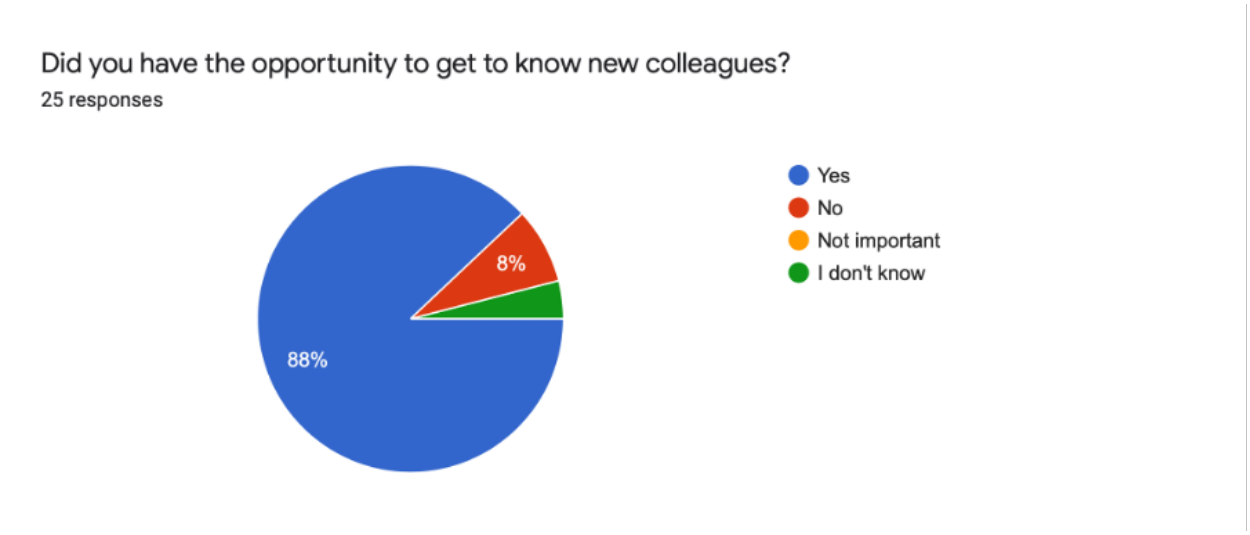
Group 13: Combination of Biodiversity & Ecology, Conservation & Restoration, Governance, Policy & Management, Cross disciplines (Rich)
Group 14: Where needed! (Lina)
1100 - 1115 Coffee break
1115 - 1215 Look at all the questions together (breakout rooms where and when needed)

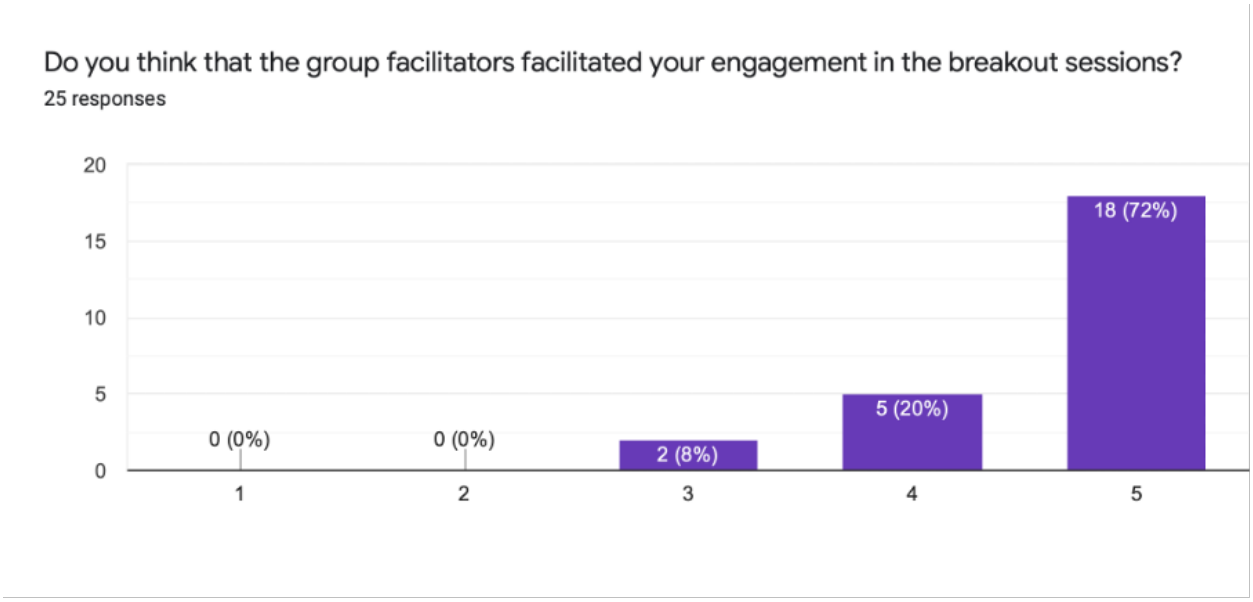
LUNCH BREAK

1400 - 1615 CET
1400 - 1500 TBD based on need
1500 - 1515 Coffee break
1515 - 1545 The final agreement of 100 questions
1545 - 1615 Presentation, the way forward (Lina & Rich)

Appendix 3 Workshop participant review

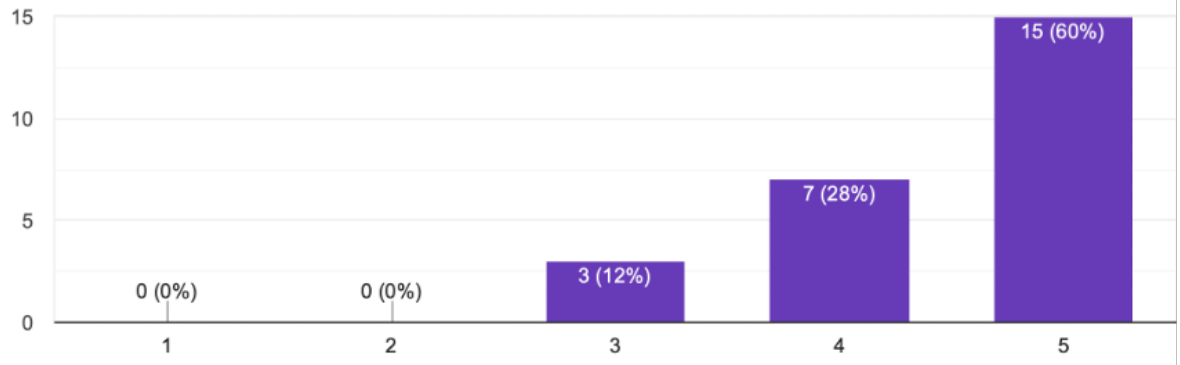
A total of 25 people participated in the post-workshop survey.





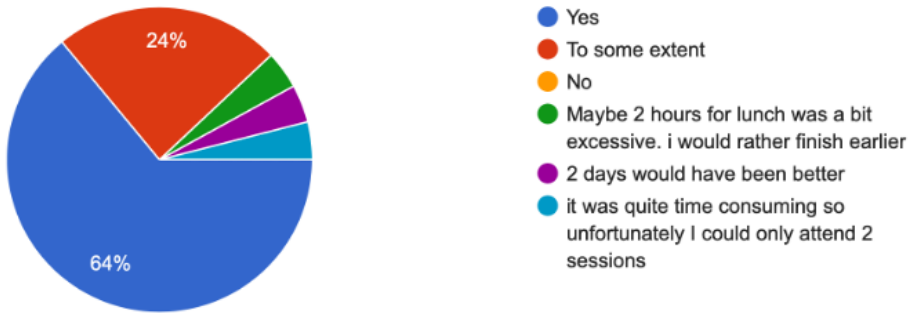
Did you find it easy and comfortable to engage during the breakout sessions?

25 responses



Did the schedule work well for you in terms of number of days, length of morning and afternoon sessions?

25 responses



Did you think that there was enough time in each session to discuss the topics?

25 responses

Do you feel that you have learned new things, had fruitful discussions and grown your seagrass network around Europe?

25 responses